Development of Virtual Musical Keyboard Layout Interfaces for Invented and Evolved Tuning Systems

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Table of contents

TABLE OF FIGURES

TABLE OF TABLES

Description of Digital Assets by Directory and Subject

The root directory contains a digitized copy of this written document.

1. Digital computer programming practices

   PD files of the Pure Data patches of all five VMKLI's

   Video demonstration of Alpha Scale on Novation Minipad Hardware Keyboard

2. Musical Practice

   Audio of all five musical compositions recorded during the research projects

   Pdf of the Musical scores created by Doctor Timothy Wise (Twirl Dung Pa) and Doctor Philip Brissenden (The Esoteric 666-Type Of Dance)

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Abstract

This research is a practice-based project where the objectives revolve around different aspects of tuning; the primary focus is to create innovative Virtual Musical Keyboard Layout Interfaces (from now on abbreviated VMKLI) through computer-based programming software tools and eventually turned into Mobile Applications (commonly abbreviated as Apps). These VMKLI's are based on five different tuning systems found in various parts of the world (commonly referred to as non-Western tuning systems). These tuning systems contain different pitches and divisions of octaves and show little or no resemblance to the Western 12-tone equal divisions of the octave (abbreviated EDO, alternatively referred to as 12-tone equal temperament) tuning system which is the basis for the vast majority of modern Western popular music of today. The Virtual Musical Keyboard Layout Interface Apps are designed as workable virtual musical instruments which will allow musicians/composers to perform music in real-time (although the aid of amplification is necessary), or as tools to record musical ideas – these Apps are intended mainly for tablets such as iPads.

Five interfaces have been produced based on Alpha, Beta, and Gamma scales invented by Wendy Carlos, the Bohlen-Pierce scale, Gamelan, traditional Indonesian tuning system, Indian (Rag), traditional tuning system and finally Arabic (maqam), traditional tuning system. The timbre of each App is constructed through digital programming software throughout; voices shaped through a combination of various digital processes in order to create sounds that invoke key aspects of the musical culture in question – i.e. not samples. Each App comprises a unique keyboard layout and exclusive set of controllable parameters; an interface design that differs from any of the other Apps created for this research project; the design seeks to invoke the essence of the tuning intent within the musical culture.

In order to test these interfaces, they are implemented within practice which forms an essential part of this research; a total of five musical compositions to accommodate the interface developed for each separate tuning system. The compositions will not be genre specific, and will not be an overt attempt to try and replicate traditional music commonly associated with the respective musical cultures, rather I seek to explore the way in which each interface results in a distinct aesthetic result.

The research entails a threefold methodology model which combines the elements of practice through a trial and error process and development of software design (part I) further supported by extensive Literature review (part II).

1. INTRODUCTION

Music and musical behaviour appear to be common traits in most if not all cultures of the world today. However, presenting a statement which claims that the phenomenon of music to be universal may be met with disputed arguments among a number of renowned scholars. Although the phenomenon of music appears to apply to literally all cultures in the world, this does not necessary imply that every single culture in the world would favour the exact same types of music; neither does it imply the same understanding, acceptance of same/similar musical principles, gestures, ideas and/or the approaches towards execution of performances and/or compositions from an entirely different musical culture. Over the past 100 years or so, numerous Western innovations of new digital devices and development of music technology has spread to the rest of the world and enabled non-Western cultures to incorporate and embrace Western ideals into various situations, including music. This contribution has resulted in increased globalization and Westernization of other cultures in the world, however, on the other hand, little information from other non-Western cultures appear to be known to the Western World.

This leads us to one of the main purposes initiating this research; since modern technology has allowed increasingly more portable solutions to simplify people's everyday life and enabled many different daily tasks to be performed on Tablets (i.e. past the obvious phoning/texting functions, such as answering/sending emails, sending/requesting payments, paying bills, watching movies, playing games etc.) – however, one aspect appears to be neglected, namely options for Virtual Keyboards which enables musicians, composers and music producers to perform non-Western tuning systems on portable Tablets.

At the outset of the project a search was made of existing resources for composers and producers to play and compose music using non-western tuning systems. It was found that there were no resources that were comparable to that which present author planned to create. The initial journey prior to the PhD research would start during the present author's period as a Masters student at the University of Salford. The initial ideas for developing Virtual Keyboard Interfaces was part of one of the assignments in a module called IEMPT (Interactive & Emergent Music Production

Techniques). This module taught students how to develop/construct audio and image/video/visual artefacts by using a computer programming software called MAX (also sometimes called Max/MSP). For this module the present author decided to create an advanced Virtual keyboard predominantly MIDI and based on 12-tone EDO yet would offer other electronic options which allowed the user/player to make adjustments to attack/decay/sustain/release and possibilities to change harmonicities. This module was the main inspiration for pursuing further development of Virtual keyboards on a far more advanced level, leading up to the initiation creating the Virtual Musical Keyboard Layout Interfaces (from now on abbreviated VMKLI's).

During the initial phase of this research project, a significant amount of time was spent assembling/gathering information about various tuning systems. Simultaneously, exploration of Western/non-Western keyboard propositions and other instruments developed from medieval times up until current-day was done in order to validate the reason for pursuing/initiating this research project. As a result, one of the most noticeable findings during this process was the absence of existing keyboard options for portable units on Tablets such as iPhones, iPads and Android systems –for both modern (invented) and non-Western (evolved) tuning systems. Further, the availability of unique custom-made keyboard layouts to accommodate some of these tuning systems turned out to be non-existent, thus providing no obvious blueprint for how these could be developed. None of the evolved non-Western tuning systems would offer any easy and compromised keyboard solutions to allow users the possibilities to play one or few "instruments" on one single portable unit – in other words, the availability of an instrument which would capture the majority of the musical qualities inherent within, to be representative of and evoke the vibrancies of a respective musical culture.

As a result it was obvious that two distinct and different segmentations proved most interesting to pursue for the research project; 1) traditional evolved tuning systems developed over the course of centuries (if not for millenniums), while 2) modern invented tuning systems developed within the past 50 years with limited and/or no custom-made instruments to accommodate the tuning systems. Thus, the selection of tuning systems was based on a balance of diversity and complexity.

In addition, recent years has shown increasing interest among composers pursuing microtonal music and the establishment of online communities for microtonal composers exist. However, the main challenge for these individuals are limitations of keyboard options to allow them to perform the music accordingly to how the tuning systems are structured/divided, thus it is obvious that an increasing potential for a selection of innovative keyboard layout interface to provide non-Western musicians, composers and producers with alternatives to enable, approach, pursue and embrace music from non-Western musical cultures. Thus, based on these findings the potential to develop innovative keyboard layout designs is validated. The anticipated outcome is that these VMKLI's can contribute and be valuable assets to bridge gaps between Western music and non-Western music in the future.

Despite that we have addressed a number of evidences that highly suggests the necessity for developing innovative VMKLI's on Tablets, it should be noted that this process would both implicate a number of advantages and disadvantages to emerge. One of the main advantages by offering VMKLI's onto iPads is largely due to the immediate accessibility and portability associated with this type of technology and currently commonplace in considerable number of households all over the world. Although noticeably larger than smart phones, they are still easily portable, user-friendly and allows for a number of everyday tasks to be performed through the advantage of larger screens/displays which makes them more suited to operating a number of Apps, watching movies (on the run) while travelling, reading kindle/books, musical scores, etc. As such, the idea to create virtual Interfaces for tablets sprang to mind early on during the initial phase of this research project.

Each of the VMKLI's features a number of different and unique aspects either inherent or different from their originating musical culture. One significant advantage of the VMKLI's is that they provide simplification of a set of actual indigenous instrumentations. In particular, the Gamelan VMKLI's encapsulates a total amount of up to 155 keys/gongs/gong-chime kettles to be performed on seven separate VMKLI's. Thus, various pitches from a number of different gamelan instruments within the same specific instrument classification have been encapsulated into distinct Gamelan VMKLI's (which comprises of all possible pitches found in a complete Gamelan Ensemble) – and are based either on a combination of Javanese/Balinese instruments (gong instruments) or separated by each of these two islands (gong-chime kettle, bamboo xylophone and metallophone instruments). The aforementioned decisions were made for the sake of simplicity, portability and convenience although with the intention to retain the integrity of the culture. Both Gamelan Sekar Pethak and Gamelan Gong Kebyar contains a number of instruments within the same classification of instruments which shares the exact same pitch yet provides slightly different timbre, thus a simplification/compromise has been made to limit these pitches each to single keys/knobs, only.

The most remarkable aspect of the Gamelan VMKLI's is that the user is provided with an immediate/instantaneous introduction which allows for efficient absorption of one of the/if not the most complex tuning system and instrumentations in this world. Further, meticulous endeavour has been made to provide intelligible navigation and hand orientation in accordance with the integrity of Indonesian Gamelan yet present a simplified design which enables the user with an easily operable key/knob keyboard layout system. In total seven separate VMKLI's were made to encapsulate a total of 26 different instruments (excluding exact number of gongs) which in most cases are doubled and/or in some as much as quadrupled - including male/female equivalents (i.e. smaller/larger versions which are tuned slightly higher/lower than the other) (Bali) or an equivalent amount of instruments tuned to the other tuning system (Java). This compromise can be justified through a few obvious challenges; the acquisition of an entire Gamelan ensemble in itself would prove severely expensive, and secondly, outside of Indonesia any access to a Gamelan ensemble would prove to be exceptionally rare outside of the context of academia.

It should be noted that the Gamelan VMKLI's distinguishes themselves from any of the other VMKLI's developed for this research project, both the Indian and Arabic tuning system have been limited to represent only the number of tuning systems explored for each, namely one (Indian) and two (Arabic) respectively. The main difference between the Gamelan VMKLI's and the two other VMKLI's (based on evolved/indigenous tuning systems) is that they have been approached from entirely different perspectives both in term of technical and sonic characteristics. Whereas the intention with the Gamelan VMKLI's was to approach them with the intention to recreate/simulate sonic characteristics of known classifications of gamelan instruments yet provide simplifications of entire gamelan ensembles to some extent; the purpose of both Arabic and Indian VMKLI's instead intended to focus on encapsulating an overall timbre from numerous instruments to signify/represent the vibrancies in which to evoke sound characteristics from each respective cultures.

Further, both the Indian and Arabic VMKLI's offer completely different keyboard layouts in comparison to the Gamelan VMKLI's. It should be noted that there is a consistency in the approach of implementations of a key/knob system to appear on all VMKLI's made for this research project. The reasons for introducing knob systems to Indian and Arabic VMKLI's is basically due to the problematic nature of introducing virtual strings to small units such as a Tablet (i.e. iPads, iPhones, Androids etc.); by offering a keyboard interface containing approximately 50 virtual strings is likely to cause a number of designing problems and add confusion to the user. One issue is that the virtual appearance would yield both a static Interface as well as provide strings indistinguishable from one another and render the effect of color coding insignificant. Thus, the selection of a knob-based system provides distinguishable knobs through colour coding which separates unique pitches apart from Western or near-equivalent pitches. Both the Arabic and Indian VMKLI's showcase a range comprising two and two and a half octaves, respectively. This is the perceived range of human voice associated with either cultures. In terms of timbre, the Arabic VMKLI's may propose a more accurate reproduction of distinguishable string-sound quality/characteristic than the Indian counterpart - in addition it features sliding possibilities in accordance with actual instruments from its inherent music culture. On the other hand, the purpose with the Indian VMKLI was to create a more unique timbre which yet still retained strong ties to and vibrancies of Indian music, however it should be noted that the focus on timbre was to steer further away from recreating string-sound characteristics.

The design of the Alpha/Beta/Gamma Scale VMKLI's were initially built around the idea of creating software to accommodate actual hardware keyboards. In this occasion the former tuning system (Alpha) was customized to fit with a Novation Launchpad Mini hardware keyboard and the VMKLI's later would be replicated onto separate Virtual keyboards interface to recreate the layout of the Launchpad Mini keyboard, which also proved to be an ideal choice for a rendition of a symmetrical keyboard Interface, in particularly for the Alpha Scale. This keyboard layout offered a symmetric layout system that made it easy to position certain central or "key" pitches (such as the perfect fifths) in a logical descending order across the range of 64 knobs. The basis of keyboard layouts for Beta and Gamma Scale VMKLI's also derived from the Launchpad Mini keyboard layout although with some customizations.

The only exception of custom-made keyboard layouts to exist prior to the initiation of this research, was Bohlen-Pierce Scale. These were provided both by one of the inventors Heinz Bohlen and musician Elaine Walker who separately proposed their own suggestions for ideal keyboard layout systems. Whereas, both have maintained or taken basis on principals from piano keyboard layouts comprising of white and black keys – however, their proposed arrangement of the keys appears differently. Different to this, the Bohlen-Pierce Scale VMKLI's incorporates a knob system where all non-Western pitches are marked green (it should be noted that the first tritave appears in such a low register that all pitches literally appear closely related to their Western equivalents) yet all tritaves and the following keys within that scope have been separated by a unique colour that applies to pitches closely related to their Western equivalents. To sum up the advantages on all the VMKLI's for this research project; all offers a significant range of pitches (independent of intervallic distance) across the spectrum of distinguishable divisions, unique keyboard layouts, and offers a variety of different timbre both unique and yet similarly relatable to their respective musical culture/tuning system.

Despite that a number of advantages have been addressed above, it is also important to discuss the number of limitations and/or disadvantages apparent by transforming tuning systems onto iPads. Obviously, one of the limitations is the lack of actual physical interaction (i.e. the ability to actually physical touch keys/knobs and the ability to estimate exact physical pressure required to produce the expected or desired velocity). Due to the physical nature of striking Gamelan instruments with padded mallets or hammers, the lack of ability to physically striking register/capabilities for touchscreens will lose some of the effect of playing actual gamelan instruments, mostly in terms of precise velocity. On the other hand, to approach both Arabic and Indian music cultures by abandoning virtual string systems would prove to be a major risk taking in general, due to the strong ties that both cultures share with string-based instruments. However, there are reasons for this decision; virtual strings proved to be too difficult to reproduce largely due to the general thinness of strings and in particular when adding up to 50 virtual string onto a small portable unit would render them all undistinguishable from one another, this problem would be further signified by separating unique indigenous pitches through colour coding apart from non-symmetric appearance of Western and non-Western pitches.

Thus, a compromise was made to propose a knob based-keyboard layout system on the majority the VMKLI's. In addition to the above, the limited size of tablets would further justify keys/knobs systems; another challenge with some of these music cultures is that they are further represented by additional different instruments exclusively to specific regions not found in other regions – all these attributes complicate matters further. Any attempts to recreate exact instrumentations onto one single Tablet (i.e. iPhone, iPad, or Android etc.) through representation on one or few virtual keyboard layouts would prove exceptionally complicated and likely impossible. Thus, in this occasion, the purpose of this research project is to create a compromise and propose original/innovative keyboard layout designs which enables the user to play instruments based on these respective tuning systems.

Another aspect of the research was to apply the aforementioned VMKLI's in order to compose and produce music compositions, the musical style of these should be defined as absolutely experimental. In general, the approach and style of music has been entirely created based on present author's intuitions and instincts and not by influences from other similar composers. These compositions are primarily targeted to or may be likely most receptable for listeners of contemporary classical music or experimental music segments.

During the initial planning of the research it was already clear to present author that the musical direction would not steer towards musical compositions intended to recreate, emulate/simulate nor necessarily approach music in a manner closely resembled/associated with each respective musical culture/tuning system. All of the VMKLI's were already incorporated into five solo compositions entirely composed by present author before any involvement from outside parties took places. These solo compositions offered firmly structured musical soundscapes or musical compositions comprising defined starts, transitions and endings (yet allowing room for musical space for other participating musicians) – and would then provide a musical navigation/map/guide for any contributing musicians involved in this aspect of the research project.

Another important factor of these compositions has been to retain the authenticity of recorded sounds; thus, all of the compositions comprise entirely of recorded sounds. However, taken into consideration the fact that the VMKLI's are digitally computer-based, programmed and artificially constructed creations - this statement may come across as somewhat conflicted to the reader. However, it needs to be properly stated that each and every sound derived from every VMKLI was played and recorded in real time. Further, the VMKLI's either played a complementary or dominating role in each composition – this also applied to the other musical contributions either played entirely present author and/or from other musicians to add musical flavors to the respective composition. In the majority of cases, as the project evolved it should be noted that the significance and presence of the VMKLI's would take a more dominating role in accordance with the ongoing progress and development for each VMKLI.

In this occasion, both the Arabic and Gamelan compositions (both of which were the last two compositions to be initiated in the research project) appears to best exemplify the dominance of the VMKLI's in the most significant way; in both cases the inclusion of ACMG plays a secondary musical role in these compositions. Despite that collaboration with other musical partners have been crucial in the final creations of the music compositions, the musical and artistic merits of the solo pieces should definitely not be dismissed by any means. During the creation of these, the present author intended for these to function as fully fledged independent musical compositions all by themselves, mainly to demonstrate the difference between the solo pieces and the addition of ACMG. Thus, the musical collaboration with ACMG was intended to add both a juxtaposition of Western instrumentations based on 12-tone EDO playing against these different tuning systems and to bring an additional layer of musical contributions to the overall mix of the finished product.
The selection of ensemble to work with/collaborate was obvious from the beginning of the research. Present author was determined to work with a large ensemble who could provide an additional musical backdrop for the solo compositions planned/prepared for the research project. The intent for this collaboration was to add further musical content to what was provided in the aforementioned solo

compositions; thus, this collaboration required musical aesthetics from an entity of experimental performers who would showcase versatile skills for both free-form and notated improvisation and encompass strong sense of individuality in their playing. Another personal ambition for this collaboration was to do live recordings of a larger ensemble in the studio as a recording engineer and add these musical contributions to the solo pieces, mix and produce these.

In addition to be a creative outlet for the present author as a means to showcase a palette of diversity in approaches of experimental music composition, the purpose with these compositions is also to display how the VMKLI's could be incorporated into and applied as a compositional tool to create interesting musical compositions. From the initiation of this research project, it was decided that the eventual development of the VMKLI's would be absolutely integral prior to any planning of any composition would occur, thus these creations would completely affect how each composition would be approached (how these evolved from basic ideas to implementation both musically and artistically), and yet affect the outcome from initiation to completion. Further, additional technical options/features to affect the timbre of the VMKLI's would also play a significant part in this process.

Measurement of success

The measurement of the overall success of the VMKLI's was largely accrued to the creation of five musical compositions. The main purpose of the VMKLI's was to test them out by implanting them through "performance" by incorporating them into musical composition defined as either experimental music, music within or closely related to contemporary classical music. On this occasion, the intention was to approach the creation of unique musical compositions, although none of them were ever meant to fully rely on previously constructed notions of music making. Thus, the execution of these musical compositions in principle should not sound like anything else that has been made before. Yet, in this process each musical composition would sound distinct and distinguishable from any of the other contributions despite that all of them were mutually initiated and largely based on the final result/outcome of the development VMKLI's. It should be noted that each composition was approach largely as individual compositions with no overall intent to conceptualize nor compile these pieces for a complete full-length album.

Another important artistic concept for all compositions, at least the ones which involved collaborations with the then current and mostly full line-up of ACMG - deals with the integrity to retain true real-time live performances without any editing process taking place except for selection of parts from various takes of performance (i.e. no editing of performances nor sampling to be shuffled around in the composition). It should be noted that for all four compositions which included musical contributions from ACMG each was recorded live in the studio at the University of Salford's Band Room (a live environment allowing for concerts and recordings of ensembles to take place) thus forcing/allowing each performer to interact simultaneously with everyone else in real-time – resulting in a collaborative group effort. During mixing, artistic choices were made to retain all performances in real-time to retain the sense of "liveness"; however, the majority of singular performance in the production would be subjected to some level of ducking/burying where emphasis was largely due to the occasional overplaying, to emphasize and to allow other more musical space to those who would play more sparsely or simply improve on the overall blend of and to provide more consistent instrumental balance of the ensemble in the final mix.

Interestingly, this approach is quite contradictory to the compositional practice found in the solo pieces by present author. The aesthetics found in the solo pieces showcase extreme cases of editing and focus to turn recordings of performances into sets of separated audio samples sometimes placed singularly or stacked on top of one another in order to interacts, either in an entirely creative or musical way (pitches from same or different instruments stacked together to form chords, dis-chords or something in-between the two). The only composition which comprises of edited performances past what was actually played is *In Search of Enchanted Soundscapes*, a collaboration with selected members of ACMG - namely Professor Alan Williams, Doctor Philip Brissenden and Doctor Timothy Wise.

In the first part of this chapter discussions were made about the rationale behind this research project. In order for the uninitiated reader to understand the significance of tuning systems and its impact on music in general, the next part of the chapter will provide sufficient examples of historical evidence of this, as well as presenting the research questions for this research project. In this context many key facets are responsible for the development of musical taxonomies that eventually become such phenomena within many a music culture. Although, it should be noted that a set of musical guidelines are important within a musical culture, still we need to raise the following question:

How do we classify which fundamental elements fall within a particular musical culture and which do not?

Tuning Systems

First of all, in order to segment these elements into a conceptualized taxonomy we arrive at a phenomenon that usually is described as a tuning system, a process that in most (if not all) cases has taken several centuries (if not millenniums) to establish. Unfortunately, definitions of any specific tuning system are not always easily explainable, the boundaries for acceptance in some cases are not always definable to the majority of (past and/or current) practitioners of musics for each and every single culture. Although we would strongly associate certain instruments with specific musical cultures, it is important to address that not all of these emerged from their respective culture in the exact physical appearance they are most identified with today; in ancient times trading routes between two or more countries/cultures were common, involving exchange of different types of goods (i.e. food, spices, textile, hand crafted equipment, general tools etc.), thus similarly an emergence of new musical instruments would be introduced largely due to temporary or definite/permanent employment in musical courts by musicians originating from another culture or through permanent settlement for other work-related reasons.

In spite of this aspect, diverse musical cultures would experience some exchange of musical instruments whether culturally related or not. To varying degrees, changes and customization would be applied to these newly adopted instruments – this implies a somewhat new set of propositions for instrument design, by incorporating new ideas into already existing instruments, or simply embracing new instruments and customize these by adopting a set of features (unique to that culture) to accommodate with the respective tuning system associated with that particular culture. As a consequence, new instruments would introduce a set of design principles that would either champion or challenge already existing ones. This process could, for instance, introduce new sonic flavours to that particular culture (not found on already existing instruments within that particular culture), and/or suggest new solutions or approaches towards instrument crafting that would improve upon previous problems/challenges found on existing instruments, which would render old instrument inferior to new ones – further, new designs would improve on issues such as limited range/register of pitches, lack of options, or flexibility that would enhance precise and fluid playing on already existing instruments.

One particular approach to identify a tuning system can be done through examining core musical instruments; commonly tuning systems are associated with a selection of unique musical instruments specifically made/crafted and/or deeply rooted within a particular music culture. Although this is not always applicable to every musical culture, a couple of examples should be mentioned here; for instance, a selection of instruments particularly found in Indian Classical Music (raga), and Indonesia (gamelan), considered uniquely associated with each specific culture.

Indian classical music can be identified and distinguished into two groups; Hindustani (comprising roughly the Northern part of India) and Carnatic (roughly the Southern part of India) classical music. Although, there are also a selection of instruments that are unique to either of these groups; the reasons for this can be attributed to much exposure of outside influence through numerous wars/occupation and noticeable immigration from nearby countries (reaching as far as Persia) in the North, while in the South barely any exposure of outside influence occurred at all. Common for both parts of India and Indian Classical Music is the appearance of numerous instruments classified as lute instruments which today are considered the symbolism of Indian music (Sorrell & Narayan, 1980, p. 48). Interestingly, lute instruments are not exclusively associated with Indian musical culture; among others, these are commonly featured in both Arabic and Western musical cultures and we should address that these instruments, most likely, were firmly established within their respective musical cultures before they actually emerged in Indian music culture.

However, among the Indian lute instruments that best exemplify the uniqueness of Indian sonic characteristics, is the *sitar*, which is a long-necked lute instrument commonly associated with Hindustani classical music. Among the most distinctive properties on the instrument, are moveable frets (in order for the sitar to produce notes that are slightly sharper/flatter), a combination of main and sympathetic (also known as chikari) strings (the two lowest tuned strings reproduces drone sounds), hollow gourds (responsible for bringing balance and resonance to the instrument) and a number of additional bridges which also includes the Javari bridge; exclusively an Indian phenomenon (which creates the shimmering and buzzing sounds associated with the instrument) - all these elements play a major part reproducing the special timbres/flavors associated with the instrument. It should be noted that the descriptions provided here are simplifications on matters that in reality are far more complex than actually proposed, and mainly offered at this point as an understandable insight to the uninitiated reader.

As an instrument the sitar is highly regarded within its own culture, even considered by some as the heart and soul of Hindustani instruments. It was considerably popularized to Western audiences by Ravi Shankar in the 1950's and 1960's when he toured the Western world exhaustively. While being the main advocate responsible for bringing awareness of this instrument to the Western world in recent times, Shankar influenced Western pop/rock and psychedelic music in the 1960's by inspiring a number of key musicians such George Harrison (first example of a sitar on a pop/rock song - *Norwegian Wood* from the album *Rubber Soul*, by *The Beatles* released in 1965) and Brian Jones (featured on the song *Paint It Black*, by *The Rolling Stones* released as a single in 1966) to pick up this instrument.

Despite its current strong position within Indian musical culture, it is unlikely that the sitar originates from India, but most likely introduced in the 13th century by one of the most important musicians ever to emerge from Indian musical history, namely Amir Khusrau. A son of immigrant parents from a region with strong ties to Persian music culture, a number of scholars have suggested that Amir Khusrau adopted and modified the Persian sehtar lute instrument to accommodate Indian music and tuning system – however it should be stressed that a number of scholars are yet uncertain about which of the current features to be attributed to Khusrau, and which ones were adopted by other musicians at a later point in time (this will be discussed later on in this Thesis) (Wade, Music in Indian - The Classical Traditions, 2008, pp. 94-95). The sehtar originally featured three strings (upon which the strings were reversed for the sitar) and only one regular bridge (not Javari bridge), while omitting moveable frets nor any gourds attached to it.

What we establish here by using the sitar as an example, is that an instrument which might not have originated from the musical culture nor the tuning system that it is currently most associated with, can, however, through a process initiated by a number of modifications spanning over a number of years (or even centuries) eventually turn into a distinctive instrument that firmly represents a completely different musical culture and tuning system than originally associated with. Thus, several instruments attributed to Khusrau can be found in Arabic music containing similar physical shapes and names.

As we have observed, the sitar is a perfect example of one particular type of instruments deeply rooted within its own musical culture and tuning system, while at the same time sharing some commonalities to similar instruments found in other cultures (due to obvious reason already stated above) – there are also other examples of instruments or even categories of instruments uniquely distinctive to their own musical cultures completely devoid of any historical commonalities nor share any of the traditional manufacturing principles found in either Western, Arabic or Indian musical cultures. One such example can be found in Indonesia, where a vast number of traditional ensembles have existed for many centuries and can be found in various although similar configurations on each island which comprise this nation; the ensembles discussed here are commonly known as gamelan ensembles. Gamelan is interesting from a number of perspectives, among the most distinguishable facet to be addressed here is the fact that the majority of all instruments in gamelan ensembles consists of percussion instruments, this also reflects the musical focus which is different to other common musical cultures; the percussion instruments maintain the dominant role and priority within most performances/compositions, while the remaining few melodic instruments present in these ensembles play a secondary role in order to complement their percussive counterparts.

How can any authentic tuning of gamelan instruments possibly be achieved (or other tuning system that demonstrates significant deviation), and how can this be transposed into digital computer-based domain through the innovation of VMKLI's and yet manage to retain the tuning principles of gamelan intact?

Due to the complexity of an extensive exploration of all configurations found in all Indonesian gamelan ensembles which covers all possible configurations of instruments and approaches towards tuning within the limitation of this type of project would prove entirely impossible, thus this research is limited to focus on only two islands, namely Java and Bali (limited to one categorisation of gamelan ensembles for each island, only (Gamelan Sekar Pethak and Gamelan Gong Kebyar, respectively). It is worth mentioning that even these islands have slight variations in terms of instrumentations, set of principles in terms of tuning, and prefer or apply tuning in their compositions slightly different from the other island. Lastly, the reason for choosing these specific islands is mainly due to Javanese and Balinese gamelan appears to be the only islands sufficiently covered by a variety of scholars.

Gamelan ensembles mainly comprises percussion instruments with the addition of a small selection of melodical instruments (which we will not discuss further in this research). The percussion instruments are made either of bronze, iron or a similar type of material, and consists of numerous metallophones, gong-chime kettle and small/large vertical gong instruments. Despite the fact that numerous ensembles are comprised of the exact same instruments, however, there are no standardized number of keys on the metallophone instruments, number of gong-chime kettles per instrument nor an exact number of smaller or larger vertical gongs in any gamelan ensemble. This further prevents us from firmly establishing a common denominator to help identify any precise pitches or measurements that would apply to the tuning of each key and each gong-chime kettle on any gamelan instrument. Deviations of up to 300 cents on the first key on one metallophone instrument compared to another in a completely different ensemble have been detected, which would certainly be quite a noticeable deviation in most other musical cultures.

Another interesting aspect about gamelan, which in some sense is self-explanatory from the information above, no two gamelan ensembles will sound exactly the same, even though they; 1) comprise of the exact same amount and types of instruments and manufactured similarly to another ensemble and/or crafted by the same maker, and 2) situated on the exact same island. Uniquely when compared to other cultures, decisions on manufacturing/tuning of each gamelan ensemble are either done by the gamelan manufacturer alone or in accordance with the leader of that particular ensemble. Tuning of gamelan instruments appears in different stages of the fashioning and finishing process, the initial tuning already begins when the instruments are crafted, a number of craftsmen hammering the instruments partially into shapes and its approximate thickness while the bronze is exposed to the furnace and appearing glowing hot, and yet another fine-tuning process during the finishing stage of crafting the instrument when additional hammering and filing occurs, this a delicate process which requires the utmost attention as the instruments are in a risk of breaking at this point and when finally being cooled down (we will go into depth about this in the chapter about gamelan).

In order to encapsulate all the information about gamelan discussed so far into one big container of information, it is obvious that we by now have encountered some problems in terms of how a tuning system for gamelan can be properly interpreted (or even conceptualized). Especially, taking into consideration that a Westerner whose point of reference to tuning involves a rather systematic approach where measurement of firmly established, exact numeric values are a great asset to help identifying tuning of instruments. In contrast the tuning process of gamelan instruments are decided by the leader and/or maker, with their personal ideas of how instruments individually and as a whole (ensemble) should be tuned. Whilst there are principles of tuning that can be discerned and will be the subject of analysis within this study, such a case might still appear rather random to a Western musician/scholar.

So, what have we gathered by observing the examples of the two very different cultures comprising Indian classical music and Indonesian gamelan? In essence, what we have observed is that the concept and understanding of tuning and how to approach tuning systems can vary from one culture to another. Also, through these two examples, that tuning systems and their distinctive instruments can arise from different reasons; in the case of Indian classical music we observed that some of the most common and most well-loved and praised instruments appear to originate from another culture, thus an adoption of these instruments has been necessary in order to integrate them into the new culture/tuning system, while the example of Indonesian gamelan, shows us that the instruments appear to gradually have emerged and the ideas and concepts of the instruments should already be inherent with the tuning system in this particular culture.

In order to possibly get a closer answer to aspects that involves conceptualization of tuning systems in general, a logical place to start might be by examining the earliest known example of one person approaching tuning of instruments. The first known person to be attributed a concept of tuning system appears to be Ling Lun, a minister or court musician under Emperor Huang-Ti in China (also commonly known as the Yellow Emperor in Western terminology), approximately 4700 years ago. Ancient Chinese historian Sze Ma-chi'en claims that Ling Lun came up with the mathematical formula for the pentatonic scale, and operates with a tuning similar to what we know today as Pythagorean intonation tuning, and in recorded theory (though not in musical application), the twelve-tone scale is considered as old as the five-tone scale (Partch, 1949/1974, p. 362). However, in modern times we do not really know much if anything about Chinese music and tuning system prior to Ling Lun, even though his importance on Chinese music has achieved an overwhelming support by a number of reputable scholars from past and present times, there is some apparent evidence that would suggest that Chinese music had developed at a significant stage prior to Ling Lun.

Among others, Kartomi claims that Chinese music already had established a classification system for instruments, namely pa yin, approximately 5000 years ago (3000 B.C.) (Kartomi, 1990, p. 34). According to this information, this would have occurred some 300 years prior to Ling Lun, and if these proposed times display absolute accuracy (which can be a problem regarding ancient documentation, also the reliability can be affected due to some information mixing factual occurrences with legend), we could firmly conclude that Chinese music would have reached a sophisticated level prior to Ling Lun. This leads us to the next question in regards to understanding how a tuning system arises;

Why does Ling Lun's contribution to Chinese music have any significance to this research?

The main reason why Ling Lun is presented here is because he appears to be the first ever documented individual to provide a concept of a tuning system in music history, and secondly because his contributions can showcase how the basis of one original idea/concept for tuning can evolve through millenniums and become a far more complex taxonomy which includes numerous instrumentations (either originating or adopted from other cultures and customized to become accepted as native instruments).

Thus, this leads onto the next aspect that needs to be discussed to further provide a comprehensive understanding of different categories of tuning systems. In order to understand the significance of a tuning system we need to examine the polarities of possibilities for change in tuning over time within a musical culture. The present author has expressed these as falling into one of three possible classifications;

1. **An evolved tuning system**, which means that it is an indigenous tuning system that evolved naturally over a long period of time, in which case no known originator can be entirely credited for the invention of the tuning system (Indian tuning system, Arabic tuning system, gamelan etc.). Such a system is certainly subject to change, but this change might be very slow and in reality the culture is likely existing in a form of stasis.

2. **An invented tuning system**, which means that one person or a small group of people can be solely attributed for the invention, different to the two other options – this invention would have been established within a short period of time (i.e. Wendy Carlos, John R. Pierce/Heinz Bohlen etc.).

3. Between these two polarities exists a further possibility where an **innovation (or innovations) within a musical culture** have solved a problem or a set of problems from an originally existing idea that arose within an evolved musical culture; as with the first option, there may be no known originator for the invention of the tuning system, although we can often trace singular individuals due to their contributions (i.e. Mersenne, Galilei, Helmholtz *etc* in relation to our own Western twelve tone equal temperament).

In Western tuning system, we have examples of individuals whose contributions probably are as significant or comparable to Ling Lun. One of the most important figures to be associated/credited with Western tuning system is Pythagoras. His innovation is commonly described as Pythagorean tuning, he proposed two different suggestions 1) a 7-tones per octave tuning based on “pure” perfect 5ths (3:2), and 2) a 12-tones divided per octave tuning, in both cases intervals would be based on Just Intonation. It might be justifiable to say that Pythagoras laid the foundation for the Western tuning approach as his proposition of a 12-tones per octave for Western tuning system is still the most widely accepted approach in modern times, although a few significant modifications have occurred since Pythagoras' time.

Interestingly, it should be noted that Western tuning has evolved most significantly in the past 400 years, from the original template of Just Intonation proposed by Pythagoras, through a battle between meantone temperament, well-tempered and equal temperament which lasted for at least a couple of hundred years, until the latter became the widely accepted approach and the standard in Western tuning system sometime in the 19th century. The concept of equal temperament might be considered a compromise compared to its predeceasing ideas, whereas intervals reproduced in mean-tone, well-tempered and Just Intonation temperaments are variably known for producing either exceptionally beautiful tones and in other cases less desirable tones; equal temperament on the other hand, appears to reproduce nice sounding tones (although none which are either exceptionally beautiful nor less desirable) all across the range of the octave. "Beauty" here, is measured according to the aesthetic encapsulated in the tuning approach.

The concept of equal temperament dates back to ancient times, and its first proper definitions in Western music appears to date back to the 4th century B.C. and were proposed by Aristoxenus, however it is unclear which exact (equal) parts these were supposed to be (Kuttner, 1975, p. 174). The first mathematical concept of a 12-tone equal temperament is commonly credited to be an invention derived from China and first published in 1596 (Partch, 1949/1974, p. 381). According to Mingyue the musicologist, mathematician and astronomer, Prince Zhu Zaiyu (1536-ca. 1610), appears to be the first person to solve the mathematical problem dividing equal-tempered scale into twelve pitches (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 131). However, opinions are divided among scholars about whether this is entirely based on original work or a continuation on previous findings (Kuttner, 1975, p. 173).

The emergence of 12-tone equal temperament in Europe likely appeared sometime around the turn of the 16th/17th century, although crediting one specific originator to this phenomenon may be somewhat controversial; by coincidence Simon Stevin appears to have made similar finding at the same time prince Zhu published his works, but whether he was aware of prince Zhu's finding or came up with the idea entirely on his own is the subject of continuous research and discussion (Kuttner, 1975, p. 167). Further, another suggestion has given credit to Mersenne as the originator to propose the idea of 12-tone equal temperament, suggesting that the idea originated through the discovery of written documents (proposing the mathematical formulas of equal temperament) arriving from a shipment of goods from China by the old silk route. Whether the shipment of these documents appeared intentionally or by accident is unknown. Although we cannot verify whether this story is true, it is quite probable.

Different from the examples we have just observed, there are examples of modern tuning systems where we can firmly credit a true inventor of such a phenomenon. Among some of the prominent musicians and composers in modern Western music, Wendy Carlos invented a set of completely new tuning systems – the Alpha, Beta, and Gamma scales, and used these tuning on her studio album *Beauty In The Beast,* released in 1986. Although, these are distinguishable and unique tuning systems likely created for a number of different reasons, one apparent being to experiment with new tones to produce better harmonies - such as reproducing more beautiful triads ((solving an existing problem found with 12-tone equal temperament) and/or as a hobby to explore something groundbreaking and new for the shear enjoyment of it), while the majority of the tones are alien to Western tuning still some of the main principles of this tuning system suggests that this is a distinguishable Western creation, not likely to have occurred in another musical culture. For instance, the fact that the divisions are based on pure intonation 5ths (3:2 = 701.995 cents) harkens back to the original ideas proposed in Pythagorean diatonic scale; although measurement of intervals are equally divided in all of Carlos' propositions, the values are based on entirely different ideas than the ones found in Western music.

Another example of a modern tuning system where we can easily identify the inventors behind the tuning system, is the Bohlen-Pierce scale. This tuning system was invented, apparently independently by two microwave engineers who coincidentally created it at approximately the same time without awareness of the other. Although, no obvious similarities to Western tuning can be found based on the measurement of singular intervals or divisions which are based on tritaves (i.e. the value of octave and 5ths combined = 1901.995 Cents per division), still traces of Western principles appears here as well since the usage of justly tuned 5ths applies in this tuning – further, two options for Bohlen-Pierce scale exists; 1) equally divided intervals, or 2) justly tuned intervals, which are common Western approaches for dividing intervals.

We have now observed a number of examples which can give some further answers or clues in order to understand some of the complexities that involve the phenomenon of tuning systems and as such it is obvious that the origin and/or originators of ancient/old tuning systems are difficult if not impossible to trace, yet numerous factors are involved which complicate matters further. Unfortunately with the reliability of old sources, sometimes only a fraction of information might appear to be true, often it is unclear what previous contributors provided/suggested, in a myriad of endless information and various contributions/propositions involving tuning – consisting either of complete suggestions, partially solved, incomplete, disappeared, stolen, and failed attempts to solve answers to tuning from certain an endless amount of contributors, could potentially have affected the evolution for a particular tuning system.

Further, some contributors may have been largely ignored because their ideas were too radical for the time; innovation generally ignored by contemporaries may yet be picked up by others at a much later point who greatly based their ideas on this previous work and propose it at a time when musicians from the same culture are more accepting of these ideas. One facet of this is that it may result in commentators and implementors receiving much more acclaim than deserved, and perhaps being improperly credited with invention to their names. Other situations may involve slight contributions where only a fraction of new information has been introduced in order to solve minor/major contemporary problems with tuning.

Summary of Factors Which Effect Tuning Within Human Culture

This introduction has summarized the factors which affect tuning and proposed a broad taxonomy of classification of tuning systems.

In order to successfully accomplish the abovementioned objectives, the following research questions have been proposed

1. How can I make both user-friendly Interfaces and at the same (time) include components that will make them capable of reproducing sounds (characteristics which can be associated with) which relates to the actual tuning systems?

Decisions as to Software Interface Development

An extensive process involving thorough examination and evaluation of a comprehensive selection of potential tuning systems was undertaken at the initiation of this research project. In this process, the key point/idea was to select five tuning systems which showcased significant divergence from one another as well as to the Western 12-tone EDO tuning system. This selection contained a variety of two distinctive types of tuning systems; 1) invented tuning systems by a specific individual/s in modern times (and developed within a limited time span) with no particular custom made instruments to accommodate these tuning principles, 2) traditional tuning systems developed over the course of centuries containing a variety of instruments deeply rooted within their respective cultural context. As a proving ground the invented tuning systems were approached first due to their less complex nature and lack of cultural baggage before I undertook more ambitious projects. The attention to both aforementioned categories required completely different approaches; processing information about modern tuning systems appeared to be easily acquired, definable and allowed for much freedom when developing both keyboard layout and timbre for the VMKLI's. On the other hand, traditional tuning systems appears to be of a much more problematic issue; due to each pertaining an intricate/complex taxonomy which involves various fashioning processes on instruments and divergent developments over the course of their history which are all deeply rooted within their respective culture. Thus, a number of issues needed to be taken into consideration; not every single tuning system contains 1) … precise calculations of intervals, 2) … firmly definable and accepted instructions on how instruments should be tuned, 3) … easily categorized groups of instrumentation.

From a technical perspective the aforementioned issues proved to be a twofold concern, all of the traditional tuning system both forced and restricted the progress of developing the VMKLI's; an extensive period of the research project entirely dedicated to explore and development of literature review related to each respective tuning system was required before work and development on the VMKLI's could be undertaken. This includes all fundamental/basic aspects of the culture/history/instruments/timbre all needed to be properly processed before actual work on the technical Interfaces could be undertaken. Although addressed previously, restrictions in this context would relate to timbre and type of instruments which are most strongly representative for each respective culture/musics, in essence this means aspects which definitely by no means could be ignored in order to establish the desired results by recreating sounds which would evoke authenticity and appear relatable to sounds associated with each respective culture. However, once all literature had been thoroughly processed then it opened up some possibilities for original and innovative thinking for entirely original keyboard layouts that would diverge from existing propositions – and to some extent the resulting VMKLI's thus encapsulates several ideas of instruments onto singular playable Interfaces.

The following two questions arise as a natural consequence of the contextualization provided in the introduction; analysis surrounding these questions provides significant evidence as to the success of each of the interface from a design perspective.

1b. How shall I recreate the instruments that are most associated with each tuning system in appearances or in what way to feel natural to play on the Interface?
1c. What sacrifices/compromises do I have to make in order to succeed?

Implementation Within Practice
2. How to develop personal composition and production practice which integrates the interfaces in collaborative endeavour?

The following questions arise as a natural consequence of the contextualization provided through this practice; analysis surrounding these questions will provide significant evidence as to the success of each of the interface from a design perspective.

2a. Which musical communities would be interested in the interfaces and what sort of concepts shall I have in mind for each musical Interface to make composers/performers more interested in them/ favour them instead of compared to the options already available?
2b. How will composers respond to my invention, will they easily adapt to the functionalities and the additional features of the Interfaces?
2c. What kind of playing positions? Deployment of existing technique, such as (but not limited to) keyboard technique will be most appropriate for each Tuning system?

And are there general principles that can be drawn from specific case studies as to how to work out layouts that will seem logical for a performer/musician/composer to understand?

And finally, a broad, encapsulating question;
2d. What kind of issues do I need to be aware of when I customize the Interfaces to make them compatible with a Tablet such as iPad?

Structure of the Thesis

Evidencing the literature review that has been undertaken in order to accomplish this project is problematic. Literature review has been undertaken from a number of interdisciplinary perspectives; some extremely straightforward, such as understanding the range software solutions available at the commencement of the project in 2018 and some highly esoteric, such as human perception of tuning and its origins. Not all of this literature review is crucial to understand and evaluate the success of the project, but it was crucial to undertake in order to gain the knowledge to design the interfaces. To the reader initiated in various aspects of tuning complexity and variety within human culture, this introduction will give a sufficiency of context with respect to tuning within culture to understand the project.

The balance of the literature review from different perspectives will appear later in the thesis and will serve as reference and background to support the central practice. The thesis as a whole will be structured;

Chapter One	*Introduction and Context*
Chapter Two	*Methodology*
Chapter Three	*Music as a phenomenon through relation, language, evolution of mankind, historical evidence of musical artefacts and earliest evidences of written/scribed documentation of music*
Chapter Four	*History and evolution of European Music and inherent Western tuning system*
Chapter Five	*Presentation and discussion about all five tuning systems dealt with in this research*
Chapter Six	*A Short Literature Review setting out the software available at the time of commencement of the project.*
Chapter Seven	*Development of the Interfaces*
Chapter Eight	*Implementation of the Interfaces*
Appendix One	*Indonesian gamelan*
Appendix Two	*Indian Ra*
Appendix Three	*Arabic Maqam*

Table 1.1. Structure of Thesis

A significant part of this research has been dedicated to the development of a substantial literature review; the reason behind this mainly relates to the problematic nature of research related to non-Western tuning systems in general – many different facets requires attention in this case; among others, division of tones are divided per octave or other dividing measurement practiced by musicians from these cultures.

Chapter 2 seeks to explain all facets of the research (i.e. both practice-based perspectives and theoretical perspectives) through a selection of methodologies (which includes the approaches and strategies from initiation to completion of project). These facets will be justified through a number of methodologic key elements which comprises of research methodology, design methodologies, design principles, research tools and research model.

Chapters 3 and 4 serves as a prologue (or precursor) prior to the presentation and discussion of all five tuning systems dealt with in this research project. The intent with the former chapter (chapter 3) is to showcase a number of phenomenon and behaviours/traits inhabited among humans and their relation to and usage of music independent of any culture (cultural association). Chapter 3 investigate aspects of the human linage and address evidences of the earliest signs of cognitive/creative behaviours among humans as well as emphasizing the creations of the earliest and most significant musical artefacts/instruments known to mankind. Further, the chapter seeks to explain some of the deeper questions related to the nature of the human perception of tuning and its development within our species before it moves onto examining the earlies known musical artefacts and eventually concludes with the earliest known concrete documented/scribed/written evidences of tuning.

Chapter 4 seeks to explore all known documented tuning practices of the Western World through the earliest evidences from ancient Greek and the various concepts of tuning introduced in European music (from its adapted principles and continuation of ancient Greek music) past ancient Greek and up until current day. This is fully dedicated to the history and evolution of European music and the diverse propositions of tuning systems and practices between ancient Greece and current-day Western/European Music.

The intent with Chapters 3 and 4 is to provide an introductory overview (or prologue to the final studies in the appendices section) of musical tuning in order to prepare and inform the uninitiated reader about the phenomenon of tuning and human perception towards sounds prior to Chapter 5. Both chapters 3 and 4 will showcase written evidence on various tuning propositions, keyboard layout design innovations and instruments; the former will be almost exclusively based on information and documentation prior the emergence of ancient Greece, while the latter will be based on information emerging afterwards and entirely limited to ancient Greek and European Musical cultures.

All remaining chapters primarily will deal with and explain the practical aspects of the research, namely the creation of the VMKLI's and later progress into the creation of the musical compositions composed and presented for this research.

In order for this research to further comprehend and provide all necessary information and tools to instruct the uninitiated reader - further investigations of instruments, such as fashioning procedures, tuning variations and particular flavouring of musical tones, sufficient knowledge about history in order to understand the origin of the culture and the emergence of its musicks etc., is essential. In certain cases, tuning of instruments requires more complicated investigation because no proper template is provided within its cultural context (or easily available), in other cases Westernization or strong influences from outside cultures have greatly affected the practice of music in some cultures, thus an important "debate" arises about how one should understand and separate between the facets of the music which are considered genuine/authentic and what has been affected by outside influences.

Thus, the requirement of a comprehendible "handbook" provided to individuals neither accustomed to or related to the cultures of these tuning systems have been necessary in this project (for further reading of these matters please forward to the appendices section). In addition to this, the literature review contains a number of (fundamental) key factors necessitated in order to substantiate a significant amount for the reasoning to validate the technical aspects/decisions made to all of the VMKLI's created for this project both invented (modern) and evolved (indigenous) tuning systems/cultures, further this work also accounts for a number of propositions of already invented existing keyboard solutions proposed in the past and present day within the notion of known Western practices – all this information will be discussed/dealt with/provided in Chapter 4

Chapter 6 provides an introduction to software developed Interfaces and keyboard layout designs, the chapter starts with a short Literature Review which showcase existing software alternatives and recent developments of keyboard layout propositions before the chapter is concluded with discussion, criticism and validation for the need of VMKLI's. The chapter will exclusively provide information regarding the current progression of software developments or limitation thereof at the commencement of this research project (although these discussions will be explained further at the beginning of chapter 6).

Chapter 7 and 8 comprises of all the practice-based facets of this research and divided into a former chapter (Chapter 7) which guides the reader through all software developmental stages of the VMKLI's from their initiation to completion, while the latter chapter (Chapter 8) is dedicated to implementation of these VMKLI's into the creation of musical compositions – this includes all additional musical and technical contributors (musicians, collaborators, arrangers, recording engineers/assisting engineers), compositional concepts, mixing approaches and production aesthetics for all five musical compositions.

The three individual musical culture studies regarding traditional/indigenous/evolved tuning systems are enclosed in the appendices and presented as separate "handbooks" in order to serve a couple of different purposes; 1) arising questions as well as providing some basic problems/concerns that Westerners encounter by exploring different traditional tuning systems - mainly how to approach different aspects/conceptualizations of tunings and the qualities associated with sounds being reproduced by instruments associated with the respective cultures (which are often experienced as puzzling to people not accustomed to these), 2) the level of complexity related to traditional tuning systems since these concerns may not likely appear to be understood without a proper guide for the uninitiated reader. However, the reader will be presented with all integral information about all five tuning systems (including the three evolved indigenous cultures) in relation to the creation of the VMKLI's in chapter 4.

The studies in the appendices section will deal with one traditional tuning system each, and primarily serves as "guides/guidelines" for the development of the five VMKLI's and eventual implementation to the five musical compositions enclosed in this research project. Thus, we can conclude that the Thesis (Besides Introduction and Methodology) essentially is divided into two distinctive parts; 1) Theoretical-based facets of the research (Chapters 2-5), and 2) Practice-based facets of the research (Chapters 6-8).

2. METHODOLOGY

The purpose of this chapter is to provide insight into the methodology used during the project - including the research model - all of which encompasses integral requirements in order to complete the current research project. The research model takes for its basis the following three different methodologies; *practice as research* and *software design as research* both of which are supported by established conformities/compliances related to methods within *grounded theory*. Thus, this research project can be explained/described as an outcome resulting from a mixed methodology rooted in cycles of Action Research (Lewin, 1946). Further, it should be noted that the latter part of this chapter will provide thorough explanations of the *research tools* used and gradually move towards subsequent discussions to showcase a firm *timeline* followed by a detailed *process of development and completion* provided by the tail end of this chapter.

This research can be defined through a number of aspects which are grounded in the phenomenon of practice-based research; inherent in this process are a significant number of theorical dispositions related to one of the main objectives for this project; namely the development of the five VMKLI's based on five different non-Western tuning systems (developed and created through digital computer-based programming software technology). The inclusion of theory has been an integral asset and provided thorough insight into the phenomenon of tuning systems across a spectrum on both evolved and invented tuning systems in order transmit the information onto the creation of the VMKLI's. As a result, the significance of the aforementioned information would eventually affect the progress for a variety of reasons; in particular this relates to the conceptualization of sounds and the initiation of (or fundamental) technical decision-making process in order to realize the widely accepted conceptions of tuning based on the five non-Western tuning systems explored in this project.

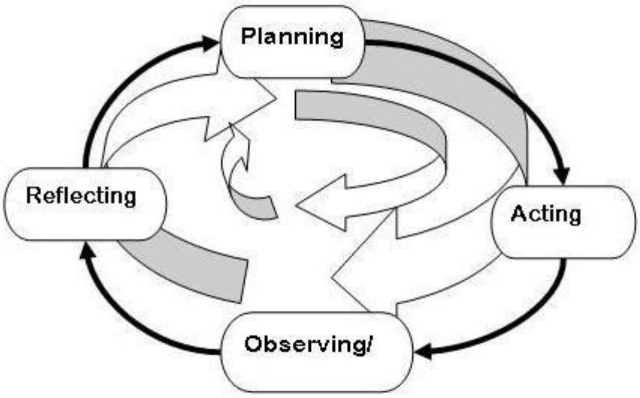

Figure 2.1. Demonstrates the process of Action Research

Taking into account the aforementioned research questions; in order to seek and develop comprehensive answers, the necessity to approach numerous innovative technological and programmable software was integral for the development of the VMKLI's. As a result, the intent conceptualizing sounds for each Virtual Musical Interface would eventually take as its basis numerous conceptual ideas derived from their inherent indigenous origins. Significant in the process, each VMKLI would retain some obvious musical aspects originating from the respective tuning system which each VMKLI would be based on.

Further, it is important to address that the main intention creating VMKLI's was never to fully recreate nor reproduce exact sounds of specific musical instruments associated with any of the various tuning systems/musical cultures explored in this research project. However, according to the evolution of the project it is quite possible that potential changes may have occurred after the assemblage and processing of all necessary data.

Prior to the initiation and development on each VMKLI, the final outcome would be impossible to predict. Thus, the resultant VMKLI's would eventually provide a mixture of expected and fully accepted conceptual ideas deeply rooted within confinements of their respective music culture and tuning system mainly through theory, while some level of experimentations within design and timbre of sound would also be integral to the creational developments towards the finalizing stages.

However, during the initial planning and preparation for this research project, one of the main objectives was to conduct a number of interviews and inviting participants to take part in case studies; primary target group was aimed at musicians and composers and to a lesser extent, music producers. The purpose with the case studies was to allow one participant each to test out the VMKLI's for the duration of approximately 30 minutes to one hour, and then let them provide me with feedback about; 1) the overall appearance of the keyboard layouts, 2) arrangements of playable objects, 3) the shape of them, 4) provide comments about additional effects and options to reshape timbre, and finally 5) provide suggestions for improvements on aspects of the keyboard layout/VMKLI, if required.

Unfortunately, this aspect of the research project would end up being somewhat compromised due to the COVID-19 Pandemic. Although, a limited number of meetings with selected members of staff at the Music Department of University of Salford were conducted in order to allow them to interact with and provide feedback on the then current prototypes of keyboard layouts and/or VMKLI's. In the end, the main supply of feedback and primary user of the VMKLI's would be myself, and the testing arena would be the musical compositions that form the backbone of the creative outputs of this project.

The developmental stages of the VMKLI's

In the process of creating all keyboard layouts and the eventual VMKLI's, the initial expectations were to apply all the assembled theory based on the tuning systems and assist integral data on fundamental understandings to be readily transmittable into the digital programming domain during the initial decision-making and consecutive developmental stages. The consecutive work on the development of all VMKLI's would result in minor reassessing on some aspects of previously encountered theory while this would simultaneously apply to the technical work and progress to be further encompassed and extended through processes associated with Action Research.

Within the overarching method of Action research various conceptual frameworks and methods were applied which render the overall methodology best described as a *mixed methodology* – the relationship between and definition of these elements is the subject of the next discussion, this includes definitions of grounded theory and how "discovered" parameters through the course of current research project whose aspects affected by the developments of methodologies based on Action Research (Lewin, 1946).

During the process providing a suitable methodology, research model, and research tools for this research project, a period of extensive reading and examining of other previously succeeded research projects took place. The conclusions drawn after reading a number of academic research projects - apparent similarities between this project and the one completed by Doctor Adam Hart at the University of Salford was apparent (Hart A. M., 2018, pp. 64-77). Among the similarities were the shared aspect of research-based research with focus on software programming developments and research tools used for the creation of independent programming software in order to develop and create tools to allow creations of musical ideas – however, it is important to address that besides these factors minimal resemblances between each projects can be found.

Both projects sought different purposes and answers to the respective research questions. Among the most apparent differences was the selection of target groups - whereas Hart's research dealt with music students entirety related to an educational/teaching environment, the target group for this research project for the most part involved myself.

Selection of Methodology

Prior to undertaking this research project, it was necessary to explore and become familiarized with available options of custom-made computer-based keyboard layout designs for a variety of different tuning systems extant around the world. My immediate discoveries revealed that focus on numerous tuning systems (indigenous or not) were quite popular among many contemporary researchers on music, however the recurring problem in this occasion was minimal attention to developments of new innovative playing interfaces - keyboard solutions in order to allow logical playable solutions for non-Western tuning systems.

Thus, the result of these findings leads to the following question: Why the need of new innovative propositions for keyboard layout designs and to what extent may these be perceived as suitable and readily available options for other purposes than the Western 12-tone EDO tuning system?
The question can be explained; however, a short recap of brief history on keyboard propositions may be required to provide sufficient information in order to bring some logical conclusion to this situation/answer. As such, it should be noted that the

significance of innovative keyboard solutions never was a phenomenon created overnight and its principles are likely to have been established during the 15th century with the emergence of the harpsichord.

The necessity for this innovation likely emerged as a phenomenon through the introduction of polyphony in music (which would be initiated during the early beginnings of the first millennium), thus affecting contemporary principles through the advancements of more complex musical and harmonically enriched elements/nuances to be encountered and eventually performed on musical instruments.

How would I approach the creation of keyboards through principles originating from creations based on the selection of the five different and selected tuning systems?

Generally, in order to approach and eventually undertake this task, a significant amount of time to pursue and evaluate an extensive amount of integral literature and immersion would eventually be required to amalgamate this comprehensive amount of significant knowledge/information about each tuning system (Grounded Theory).

However, it seemed apparent that decisions on designs could not be achieved without fully understanding a number of key aspects/facets within the respective culture explored; in this occasion targeting integral identifiable elements deeply rooted within the confinements inherent in the history of selected instruments and further fuelled by a level of established/inherent/contemporary hierarchic stature of these instruments and examined how these were adopted into their respective culture.

In this occasion, a significant amount of time was dedicated and devoted to conceptualizations on different aspects of design which in turn would prove to be one of the most crucial elements during the development of the software artefacts for this research project. In general, the eventual results would have significant impact on all elements of the creation of Virtual Digital Musical Interfaces (as they all would be executed and created through digital computer programming software). The concept developing software artefacts would require examination of two types of designing principles; the first being the overall visual appearance which also included another important aspect in order to encompass the overall decorative visual appearance for each keyboard layout, as well as all various features included on each Interface.

Further, in this process the limitations on visual aspects also applies to the final decisions discerning numerous dispositions of knob/key keyboard systems applicable to and in effect eventually used in correspondence with (or would provide some) inspirations for the final appearance on each keyboard layout. In addition to the above, a number of other visual designing principles to deal with various aspects of colour coding; by this meaning that a significant amount of decisions would be made using specific set of colours assigned to each Interface where the colour coding used for keyboard layouts most importantly would be assigned to each playable key/knob etc.

In order to aid any uninitiated reader through the overall understandings of and allow navigations through a variety of pitches in relations to the specific tuning systems for this research project, and in order to assemble these ideas through a coherent system which would eventually incorporate these ideas across intercultural purposes and aided through applying a four-way color-coding pattern based on the following criteria: 1) pitches that appears to be in correlation/or close approximation to pitches commonly associated with Western tuning systems (in accordance with pitches found in the Western 12 tone equal temperament system), 2) pitches that signify important reference points commonly associated with Western tuning systems as well as other music cultures (perfect fifths, etc.), 3) particular pitches that displays a succeeding division (octaves, tritaves, or other types of divisions), and 4) unusual pitches either unique or most commonly associated with a specific music culture (i.e. microtones or larger intervals in varying degrees). Further, particular color-coding patterns would also apply to various functions that eventually accompany each specific Interface.

The second principle of design, directly relates to the technical aspects on all Interfaces created for this research project; among the most crucial of these would involve decision-making in terms of sound reproduction which would include ideas/concepts in relation to how the sounds on each Interface would be constructed and conceptualized. This aspect would relate to the anticipated reproduction of sounds developed through a significant amount of time after numerous hours of preplanning, testing out the outcome of the prospects, then re-evaluate the then immediate current results and further implement these various prospects and propositions through programming, if necessary/needed. This process would be determined and enhanced with a basis on the following criteria: 1) dedicated attempts at recreating authentic sounds/timbres considered deeply associated with and rooted within the respective tuning system in question - although this would involve sounds to be approached with some level of logic and yet simultaneously subjected to some level of experimentation or “colorization” applied to the timbre in order for the instruments to achieve the satisfactory final results; through an admixture of combined shapes of waveforms, 2) allow the embodiment of singular instruments with strongly identifications to its respective tuning system (i.e. sitar, ‘ud etc.) to be the basis for its sound reproduction, or 3) to be completely rendered through new emerging ideas where the sole focus would be to create innovative sounds/timbres with a primary aim to take the basis on tuning relation between instruments on or other musical interrelations between sounds of instruments rather than focus on actual recreation on sounds of real instruments. It is important to address that all sounds (including effects from all additional features/functions) expected to be constructed solely through digital technology created using the programming software *Pure Data* (*PD*).

Further, the second principle of design was intended to affect any additional features/options to be included on each Interface, then the level of success and eventual effect on timbre would be assessed by myself based on interaction with and resulting effect on this “colorization” process to appear on the original sound signal. It should be noted that these additions would be affixed either as singularly fixed (i.e. non-adjustable) functions (for instance effects like tremolo, pitch bend etc.), while other features would allow adjustable parameters to interact greatly or slightly with the original sound source (i.e. effects affixed to knob or fader controllers) by allowing the user to add the amount of alteration within a fixed set of parameters to their own satisfactions. The creation of the VMKLI’s would forward the developmental stage to be a continuous and ongoing process until the finished results of the research to eventually emerge, as per Action Research and also defined through established confinements commonly associated with *grounded theory*.

Further, all aspects of design addressed so far would interrelate with one another to some extent; however, in order to address this more clearly, each function would eventually trigger and affect the activity associated with other aspects of the designing process (i.e. colour coding intended to aid in the decision-making process significantly with the emergence constructing the design of keyboard layout for each keyboard layout/VMKLI). Interestingly, all of these additions would initially start out as creative considerations which would be implemented by myself and tested out at various stages during the course of the research project in order to seek how their creative potentials would work in correlation with each VMKLI; after this stage these ideas would go through further stages of evaluations, tests, and re-evaluations before finally accepted or rejected by myself in the process.

In order to develop technical aspects for *software design* (which are associable with and discernible with each and every VMKLI), a number of issues occurred after sufficiently exploring each and every tuning system for this research project. The most significant discovery was the extreme level of complexity between the various tuning systems, in particular between evolved and invented tuning systems.

On this occasion, the modern tuning systems would prove to provide far less obstacles and identified through a limited set of established conformities, showcased through: 1) the size of intervals (intervallic values and their calculated space in-between intervals equal or not) corresponding to the respective divisions on the respective tuning system (with the exception of the Justly tuned version of Bohlen-Pierce scale) – in all cases, mathematical calculations would be achieved and demonstrated through fixed parameters of frequencies/pitches transferrable without much difficulty, and 2) the fact that both tuning systems would be associated with one category of instrument, namely electronic keyboards (different from traditional evolved musical cultures which are identified through a variety of instruments which encompasses its respective tuning system). In the case of alpha/beta/gamma scales, the inventor (Wendy Carlos) would entirely rely on a digital hardware synthesizer confined/integrated to a 12-tone piano keyboard layout system and retune each individual pitch in order to reproduce the sounds which are heard throughout the album *Beauty In The Beast (1986)*. Differently, Bohlen-Pierce Scale mainly would be subjected through numerous dedicated keyboard layout propositions, yet similarly would showcases little to no effort in development providing a unique timbre distinguishable and or lasting to become associable with the respective tuning system in the future.

As a result, this research project required a *bottom-up design methodology* (in accordance with other aforementioned aspects of the research established within grounded theory) to pursue aspects of design in order to construct software developments through gradual steps in accordance with the ongoing progress and development as the project would evolve. This can be described as a production of 'emergent' behaviours (*complex system*), rather than a *top-down methodology* which would allow a specific and planned goal of how the software developed through its initial preparation prior to the start of a research project (*complicated system*), largely due to the unpredictable outcome of software design to be anticipated beforehand (Wright, 2012). The exploration of the evolved tuning systems would require an extensive reading process to sufficiently acquire and comprehend all required information in order to further pursue and complete the practice-based work, thus required a bottom-up design methodology in order to succeed.

The various tuning systems would offer entirely unique set of characteristics to this project, thus all required completely different approaches through the perspective of conceptualizing distinct design for Virtual Digital Musical Interfaces; this is not completely limited to the concept of tuning and/or divisions of intervals/pitches (although it applies to the majority of these aspects as well), thus the requirement of further separating/segmenting the tuning systems (explored in this research) into two categorizations; 1) modern tuning systems (Alpha, Beta, Gamma scales, and Bohlen-Pierce scale), and 2) traditional tuning systems (Gamelan, Indian, and Arabic tuning systems).

The former group comprises a number of shared commonalities: the establishment of these tuning systems are not widely recognized besides a number of limited musical communities and were proposed by very limited amount of individuals within the past 50 years (thus these tuning systems have not evolved over a significant period lasting many centuries in comparison to their ancient evolved counterparts), lastly no distinct nor unique musical instrument can be singularly identified with either musical culture (although Bohlen-Pierce scale has been subjected to numerous examples of customized hardware keyboard – all of which have taken their basis on confinements derived from traditional piano keyboard layout) - thus no particular sounds/timbre can be distinguishable identifiable with either tuning system; in addition to this, no distinct musical instrument (past electric keyboards with custom made keyboard setups) can be uniquely associated with either tuning system (with the exception of Bohlen-Pierce Scale) nor any established system to forward unique practices can be identified prior to the initiation of this research project.

Thus, all of the aforementioned information would allow quite a few advantages when conceptualizing design in comparison to the evolved traditional tuning systems: among others, they would allow for much space of creative freedom (although this creative control would be remote within certain restricted confinements overall) both in terms of developing unique keyboard layouts as well as shaping unique sounds/timbres within certain restricted and accepted confinements (solely based on measurements of and divisions of intervals). Further, additional inventive features would be added without the expense derived from any distinct flavours strongly associated with the respective tuning system (among others, such as the fundamental drone tone found on instruments in the Indian tuning system).

On the other hand, each evolved traditional tuning system would showcase a number of obvious distinctions and eventually would reveal quite a number of boundaries which would require different level of attention prior to consideration of any designing and technical work be initiated. On this occasion, exploration of many different facets required close examination and eventually gradual processing of information in order to collect integral and sufficient characteristics associated with each particular tuning system and incorporate these onto the conceptualization on both aspects of design, during the developmental stage.

Software Development as Educational Research

In terms of choosing a methodology model for software development, a model called *'Software Development as Research'* (abbreviated *SoDaR*) was applied. This approach was originally proposed by (Brown, 2007), although it appears to relate to software development in relation to educational research (i.e. teaching pupils/students) based on a target group, although different from this research project, still many apparent similarities of this model coincides with this research. Hart describes the SoDaR model as follows:

"… a methodological model which 'is concerned with deliberately employing designed systems that embody a hypothesis about educative experiences, in order to illicit new research findings.' Software Development as Educational Research (SoDaR) situates software design in a context of constructivist educational research (see Brown 2012), an iterative process which draws directly from student experience and learning outcomes. The methodology aligns with complex system design, recognising the validity of emergent behaviours and rejecting the notion of absolute faithfulness to the initial design specifications present in top-down models …" (Hart A. M., 2018, p. 65).

Brown identified three stages of SoDaR "… 1) identification of the learning opportunity for which software development is required and establishing an appropriate approach to take advantage of that opportunity, 2) design and production of the software, and 3) implementation and refinement of the software via application in an educational setting (Brown, 2007, p. 3). Each of these three stages include processes of description, data collection, and reflection. There are some existing practices that SoDaR takes inspiration from, including software development cycle, extreme programming, action research, case study research, and activity theory" (Brown, 2007, p. 3; Bryars, Jesus' Blood Never Failed Me Yet, 1993). Although the third stage originally involved software development proposed for a target group primarily within an educational setting (i.e. computer software development/artefact presented by a creator (teacher) in order to forward interactions, response and eventual feedback from its participants - in this case music students). Initially, this research was aimed at a similar category of target groups by involving various music students to interact for similar purposes (i.e. engagements with the created technical artefacts, followed by response and eventual feedback). Unfortunately, due to unforeseen circumstances as a result of the COVID-19 pandemic, this aspect of the research could not be fully completed as initially planned, and would eventually be overseen, tested, evaluated and executed by myself in the end.

By applying the aforementioned methodology model, it allowed me as a researcher to draw minor conclusions gradually as the research project would evolve, progress and eventually transform aspects of the information onto the creative decision-making processes. Thus, expectations from the outcome of this model would result in some apparent alterations/changes from the anticipated outcome in comparison to my own expectations, in which I believed to be pursued according to more traditional approaches allowing the researcher to draw the final conclusions towards the end of the research project. Further, since an important aspect of SoDaR deals with interactions from other people (and their direct feedback) by testing out software artefacts constructed as part of a research project, it supports a qualitative research process. However, despite the similarities between certain aspects of methodology between Hart and myself, Hart would approach a group of participants and allow them to provide some aspects of the final evaluation and overall software designing process through addressing their subjective/objective opinions, differently I would end up predominantly doing the majority if not all of this work by myself.

Grounded Theory

Grounded theory was first introduced by Glaser & Strauss (Glaser & Strauss, The Discovery of Grounded Theory - Strategies for Qualitative Research, 1967/1999) who developed this research methodology after teaming up as a research team observing deaths at hospitals in the United States in the early 1960's. In this occasion, sociologist, Kathleen Charmaz (1939-2020) explains that integral to the fundamental principles of grounded theory is *positivism* (*natural sciences*) validating and falsifying hypothesis and theories (objectivity, generality, replication of research), with an emphasis to seek answers through observations, experience and data (*empiric*), and through the phenomenon on positivism "… led to a quest for valid instruments, technical procedures, replicable research designs and verifiable quantitative knowledge" (Charmaz, 2006, pp. 4-5).

Charmaz further explains that: "… grounded theory methods consist of systematic, yet flexible guidelines for collecting and analysing qualitative data to construct theories 'grounded' in the data themselves. The guidelines offer a set of general principles and heuristic devices rather than formulaic rules … Thus, data form the foundation of our theory and our analysis of these data generates the concepts we construct. Grounded theorists collect data to develop theoretical analyses from the beginning of a project." (Charmaz, 2006, p. 2)

As such, the dimensions on grounded theory which are related to this research project would further enforce a process allowing grounded theorists to collect, study and synthesize data through qualitative coding, which would enable the researcher to attach/label segments of data – a process in order to collect and sort out, while simultaneously allowing vast amount of and subsequent data to be collected and allow integral individuals the possibility to learn and be able to observe and process theoretical analyses (Charmaz, 2006, pp. 3, 10).

Mixed Methodology

In the discussion of different aspects of methodology, the necessity to seek different variables was taken into consideration in order to support different approaches of the methodology itself, thus resulting in a phenomenon commonly described as mixed methodology. The term mixed methodology commonly suggests a process which involves a selection of different approaches towards methodology to be combined and interrelate to each other, in order to successfully support the research process. In the next few paragraphs we will discuss the different approaches used in this research.

Software Development as Research (abbreviated SoDaR) is a fairly recent approach to Methodology, it should be pointed out that this approach initially was developed within the past 15 years; thus quite possibly numerous individuals may still be juxtaposed in-between two polar opposites – namely, 1) divided between individuals who possibly would question its validity as a Method due to its fairly recent proposition and argue about its validity due to its likeliness of still being at a stage of infancy, while 2) others may be able to foresee the potential and possibility to improve and expand upon this in years to come.

In this research, SoDaR was applied in combination with grounded theory for the following purposes in order to produce/achieve two categories of main outputs (largely due to the nature of this project being a practice-based project): 1) a practice based output was development through software artefacts, and 2) a theoretical output which dealt with examining the tuning systems, for the application and the overall examining of this practice.

By applying SoDaR it allowed me the possibility to produce practical output although requirement of interrelations with an additional Method was necessary in order to provide valid results; in addition to this, the inclusion of and combination of a theoretical element would be required in order to fulfil both aims. Thus, grounded theory was a sufficient/adequate option largely due to its ability to support/aid in analysis and extraction of the data gathered throughout the project. Grounded theory allowed for an analytical coding Method and supported the inclusion of complex system (i.e. bottom-up approach) of design in order to enhance emergent behaviour and interrelated considerations for software development, yet allow both technical and musical creativity. Grounded theory was also an adequate alternative for outcome/results of the software artefacts (for the most part) expected to yield unpredictable outcomes without the inclusion of thorough analysis and processing of all necessary data in advance.

Research Tools

Largely due to the predominantly practice-based aspects of this research, a set of *research tools* were necessary in order to produce a set of outcomes (i.e. the resultant creations of software artefacts) and in this occasion the requirement of Programming Platform as a research tool was integral to this process and the eventual success. In the end, this particular research tool was required in order to incorporate a comprehensive theoretical outcome.

However, selection on research tools for this project would prove to be a difficult task; in the beginning of this research project determination on selecting the object-oriented programming language software Max as a research tool appeared to be the ideal tool in order to construct and develop the resultant outcome of software artefacts. However, apparent during the developmental stages, despite that early prototypes for the two invented tuning systems were created at this stage of the research project, a compatible software which enabled performance according to the expected function planned beforehand, would prove challenging. During this work, it turned out that Max would not achieve the expected results (as a research tool) thus search for a substitutable programming software approximately halfway during the research project and eventually after extensive examining of its various technical features, it was decided that Pure Data (PD) overall comprised the integral facets to successfully achieve all the expected assets required to develop and create the software artefacts.

Similar to Max, Pure Data (PD) is an object-oriented programming language software which enables the user similar freedom to create the majority of the functions and technology of Max although at a noticeable more advanced level, containing a few differences and proposes another set of challenges compared to the aforementioned programming software.

In addition to the ability to develop and create software artefacts, Pure Data offers a variety of different programming opportunities which enables creations on various types of audio/visual arts design; among others, video/imagery to create visual effects/manipulation suitable for art installations either in accompaniment of audio or not. Different from some other alternatives, there are a few advantages using Pure Data - it is a freeware (i.e. entirely free to obtain by anyone) and operable on all major computer systems (i.e. Windows PC systems and Macintosh OS systems), while fully operable as a processing platform for tablets (iPhones/iPads/Androids etc.).

Further, the advancement of a larger community of computer programmers commonly use this programming software to construct various types of Apps/objects/effects software, some of which can be approached by accessing certain internet forums and enables users to upload and share freeware resource (programming patches). Thus, this type of programming technology is represented by a substantial supportive environment/network which enables free assistance/aid/share on technical ideas and development.
Another potential source of information can be obtained by frequenting uploaded videos on a streaming channel such as YouTube; which is a useful resource to access due to a vast number of programmers who upload videos and offer tutorials on computer programming by constructing various objects and Apps - technical work that can be of great inspiration and further provide expansion on common technical knowledge.

Since Pure Data is an object-oriented coding language programming software it allows the user to make constant on-going real-time changes to any creation. Thus, allowing the user to make changes, alter, or improve aspects that previously did not work properly, partially worked or singular functions are operable to a limited extent, without the limitations of a software that would solely create fixed artefact non-adjustable at a later point.

Pure Data as a programming software provided gradual technical progress mainly through a trial and error approach (i.e. learning by doing), and allowed me as an user to initiate work from one technical standpoint, and then apply changes whenever additional data had been gathered, analysed and processed (acquired through reading/processing of theoretical knowledge - in this case tuning systems were of high importance) and finally perform/do fine reading to extract and expand on the already acquired knowledge thus further advancing the technical skills in order to improve the current progress.

In this situation, my own experience as a primary user would provide further alterations or expansion on some of the technical ideas simply by testing out, evaluate/re-evaluate and drawing out a number of different conclusions throughout the creational process; all of these aspects supports a bottom-up approach to programming – and were beneficial in comparison to a number of other programming software which are completely based on text-based coding language programming software, such as C or Python.

Previously in this chapter, three principles of design were discussed – fortunately Pure Data allowed all of these functions to be performed within the capacity of one single platform (i.e. execution of the design, development and deployment). Despite a number of versatile functions, Pure Data also includes a set of disadvantages that needs to be addressed as well. In terms of the overall qualities as a programming software, Pure Data is a very complex programming software platform which requires a steep learning curve and likely demands engagement across significant amount of time before any user would reach the adequate level of knowledge and confidence in order to create independent software artefacts or Apps according to a professional level (without the supply/aid from a trained computer programmer through singular tutorials or assistance). Mainly due to being a readily available freeware any additional funding and economic support is likely to be very limited (with the exception of the creator Miller S. Puckette who may be the most significant economic contributor) and this appears to be apparent on some facets within certain technical aspects of the programming software.

Pure Data appears to contain the occasional bugs which may affect the overall operating fluidity despite regular updates being released (current version PD 0.54 released as per 04.10.2023). In particular the software may freeze/crash occasionally and the lack of an inbuilt auto-saving function prevents the user from recovering progressed work achieved between the previous save and the eventual technical freezing. In addition, minor programming mistakes by the user may cause or significantly render the operability of the software resulting in sounds being cut off, loud bursts of sounds and/or sometimes reinforce the software to be restarted in order for the audio interface to be properly set up and reconnected with the computer.

Additional software

In addition to Pure Data, it was necessary to apply additional software to transport the technology achieved through the development of software artefacts in order to turn them into fully functional separately operational Apps for tablets (iPhones/iPads/Android etc.). The software selected to perform this task is called MobMuPlat, Doctor Adam Hart provides a sufficient explanation on the functionality of this software by describing it as a “mobile music platform [used] for building graphical user interfaces with audio engines made in Pd” (Hart A. M., 2018, p. 69). A number of additional software were applied during this research, although not directly integral for the creation of the VMKLI’s; these were all Digital Audio Workstations (abbreviated as D.A.W.) such Ableton Live, Logic Pro X, ProTools, (and Max). Each of these features a unique set of different functions that were impossible to perform on either of the other D.A.W’s, thus the use of all individually were a crucial part composing and producing the five compositions submitted for this research project. Some of these D.A.W. were also used in relations to emergent behaviour during concert performances.

Hardware

Various hardware from the University of Salford, in particular various musical instruments (in particular synthesizers) as well as various hardware equipment from the various recording studios (such as hardware equalizers, compressors, various microphones, headphones, mixing desks, audio interfaces, tape machines etc. – all of these assets were crucial especially during the compositional and production stages of the compositions submitted for this research. Additional hardware used were Macintosh MacBook Pro Computer which was used to operate all software (i.e. Max, Pure Data, MobMuPlat and all D.A.W.s), in addition to iPads.

Research Model

Timeline

For the duration of this research project, various stages of development took place, these stages were separated into extensive periods where acquisition and absorption of theoretical knowledge and practical work was undertaken. Hart provides a sufficient description of this process by stating that "… the developmental relationship between the software and learning activity can be thought of as a form of equilibrium" (Hart A. M., 2018, p. 70).

Phase 1: July 2018 – December 2018

This was the first period of the research project. Various activities involving both theoretical and practical work were undertaken. Beginning stages were slightly chaotic due to establishing a logical work pattern, approaching the research project as a gradual process. The most significant contribution of work produced in this period was an early prototype of Alpha, Beta, Gamma, scale and similarly advanced prototype of Bohlen-Pierce scale. The latter two months of this particular phase was dedicated to the initial exploring of gamelan tuning system.

Phase 2: January 2019 – December 2019

This phase of the project was mostly dedicated to exploring all traditional tuning systems. Continuation from end of Phase 1, proceeding exploration of the gamelan tuning system occurred for another three-four months, followed by exploration of Indian tuning system for two months and lastly Arabic tuning system during the last two to three months. By the end of September/beginning of October sufficient theorical framework on all the five tuning systems had been compiled from various sources. During this process, literature review about each indigenous tuning system was initiated, with additional improvements to occur up until the first half of November. From November to the beginning of December, tutorials on Pure Data was undertaken. Beginning from December – a musical draft of a composition (which involves the usage of Alpha, Beta, and Gamma scales) was made and proposed as a suggested collaboration with then-current staff member at University of Salford, named Doctor Timothy Wise.

Phase 3: January 2020 – May 2020

This period was affected by a few unforeseen challenges. Just prior to New Year my previous computer crashed and as a result some of the latest progress up until that point was permanently lost. By the end of January until the beginning of February further improvements on the chapter about Arabic tuning system occurred, followed by a period of involvement with two of my own musical compositions (pieces which would eventually turn into "*In Search Of Enchanted Soundscapes"* and *"Twirl Dung Pa"*) and in addition to offer assistance with another composition for one of the staff members, fellow member of ACMG, Justine Loubser. All these compositions were prepared for a concert supposed to take place on the 26 March 2020 at Manchester Museum and eventually cancelled due to the COVID-19 pandemic at the end of March. In the period leading up to the planned concert, Doctor Wise had initiated work on a graphic score for our collaboration. Simultaneously, while working on the two aforementioned musical compositions, exploration on the history of Western tuning system was initiated, from late March up until May a nearly finished draft of the Methodology chapter was completed.

Phase 4: June 2020 – December 2020

This phase was dedicated entirely to writing on the PhD Thesis. During this period, work on the Introduction chapter, chapter 3 and chapter 4 (history of music and history of Western Tuning Systems) were initiated and nearly completed, simultaneously further corrections and additions on all three chapters about the indigenous tuning systems were undertaken. The composition called "*In Search Of Enchanted Soundscapes"* was completed, mixed and produced by July.

Phase 5: January 2021 – July 2021

Similar to the previous phase, current phase was largely dedicated to writing on the Thesis. During this period the final corrections on the three chapters on traditional tuning systems were accomplished, in addition the chapters on history of music and tuning and history of Western Tuning Systems were nearly completed. From late May and throughout Phase 5, work on developing keyboard layouts on all VMKLI'S, this was initiated by brainstorming, creating sketches on layout and design by using Pure Data.

Phase 6: August 2021 – December 2021

This phase was entirely dedicated to practice-based aspects of the research project. The focus was to achieve as much progress on the VMKLI's as possible in addition to initiate and complete the final three music compositions. By October, both "*Alien Transparagus And Seven Dead Minions"* and *"Music For People Who Doesn't Have Any Real Friends"* had been composed, simultaneously at this stage both the Arabic and Indian VMKLI's were nearly finished. A recording session was conducted on 1st December in order to record ACMG's contributions to both of the aforementioned compositions, while the rest of the month was spent working on the final composition called The Esoteric 666-Type Of Dance.

Phase 7: January 2022 – August 2022

This phase was for the most part dedicated to practice-based aspects of the research project. Throughout January work on the final composition proceeded and was completed by the end of the month. Once this composition was completed, mixing and production on "*Alien Transparagus And Seven Dead Minions"* and *"Music For People Who Doesn't Have Any Real Friends"* was completed. A recording session was conducted in June in order to record ACMG's contributions to the final two compositions completed in this project, namely "*The Esoteric 666-Type Of Dance"* and "*Twirl Dung Pa"* – up until this point both Doctor Brissenden and Doctor Wise had completed their graphic score for our collaboration. Meanwhile, from February up until August, work on chapters about the VMKLI's and all of the Musical Compositions started and was completed during this period. The rest of this period was dedicated entirely to finishing mixes on the last two compositions.

Phase 8: September 2022 – December 2022

This phase was entirely dedicated to writing, make the final corrections, finishing and arrange all chapters in the PhD Thesis. The chapter which encapsulates all five tuning systems, (the last chapter to be written) was initiated and completed during this period. To a less extent, some minor tweaking on the final mixes on the music compositions as well as the last technical touches/polishes was applied to the VMKLI's – and proper testing to check workability etc.

Data Collection and Analysis

The Methods used for assembling data in this research project were achieved through different approaches. The following Methods for data collection occurred through the following artefacts; practice-journal which were used to store written information and documented either using the text-based computer software called Word, or documented using sheets of paper/notebooks. The information stored was used for various reasons, these writings contains information from and documenting many different aspects of the research - mainly comprises observations done throughout the research, and contains mapped out – planned, advanced or spontaneous ideas or information about sources, analysis, processing (of information) and related subject matter read throughout the research project. The memos would also contain information on ideas that were considered used, or specific propositions about programming, or even drawings of sketches in order to test out different ideas and aspects designing the Virtual Digital Musical Interfaces. Further, some memos also contain information and discussions from supervision meetings, storage of music references considered and ideas for musical compositions etc.

It is important to address that the approach for data collecting would eventually be exposed to some alterations during various stages of the research project, whereas some of them ended up being exactly, close to or partially as planned, either because the target sought would appear predictable, impossible to predict, partially or would not coincide with, irrelevant or derive too far away from the topics of the or direction of the project – still all possibilities would require testing before eventually accepted or abandoned (one good example would be the correlation between Max and TouchOSC, or possibly Max and MobMuPlat – neither alternative to yield a satisfying result, but required testing prior to draw these conclusions).

Lastly, musical composition and software artefacts needs to be addressed, although it is reasonable to state that the involvement of these appeared to have a partial effect on the data collection as they were more related to the result of data collecting rather than being part of the data collecting process. However, still this made them very significant and influential for the analytical process, in order to compose music and to develop software artefacts for this project. The research project was greatly dependent on the information provided through data collection achieved after exploring all of the five different tuning systems, and a vast amount of this required processing prior to any developmental work on the creation of the Virtual Musical Interfaces (in particular the traditional tuning systems) could be possibly achieved.

3. HUMAN PERCEPTION AND INTERACTION TOWARDS THE PHENOMENON OF MUSIC

"The first sound experiences were with monophonic concepts, among the first types of instruments produced to recreate musical sounds were such instruments as bamboo pipes, the ancient kanon, or monochord. "[They] were in each case a Monophonic starting point-that is, a column of air which in its vibration, or length, represented 1, and a section of chord which in its vibration, or length, also represented 1." (Partch, 1949/1974, p. 361)

In this chapter we will explore musical tunings in accordance with the development of human musicality, an interesting, multifaceted topic. This complexity however, presents a number of challenges for researchers/scholars. In order to seek answers, they are required to deal with many different variables which under normal circumstances likely would introduce a number of unpredictable and surprising answers/outcomes. Extensive music studies dealing with tuning systems and musical instruments from other musical cultures appear to be very problematic topics in general; sufficient knowledge regarding a number of separate yet specialized fields of research are required.

To further complicate matters, similarly a vast number of different opinions and opposing answers and outcomes may either appear as predicted, expected or to variable degrees, surprising; and prevent firm rendition of concrete answers with respect to human perception of music and musicianship. Charles Darwin once "… recognized the correlation between language and music as a possible as the origin of our species' abilities to communicate" (Patel, 2012, p. 4).

Perception and interpretation of music to some extent may be viewed as a cultural phenomenon with roots in formative experiences of gradual learning (a process similar to when a child is learning a native language through observing their parents and/or peers) a process which is initiated as an infant and gradually progresses up towards crucial teenage years, when the effect music possibly may be at its strongest in an individual's life and quite possibly integral to affecting and/or shaping an individual's identity.

Relation and Language

The most recent research discourse on music has shown increasing emphasis on the relationship between music and language. The mastering of a language is a necessity in order to function effectively within human society. It would be difficult to put music entirely in a similar category. People's personal experience and appreciation of music in their everyday life varies to a great degree; it should be noted that some individuals hold music at an utmost strong position and a life without music would be rendered unbearable, while others have little interest in music in general and may perceive its qualities rather distracting or intruding in their everyday life. Interestingly enough, however the average person likely appears in between these two polar opposites. Professor and Director of the Centre for Music and Science at University of Cambridge, Ian Cross (1999, in press), suggests (in opposition to previous psychological belief) that our musical and quasi-musical skills are highly adaptive where proto-musical aptitudes already start from early infancy simultaneously with acquisition of speech and language and quite likely play a key part in the ability to evolve our structure of conscious thought – meaning our interpretation of the world and our surroundings, in addition to how we interact with other people (D'Errico, et al., 2003, p. 47). In other words, in this context one can view music as a learned activity which helps to shape personal and cultural identity.

The comparison to language may be validated for a number of reasons: in the context of cultural connotations and reasoning, exposure to a particular type and genre of music through repeated listens either voluntary or involuntary over a significant period in someone's life, may affect and render the listener's ability to recognize and/or connect with certain types of music in the shaping of their own personal and cultural identity.

The phenomenon of music may be further linked to an individual's ability to learn fundamental human activities (such as walking, talking etc.), although music listening and understanding/interpretation of music likely affect individuals differently from one another. One particular reason for this assessment relies on evidence provided in an American documentary made in 2014 called "Alive Inside" which focuses on a number of patients placed in a nursing home suffering of Alzheimer, this documentary mainly deals with patients suffering from dementia and how they interact when listening to music (Rossato-Bennett, 2014).

The documentary follows a volunteering worker named Dan Cohen at a nursing home who handled patients suffering from Alzheimer's; one of the main purposes with the documentary is to observe patients (of the most extreme cases of Alzheimer) before and after they have been provided with a set of headphones in order to listen to the music they once loved at some stage during their life. It should be pointed out that prior to any engagement with music these individuals appear to show limited capabilities of mobility or expressing themselves in an intelligible matter.

Stimulation from visits by close family members and staff result in only superficial changes in their behavior. However, when allowed to listen to some of their favorite music from the past, a truly drastic change becomes apparent by observing their facial expressions, which indicate a noticeable higher mental and/or emotional awareness/presence. Furthermore, immediately after the music has been turned off, these patients suddenly appear capable interacting with people around them on a significantly higher level than previously; fully capable of answering questions about their general relation to music (i.e. the band or artist they were listening to on the headphones), and for a brief moment regain the ability to recount specific occurrences earlier in their life – all of which seemingly were difficult to answer prior to listening to music.

This demonstrates a concrete link between music and memory, and suggests that there may be some correlation between music and its relation to basic human learning. However, dementia studies provide limited insight to this aspect. A better case study is given by the related case of Clive Wearing.

English musicologist, conductor and musician Clive Wearing (1938-) used to be a renowned conductor working at the BBC shortly before his illness in 1985. A 2005 documentary called *The Man with the Seven Second Memory* specifically focuses on Wearing, his disease, his current mental state and how he interacts with his closest family (Treays, 2005). Wearing was struck down by a virus which rendered the hippocampus, (an area of the brain crucial for memory and learning) to be completely destroyed, "… leaving him with dense amnesia" and "20 years later, his memory is only limited to a seven-second memory before his mind goes blank" (Treays, 2005).

His illness literally removed all of his memories in life; he retained the ability to speak, recognized his name, his children and his wife. Besides this linguistic ability, he has a sense of reflection and intellect, and surprisingly enough (despite no memory of it afterwards), a range of musical abilities, including the ability to render complete musical pieces, completely unaffected by the disease (Treays, 2005). Wearing's circumstances and musical abilities provide a unique insight into the nature of musical cognition and have been the subject of much study. Wearing is, for example capably of conducting a choir rehearsal, and coaching improvements in the choir. His ability to sight read at the piano is also largely unaffected by the disease, and if prompted over several days, his renderings of pieces will show improvement consistent with normal patterns of musical practice.

What we can conclude by these two specific examples is that the significance of music on music listeners and musicians appears to holds a unique place in their state of mind, despite losing all of their other physical and/or mental capabilities in life.

Earliest Traces of Cognitive Behaviour in Humans

According to American astrophysicist Michael Hart (1932-), American psychologist Frederick Coolidge & American archaeologist Thomas Wynn - the earliest known stone tools appears to date back approximately 2.7-2.5 million years ago, discovered through archaeological excavations in Tanzania (often termed as the Oldowan industry by archaeologists) and Gona in Ethiopia (approximately 2.6 million years ago) (Nowell & Davidson, 2010, pp. 1-2), (Coolidge & Wynn, 2009, s. 97). These appears to be stone tool hand axes created by Homo habilis (the earliest known ancestor to all human species) through stone knapping although these tools only shows primitive unrefined creational skills made with only a flake or two chipped off by using another stone (presumably at slightly more advanced or similar level to that of a chimpanzee), (Nowell & Davidson, 2010, pp. 1-2).

This has led to numerous researchers seeking answers to the cognitive capabilities of Homo habilis (who generally possess half the brain size of Homo sapiens sapiens), thus observing the behavioural traits and cognitive skills of our common ancestor, namely the chimpanzee or possibly a close 'cousin' such as the bonobo (formerly called pygmy chimpanzee). Among a number of different studies on this subject, one of the most significant ones was conducted on a bonobo named Kanzi.

Kanzi showed capability of handling up to 600 “lexigram” symbols (which are abstract meanings related to food or activities) printed on paper or on a computer touch screen; thus, it is observed that bonobos can think, make plans and understand simple spoken English. In addition, observations were made later on in order to showcase Kanzi’s abilities at flint knapping. Kanzi was taught flint knapping by the anthropologist Nick Toth and after a great deal of coaching it remained evident that he did not appear to approach this task with any strategy, precision, and most particularly any sense of rhythmic entrainment. His tools were sharp, but entirely crude – approximately equivalent to human capability at the outset of the stone age. (Roffman, 2012). It should be addressed that one of the key skills of flint knapping is to recognize the subtlest variations in sound which the stone produces when struck, as this determines where and how hard the next strike needs to be in order to achieve expected/desired shape when struck (Morley, 2003/2006, p. 73).

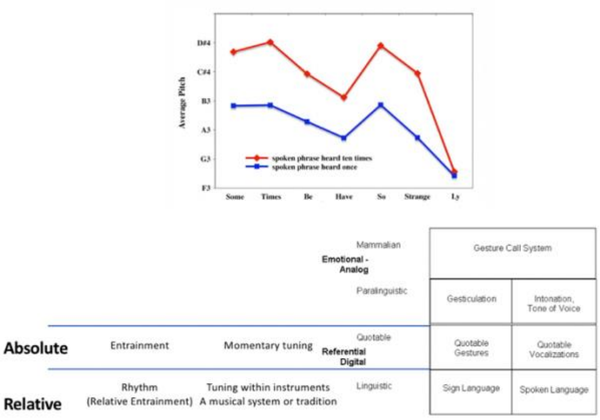

Figure 3.1. Perception and levels of accuracy between spoken and sung language From Burling & Deutsch – Published Lecture (Brissenden, 2022)

D’Errico, et all trace the next significant advancement in human evolution to be approximately 1.8 million years ago; a significant advancement in tool fashioning and craftsmanship can be detected best exemplified in the remarkable discovery of six wooden spears at the archaeological site Schöningen in Germany, which clearly prove that humans were capable of fashioning pointed tools used for hunting and already possessed the understanding to shape wood through various shaving and scraping objects as far as approximately 400.000 years ago (D'Errico, et al., 2003, p. 12).

The earliest known example to substantiate artistic evidence in human nature derives from discoveries of up to 8000 ochre pieces and an elaborate bone industry at the excavation site at Blombos Cave in South Africa dated approximately 75.000 years ago - described by d'Errico as "… the most ancient irrefutable evidence for symbolic behavior …" and that the "… techniques employed in bone modification at this site are complex and must have been acquired through linguistic communication rather than by observation or mimicry" and "…is evidence of coherent behavior and technical knowledge shared and transmitted within a community" (D'Errico, et al., 2003, pp. 4, 6).

The Upper Paleolithic Era (approximately 40.000-10.000 years ago) demonstrates further human advancement in cognition; the arrival of metal and the ability to create more advanced tools including musical instruments through separate or combinations of materials such as tin, copper, bronze, brass etc. paved the way for important innovations in the future. The first evidence of these materials appears to have occurred in the Middle East approximately 8200 years ago, and later one of the most important innovations in the history of mankind, namely writing which was first developed in the Middle East approximately 6000 years ago (Hart M. H., 2007, pp. 147-148, 167).

It should be noted that it is impossible to decipher entirely an exact time-line when hominids were capable of classifying sounds or had the capability to render a sequence of musical sounds in any "logical" succession recognizable to modern ears. However, hominids must have been able to classify sounds in at least five different cases (if not more); 1) through the capabilities of stone knapping –the sound of one stone being struck against another stone in order to produce sounds (if not immediately recognized as a rhythmic tool), 2) the innovation of bow (and arrow) where the string (initially made of animal gut) would initiate the recognition of sound to produce different pitches while being tightened (and optimized for its hunting purposes) and natural change of timbre in accordance with specific length, thickness/material and/or the tightness of string/s. Further, 3) the usage of animal bones as sound producers (likely used initially as calling, signaling or warning tools) with the access to a selection of specimen of different sizes and thickness to recognize difference in timbre, 4) animal skin originally stretched out to dry, initially used for clothing and tents and eventually used to create musical instruments by attached and tightened onto a frame of wood surrounded by a hollow middle part – allowing for reproduction of deep and loud sounds, 5) wood dried to lose moisture, and tension capabilities, eventually to be used as diverse percussive and musical instruments. Whether all of these items originally were assigned to tasks unrelated to music, or their usage emerged in the context of musical circumstances is impossible to determine. But musical skills are integral to each and they all eventually emerged as tools for musical sound reproducers which makes them subjected to the phenomenon of tuning in context of music.

Historical music artefacts

In this section we will present and provide brief explanations on musical instruments from ancient times. These artefacts showcase significant human development throughout history and may provide us with some insight as to why specific musical principles significantly differentiate entirely from one musical culture to another.

Categories of ancient instruments

Archaeologist and anthropologist Iain Morley (1975-2021) suggests that there were five different main categories of musical instruments associated with the Paleolithic Era, 1) the most prolific are considered to be flutes or pipes, 2) next group is phalanges (bone of finger or toe) interpreted as whistles – 3) objects interpreted as bullroarers, also some bones have been found with found notched with parallel grooves, that could possibly be rasps – 4) is based on the caves themselves through the reverb/resonances in which would enhance/affect the sounds – in addition to 5) features of the cave considered to be the sounding devices (Morley, 2003/2006, p. 33).

First evidence of musical instruments

Since a vast number of instruments dating back across a time span of 30,000+ years have been uncovered through numerous archaeological excavations both in the past and in recent years; it is important to limit the number of these findings to a small selection of the most groundbreaking and significant in the course of musical history; thus, despite wide recognition/acceptance of these as sound producers its inherent additional attributes can be emphasized as follows: 1) age/antiquity either independent of or associated within its cultural context, 2) the significance of the musical instrument in either one (its exact impact - on the evolution on that specific culture and/or tuning) and/or other cultures (who have adopted same instrument) upon which a possible correlation may be traced.

It is impossible to know the exact emergence of the earliest musical instruments; we should not rule out that a significant amount of information has been lost to a number of factors; such as natural disasters, destroyed/abandoned/perished, become obsolete and replaced by new ideas, and lack of interest to document the information through physical transcriptions. Certain antique instruments preceding the ones we already know may have been made on perishable material and not survived into modern age.

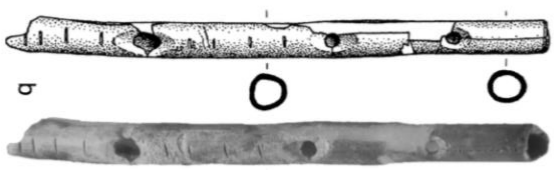


Figure 3.2. the best preserved flute specimen discovered at Geissenklösterle (d'Errico p.40), Figure 3.3. Flute specimen discovered at Hohle Fels, Photo: Hannes Wiedmann (Creative Commons)

The earliest verified musical flutes extant were discovered through archaeological excavation at three different sites; Geissenklösterle, at Hohle Fels (both in Germany), and at Isturitz in France. The two specimens found at Geissenklösterle are made of of swan ulna or radii dated 36,800 (± 1000 BP) years ago, and appears to be attributed to Homo sapiens sapiens (Morley, 2003/2006, p. 55). Unfortunately, none of these two specimen at Geissenklösterle appears in completely preserved form; although one of them appears to be fairly close to its supposedly estimated size (18-19cm) and contains three complete holes and approximately 12cm long, while the other consists in a much more fragmented state retaining one complete hole (Morley, 2003/2006, p. 55). Despite the close geographical approximation between Geissenklösterle and Hohle Fels and musical artefacts of similar vintage, the sole specimen found at Hohle Fels dated approximately 35,000 years ago appears to be made of one single piece of ivory bone and surprisingly enough appears in a complete form containing five playing holes (Wilford, 2009).

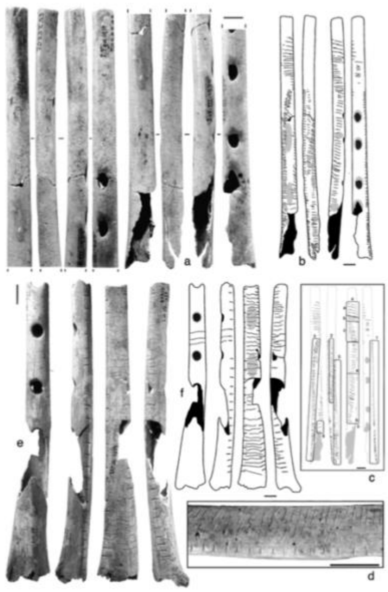

Fig. 10. (a, b, (e, f)) Photo and tracing of the two most complete pipes from the Gravettian levels of Isturitz Cave. Grey areas around the finger holes and at the rear of the pipe indicate concentrations of polish interpreted as use wear; (c) sketch identifying sets of marks made by different tools; (d) close-up view of sets 1–3. Scale = 1 cm.

Figure 3.4. The collection of flute specimen discovered at Isturitz (d'Errico p.40)

However, the most significant discovery of musical sound producers from this particular era appears to be the discoveries at Isturitz which comprises the widest selection of sound reproducers uncovered so far (the amount consists of at least 17 specimens although may vary slightly depending on the author/scholar) dated between 20,000 and 35,000 years old. Despite showcasing a remarkably advanced craft for their age, the age difference also reflects a different level of craftmanship and sophistication between the older and the newer specimens. Three of the oldest specimens, where one is a complete four-hole pipe, the second a "…near-complete four-hole specimen …", and the oldest Aurignacian specimen found with "… the substantial surviving portion includes one finished end and three finger-holes" (D'Errico, et al., 2003, p. 39). Further, the design of such sound producers appears to have remained unchanged until at least Mediaeval times in Europe and the Americas while the earliest definite case which showcases a "block and duct" (one hole) flute (block in the middle of the bone possibly made of wood or resin) was discovered through excavations at Goyet in Belgium (32,000 years ago) dating back to the Gravettian Era (approximately 33,000-21,000 years ago) (Morley, 2003/2006, p. 56).

Despite the significance of various specimen of sound producers discovered at Hohle Fels, Geissenklösterle, and Isturitz - a few questions arise; At what level of musical understanding/knowledge did humans possess approximately 35,000 years ago? Did they possess the ability to reflect on a logical progression of musical tones similar to how music is approached today? Did the five-hole bone flutes from ancient times accurately reproduce what currently is known as the pentatonic scale as is often speculated?

Issues with specimen of ancient instruments

Unfortunately, despite much research no firm conclusions on exact tuning procedures can be established firmly established past the fact that they were, beyond doubt, consciously tuned to known variants of four, five (or possibly three) individual tones. Further, it is impossible to know the nature of the music that was performed on these instruments.

Another issue which may complicate matters further, the flutes discovered at Isturitz were crafted across a possible time span of 10,000 years - while only one specimen of the older flutes may appear complete (containing four finger holes and showing various amounts of deterioration), still the newest specimens manifest more advanced craftsmanship than the older ones. d'Errico accentuates that

> "… the tuning implications of the finger-hole placements cannot be precisely determined, for in such systems (unlike true flutes) the form and tensile strength of the reed (or lips)—which are unknowable—strongly affect the frequency of each output sound. However, finger-hole placement—at least half of the tuning equation—is preserved and from this and other details we may draw some comparisons", and " … every hole … has been chamfered (beveled) so as to present a smooth, slightly concave plateau to the fingertip" (D'Errico, et al., 2003, p. 42).

D'Errico addresses that the abovementioned features appear to be commonly found amongst later bone-pipe traditions, and appear rather reed- or trumpet-voiced – providing richer sounds with quite different acoustical implications and seems to be "…designed to be played two-handed, and in a subtly off-center playing-position" (d'Errico, et al., 2003, s. 41). Interestingly enough, he continues by suggesting that these specimen of flutes "… cannot represent humankind's first attempts at piping, any more than the earliest known harps and lyres of Sumerian civilization around 5000 years can have been" (d'Errico, et al., 2003, s. 46). Doctor Philip Brissenden, at University of Salford in his article "The Origins of Tuning", appears to concur with d'Errico's assessment suggesting that the size and spacing between finger holes to be a significant factor which determines tuning of ancient instruments, and to a less extent the actual shaping (beveled/chamfered) of and orientation of finger holes, and other markings on the pipes. Brissenden further suggests the technology in which to construct musical instruments is likely to have existed prior to 20,000-35,000 years ago; and that *drone* is likely to be the function of the first tuned musical instruments – and that hole tuning would follow the tuning of the fundamental harmonic capability of the pipe itself (Brissenden, The Origin Of Tuning, 2015, p. 1).

Fashioning and material of ancient instruments

Among the material known to have been used for creating ancient sound producers, obviously two distinct types of ‘animal bone’ material appears to be common denominators; 1) bullroarers, rasps and phalangeal whistles mostly derived from bear, hare, elk horn, chamois, pig, bear, and hoofed animals such as reindeer - antler or bone, and 2) bird-bones of faunal (the most commonly used and receives highest recognition as a genuine sound producer), eagle, vulture, swan ulna, and graylag goose which all roughly consists of 40% of the approximately 122 reputed pipes or flutes extant from ancient times (Morley, 2003/2006, pp. 62-63).

Interestingly, the type of bone material tends to be rather consistent depending on the craftmanship found in specific parts of Europe; in 1) France and Western Europe the majority of sound producers appears to derive bird-bones (such as the 18 specimens derived from Isturitz), while 2) hoofed mammals or bear-bone appears to originate from central or eastern Europe (Morley, 2003/2006, pp. 62-63). However, to sum up the entire history of musical instruments would easily prove to be too vast and complex for this type of Music Study, thus, further examination of ancient instruments will be limited only to the most integral specimens known to have existed in the intervening period between the discoveries at Isturitz up until ancient Greece. It should be noted that ancient instruments from China, ancient Greek, and Arabic instruments are of particular interest, since these instruments display a sophistication, craftmanship and tuning intent more recognizable to contemporary approaches of instrument fashioning.

Among the earliest known musical artefacts besides the ones already mentioned appears to be a vast amount of bamboo sheng mouth organs (which are reed-voiced and lip-reed multiples) originating from China and of unknown (although possibly of extreme) antiquity. Unfortunately, due to the fragility of the material used it is impossible to date any actual origin of this instrument; however, d'Errico addresses that no known specimen of this instrument appears to exist until after the Paleolithic Era, and due to its perishable material is unlikely to have survived if abandoned in nature for a long period of time (D'Errico, et al., 2003, p. 48).

According to ethnomusicologist and composer Doctor David Mingyue Liang (1941-), the next line of extant instruments appears to be ancient Chinese clay rattles (possibly of wood or bamboo prior to the clay technology) and (clapperles) bells dating back 7000 or 6000 years ago; although a number of wind instruments of similar vintage exist, such as end-blown bone or clay whistles in tubular or ovoid shapes, and clay vessel flutes or ocarinas exhibiting a variety of shapes with the number of fingerholes ranging from one to four excluding the blowing hole (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, pp. 43, 46). Three examples of sound producers (all dated approximately 4000 B.C.) have been subjected to pitch testing; "… (a) a tubular-shaped whistle having a pitch of F_5, (b) an ovoid vessel flute with a single fingerhole having pitches $C\#_6$ and E_6 in a minor third interval, and (c) a spherical-shaped vessel flute with two fingerholes having pitches E_5, B_5, and D_6 in a fifth plus a neutral third relationship" (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 46). Interestingly, it should be noted that the occurrence of the third interval appears in two of these instruments.

The earliest specimen of stringed instruments

The initial emergence of stringed instruments appears to be a more complicated matter. However, the earliest known examples of such was discovered near the royal tombs at Ur (current-day southern Iraq) where the earliest known extant selection of harps and lyres and plucked [string] instruments (with the addition of physical evidence which depicts musical execution of these) dating approximately 2500 B.C. (Burkholder, Grout, & Palisca, 2010, p. 6). d'Errico suggests that their physical appearance and craftmanship "… possess a sophisticated structure and are in no sense 'primitive' or newly developed" (D'Errico, et al., 2003, p. 35).

Another interesting case is the qin (seven-stringed zither) which appears to be the most renowned instrument in Chinese musical history. Among others, Liang suggests that it emerged simultaneously with the initial beginnings of the Chinese civilization;

however this information is impossible to verify with certainty since no such instrument predates 600 B.C., although mentioning of the instrument can be traced back to a written source called Qin lore (approximately 2600 B.C.) (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, pp. 197-198). Besides this, the earliest discoveries of ancient instruments in China appears to derive from the Neolithic cultures of the Xia period (approximately 2100-1600 B.C.), although the existence of artefacts with "pictographic references to music" appears to be slightly older and dates back to the late Shang dynasty approximately 2^{nd} millennium B.C. (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 34).

Although the existence of ancient instruments up until the ancient Greece are not limited to the ones mentioned here it should be noted that these have been selected based on their significance in musical history with respect to the emergence of tuning as musical phenomenon.

The Significance Of Established Music Cultures

Chinese Music

An interesting place to start when examining musical cultures from a Western perspective is Chinese music. There are various reasons for this; 1) it contains some of the oldest preserved documentation of music throughout history, 2) in accordance with this it also provides some of the oldest conceptions of tuning including mathematically calculated formulations of tuning systems, and 3) the Western 12-tone EDO tuning system appears to derive from the China.

Before examining some historic key aspects of Chinese music, it is necessary to have a brief look at what characterizes contemporary Chinese music since it may yield some recognizable traits found in other cultures. They may not offer much explanations in terms of Western music since these two cultures may not have much in common past the usage of the 12-tone EDO tuning system.

Liang suggests that Chinese scholars were advocates of acoustics at an early point in history, although "… the theoretical formulations for just intonation, the cycle of fifths theory and even an equal-tempered scale, all remained essentially at the level of intellectual exercises"; and since a vast amount of musical temperaments were executed separately from regions, the execution of music appears to have emphasized descriptive stylistic foundation rather than theoretical principles (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 22). Currently, three distinct features are uniquely associated with Chinese music; the first – is related to tuning relations of specific instruments (certain instruments provides neutral interval to others natural interval) in certain ensemble and limited to specific styles of music, the second - is poly-temperament (also known as flexible temperament which involves a number of different temperaments played simultaneously during performances of musical pieces, while the third – revolves around timbral development (i.e. emphasis on tonal colour in music, differently from the rhythmic and harmonic development found in other cultures) which consists of a hybrid of organological properties of instruments, playing techniques and environmental circumstances (weather, season etc.) rendering musical pieces both by the melody and the type of instrumentations used (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, pp. 22-24).

Despite that the aforementioned three features all are unique to Chinese music, the phenomenon of slight “mistuning” in presented music by itself is not limited to Chinese culture only, to varying degrees this is also emphasized in other cultures where this aspect plays a larger or lesser role - such as in Indonesian, Indian, and Arabic music.

Although, we have briefly observed some aspects associated with modern Chinese music, it is time to examine some of the earliest documentations of ancient Chinese music in order to establish some possible answers in relation to musical tuning and how it possibly may have affected other cultures across the world. Apparently, many aspects of Chinese music have been implemented prior to medieval times according to both contemporary and ancient sources. Some of the oldest written/documented evidences of music originates from China - whilst most of the oldest instruments remains have been discovered outside of China - at various excavation sites around Mid-South of Europe and Middle East only scant evidence of written/scribed information appears to exist from this continent prior to the emergence of ancient Greek thought.

Inherent in the discussion of Chinese music, it is generally believed that the invention of any musical tuning system is attributed to Ling Lun, regarded as a Chinese minister or court musician serving under Emperor Huangdi (also known as the Yellow Emperor), approximately 2700 B.C. (Partch, 1949/1974, p. 361). Mingyue indicates that the ideas/conceptions of tuning may not necessarily originated from China, and that Ling Lun (under the orders of the Yellow Emperor) "… travelled West to search for the standard pitches, lülü, which resulted in the establishment of twelve pitches within an octave based on the fundamental huangzhong pitch", and as a result of the "… search for the lülü, China initiated the theoretical concept of a standard tonal system" (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, pp. 37-38). Based on this information it seems plausible that the idea of a twelve-tones per octave tuning system was already established as far back as 4700 years ago.

Music theorist, composer and innovator of musical instruments, Harry Partch (1901-1974) explains that this tuning system shows similarities to Pythagorean intonation tuning and states that Ling Lun used two sets of six bamboo pipes in order to demonstrate this formula (known as "lü" in Chinese), "… one a Pythagorean semitone above the second, thus giving one version of a Pythagorean twelve-tone scale" (Partch, 1949/1974, p. 362). According to Partch, Ling Lun supposedly started "… with a length of bamboo pipe arbitrarily called 81 parts. A third of these parts is then subtracted and a third of the remaining parts added, alternatively, through four computations. The result is five pipes of 81, 54, 72, 48, and 64 parts. The pipe of 81 parts is of course 1/1, to use the Monophonic symbol, and the others are 3/2, 9/8, 27/16, and 81/64, respectively. Arranged in order of pitch, they are: 1/1, 9/8, 9/8, 9/8, 81/64, 32/27, 3/2, 9/8, 27/16, 32/27, 2/1" (Partch, 1949/1974, p. 362). There are also some ancient sources which suggests that Ling Lun also conceptualized a five-tone scale/system per octave, although this is disputed among scholars on Chinese music (Partch, 1949/1974, p. 362).

Early on in the history of Chinese music, during the Zhou dynasty (approximately 1046-256 B.C.), the Chinese appears to have viewed the phenomenon of music "…to be fundamentally a cosmological manifestation of nature in equilibrium [yang] and disequilibrium [yin]"; the unity of the two latter terms (yin/yang) also represented female and male, earth and heaven, and supposedly shaped the universal order which appears to have comprised structure and organization of music (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 63). At this point in history (Zhou period), two types of scales appears to have been used in Chinese music, namely a five-tone pentatonic scale and a seven-tone scale, both of which were similar to one another except the latter also incorporated the tones “F#” and “B” (called bian tones in Chinese) “… derived by furthering the five-tone scale of the cycle of fifth method to the seventh generation” (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 66).

The first example of mathematical calculation of a twelve pitched tuning system seems to have appeared in the 3rd century B.C. and found “… in the “Spring and Autumn Annal of Master Lü” (Lüshi chunqiu) compiled by Lü Buwei” (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 67). Simultaneously, the development of the ‘bayin’ classification system for musical instruments emerged (also known as the eight timbres due to the materials that the instrument was made of; stone, metal, silk, bamboo, wood, earth, gourd or skin) and based on acoustical timbral criterion which symbolizes the unity of sound and nature with instruments, and represented by the material that they are made of in correlation to cardinal directions, seasons and events that was further embodied in cultural conceptions and symbolisms (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 64).

Early on in Chinese history, the essence of cosmological harmony in music appears to have been related to specific numbers and assigned correspondingly to specific places or occurrences. The symbolic number for earth was 2 and heaven 3, thus “… the harmony between earth and heaven therefore symbolized by the ratio 3/2, by which the ancient pentatonic scale was derived through a process of a cycle of fifths”; a theory which according to Liang dates back before the 7th century B.C., thus it appears to have existed prior to Pythagorean tuning (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 65).

Discoveries of ancient music from the Arab World and instructions

Simultaneously with these innovations, it should be noted that other parts of the world would also experience similar developments ‘supposedly’ rendered independently from any knowledge of the tuning conceptions associated with Chinese music. Interestingly, the history in or around the Middle-Eastern and current-day Arabic World has changed through among others the aforementioned archaeological discoveries during the past 100 years or so. Partch claims that despite that the great civilizations such as the Assyrian-Babylonian, the Egyptian, and the Chinese all predates ancient Greek; however any evidence from either Egypt nor Babylon "… disappeared millenniums ago"; although he does not reject the possibility that contemporary mathematicians, scientists, harp and bamboo players of the aforementioned culture(s) may have approached music from a scientific perspective (Partch, 1949/1974, p. 361). However, Partch's claim about the lack of existing documentations is now outdated - evidence of this can be found on a few specimen of flat clay tablets with references to music (through impressions in cuneiform) which were uncovered through archaeological excavations in ancient Mesopotamia (i.e. the land surrounding the rivers Tigris and Euphrates and also Babylon) dating approximately 2500 B.C. (Burkholder, Grout, & Palisca, 2010, p. 6)

Figure 3.5. Clay tablet documenting the names of 23 types of musical instruments - Sumer, Ancient Mesopotamia 26th C. BCE. Photo/rights: Schoyen Collection, Oslo

Burkholder et al. further elaborates that scribed information in regards to tuning procedures and performing techniques were already in use from approximately 2500 B.C., despite that the most common approach to transmit musical knowledge still relied on oral tradition. For instance, ancient evidence depicts instructions for tuning of a stringed instrument which may indicate that the Babylonians had established a seven-note diatonic scale at this point in history, however, Burkholder et al. also strongly suggests that Babylonian theory and practice to some extent influenced that of Greece and eventually future European music (Burkholder, Grout, & Palisca, 2010, pp. 7-8).

Conclusion

A number of interdisciplinary fields of research have been assessed, examined and accounted for. The earliest part of the chapter focused on many different facets of human behavior in relation to precursors of musical activities examining the emergence of human musical cognition – objects and procedures that require "tuning" skills even though the design intent of such objects was probably not to make music.

The earliest true musical instruments provide some answers to how instruments were tuned in ancient times – and may therefore draw a parallel/link to how various cultures may have approached tuning and evolved from there up until current times. The most important factor to note is that tuning emerged as a phenomenon across a range of cultures and demonstrated variety of approach from the outset.

It has been repeatedly asserted by various authors that music is universal to human culture I have argued that it is at least near universal. However, more interesting is perhaps to ask whether tuning is universal. From the point of view that music is found in literally all cultures across the world, then the answer is (undeniably) yes. But if we alter the original question and allow it to be further segmented into involving solely one specific type/genre of music, then the answer is definitely no. However, before we approach any of the obviously clear and/or other commonly conformed assessments related to various ideas associated with ancient understanding of tuning concepts of music, it is important to signify that the effect of Western culture and its contributions to the rest of the world definitely appears to be the most dominant in the past 100 years or so (and in some cases dating back a few centuries), thus indispensable for the development of the current stature that Western culture possesses across the world.

The next chapter will be entirely dedicated to Western/European Music including ancient Greek Music, Culture and Tuning. The purpose of this chapter is to provide the reader with some of the inner "mechanics" of what defines an evolved tuning system and explore a number of significant changes across several centuries (if not millenniums) to make the reader understand the complexity of evolved tuning systems.

Further, Western music has greatly affected literally all other cultures across the world. This includes various Western innovations related to music ranging from instruments, features that enables amplification/electrification, recording devices/equipment/facilities – and various options for playback (which in some cases also includes possibilities of recording) devices introduced since the arrival of the phonograph in 1877 by Thomas Alva Edison (1847-1931), followed by gramophone records (Emile Berliner 1851-1929) in 1887, magnetic tape (Fritz Pfleumer 1881-1945) in 1928, phonogram records introduced by Columbia Records in 1948, CD (Sony and Philips) in 1980, and eventually Digital Files and Streaming/Services; all of which has greatly contributed to widespread distribution of Western music.

Thus, as a result the current acceptance of Western music is to be found in most if not all cultures across the world; further, fundamental elements of modern Western music are commonly found in these cultures (i.e. rock, pop, jazz etc.), while in other cases elements from Western music appears to be fused with indigenous (whether modern or traditional) styles music in order to create a hybrid of musical diversity which pushes boundaries and allows for experimentations of different musical styles.

4. THE HISTORICAL EVOLUTION OF WESTERN MUSIC AND TUNING SYSTEM

“Strict and perfect equal temperament was not required for piano music until twentieth-century … [and] based on the whole tone scale which has even scale steps. In contrast to this, the ancient scale, commonly known as the diatonic scale, has uneven scale steps. This unevenness promoted tonality. Equal temperament is the only completely atonal temperament that has existed in history, and that is why it has no traces of chord shading or key-coloration” (Jorgensen, 1991, p. 2).

I would expect most readers of this study to have a tuning enculturation that originates in Western 12-tone equal temperament. We have a heavy exposure to this from a very early age, whether the Western music culture applies to the current reader or not. We have considerable ability to recognize even subtle deviations from equal temperament. Thus, its vital in any serious study of tuning such as this, even if it seeks to redress the historical bias of recounting histories of tuning in favour of western music history to understand the history of how and why we came to tune the way that we do in the west.

Before we properly elaborate on some of the fundamental key factors intended to be scrutinized over the course of this chapter, we should briefly address the aforementioned statement by Jorgensen. The statement apparently constitutes a vast period of history lasting a few millennia while simultaneously affirming some important outside influences from other cultures (including pivotal tuning conceptions derived from China) as having greatly affected the ensuing direction of Western music. However, one of the main objects of focus in Jorgensen’s statement includes one of the most essential periods in the shaping of Western music into its current state; namely the period of the foundation of modern conceptions of Western tuning systems and the emergence of 12-tone equal temperament, which occurred essentially in-between the period of Bach up until the time of Debussy and Ravel. Thus, this statement literally manages to summarize what will be discussed throughout this chapter.

The focus onward will mainly revolve around historic progressions of Western music, while the inclusion of a few other important cultures will be apparent in order to provide comparisons and/or possibly uncover correlation between common aspects existing in the Western musical culture and other cultures.

The phenomenon of singular musical cultures rarely (if ever) appear as entirely indigenous constructions based on conceptions independent of any outside influences; to various extents, every musical culture contains elements of and/or influences originating from other foreign cultures, although this may not always seem too apparent. Thus, it should be noted that a number of indigenous cultures retain a diversity of foreign influences directly/indirectly related to fundamental aspects of their respective tuning system; in particular this may relate to how divisions of intervals are calculated although the conceptualization of intervals still may be considered as a cultural phenomenon by itself.

There are many reasons why cultures have absorbed influences from other cultures, the most obvious appears to be; trades from caravan routes and/or sea routes, or sudden shifts/changes of rule, religion or acquisition from larger empire/s (i.e. Roman Empire, Byzantine Empire, Ottoman empire *etc*.) where established values/conceptions were met with opposition by the new rulers thus forcing the inhabitants to accommodate new beliefs/conceptions, as a result influences might manifest as blends of indigenous music with these emerging new conceptions.

The emergence of ancient Greece

The period in-between 2500 B.C. and up until the emergence of ancient Greece approximately 800 B.C. only provides scant if any evidence of progression in music (i.e. further developments of fashioning approaches applied to old or new instruments and/or new additions to conceptions of tuning) in either the Western, Middle-Eastern and Arabic World. Interestingly, the subsequent time period which comprises the entirety of ancient Greece provides a completely contrasting imagery compared to this (previous) era. This is further elaborated by Burkholder et al. who claim that "Ancient Greece is the earliest civilization that offers us enough evidence to construct a well-rounded view of musical culture …" (Burkholder, Grout, & Palisca, 2010, p. 9).

Burkholder et al. suggests that the Greeks considered music to be both art and "… science closely related to arithmetic and astronomy" (Burkholder, Grout, & Palisca, 2010, p. 12).

Ancient Greek Music

Interestingly, Western music has experienced an ongoing concern throughout its history in terms of the execution of philosophies/disciplines related to the musical and tuning theory and practices of ancient Greece. In this occasion, the following two principal disciplines (types) on writings of music were first introduced in ancient Greek music theory; "… (1) philosophical doctrines on the nature of music, its effects, and its proper uses [Plato, Aristotle and Aristoxenus], and (2) systematic descriptions of the materials of music, what we currently regard as music theory [from Pythagoras]"; which suggests an effective timeline of Greek music theory to have existed from Pythagoras of Samos (fl. 540-510 B.C.) to Aristides Quintilianus (4th century) (Burkholder, Grout, & Palisca, 2010, p. 12).

Pythagoras

Pythagoras' indispensable contributions to musical tuning provided a number of propositions still recognizable in the current Western tuning system. It is important to recognize at the outset that the Pythagorean scale originally was a seven-tone scale. The significance of Pythagoras' innovations rely on his musical calculations exemplified by using a length of string in relation to the position of a bridge in order to provide measured pitch - thus enabling the string position to be divided into two parts and in compliance producing two consonant musical tones in accordance to the ratio of whole numbers (Ellis & Helmholtz, 1895, p. 14). In order to provide an understandable overview of this method, the relation (string length and bridge) may be sufficiently covered by providing the following examples: if the bridge is positioned in a manner so that **2**/3 of the string appears to the right, while **1**/3 to left - the two lengths appears in the ratio 2:1 (an octave); further if the position of the bridge is placed so that **3**/5 of the string to the right, and **2**/5 on the left we are left with the ratio of the two lengths as 3/2 thus yielding a perfect fifth interval (Ellis & Helmholtz, 1895, p. 14).

Further, it should be noted that the phenomenon of ratio numbers in relation to music appears to have sustained a completely different significance in ancient Greek terminology compared to modern Western practices; in general, the usage of numbers within the philosophy in ancient Greek theory often appears to have been assigned to various aspects of earthly existence either related to human existence, nature or positions of planets or other significant universal localities (i.e. moon, sun, stars etc.) - all integral to form and/or symbolize astronomical consonance in relation to the universe. Accordingly, we also witness similar significance to this phenomenon in ancient music theory and in particular when we further examine numeric values of ratio numbers; Partch addresses that ratios of three (3/2) and (4/3), would limit the number three as the symbol of musical order (as well as universal), and the ratio 74/73 derived from "circle of fifths" – and eventually rendering "Pythagorean" to fit any scale of tones transposed from a succession of 3/2's into one 2/1 (Partch, 1949/1974, p. 363). It is worth mentioning that the aspect of the 74/73 ratio is not limited to the aforementioned case only, it also constitutes the Pythagorean comma (equivalent to approximately 23.5 cents and in modern terms can be described as a microtonal interval) which is a phenomenon not entirely limited to the history of Western music, but can also be found in medieval tuning conceptions in the Arab World; for instance, the usage of Pythagorean comma is found in al-Farabi's proposition of 25-tone per octave tuning system from the 10th century and to a larger extent in Safi al-Din's 17-tone per octave tuning system from the 13th century (however these examples of indigenous tuning will be thoroughly examined later on in Chapter 5 and Appendix 2).

It appears that Pythagoras was capable of understanding that the string lengths if based on premises that the same quality and material (used for crafting the strings) appeared fully compliant – and contained the same tension it would then render the "… perfect consonances of the Octave, Fifth, or Fourth, [thus] their lengths must be in the ratios of 1 to 2, 2 to 3, or 3 to 4 respectively …"; interestingly enough, Ellis & Helmholtz suggest that it is quite probable that the origin of these ideas did not entirely stem from Pythagoras himself, but actually predated the ancient Greek period and instead introduced by priests from ancient Egypt (Ellis & Helmholtz, 1895, pp. 1-2).

A number of other significant scholars and theorists of similar stature would later expand on Pythagoras' ideas. Ellis & Helmholtz suggests that the 'Pythagorean law' (a term often used to describe Pythagoras's concept of tuning) was later expanded to include other aspects – such as the concept of measuring the number of vibrations on strings, which was achieved "…by passing from the lengths of strings to the number of vibrations, and thus making it applicable to the tones of all musical instruments, and the numerical relations 4 to 5 and 5 to 6 have been added to the above for the less perfect consonances of the major and minor Thirds …"; however, it should be noted that no specific individual/s has been credited for this innovation, but Ellis & Helmholtz refers to these contributions merely as "later physics" (Ellis & Helmholtz, 1895, pp. 1-2).

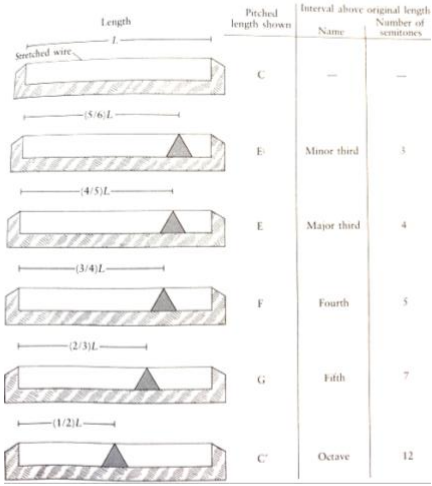

Figure 4.1. Pythagoras's demonstration of stretched wire in relation to a particular frequency in order to produce a tone of a particular pitch (Pierce, 1983/1992, p.21)

According to what we have addressed above, in addition to a variety of other sources derived from ancient Greece - it is apparent that Pythagoras' stature in Western music is indispensable and therefore it should not be unreasonable to consider him a forefather of Western music and tuning system. However, the main concern is whether all of his contributions to music are justifiably attributed to him or not. As we witnessed prior in this chapter, Ellis & Helmholtz suggested that at least some aspects on his theory on string lengths in correlation with tones and numerical values may have originated from ancient Egyptian priests predating the ancient Greek era, and not by Pythagoras himself. In the previous chapter Partch addressed that any evidence from ancient Assyrian-Babylonian and Egyptian civilizations disappeared millennia ago, and further suggested that the origin of certain musical aspects associated with ancient Greece may have a completely different origin. In addition, Burkholder et al., suggested that Babylonians possibly established a seven-note diatonic scale and that their theory and practice to some extent influenced ancient Greek.

Contact between ancient Greek music and music from ancient Arab World

It is obvious that the area currently comprising the Arab World (or parts of it) already appeared to be a highly sophisticated civilization (at least for its time) by approximately 2500 B.C., mainly on the basis of the archaeological discoveries depicting both the earliest known example of written language and musical instruments. In particular, the latter example may substantiate the aforementioned suggestion by Ellis & Helmholtz, since some of the instruments such as harps and lyres were formerly considered to have originated from ancient Greece. Partch indicates that Pythagoras was renowned for being a traveller who went to various parts of current Arab World and possibly as far as India (this will be described later in this chapter). This provides evidence that interaction between ancient Greece and Arab World existed as far back as 500 B.C., however, whether Pythagoras travelled there to spread (pass on) his knowledge or/and to claim ("steal") written works without crediting the original authors can only be left for speculation.

It is not unlikely that Pythagoras expanded on previous theoretical ideas derived from the Arab World in order to come up with his own conclusions, a second possibility is that he based some or large extent (if not all) of his self-proclaimed work on music theory entirely from other ancient Arab sources, while a third possibility is that he came up with these ideas entirely by himself, accordingly to what is written in a number of old history books. Taken into consideration the vastness of his contributions in general, it seems unlikely that he would entirely base his discoveries on other authors work, although none of the aforementioned suggestions should be entirely excluded either. However, due to limitations of sources to contradict the inventions attributed to Pythagoras we can only leave these matters purely as speculation.

Philolaus

The earliest known evidence to showcase mathematical divisions of what is commonly regarded as the major scale in Western music theory appears to have been manifested by one of Pythagoras's students named Philolaus (470-385 BC). Already, in the initial period of ancient Greek music history, the naturalness of purely established and unadulterated tones such as the octave, the perfect fourth and the perfect fifth appears to have been a well understood and accepted tuning aesthetic. Thus, it should be noted that the significance of Philolaus's discoveries within the realm of ancient Greek music history (although his contributions may be somewhat neglected in the grand scheme of significant ancient Greek writers/philosophers throughout the history of its music) can be largely attributed to his formulas; which are considered to be the first case of mathematical differentiation between succession of tones in the major scale while also revealing that specific tones proceeding up the interval of a perfect fourth from any given note, and then up the interval of a fifth to result in the/a final note to appear an octave above the first note.

The other significant aspects of Philolaus' contributions appear to revolve around his discoveries of mathematical formulas which provided explanations of the ratios in-between two tones; and in this particular occasion he may have been the first to identify and define the major second interval. Despite that Philolaus was able to produce calculations that appear somewhat logical - simple whole number ratios and explainable through a set of corresponding natural notes/tones to accommodate these, still a number of unusual ratios also appears to have occurred. Thus, Philolaus's contributions would constitute expressions of intervals that constitute a recognizable tuned major scale, and the execution of intervals of the major scale have witnessed only slight alterations since the ancient Greek period; Brissenden provides an explanation of Philolaus's discoveries as thus:

"The founding principle of Philolaus system is to use reciprocals. The reciprocal of the perfect fifth is the perfect fourth, because both together will form an octave (3/2 x 4/3 = 2). This principle can be extended to include the thirds and sixths which were in common usage we have learned by the time of the Rennaissance. Displayed below is a table in order to demonstrate these calculations; 4/3 x 9/8 is the the equivalent of 3 to 2. 9/8 thus providing the first definition of a whole tone - Philolaus then divided the octave as far as was possible using this ratio. And then found that the final ratio 256:243 was the same discrepancy in both the lower half of the octave and the upper after 2 major seconds for the perfect fourth. And 3 major seconds for the perfect fifth. Now whilst 256/243 remains a whole number relationship – at this extreme its unanswerable that human perception cannot tell the difference between incremental whole number changes. 256/243 is not a definition of a semitone that we would recognize as being very useful today and it is perfectly possible to find other definitions of the semitone" (Brissenden, Four Lectures on the subject of Tuning and Perception of Tuning; An Exercise in Decolonizing the Music Curriculum, 2022).

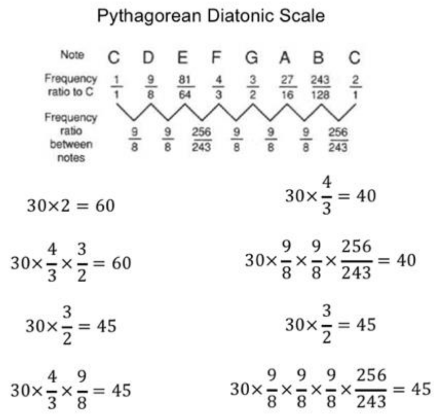

Figure 4.2. Diagram from Brissenden's The problem with tuning

Aristoxenus

After Pythagoras and Philolaus, another wave of influential figures from ancient Greece were destined to affect the conception of Western tuning in the coming centuries. Probably the most significant philosopher on music (apart from Pythagoras) was Aristoxenus (approximately 375-335 B.C.). Interestingly, Aristoxenus (a student of Aristotle) was a great opposer to Pythagoras' previous conceptions of a tuning system which was based (entirely) on mathematical calculations and instead suggested that individuals should judge musical sounds and their properties by using their ears; he addressed the following in his thesis (Elements of Harmony):

"A tone is the difference in compass between the first two concords, and may be divided by three lowest denominators, as melody admits of half-tones, thirds or tones or quartertones, while undeniably rejecting any intervals less than these. Let us designate the smallest of these intervals as the Enharmonic diesis, the next smallest Chromatic diesis, and the greatest a semitone" (Partch, 1949/1974, pp. 365-366).

As we already addressed previously - with the emergence of Aristoxenus it appears that ancient Greek music evolved into two different 'threads' in the history of Greek acoustical science; the first was initiated by Pythagoras (Pythagorean school, i.e. philosophers who approached acoustical science through the lens as mathematicians) who dealt with "… the study of musical pitch and the relationships between notes of different pitch", while the other 'thread' (Aristoxenus school i.e. considered themselves as physicists, or as Natural Philosophers) who departed from the former conception and focused on "… the study of the physical phenomena of sound" where "…the notes were … points with no magnitude, and that the intervals between them were the measurable quantities. Members of this school … were merely judging the 'quantities' of the intervals by ear and by guesswork" (Landis, 1999/2001, pp. 130, 132).

Interestingly, Aristoxenus is often cited as one of the most important writers on ancient Greek music; apparently his love for music is undeniable and inherent through his father whose musical background seems to have played a significant part in Aristoxenus' work. Further, he is frequently cited in many significant books about music theory independent of whether they derive from ancient Greek antiquity or from a more recent (contemporary) time period. Also, it should be clarified that despite his influence by and recognition of the importance of the Pythagorean scale, his main concern dealt with the exact conceptualization and measurement of individual tones. This leads us to Aristoxenus' other significant contribution to Western music - a recurring concern among numerous scholars/philosophers/theoreticians/mathematicians since the 16th century Western music, although its - impact has mostly been manifested within the past 200 years as a result of proper tools to allow for accurate calculation of intervals; namely we are talking about the phenomenon of equal temperament (we will cover this extensively later on in this chapter).

German writer of ancient Chinese music, Fritz A. Kuttner (1903-1991) suggests that Aristoxenus may have been the first to provide the "… first precise definition of equal temperament: he offered values represent certain seemingly equal parts or divisions of the octave, but it is unclear what these "parts" actually are…", however, this assessment has been met with some speculation, among others by acoustician and composer James Murray Barbour (1897-1970) who pointed out "… that several other interpretations are just as possible" (Kuttner, 1975, p. 174). Despite the significant contributions attributed to Aristoxenus, it is important to address that he was not the first in a lineage of philosophers to come up with the conception "nature of music" in relation to tuning entirely by himself; his two predecessors Aristotle (384-322 B.C.) and Plato (approximately 429-347 B.C.) were (and are) far more renowned philosophers in general although not necessary in the context of music.

Plato and Aristotle

Among others, Burkholder *et al*. assert that through Plato's and Aristotle's writings philosophical ideas from ancient Greece approached "astronomy through the notion of harmonia", a phenomenon which dealt with the interrelation between a few different aspects comprising mathematic laws and proportions believed to substantiate "… both musical intervals and the heavenly bodies, and certain planets, their distances from each other, and their movements were believed to correspond to particular notes, intervals, and scales in music" although Plato's provided "… poetic form in his myth of the "harmony of the spheres, the unheard music produced by the revolutions of the planets" (Burkholder, Grout, & Palisca, 2010, p. 13).

Tuning innovator and author John R. Pierce (1910-2002) seems to share the view of Plato's significance in terms of music by suggesting that among singular contributions attributed to him was that he managed to identify "… the five regular polyhedral with the four elements and the universe (tetrahedron, fire; cube, earth; octahedron, air; icosahedron, water; dodecahedron, the universe)"; evidently this came about due to an increasing interest to showcase that "… the relation between the lengths of strings and musical intervals is empirical" (Pierce, 1983/1992, p. 20).

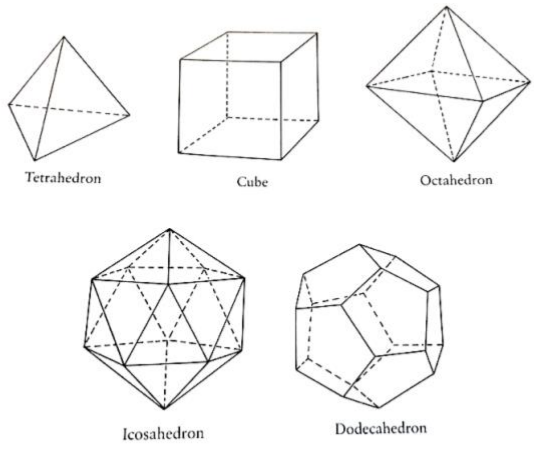

Figure 4.3. The five regular polyhedral as identified by Plato (Pierce, 1983/1992, p.22)

Ptolemy

The correlation between music, human soul and harmony in connection with numbers and universal orders would still have a significant impact on future writers on ancient Greek music in the coming years. For instance, this appears to have been similarly outlined by Claudius Ptolemy (approximately fl. 127-148 A.D.), in addition to being considered as the main astronomer of antiquity, he was also a significant writer on music (Burkholder, Grout, & Palisca, 2010, p. 13). Jorgensen claims that Ptolemy introduced the natural just intonation diatonic scale ("intensi Diatonica" scale) in the 2nd century, which contained major whole-tones and minor whole-tones that were averaged to be in the same sizes (Jorgensen, 1991, p. 9). Further, Cleonides (approximately 2nd or 3rd century A.D.) wrote the treatise *Introduction to Harmonics*, where he observed that within the diatonic genus the "…three main consonances of perfect fourth, fifth, and octave" were further characterized and divided into tones (T) and semitones (S) - he recognized that this could be done only in a few ways which he grouped into 'species'; the first octave species are Mixolydian (B-b), Lydian (c-c'), Phrygian (d-d'), Dorian (e-e'), Hypolydian (f-f'), Hypophrygian (g-g'), and Hypodorian (a-a') (Burkholder, Grout, & Palisca, 2010, p. 17). Burkholder *et al*. believe that these octave species are similar to the seven diatonic tunings already established by the Babylonians prior to ancient Greece (Burkholder, Grout, & Palisca, 2010, pp. 15, 18).

Physical evidence on ancient Greek music

In terms of physical evidence on music of ancient Greece, a vast number of ancient objects exists, among the most common are clay pots which depict musical activity and form some of the basis that researchers and scholars have been able to establish. The following instruments are the most common in ancient Greek music: the aulos, lyre and kithara, other instruments used were harps, panpipes, horns, early form of organ, and a variety of percussion instruments such as drums, cymbals, and clappers (Burkholder, Grout, & Palisca, 2010, p. 10). However, when we approach the subject of musical instruments (and art) of presumably ancient origin, we may encounter a few challenges (as has been addressed previously in this chapter).

In accordance with this assessment, some debates have emerged about the origin of the aulos. Landis addresses that a marble sculpture from Keros (currently a Greek island in the Cyclades) dated between 2800 B.C. and 2300 B.C. depicts an aulos, however, the main issue revolves around whether the island at that point in history would be considered to be part of Greek or Carian culture, and debates revolves about the unusual shape of the vase which shows similarities to the appearance of more modern vases (Landis, 1999/2001, p. 25). Landis strongly suggests that the instrument has existed in some developed state/form since at least the 6th century B.C., and is evident through depictions on Greek vase-paintings from the same time period (Landis, 1999/2001, p. 26). The ancient aulos appears to have comprised a pair of pipes, with vibrating reeds in their mouthpiece, with the arrangement of holes to enable each pipe of the aulos to play a scale of six ‘natural’ notes (with the option of raising the pitch of five of them by a small amount) - according to sufficient literary evidence, three ancient aulos scales existed; the Dorian, Lydian and Phrygian, and until halfway through the fifth century B.C. there were three types, or sizes, of aulos, one bored for each of the scales (Landis, 1999/2001, pp. 2, 35).

Landis states that the existence of lute instruments (depicted on statuary or terracotta figures) appears to have been part of ancient Greek music since the latter part of 4th century B.C., and divided into two different types: 1) “… containing oblong soundbox and straightsided fingerboard” with a “… longitudinal ridge down the back of the sound-box …”, while 2) “… is more or less pear-shaped, with no clear demarcation between sounding-board and neck” (Landis, 1999/2001, pp. 77-78).
It is important to address that despite information provided in history books may strongly suggest or indicate that specific instruments to be of Greek origin, mainly on the basis that no earlier existence (in any other musical culture) can be traced prior to ancient Greek civilization, or no other physical specimen extant from other cultures of same or earlier vintage can substantiate another origin; still it is unreasonable to presume that such instruments may have been of Greek origin unless some other firm evidence can prove otherwise. Among others, Partch appears to concur with this view; he points out that aspects of history such as “… art and divinations …” formerly attributed to ancient Greek, may in fact be of “…remote origin” (Partch, 1949/1974, p. 361).

The previous assessment can be exemplified through instruments such as lyres harps and stringed lute instruments, which until the last 100 years ago or so were largely believed to have to originated from ancient Greece; although archaeological evidence near the royal tombs at Ur in southern Iraq (as previously described), firmly proves that that these (or similar) instruments existed prior to the ancient Greek civilization, thus the invention of such instruments cannot be entirely attributed to ancient Greece by itself, although the contemporary design, size, amount of strings and tuning on the instrument may well, in fact be a culture specific phenomenon. The musical instruments discovered in southern Iran prove that harps and lyres predate the ancient Greek civilization, although these instruments contain some different configurations to their Greek counterparts. Further, there is evidence of a number of ancient instruments to appear in Indian music which are believed to be of Arabic origin, while interaction in ancient times between the Arabic and the Western culture largely suggests exchange of instruments between the two cultures. To complete the picture, Chinese culture also contains musical instruments derived from foreign cultures dating back to ancient times, both from neighbouring nations as well as Indian music (such an example is the pipa).

Similarly, to the *qiyan* tradition (female musicians who were also prostitutes) of ancient Arab music, a similar tradition appeared among *auletris* (female aulos players) of ancient Greek, a term that was "… regularly used to mean a high-class prostitute" (Landis, 1999/2001, p. 7). Despite that we have previously addressed various musical coincidences (i.e. evidences of similar instruments or other aspects of music) to appear between the Arab World and Greece; interestingly enough, this appears to be another indicator of interactions between the two cultures. However, it is difficult to attribute this type of profession (female musician/prostitute) to either ancient Greece or ancient Arab World, as it may have existed in the Arab World prior to ancient Greece music tradition or possibly resulted in the *qiyan* tradition to be influenced by the *auletris* tradition (unless this type of profession was also apparent in other ancient cultures as well). Another significant aspect which also unites both ancient Arab World and ancient Greece; is tetrachordal theory - while originally attributed to ancient Greek music, it is also considered a significant part of Arabic music.

Concept of Tetrachords

Burkholder *et al.* suggests that the ancient Greeks introduced the concepts of tetrachords (four strings), which comprised of four notes (mostly) spanning a perfect fourth, and a genus (classes) that distinguished into three different categorizations of tetrachords; diatonic, chromatic and enharmonic (Burkholder, Grout, & Palisca, 2010, p. 15). All of these terms appear in Western music today, although the ancient Greek conception of the terms ‘chromatic’ and ‘enharmonic’ does not appear to hold the exact same meaning today (Landis, 1999/2001, p. 90).

When examining some of the most groundbreaking and important aspects of early ancient Greek music – one recurring discussion among contemporary scholars revolves around the exact origin of some of the theoretical aspects of tuning and musical instruments and whether they are the product of ancient Greece or derive from the area currently comprising the Arab World (predates the ancient Greek period). In general, this mainly concerns the earlier stages of music associated with the ancient Greece civilization, and in this occasion, unfortunately it may affect and to some extent question the reliability of Pythagoras’ musical contributions. It should be stressed that this is by no means meant to be any criticism of Pythagoras (taken into consideration the vastness of his overall contributions to ancient Greek civilization, it is highly unlikely that he would claim all of his ideas in absence of external sources).

European music culture

“European culture has deep roots in the civilizations of antiquity. Its agriculture, writing, cities, and systems of trade derive from the ancient Near East. Its mathematics, calendar, astronomy, and medicine grew from Mesopotamian, Egyptian, Greek, and Roman sources. Its philosophy is founded on Plato and Aristotle. Its primary religions, Christianity and Judaism, arose in the ancient Near East and were influenced by Greek thought. Its literature grew out of Greek and Latin traditions and drew on ancient myth and scripture and architecture. From medieval empires to modern democracies, governments have looked to Greece and Rome for examples.” (Burkholder, Grout, & Palisca, 2010, p. 4)

The remaining part of this chapter will be dedicated to explorations of a limited number of musical cultures where medieval and modern Western music are the main focal point; to a less extent we will examine minor influences from Arabic music and a brief inclusion/examination of medieval Chinese music in order to provide a sufficient overview about the development of Western music and tuning conceptions which eventually will showcase how these cultures across a number of centuries have influenced one another.

It should be noted that only slight if any noticeable changes appear to occur in Western music in the intervening period between ancient Greek and the Roman Empire when the former merged into the latter approximately 146 B.C. However, traces of influence from "Pythagorean tuning" may possibly have appeared in ancient Chinese music at this point in history. According to Kuttner, adjustments or possibly a manipulation of the numbers in "Pythagorean" tuning appeared in the ancient text called Huai Nan Tzu, by Prince Liu An of Huai Nan approximately 122 B.C. (Kuttner, 1975, pp. 171-172). This assessment may indirectly be substantiated by Partch, who addresses that Pythagoras was a known traveller in his time, and documentation of his travels includes Egypt, Chaldea, Babylon, and possibly as far as India; Partch states that he "… recall seeing a Hindu book on musical theory which stated that Pythagoras visited India, bringing the Harmonical Proportion to its presumably benighted musicians" (Partch, 1949/1974, p. 363).

Similarities of instruments and possible adaptions/customizations of musical instruments found in different cultures

While it appears that contact between China and other cultures after the Han dynasty was already established, the introduction of various instruments to China substantiates interaction across a significantly wide periphery (area of land), best exemplified by the introduction of the pear-shaped pipa of Indian origin (approximately 202 B.C.-220 A.D., and possibly emerged through ancient trade caravan routes), the konghou harp of Persian origin (introduced approximately 100 A.D.), a number of hand drums (introduced approximately 613-628 A.D.) from India and Middle-East, and the yangqin dulcimer from Europe or Middle-East (no exact timeline for this is verified, although it had become a prominent instrument in late 19th to 20th century) (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, pp. 28-29, 31, 83). Although, difficult to prove, it is not unlikely that the awareness of Pythagorean tuning or instruments tuned accordingly to Pythagorean tuning could have emerged in Chinese musical culture at some point during medieval times if not before.

Interestingly, in accordance with what we have witnessed previously by examining the ancient history of Greece and Arab World, Chinese music was also affected by and exposed to a number of musical instruments through interactions from neighbouring nations/cultures at various points in ancient times, although these occurrences are differentiated by millennia in comparison to the aforementioned examples; according to Mingyue, the emergence of instruments from Indian and Persian origin first appeared at the dawn of modern era (approximately 100-200 A.D.) while another wave of foreign instruments from European/Middle-East areas emerged in China around the middle of the first millennium (approximately 500 A.D.). Interestingly enough, however, when taking into account these additions or incorporations within the overall palette of Chinese music, none of these instruments appears to be commonly found within their indigenous musical cultures today.

This also leaves us with another set of questions as to how we can possibly interpret ancient musical instruments associated with China. Any instruments to be incorporated from one musical culture into another will be exposed to some degree of modifications either slightly or significantly different from their inherent culture. Such a process can take various forms, and the changes may occur across a limited number of years or even as much as centuries in the making to achieve utter perfection.

All of these foreign influences may have affected Chinese music to some or less degree, thus it is not unlikely that this may have affected the tonal characteristics between ancient and modern Chinese instruments. One such example is addressed by Mingyue, who believes that the sound reproduction on Chinese instruments prior to the 10th century appear surprisingly different from what is generally considered Chinese sounding in a traditionally sense (after the 10th century) – where the former may have pertained a distant association to Western Asiatic and probably Middle Eastern music overtones, although he suggests that it is unknown whether instruments sounded similar to music from and beyond Central Asia or if it was “foreignized” from those particular parts of the world (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 111).

Earlier in this chapter we addressed the possibility that Aristoxenus could have been the philosopher to offer the first precise definition of equal temperament, a definition is not a calculation however, nor does it constitute an achievable tuning strategy and a number of Chinese astronomers, mathematicians, acousticians, and scientists have played a much more significantly role bringing this phenomenon to Europe and evidently, to Western music.

Possibly, the earliest traces of an equally tempered tuning system in Chinese music can be attributed to the mathematician, astronomer and acoustician Ching Fang (approximately 45 B.C.), although Kuttner suggests that this was originally initiated as an experiment meant to yield completely different results. Fang discovered a 53-division of the octave by accident - a discovery which later would turn out to be significant in Western music, and in particular to renowned individuals such as Marin Mersenne and Athanasius Kircher in the 17th century (Kuttner, 1975, p. 172). Kuttner explains the 53-division of the octave as follows:

"He extended the traditional up-and-down principle from 12 to 60 steps of perfect fifths and fourths, creating a spiral of five arcs defining 60 microtonic intervals, Selecting the 12 pitches among the 60 which came closest to the quantities of an equal temperament then only dimly surmised, he achieved a credible approximation to the theoretically correct values … [His objective was] to reduce the comma and create, by approximation, an almost closed system of 12 not too unequal semitones (alternatingly 110 and 94 cents). In fact, at step no. 54 out of 60 he found that the comma had been reduced from 24 to 3.59 cents. He must therefore be credited with the invention of the 53-division of the octave … His measuring instrument chun, especially designed for the purpose, was actually more efficient than the chun used after his example 1600 years later by Prince Chu" (Kuttner, 1975, p. 172)

Col. 2

Ching Fang
c. 45 B.C.
60- or 53-Division

Step No.	Cents
0	0
48	93.84
2	203.91
50	297.75
4	407.82
52	501.66
47	591.88
1	701.96
49	795.80
3	905.86
51	999.70
5	1109.78
53	1203.62
Max. Dev.	9.78
Tot. Dev.	52.02
Mean Dev.	4.73

Table 4-1: Ching Fang's 53-division of the octave (Kuttner, 1975, p.176)

Kuttner suggests that astronomer and mathematician Ch'ien Lo-chih (fl. 415-455 A.D.) would continue in the same realm – only to refine what Ching Fang had previously discovered; he extended from 60 to 360 steps per octave, resulting in a reduced "… comma to 1.845 cents and gaining a series of 12 semitones selected from the 360 pitches which form a truly excellent approximation to the theoretical values of equal temperament." (Kuttner, 1975, p. 172).

Supposedly, a number of astronomers, mathematicians, acousticians, and scientists between early 6th century until the 10th century would make significant contributions in the development of an equal tempered scale. Kuttner believes that the previous work done by acoustician Ch'en Chung-ju (approximately 516 A.D.) and scientist/engineer Wang P'o (approximately 959 A.D.) is central as a precursor to the work of Prince Zhu (1536-?) (commonly credited for the innovation of 12-tone EDO tuning system), and that he was likely aware of this by the time he began his studies. Thus, it should be impossible to entirely credit him with the innovation of the 12-tone EDO (Kuttner, 1975, pp. 172-173). Although, we will examine the phenomenon of equal temperament more thoroughly at a later point in this chapter, it is interesting to witness that the initial conception of equal temperament (although still far from its current advancement) can be traced back as early as approximately 2000 years ago.

Innovations of late ancient and medieval European music

We have just witnessed a number of new interesting propositions for tuning and other changes to emerge in China during the course of the first millennium of modern era (i.e. 0-1000 A.D.). Meanwhile, European music appears to have been somewhat stagnant in the intervening years between the 4th century and up until the 8th century, when eventually traces of new emerging ideas and influences began to take shape. Landis claims that European music operated with a number of scales across the span of several centuries; early on, the modal scales associated with Gregorian chant (monophonic sacred vocal music) contained a variety of seven tone scales in distinctive orders, while only two of them appears to have survived and eventually develop into the commonly used major and minor scales of today (Landis, 1999/2001, p. 86).

Guido of Arezzo and Staff notation system

The 10th century would witness one of the most significant innovations to occur in the history of music, not only limited to the European/Western music culture but widely used in literally all cultures, namely the phenomenon of a staff notation system for reading of music. Apparently, the first proper example of this or at least rendered recognizable accordingly to modern standards, was proposed by music theorist Guido of Arezzo (approximately 991-1033 or later), who proposed the modern staff notation (originally intended for sight-singing) still used in Western music today and which is commonly referred to as solfège/solfeggio. Burkholder *et al.* suggests that Arezzo discovered that the syllables in one particular hymn (Ut queant laxis) corresponded to the tones in the sequence of C-D-E-F-G-A, and from there he identified that the first six phrases - started as thus; ut, re, mi, fa, sol, la (although, the syllable ut was later replaced with do) (Burkholder, Grout, & Palisca, 2010, pp. 43-44).

In the aftermath of the 10th century and in the next few centuries (whether this is relatable to the introduction of the aforementioned staff notation or not is difficult to pinpoint), it appears that future musicians became increasingly aware of the possibility to introduce more notes in order to accommodate and enhance new emerging and complex approaches towards musical compositions. This resulted in a gradual solicitation for the need of a wider palette of notes to select/choose from, which resulted in a reevaluation of tones that had been formerly considered dissonant, less desirable, and/or out-of-tune by renowned scholars from previous eras; eventually out of this Western music witnessed the introduction of polyphony.

Polyphony in music

Burkholder *et al.* suggests that between the 11th through to the 13th century the emergence of polyphony in music spread across Europe (across the periphery from Spain to Scotland); and according to Burkholder *et al.* was a practice which allowed for "… the coordination of multiple parts, interest in vertical sonorities, and use of counterpoint and harmony to create a sense of direction, tension, and resolution became characteristics of the Western tradition that set it apart from almost all others", with compositions which were based on written notation and then sight-read instead of improvised or orally (memory based) performances (Burkholder, Grout, & Palisca, 2010, pp. 92, 111-112).

Definitions of tuning practices in European music past Pythagorean tuning

Before we get into specific details about the later more widely used temperaments/concepts of tuning systems proposed in Western music, it is necessary to provide a brief summary of the tuning practices executed in European music past Pythagorean tuning system (lasting up until the 15th century) and up until modern times. Although, only a few different practices are known to have been used (while the differences between them are somewhat distinguishable today), most if not all of them were originally referred to by completely different terms, and were not addressed by their current names until centuries afterwards (with the possible exception of what is currently considered equal temperament).

An example of classification and re-classification can be gleaned for example from a reading of Jorgensen. On the basis of late 20th century terminology, Jorgensen, describes Just Intonation as "…a restrictive, irregular, noncirculating tuning system based on nature", and divides theory of Meantone temperament into a regular and historic (classified as modified meantone temperament) category, whereas the former retain some of the same qualities as Just Intonation besides that it is a "regular" and "… noncirculating temperament that contains no color in the usable keys", while the latter also retains some of the same character as the other, it is described as irregular although "… containing color variety that supported the characters of the keys" (Jorgensen, 1991, p. 10).

Further, Jorgensen describes well temperament as "…an unrestrictive, irregular, circulating temperament containing key-color contrasts that supports the characters of the keys", although variations exists such as the Victorian temperament, essentially a well temperament except that it contains less color contrasts of the keys; and finally equal temperament which is described as "… unrestrictive, regular, circulating temperament that contains no color contrasts" (Jorgensen, 1991, p. 10).

Emergence of European instruments

As the history of Western music progressed past the first millennium of modern era and beyond - the introduction of polyphony allowed for more complex layering of melodies to be played on instruments and in compliance with this, a number of new emerging instruments were introduced (among others, the organ and its accompanying keyboard interface would emerge in the 13th century); all of these innovations would yet provide a new set of challenges in terms of approaches for performances and composition making. In the following centuries, musicians would further embrace pitches/notes previously deemed dissonant and out of key in previous eras, resulting in a more advanced palette of sounds to be part of the music.

However, this led to another set of problems with existing concepts of tuning; the diatonic seven-tone scale derived from ancient Greek still applied to music back then, and with these new additional notes to appear, the perception of tones previously considered dissonant found their way gradually into the music.

The main problem with these additions is that they did not entirely harmonize with the already established/existing pure tones, thus the encountering of “wolf tones” occurred (which is a common expression for out-of-tune). This problem initiated a longer period comprising a number of centuries where various Western scholars tried to provide different solutions in order to retune notes on instruments so that each note would harmonize with another when circulating/cycling through its possible tonal centres. In essence, this would provide us with compromised tuning systems (or temperaments), forcing the formerly pure tones to be slightly retuned to accommodate new additional notes on the expense that they would sound less beautiful and harmonious. This may be best exemplified by the current standard used in Western music today, namely equal temperament; this tuning system (equal temperament) is generally regarded in as a compromise in order to enable cycling through Perfect Fifths without encountering any “wolf notes”.

Renaissance and rethinking of tuning conceptions

The initial start of the Renaissance period in the early 15th century was a ground-breaking period in the history of Western music, in addition to the introduction of more portable keyboard instruments a necessity to propose new innovations of features to accommodate more complex performances/playing and the increasing use of other tones to be executed in music, was important. For instance, the wider use of thirds and sixths in Renaissance music proposed a major challenge to music theory and the then contemporary Pythagorean tuning system, thus forcing the creation of a new approach to tuning in order to accommodate these new practices. Previously, medieval theorists based consonance only on a limited number of intervals: the octave, fifths, fourths (the latter two were perfectly tuned); however with the addition of thirds and sixths (due to the natural tones to be rendered dissonant and out of tune) a compromise was required (Burkholder, Grout, & Palisca, 2010, p. 159). In 1482, Spanish mathematician and music theorist Bartolomé Ramis de Pareia managed to propose a tuning system that rendered perfectly tuned thirds and sixth and systems which are similar to Ramis' has later become known as just intonation (Burkholder, Grout, & Palisca, 2010, p. 159). Commonly, during the initial stages after first being introduced, all of these tuning conceptions were usually distinguished as simply; an "older" and "newer" tuning system.

Just Tuning, whilst integrating the thirds and sixths, introduced another set of problems which forced certain intervals to be tuned slightly out of tune in order to accommodate other key intervals/tones commonly used by contemporary musicians. During the 16th century, a number of emerging "compromise tuning systems" required more flexible solutions for adequate keyboard layout designs which would be capable of executing wider ranges of harmonies by compromising tonal quality for each interval; further, the introduction of chromaticism (related to the twelve-tone scale) rendered not only the range of diatonic pitches and chords (also recognized as the "white keys" on a keyboard instrument) but also combined pitches associated with the chromatic scale thus providing additional tonality to the already common diatonic scale (Burkholder, Grout, & Palisca, 2010, p. 162). It should be noted that the seven white notes and five black notes formulation of the keyboard – a near universal today, was by no means standard, and instrument designers continued to experiment with keyboard design and alternative coupling mechanisms as an alternative to increasingly compromised and complicated tuning strategy.

Roughly, a century later another significant proposition which would later become a major contender to a perfect and ideal temperament or tuning of choice - the invention of mean-tone temperament. Partch attributes the invention of mean-tone temperament to the blind organist, writer and professor Francisco de Salinas (1513-1590) (Partch, 1949/1974, p. 374). Interestingly, one of the most widely used instruments of the 16th century Renaissance music, the lute (also referred to the 'household instrument' of renaissance music) originated from the Arabic 'ud (Burkholder, Grout, & Palisca, 2010, pp. 267-268).

Prince Zhu Zaiyu and 12-tone Equal Temperament

Simultaneously with the groundbreaking innovations in Europe during the Renaissance, new emerging ideas from 16th century China would forever leave an indispensable imprint on the future of Western musical culture; in large due to the innovation of equal-tempered tempered scale of twelve pitches which is widely attributed to musicologist, mathematician and astronomer prince Zhu Zaiyu (1536-approximately 1610). In the treatise Lüxue xiushuo ("A Revised Study on Lüxue") from 1584, prince Zhu provides solely firm numerical exercise of tuning procedure which is accomplished by repeatedly dividing the fundamental pitch (huangzhong) by the 12^{th} root of 2 shown below:

$\sqrt[12]{2} = {}^{\log 2}/_{12} = {}^{.30103}/_{12} = 2508583 = 1.05966$. (Liang, Music of the Billion - An Introduction to Chinese Musical Culture, 1985, p. 131)

In a later treatise called Lu Lu Ching I (written approximately 1595/96), prince Zhu's 1596 publication provided information that the "… computation would have to begin, for certain tones, with numbers containing 108 zeros, of which the 12^{th} root would have to be extracted, … by taking the square root twice and then the cube root. This lengthy and laborious procedure was followed without error." (Partch, 1949/1974, p. 381). Despite that Kuttner consider prince Zhu to be among the most important historians of Chinese music, in addition he concurs that his achievements are widely significant – however, he suggests that his work appeared to be a continuation of his father's studies (while also possibly building on previously work by Chinese authors (addressed earlier in this chapter) (Kuttner, 1975, pp. 163-164).

Coincidentally at the same time of prince Zhu's propositions, the Flemish mathematician and inventor Simon Stevin (1548-1620) wrote a treatise called "Van de Spiegheling der singconst " (exact date unknown) which appears to be the first example of a Westerner to propose a Western musical theory containing mathematical formulation (similar to the proposition made by prince Zhu) of equal temperament as $\sqrt[12]{2}$, and demonstrated by using a monochord "… which defines the 12 semitone values, correct to four decimal places, as 12 successive powers of the twelfth root of 2" (Kuttner, 1975, pp. 167-168). However, Stevin's work is subjected to a number of controversies; first of all, Stevin never published his work himself thus it was not published until 1884 by Dutch mathematician David Bierens de Haan (1822-1895), further it is not known whether Stevin was aware of prince Zhu's work or whether he recreated this work without giving him credit (that this information reached Stevin for some unknown reasons), while lastly, a number of authors including Barbour suggests that Stevin's essay dates back to 1595 or 1596 (Kuttner, 1975, p. 168).

It should be addressed that Kuttner opposes to the idea that prince Zhu provides any mathematical or theoretical definition of the temperament in his 1584 treatise, while suggesting that Stevin's proposition actually defines equal temperament "… as a series of mean proportionals between two extremes, calculates the semitone as the twelfth root of 2, and the 12 monochord pitches as the 12 consecutive powers of that twelfth root" and addresses his work on arithmetics (Kuttner, 1975, p. 169). Thus, according to Kuttner, the only signifier is the arithmetical work upon which Stevin published in 1585, which concludes that Stevin's treatise was written in 1585 or later; as a result Kuttner is convinced that "… unquestionably Stevin and Chu worked in complete independence from each other, without knowledge of the work done on the other side of the globe. They both produced original thought and results and have both claim to independently achieved solutions" (Kuttner, 1975, pp. 169-170). Thus, Kuttner states that prince Zhu "… was apparently working in a vacuum of 600 years which made it possible for him to claim a great innovation. Just as Stevin in Europe, Prince Chu was the Errechner (calculator) of this temperament, not the inventor" (Kuttner, 1975, p. 173).

Development of devices/tools used for calculation/measuring pitches from Renaissance and to current day

French music theorist and acoustician Marin Mersenne (1588-1648) published Harmonie Universelle, Owen Jorgensen states that "Mersenne revealed the exact ratios for equal temperament in his … chart … [where he] furnished equal temperament figures between the numbers 100,000 and 200,000. 200,000 to 100,000 is the ratio of a just octave", Jorgensen addresses that "There are no errors in these figures" (Jorgensen, 1991, p. 15). Mersenne apparently credited Aristoxenus, Zarlino and Franscisco de Salinas for the philosophy of equal temperament however no mentioning of Ling Lun appears in his work (Jorgensen, 1991, p. 15).

Accurate theory however, does not necessarily equate to the means to a tuning strategy. Equal temperament was commonly referred to as "keyboard temperament" prior to the 18th century, in terms of implementation its principles were influenced by the natural just intonation scale proposed by Ptolemy (in the 2nd century A.D.), however, instead of the natural whole-tones of Ptolemy, mean-tone temperament introduced new average sizes (or 'mean' tones) to be rendered neutral whole-tones (which were neither major nor minor); thus mean-tone temperament comprised two whole tone scales (1) B-flat, C, D, E, F-sharp, G-sharp; and 2) E-flat, F, G, A, B, C-sharp), of which should contain ten whole tones that are exactly the same size. However, this resulted in a "join" point between the two; the whole-tones G-sharp B-flat and C-sharp E-flat were equal to one another, but they are larger than the whole tones within the individual scales) (Jorgensen, 1991, p. 9).

Probably, one of the most significant figures responsible for populating equal temperament was German organist, music theorist and composer Andreas Werckmeister (1645-1706). Werckmeister appears to have viewed equal temperament possibly as an ancient phenomenon since similar principles appeared in an older treatise (he read) written by a theologian who suggested that "… not only derived all musical consonances from Solomon's temple, but also in particular has quoted a mathematical description of the molten sea that stood upon twelve [all-too-equal] oxen" (Partch, 1949/1974, p. 384). However, it should be addressed that the understanding of what was considered as equal temperament between Werckmeister, his nearest contemporaries and the consecutive writers on music up until the writings of Ellis & Helmholtz by the end on the 19th century actually is what modern scholars by the 20th century have regarded as well-tempered tuning.

The reason for this distinction mainly concerns a number of substandard (at least taken into consideration future inventions which allowed for more accurate calculations) methods and measurement tools which were applied in order to render these calculations as an achievable, practical tuning strategy between the 17th to 19th century. Unfortunately, none were fully capable of providing exact intervallic calculation in accordance to the mathematical formulas provided by scholars/theoreticians/mathematicians from either contemporary times or from the previous century.

According to Jorgensen, this misconception of the term "equal temperament" appears to have dated back to the 16th century and involved all types of temperaments/tuning systems which allowed for "… modulation freely through all the tonalities without encountering wolf intervals" (Jorgensen, 1991, p. 9). However, as implied in the previous paragraph, none of Werckmeister's propositions for temperament would be considered to be within close approximation accordingly to modern definitions/requirements of equal temperament (Jorgensen, 1991, pp. 8-9).

In the last few paragraphs the focus has been maintained on a number of important individuals largely responsible for the acceptance of what eventually would become equal temperament, however it is also important to include the contribution from a number of scholars from the 18th and 19th century who opposed to these ideals and were strong advocates of mean-tone temperament. By examining their contributions, it is apparent that some of these can be traced to modern tuning practices of today. Among the most significant individuals is the English mathematician Robert Smith (1689-1768) and later Scottish physicist and mathematician John Robison (1739-1805) who wrote their treatises in the 18th and 19th centuries, respectively. Smith appears to be the first individual to propose the modern tempering technique known today as the “theory of beating”, (i.e. measuring beating frequencies by ear), a practice which appears to have been initiated first on organs by Scottish inventor and engineer James Watt (1736-1819) (Jorgensen, 1991, p. 91). Interestingly enough, during 18th century England, it appears that well temperament was more common than mean-tone temperament, however proposals for equal temperament was rejected in Britain as late as in 1790 (Jorgensen, 1991, pp. 116, 229).

Standardization of reference pitch

Another significant innovation in Western music is the standardization of reference pitch. English musicologist, conductor and musician Robert (Thurston) Dart (1921-1971), claims that from approximately 1600 to 1820 or thereabout – “… the internationally used pitch for instrumental music remained fairly steady at rather more than a semitone below the one in use today (a’ = 440). The tuning fork was not invented until 1711, and there was in any case no particular reason for enforcing the international use of a single exactly determined pitch, so that no one tried to do so.” (Dart, 1967, p. 56). German silk manufacturer and self-taught musicologist Johann Heinrich Scheibler (1777-1837), was famous for two contributions to music 1) proposal at the Stuttgart Congress of Physicists in 1834 – for tone A to be “… standardized to have a frequency of 440 vibrations per second at 69 degrees Fahrenheit” (≈ 20.6 degrees Celsius), and 2) the tonometer, which was a set of “… 56 tuning forks in the octave A to A that were each tuned to be four vibrations or beats apart in frequency – thus "… Scheibler was able to manufacture tuning forks accurately for each frequency of the equal temperament scale" (Jorgensen, 1991, pp. 467, 1).

Scheibler's tonometer would be further expanded upon by future individuals and eventually turn into a more sophisticated measurement tool in the following decades towards the end of the 19th century. At that stage, the tonometer would include a wider range of tuning forks which enabled for more accurate pitches to be determined in comparison to the tuning forks originally invented by Scheibler. The advancement of these new tuning forks also afforded the possibility to finally achieve precise measurement of intervals in accordance with modern terminologies of equal temperament, thus replacing the centuries long tenure with the conceptualization that would constitute well-temperament by current-day modern terminologies.

While, the term 'equal temperament' extended to comprise the then-contemporary tuning conceptions of its time; the newly proposed conception provided by English mathematician and acoustician Alexander John Ellis's (1814-1890) allowed for an entirely new approach where the measurement of intervals was expressed using a new mathematical approach termed 'cents', where each semi-tone (in the 12-tone EDO tuning system) was distinguished by a perceptual scale of 100 cents; this is the first example where a perceptual scale was cast from the perspective of an enculturation to the exactly measured intervals of equal temperament.

As addressed above, at the time of Ellis's analysis in 1885, the tonometer had reached a much more sophisticated level and now included "… 105 tuning forks ranging from A below middle C to a rather flat D, a major ninth above middle C" – which allowed for calculation of frequencies with an accuracy of up to two decimal places. Ellis then converted the intervals into his self-invented measurement (cents), where he then rounded off to the nearest whole 100 cents,. "By using logarithm tables, he often calculated commas and ratios out to seven decimal places" by which Jorgensen concludes that he has found no errors in Ellis's calculation (Jorgensen, 1991, p. 1).

The modern equal temperament is complete compromise between the in-tune and out-of-tune chords from just intonation. Only the unisons and octaves are still in just intonation. The gain in equal temperament is that all the harmony or keyboard resources can be used, but there is a loss in the quality and harmoniousness of the most commonly used chords. Also, there is a complete loss of “key-colourisation” (Jorgensen, 1991, p. 1).

Dutch mathematician Alina Honingh attributes the idea of consonance theory based on the phenomenon of beats to Helmholtz, in his treatise *Sensations of Tone* (1863), through the use of sine wave partials (a method which sums two sine tones (of sounds to) produce beating when their frequencies are close together) Helmholtz argued that dissonance occurred because of rapid beating of the partials of a sound, while consonance lacked any such beats (Honingh, 2006, p. 15).

Apparently, Helmholtz demonstrated his analysis of musical sound accordingly to a few basic physical principles further illustrated through the combinations of tuning forks in order to showcase that the quality (or timbre) of a tone to be reliant on the intensity, order, and number of harmonics (overtones and partials) present in a note (Holmes, 1985, 2002, p. 13). It should be noted that these attributes alone would not constitute the wholeness of a singular musical note, however Helmholtz would show that such tones also consisted of a fundamental “… tone accompanied by related vibrations (harmonics) above the pitch of the fundamental, which create timbre, or tone color” - upon which Helmholtz’s “… theory suggested that sound should be analysed by its component parts” due to the fact that “… every instrument exhibits its own unique mixture of harmonics”; interestingly enough, Helmholtz’s theories did not only inspire new approaches to all natural types of sound analyses, but it also included sounds of noises as well (Holmes, 1985, 2002, pp. 13-14)

This research and demonstrations represent a considerable development in the understanding of the complexity of musical sound, and the deeper understanding of wave propagation. Pierce suggests that von Helmholtz “… analyzed sounds by means of resonators that respond strongly to sinusoidal components near a particular resonant frequency. In the nineteenth century the only available resonators were the Helmholtz resonators that Helmholtz himself devised” (Pierce, 1983/1992, p. 45). Understood as propagation through air, the phenomenon of sine (or sinusoidal) waves involves amplitude, period and phase which render the rises and falls of air pressure over time. The term Hertz (one cycle per second) now became the standard, so-termed in honor of German physicist Heinrich Hertz (1857-1894), in order describe/designate cycles per second (Pierce, 1983/1992, pp. 38-39).

Throughout this chapter, we have addressed many different aspects of Western music culture covering the period from ancient Greece and up until the late 19th century with the emergence of Ellis's innovation of 'cents' which finally enabled the possibility to properly provide exact and firm calculations of intervals numbers for equal temperament. Interestingly, despite that little focus has been devoted to the period succeeding the end of 19th century so far in this chapter, it is highly relevant to the musical compositions that will be composed and provided for this research.

Conclusion

The purpose with this chapter is twofold. Firstly, it displays the considerable complexity, intricacy and divergences that characterize the path of an evolved tuning system, as distinguished from an invented tuning system. Secondly, and considering that most readers of this work will be enculturated to western music it renders this complexity recognizable to a Western reader.

5. THEORETICAL PRACTICES OF THE FIVE TUNING SYSTEMS

Up until this point of the research we have discussed a number of different tuning systems across the world (including our own Western tuning system), briefly presented how these emerged and examined the various stages of development through firm evidence of extant historical documentation both in writing and physical artefacts. However, at this stage in the project it is necessary to focus on the most fundamental aspects of the tuning principles significant in the development of each and every VMKLI developed for this research project.

The first section of this chapter will revolve around sufficient information about the two invented tuning systems while the second part will analyse the three indigenous (i.e. evolved) tuning systems. Due to the complexity and vast amount of information required to fully understand all necessary aspects of each indigenous musical culture, this chapter intends to provide solely the most fundamental aspects from these cultures in order to explain the development and creation of every VMKLI created for this research project – in all cases this includes division of intervals within the respective tuning system with the exception of gamelan which will include classification of instruments and individual tuning for each metallophone/gong/gong-chime kettle instrument. In order to learn more about these musical cultures, three extensive and thorough studies of each indigenous (i.e. evolved) tuning system can be read in full in the appendices section at the end of this thesis.

It should be noted that the level of complexity and scope between the invented and evolved tuning systems are entirely different; the invented tuning systems are modern inventions which emerged in the latter half of the 20^{th} century by Western individuals - they do not always contain custom made instruments nor keyboard layouts specifically designed to enable performers to properly execute intervals within the tuning parameters of each respective tuning system. Further, this may be an obvious reason why development of the unique properties of these tuning systems into musical artefacts is largely absent; currently (at the initiation of this research project) in both cases sound reproduction and timbre resembles rather basic setups featured in electronic keyboards.

Composed or performed music associated with modern tuning systems are non-genre defining, by this we mean that there is no specific genre that relates to this type of approach, however, currently modern tuning systems are mostly associated with electronic and experimental music genres. The first tuning systems we will discuss in this chapter is a small collection of tuning systems created by musical composer/innovator Wendy Carlos, namely Alpha, Beta and Gamma Scales.

Figure 5.1. Photo of Wendy Carlos

Alpha, Beta and Gamma Scales

As previously mentioned, Alpha, Beta and Gamma Scales were invented by one singular person, namely American musician and composer Wendy Carlos (born Walter Carlos; November 14, 1939). Studying at Columbia-Princeton Electronic Music Center (currently known as the oldest center for electronic and computer music) she was part of a student environment/community that embraced more experimental approaches to music and compositional techniques. Interestingly, Carlos is not first and foremost recognized for inventing tuning systems but mostly renowned for her critically acclaimed soundtrack scores featured in Stanley Kubrick's movies such as *Clockwork Orange* and *The Shining*. Secondly, she is known for being one of the earliest advocates of and also assisted in the development of the first commercially available keyboard synthesizer, namely the Moog synthesizer (invented by Robert Moog). However, her first claim to fame was through the commercially successful release *Switched on Bach* (based on rework of classical works by Johann Sebastian Bach done on the Moog synthesizer) in 1968.

The first appearance of Alpha, Beta and Gamma Scales tuning systems was featured on Carlos' own album Beauty in the Beast (1986); some explanation behind the initial development of these tuning systems can be found in the accompanying liner notes to said album – the original ideas emerged through experimentation on an early digital synthesizer which was first featured on her preceding album *Digital Soundscapes (1984)*, (Carlos, Beauty in the Beast (Liner Notes), 1986). After the release of this album, Carlos discovered the possibility to retune pitches by calculating exact Cents values by writing computer programming, and realized that this information could then be transferred back to the same digital synthesizer in order for it to play back the retuned pitches. Carlos herself, describes the entire process as a result of trial and error (Carlos, Beauty in the Beast (Liner Notes), 1986). However, the purpose with all these tuning systems is never to stray away from the notions of consonance and dissonance understood from Western music constructs, but just to find another way of looking at the problem.

In her article "Three asymmetric divisions of the octave" (Carlos, Three Asymmetric Divisions of the Octave, 1996) Carlos puts forward some of the reasoning behind this tuning system, 'why not", she argues "as an experiment, investigate divisions which are not integer based, but allow fractional parts? That will lose all octave symmetry, but if we handle the octaving later, we might be able to find some really interesting equal-step specimens. Several years ago I wrote a computer program to perform a precise deep-search investigation into this kind of Asymmetric Division, based on the target ratios of: 3/2, 5/4, 6/5, 7/4, and 11/8. Here's what it discovered. Between 10-40 equal steps per octave only three divisions exist which are amazingly more consonant than any other values around them, like lush tropical islands scattered in a great ocean of uniform chaos. I call them Alpha ('alpha'), Beta ('beta'), and Gamma ('gamma')." Thus, Carlos's reasoning for adopting these tuning systems was to find/discover similar consonances within a different scale set than 12-EDO.

One of the most interesting aspects of these tuning systems in the context of academic research is that little or no evidence besides the work produced by Carlos herself – appeared to exist at the initiation of this project and no existing propositions for keyboard layouts. The main reason why these tuning systems all have been encapsulated together into one VMKLI is because they are all comprised of equally divided intervals within the division/range of perfect fifths; besides this common denominator, only scant resemblances can be detected between either of these tuning systems. Some brief characteristics of these systems; they produce pure Perfect Fifths (simple ratio 3:2), very good Major Thirds (simple ratio 5:4) which are closer to their actual ratio numbers than in the Western 12-EDO and wonderful triads – the ratios for the whole can thus be expressed as 4:5:6 because 6:4 is the same as 3:2. On the other hand, it produces less ideal Fourth, and poor octaves which are either too narrow or too wide.

Alpha Scale

The Alpha scale comprises of 9 equal steps of 77.965 cents leading up to the division of the perfect fifth (701.69 Cents); it should be noted that in this occasion the perfect fifth is closer to the Just Intonation Fifth (701.96 Cents) instead of the Western 12-EDO Fifth (700 Cents). Although no exact phenomenon of octave-based divisions exists in this tuning system, a calculated measurement of 15,3915 steps is required to reach each octave. Unlike the Equal Temperament where each division starts in "C", and next division (octave) starts in "C" *etc*, as previously mentioned the Alpha Scale is set apart as a nonrepeatable octave tuning system thus each division will start in an entirely different key than the previous one.

steps	0	1	2	3	4	5	6	7	8	9
Key or closest equivalent (if applicable)	C	C#	D (.25flat)	D (.25sharp)	Eb	E	F (.25flat)	F (.25sharp)	G (.25flat)	G
Western Interval names				Septimal Major Seventh	Minor Third	Major Third				Perfect Fifth
Cents	0	77.965	155.93	233.895	311.86	389.825	467.79	545.755	623.72	701.685

Table 5.1. Alpha Scale

Beta Scale

As previously addressed above, this tuning system maintain a similar pattern closely related to the Alpha Scale, however, the major difference is that this tuning system is divided into 11 steps per Perfect Fifth instead of 9, thus resulting in smaller steps of 63.83 Cents per interval/step.

steps	0	1	2	3	4	5	6	7	8	9	10	11
Key or closest equivalent (if applicable)	C	C (.25sharp)	D (.25flat)	D	Eb (.25flat)	Eb	E	E#	F	F#	G (.25flat)	G
Western Interval names						Minor Third	Major Third					Perfect Fifth
Cents	0	63.83	127.66	191.49	255.32	319.15	382.98	446.81	510.64	574.47	638.3	702.13

Table 5.2. Beta Scale

Gamma Scale

The major difference with Gamma Scale is that it is literally divided into twice as many intervals compared to both Alpha and Beta Scale. 35.09 Cents per step.

steps	0	1	2	3	4	5	6	7	8	9	10
Key or closest equivalent (if applicable)	C	C (.25sharp)	C# (.25flat)	C#	Db (.25flat)	Db (.25sharp)	D	D# (.25flat)	D# (.25sharp)	Eb	Eb (.25flat)
Western Interval names				Minor Second						Minor Third	
Cents	0	35.09	70.18	105.27	140.36	175.45	210.54	245.63	280.72	315.81	350.9

steps	11	12	13	14	15	16	17	18	19	20
Key or closest equivalent (if applicable)	E	E (.25sharp)	E#	F	F (.25sharp)	F# (.25flat)	F#	F# (.25sharp)	Gb	G
Western Interval names	Major Third						Diminished Fifth			Perfect Fifth
Cents	385.99	421.08	456.17	491.26	526.35	561.44	596.53	631.62	666.71	701.8

Table 5.3. Gamma Scale (separated by an upper and lower row)

Bohlen-Pierce Scale

For the uninitiated reader on invented tuning systems it may not come as a surprise that Wendy Carlos's Tuning Systems and Bohlen-Pierce Scale appears to be mentioned frequently in discussions about invented tuning systems; there are two distinct reasons for this; one obvious explanation is that both inventions were the creations of Westerners who sought new approaches towards tuning within a short time span of approximately 14 years, secondly, neither tuning system will never reach the octave nor repeat on the same key for each consecutive division – abandoning the near universal principle of accurate 2:1 octave representation represents a distinct break with tradition and the systems all share this property, and instead of the octave reference the perfect fifth as a point of division and repetition albeit at the full 3:1 third harmonic ratio in the case of Bohlen-Pierce. However, beyond this, literally no resemblance can be found between either invention. Whereas Carlos's tuning systems embraces some new progressive ideas in the search for alternative tuning, still the emphasis remains on significant key intervals and principles already established in Western tuning terminologies/principles (including the principle of consonance and dissonance) are maintained; interestingly, no similar evidence appears to be found in the case of Bohlen-Pierce Scale.

Figure 5.2. Heinz Bohlen, Figure 5.3 John R. Pierce

As indicted above, Bohlen-Pierce is a modern tuning system, its history is interesting because the creation involved two different inventors who both were employed within the microwave engineering industry and literally by sheer accident came up with the same/similar conceptual ideas for a tuning system independently despite that neither ever met nor were aware of the other's discovery/contribution until much later.

Figure 5.4. Custom built keyboard by Heinz Bohlen 1972/73, note that the yellow keys are non-playable

Bohlen-Pierce Scale was initially developed in the early 1970s by German-born microwave engineer named Heinz Bohlen who sought the potential of alternative tunings after he became a recording engineer recording concerts at *Hamburg Hochschule für Musik und Theater*. During this period, Bohlen recognized certain “limitations” within the Western 12-EDO tuning system and began to initiate conceptualizations of entirely new options/ideas for a tuning system through experimentation by re-tuning of pitches on his electric organ while simultaneously propose a new keyboard layout by restructuring the order of keys on his own electric organ to accommodate this new tuning concept (see picture above).

Approximately six years later (excerpt from Elaine Walker’s thesis), another microwave engineer named John R. Pierce came to similar conclusions for a conception of tuning system, thus leading to the eventual name of Bohlen-Pierce Scale. The only resemblance to anything remotely Western about this tuning system is that it combines two integral key measurements/components commonly associated with Western music to form divisions of intervals; namely octave although further extended by the addition of perfect fifth (701.995 – Just Intonation ratio values) in order to form tritaves, (1901.995 Cents per division) given as thus 3:1 – which is different from the more commonly used division of octave 2:1. Further, each of the tritaves are divided into 13 intervals which allows for two possible options, either as 1) Equally Tempered intervals separated approximately 146 Cents apart and 2) Justly tuned temperament with unequal separation of intervals between 133 and 169 Cents apart.

Further, Bohlen-Pierce Scale does not contain any exact pitches that corresponds to the traditional 12-EDO Western tuning system. As a result, it is not unlikely that some or possibly most tones/pitches in this tuning may be perceived as out of tune to the western enculturated casual listener. Similarly, to Alpha, Beta, and Gamma Scale no divisions ever repeats at the octave.

Figure 5.5. Picture of Elaine Walker

However, different from Alpha, Beta, and Gamma Scales, examples of custom-made instruments for this tuning exist; guitars, clarinets, stredicis, kalimbas, metallophones, and keyboards have been adapted to play Bohlen-Pierce Scale - although no evidence of uniquely crafted nor innovative instruments (besides alternative black and white keys setup from piano based keyboard layouts) specifically made for this tuning system appears to exist at the initiation of this research project. In addition to the aforementioned keyboard proposition by Heinz Bohlen, the most renowned advocate for and innovator of custom-made keyboard layout propositions for Bohlen-Pierce Scale is musician and microtonal composer Elaine Walker. Below displays her proposition of Bohlen-Pierce Keyboard Layout customized for traditional piano keyboards.

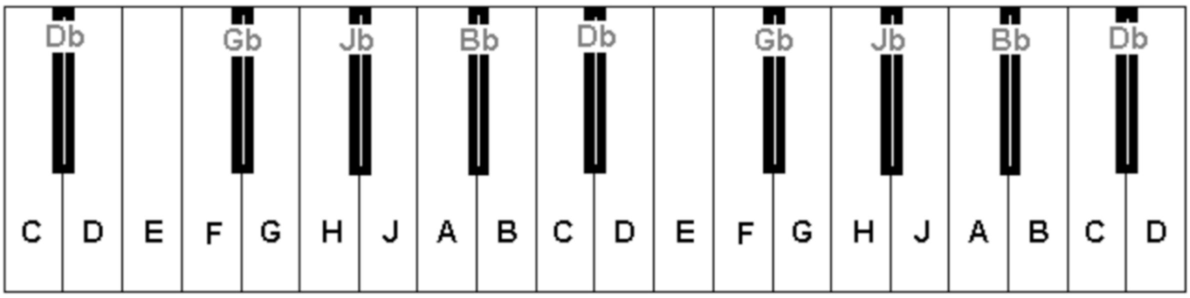

Figure 5.6. Elaine Walker's proposition for Bohlen-Pierce Scale Keyboard Layout. Referencing the C-Lambda Mode.

Elaine Walker has a Music Synthesis Production degree from Berklee College of Music (1991) and a master's degree in Music Technology from New York University (2001). In addition to this, she has a career spanning more than 30 years releasing several albums under different aliases – most notably under the moniker, Zia. Walker frequently uses Bohlen-Pierce Scale tuning to compose music although experimenting with various other conceptions derived from Western tuning principles with innovative ideas to divide the octave into further intervals and also incorporating other different tunings into her music.

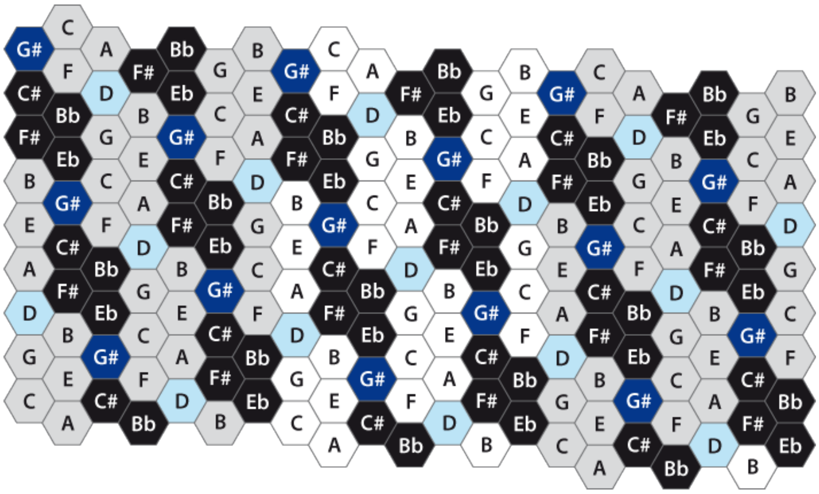

Figure 5.7. The Axis 64-key/knob hexagonal keyboard harmonic table for reference. Exemplified by lighter notes in white as on piano while darker notes represent sharps and flats. (C-Thru Music, 2021)

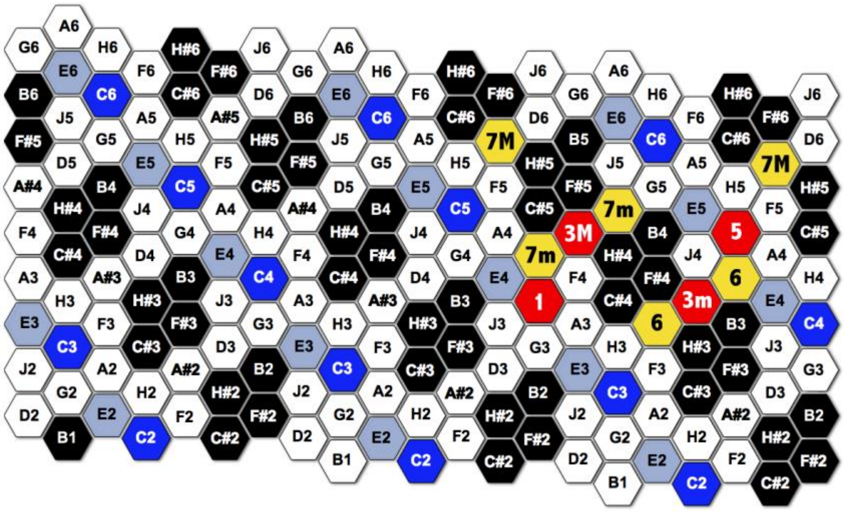

Figure 5.8. Elaine Walker's proposition for arrangement of keys on Axis-64 keyboard layout, Dur II Mode

In addition to the aforementioned proposition for Keyboard Layout, Walker has proposed a Keyboard Layout which has been adopted to the Axis 64 Keyboards (shown above). Below there are two different tables which displays the division of intervals between equally divided and Just Intonation variation of Bohlen-Pierce Scale.

steps	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Key or closest equivalent (if applicable)	C	D	Eb	F	F#	G	A	Bb	C	C#	Eb	E	F#	G
Western Interval names														
Cents	0	146.30	292.61	438.91	585.22	731.52	877.83	1024.13	1170.44	1316.74	1463.05	1609.35	1755.66	1901.96

Table 5.4. Bohlen-Pierce Scale, Equal Temperament

steps	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Key or closest equivalent (if applicable)	C	D	Eb	F	F#	G	A	Bb	C	C#	Eb	E	F#	G
Western Interval names														
Cents	0	133.24	301.85	435.08	582.51	736.93	884.36	1017.60	1165.02	1319.44	1466.87	1600.11	1768.72	1901.96

Table 5.5. Bohlen-Pierce Scale, Just Intonation

It should be noted that the non-octave conception of Bohlen-Pierce Scale affects the starting key on each tritave/division thus these appear different for each consecutive division – this is contrary to the 12-EDO where each division starts from the key of C. In the tables featured above the starting key has been set to C and in order to demonstrate what is proposed in these tables; the first tritave comprises c-G (in the next octave), next G-D, D-A *etc.* – for the sake of simplicity we only display the first tritave to give the reader an idea of the spatial difference for each interval between the two configurations for Bohlen-Pierce Scale. When we move further up the tritaves an imbalance in easily translatable key designation (according to Western terminology) becomes increasingly apparent due to the unevenness of the tritave with respect to the octave.

In terms of tonal qualities, any close comparison between the Alpha, Beta and Gamma Scales and Bohlen-Pierce may be difficult to draw; although in all cases it is not unlikely that an uninitiated western listener may perceive such pitches/tones as being out of tune. The out of tune (or alien) characteristics or qualities likely will become even more apparent when listening to pitches being played from the Bohlen-Pierce Scale – this can be easily explained since no exact nor similarly tuned intervals are shared between this tuning system and the Western 12-EDO tuning system. As previously mentioned above, Alpha, Beta and Gamma Scale produce wonderful Major Triads (4:5:6), although such a phenomenon cannot be achieved/performed on Bohlen-Pierce Scale in a natural way, however, a re-imagining of the triad may be achieved by a full ratio value of 3:5:7.

Tuning of indigenous cultures

For the remainder of this chapter the focus will solely revolve around the phenomenon of the three indigenous and therefore tuning systems previously discussed in this research project, namely the tuning approach taken within musical cultures of India, the Arab World and Indonesia.

A major difference between modern (invented) and traditional indigenous (evolved) tuning systems can be distinguished by the following; the evolution of traditional tuning systems takes place over time intervals magnitudes of orders larger than invented tuning systems, it takes place within a musical culture and it involves a vast number of significant individuals either known or unknown to us in modern times (i.e. Amir Khusrau and Tansen in the Indian music culture; al-Farabi, Safi al-Din, and Laborde in Arabic music culture *etc.*) who have each played a major part in the evolution of their respective musical culture within its history – mainly this relates to their influence on conceptional/executional practices on tuning principles and instruments either originating/emerging from its culture, influenced or emerged from other cultures and adapted or into becoming a distinctive instrument of present day.

Evidentially, the development of traditional tuning systems is a result of many, either lesser of significant changes which have occurred over the course of many centuries and in some cases millenniums before eventually the respective culture would demonstrate its current form. Thus, before we proceed any further with this chapter it is important to address that the level of complexity and vastness of information applicable to each of the indigenous musical cultures (presented in this research) likely will prove too difficult if not incomprehensible to the uninitiated reader without approaching a proper exploration/examination/study first. In order to provide the reader with a comprehensible overview which covers all necessary aspects about these indigenous musical cultures, three separate studies for Indonesian gamelan, Arabic Maqam and Indian Rag have been included in the appendices section at the end of this research project. Thus, for the aforementioned reasons this chapter will solely deal with the most fundamental information regarding tuning systems (with the sole exception of gamelan which also includes the addition of a classification system for instruments) which was a necessity for the creation of VMKLI's.

Indonesian Gamelan

The phenomenon of Indonesian gamelan is by far the most complex and most mult-faceted among the indigenous tuning systems examined within this research. This is not limited to general conception of the respective tuning systems and strategies but also in the detail of the instrument-making and fashioning processes – evidentially showcasing a vastly different approach, in terms of practice and craftsmanship when compared to Western, Arabic and Indian music due to the absence of a fixed template, nor any reference established for exact/accurate tuning of instruments. Although, Indonesian gamelan features both rhythmic/percussion and melodic instruments, the rhythmic instruments play the primary role in the ensembles and comprises of the vast majority of instruments - this also opposes to the practices of the aforementioned music cultures. As a result it should be noted that this research will solely focus on rhythmic/percussion gamelan.

The entirety of Indonesia operates with a number of different tuning systems and in some cases different configurations of these; additionally, the nation comprises of many different categories of gamelan ensembles which share a number of common instruments yet maintain their own distinct and unique selections and combinations of instruments. Due to the vastness and complicated nature of Indonesian gamelan ensembles in general, the focus on this research is limited to two distinct types of gamelan ensembles from Java and Bali only, namely Gamelan Sekar Pethak and Gamelan Gong Kebyar, respectively.

The exact tuning of instruments is determined in agreement between instrument makers and leaders (a position only entrusted to the most accomplished, skilled and longest serving members of the ensemble) of the respective gamelan ensembles – thus no single gamelan ensemble will be tuned or sound exactly the same as any other. Individual instruments are unique to each ensemble, and cannot be interchanged with instruments from another ensemble, and it is more correct to think of an entire gamelan ensemble as a single instrument. It should be noted that for Javanese and Balinese gamelan, two different tuning systems are used; Java uses two different tuning systems, one is a pentatonic tuning system called Slendro (five equidistant intervals per octave) and the other Pelog (seven unequally divided intervals per octave) and apparently all Gamelan Sekar Pethak ensembles carries one set of instruments (or one in the case where instruments shares coinciding tones for both tuning systems) tuned to each of these tuning systems, while Bali only uses a customized five tone version of.

The fashioning process is slow and requires much attention to details – thus handling of the instruments in this process is very delicate due to their fragile nature where the risk for slight errors or even breakage is very high. As indicated above, even though tuning of instruments is individually decided (between leader of the respective gamelan ensemble and instrument maker), still the tuning systems are central in this process although they appear to be rough templates or guidelines for how the instruments are tuned and vary against one another.

Similar to other nations in South-East Asia, a variety of gong, gong-chime kettle and metallophone instruments are commonly found in Indonesian gamelan and unsurprisingly these types of instrumentations appear both in Gamelan Sekar Pethak (Java) and Gamelan Gong Kebyar (Bali). However, it should be noted that the fashioning processes, shapes, sizes, timbre and number of keys or gongs between the islands are slightly different from one.

Different from all other musical cultures dealt with in this research, there appears to be no fixed or fully established classification system for gamelan instruments. On the other hand, a number of vastly different propositions for categorization of gamelan instruments made by both natives and Westerners exist, however, none appear to be entirely satisfying. Thus, as an additional element to this research, the present author has developed two separate yet distinct classification systems for gamelan instruments which relates to the instrumentations found in Gamelan Sekar Pethak and Gamelan Gong Kebyar, respectively. These classification systems have been integral for the development of the Gamelan VMKLI's created for this research.

In addition to the intricate process developing a classification system, a vastly more significant challenge for this research project was to resolve the complicated nature (at least from a Western perspective) related to the common practice of non-fixed intervals associated with Indonesian gamelan music; according to a number of renowned authors on Indonesian gamelan the discussion about tuning of instruments operates with estimated pitch/note values, although the parameters of such can vary significantly, as such the difference between two intervals on one specific instrument can vary as much as 300 cents between one ensemble and another (please read chapter on gamelan in the appendices section for further details). Due to the complex nature of computer programming software which require exact numeric values for accurate reproduction of sounds/pitches, a significant portion of data had to be collected and analyzed prior to developing a sustainable taxonomy to provide approximate estimations of intervals on gamelan instruments. Thus, the following information is an encapsulation based on findings from a number of different authors on Indonesian gamelan.

Author's Classification of instruments

The purpose of proposing a classification system here has been to display a classification that encompasses the ensemble as a whole and provides information understandable to the uninitiated reader, while further emphasizing the relationship between fashioning and tuning in both Gamelan Sekar Pethak and Gamelan Gong Kebyar ensembles.

To a great extent this process was inspired by examining several different propositions of classification systems provided by scholars from both Western perspectives and Indonesian perspectives.

Classification of instruments in Java

The instruments displayed under the classification system of Java, are based on instruments commonly found in current Gamelan Sekar Pethak.

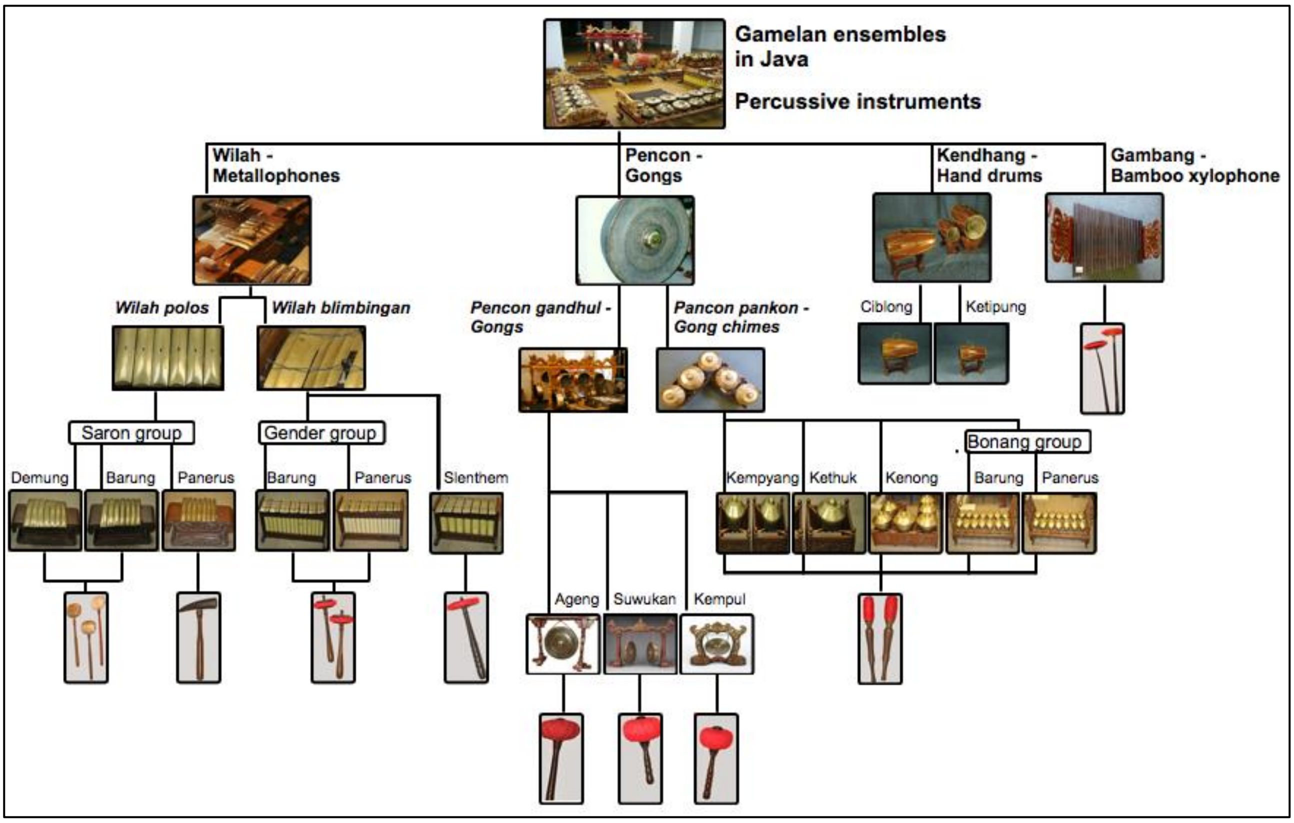

Figure 5.9. Classification system of Javanese instruments based on my proposition

Categories of Javanese instruments

The Javanese gamelan instruments have been grouped into four main categories; 1) Wilah (metallophone instruments), 2) Pencon (gong instruments) 3) Kendhang (hand drums) and 4) Gambang (bamboo xylophones instrument), the inclusion for the latter is because this is the only instrument that appears to be integral in current gamelan sekar pethak ensembles. Most groups of instruments are further divided into subgroups, where instruments are grouped into female (the larger sized and lowest pitched of the pair) - barung, and male (the smallest and highest pitched of the pair) - panerus counterparts. It should be noted that barung/panerus usually appears to be reserved for kendhang and saron instruments only, but applied to other instruments to simplify matters.

Classification of instruments in Bali

Because of obvious and distinct differences between instruments found in Javanese and Balinese gamelan ensembles, an additional classification system entirely dedicated to Balinese gamelan instruments has been completely necessary for this Music Study. The instruments classified here are based on instruments commonly found in Gamelan Gong Kebyar ensembles.

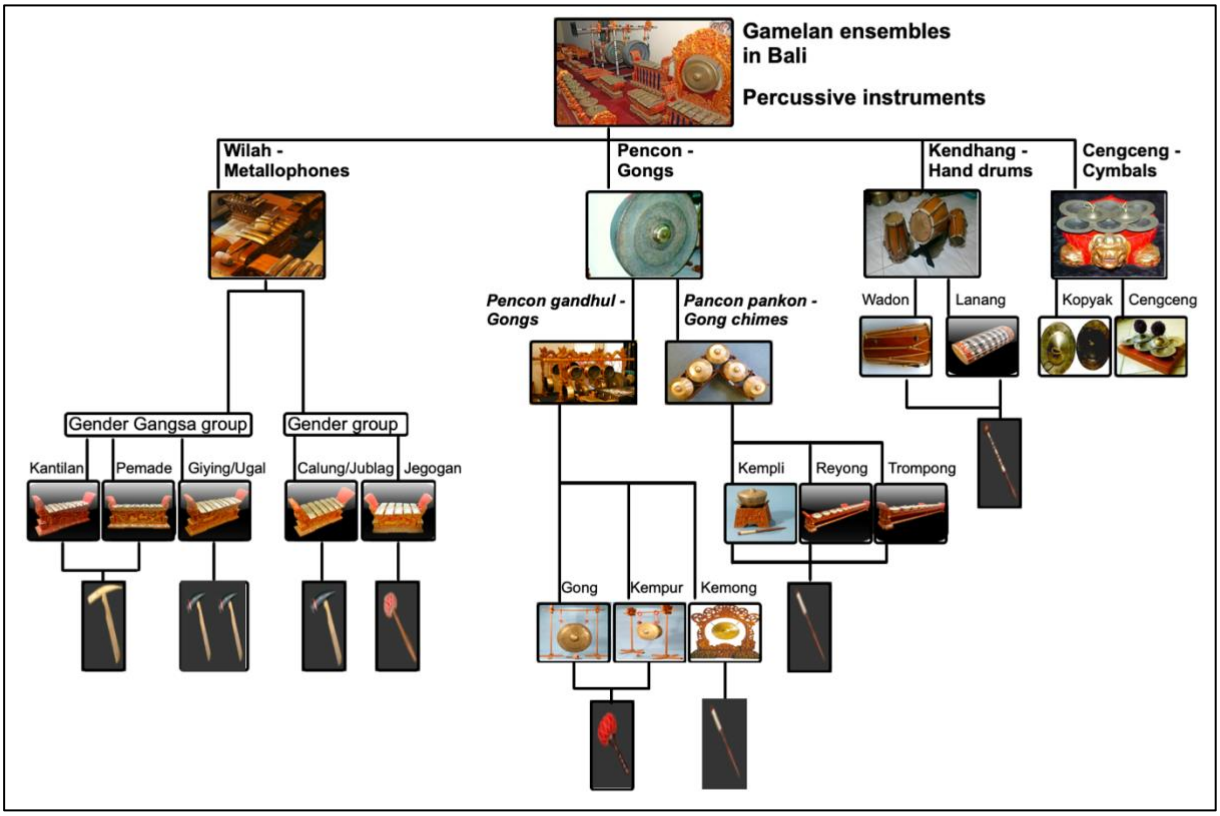

Figure 5.10. Classification system of Balinese instruments based on my proposition

Categories of instruments

The Balinese instruments are grouped into four main groups; 1) Bilah (or Daun (metallophone instruments)), 2) Pencon (gong instruments) 3) Kendang (hand drums) and 4) Cengceng (cymbals). In Bali, the terms used for metallophone keys are either Bilah or Daun, but for the sake of simplicity (and its resemblance to the Javanese word wilah), bilah will now be used to refer to keys on Balinese metallophone instruments. Also worth pointing out, the terms Pencon gandhul/pangkon has been applied to instruments in order to properly classify Balinese gong/gong-chime instruments since there appears to be no proper word to describe these instruments in Bali.

Both Javanese and Balinese gamelan ensembles share similar types of percussion instruments, such as gongs, gong-chimes, metallophone instruments, and wooden drums. Balinese gamelan instruments have much in common with their Javanese counterpart. The majority of the core instruments associated with Javanese gamelan ensembles, such as metallophone instruments with tube resonators, gongs, gong-chime instruments, and hand drums are also integral to Balinese gamelan ensembles. However, all of these instruments contain minor or major differences compared to their neighbouring counterparts. Similar to Java, Balinese gamelan ensembles also lack standardization, which means that the number of instruments, as well as the number of keys, gongs, or gong-chime kettles found on various instruments also can be quite unpredictable. However, due to the lack of a specific tuning reference applied to the instruments and their similarities to other instruments found in other cultures all over the world, inclusion of kendang/kendhang and cengceng instruments have been omitted for the creation of gamelan VMKLI's.

Tuning

Slendro

The generally accepted tuning systems used in Indonesia is slendro; which is a pentatonic system containing five approximately equidistant tones per octave. The five-tone slendro system shows similarities to the pentatonic scale found in many cultures all over the world despite being anhemitonic, which means that none of the five tones are semitones, although the tones are spaced with fairly close approximation to each other. The casting of the individual pitches within slendro is not easy to understand from a western perspective, thus a statement provided by Sorrell seems adequate to include here in order to bring some clarity:

(Slendro does not contain any semitones) … which would also describe the scale obtained on the black notes of the piano. The crucial difference is that the five of slendro are more or less equally spaced, while the black notes have clear differences between whole tones and minor thirds. The problem for the Western ear is relating the pitches of such a subdivision. Divisions of the octave into twelve equal intervals (semitones), six (whole tones), four (minor thirds: the dimished seventh chord), three (major thirds: the augmented triad) and two (tritones) are familiar, but the 'missing' division between one and six is not used in Western music, and this is the territory of slendro. If the octave is divided into five equal parts, the resultant interval will lie between a whole tone and a minor third. The somewhat elusive quality of slendro is that we cannot say exactly where, because in practice the octave is not divided into five precisely equal steps. (Sorrell N. , 1990, p. 56).

Pelog

The pelog scale is based on a seven-tone system and can be described as heptatonic. In order to give some rough estimation about the tones in pelog, it is fair to say that the seconds and thirds are the most distinguishable among the intervals, while the others appear within a closer approximation. The combination of very wide with comparatively narrow intervals found in the pelog scale is responsible for providing its resulting music with its very distinctive "shimmering" tonal character. Contrary to pelog, slendro is generally characterized to reproduce a smooth and harmonious progression. It is further important to address that the two tuning systems are never performed at the same time nor are instruments from one tuning system combined with instruments from the other during a performance. Balinese gamelan uses a five tone configuration of the pelog scale, with their own distinctive approach to division of tones. In common with the Javanese approach it does not demonstrate a standardized division of tones per octave.

To further complicate matters, neither slendro nor pelog resemble the five-tone or seven-tone systems (commonly found in other parts of the world) entirely, the tones neither divided exactly into either whole tones nor half tones, no such building blocks exist, and the intervals do not conform or model elements of the harmonic series. The closest resemblance comparable to a Western based tuning system, however, can be attributed to the slendro scale, which is divided into near equal intervals per octave. The concept of tuning in Indonesia is mainly based on approximation of tones, and there is no fixed arrangement nor system in order to make tones accommodate what is commonly established in Western terminology which offers precisely calculated pitches. Tuning strategies take account of many different concepts, an emphasis on regional, perhaps even the ideas and practice of individual makers appears to be a valid approach to understanding. No instruments are tuned to exact cent or frequency/Hz values because the tuning of instruments and gamelan ensembles are not standardized but usually agreed between a manufacturer and client.

The tones on Javanese instruments are divided as follows: slendro (1 2 3 5 6), and pelog (1 2 3 4 5 6 7), it should be noted that tones 4 and 7 are left out in slendro tuning. Subscript dots are used in order to display the lower octave on instruments while superscript dots are used for higher octave. Most Javanese ensembles commonly use both tuning systems, while Bali on the other hand prefers pelog although with some alterations to it - either as a four or five tones per octave (slendro configuration.

McPhee proposed a comparison of the slendro and pelog scales (both shown as five tones) in order to give some clue about how we can understand and interpret approximate differences between intervals on these two scales; within performance practice, pelog rarely (if ever) uses more than five tones, thus is only displayed with five intervals here (McPhee, 1976, p. 52). As is evident from the examples (in both cases) intervals rarely resemble those found in Western 12-EDO tuning system, however, it is important to note, that the values shown here would likely would not match the tones found on instruments in any individual example of a gamelan ensemble either!

Slendro

	195	205	272	259	269
C#	D#	E#	G#	A#	C# (12-EDO)

Table 5.6. McPhee's proposition for slendro tuning (McPhee, 1976, p. 52)

Pelog

	134	172	412	82	400
C#	D	E	G#	A	C# (12-EDO)

Table 5.7. McPhee's proposition for pelog tuning (McPhee, 1976, p. 52)

Judith Becker has come up with a system similar to the one proposed by McPhee; although in Becker's model all the intervals for the pelog scale are displayed, and as we can see from the example below, we no longer observe any gaps of approximately 400 Cents between intervals (Becker, 1980, p. xvi). It is important to address that McPhee's example of a pelog scale dealt with only five tones instead of seven, thus two intervals/tones were left out. Despite both McPhee and Becker used a similar approach towards their interpreted tuning of slendro and pelog scales, an interesting observation, however, is that the approximate value of intervals from Becker's examples in fact do not match any of those provided by McPhee. Further, It is worth mentioning that one of the intervals deviates by as much as 53 cents! The most distinguishable contribution from Becker's example is that we are able to get a clearer perspective on how all tones on the pelog tuning system possibly are divided. Collectively, the contribution from all authors manages to make the concept of measuring intervals clearer, and further it is now easier to understand what both Sorrel and Anderson Sutton refers to in their description of tuning, although with the addition of McPhee and Becker we are able to establish a reference in order to understand how pitch numbers are assigned to slendro and pelog scales. Becker also explains that it is impossible to accurately show exact notes on staff so these appears within the nearest key according to Western tuning.

Slendro

1	2	3	5	6	i (upper octave)
220	280	236	242	248	
Staff notation proposed for slendro as C-D-E-G-A					

Table 5.8. Becker's proposition for slendro tuning (Becker, 1980, p. xvi)

Pelog

1	2	3	4	5	6	7	i (upper octave)
120	144	297	117	126	155	246	
Staff notation proposed for pelog as E-F-G-A-B-C-D							

Table 5.9. Becker's proposition for slendro tuning (Becker, 1980, p. xvi)

Further, Tenzer suggests that a rough pelog sample (as he calls it), can be played on the following white keys on the piano E-F-G-B-C (Tenzer, Balinese Music, 1991, p. 32).

Tuning of individual instruments:

Both Sorrell and Tenzer have described tuning of individual instruments in great detail, however, two completely different approaches have been proposed. As we observed earlier when we discussed tuning, Sorrell uses number sequence for slendro and pelog scales in order to describe the individual tuning of instruments while Tenzer appears to use the propositions presented by Andrew Toth, to describe tuning through measuring beat frequencies. Both authors have provided the majority of the following information, although minor contributions from others also occurs.

A compromise that incorporates the suggestions from Becker, Sorrell and Tenzer have been taken into account, Becker's staff notation suggests the starting key for pelog to be somewhat close to E, Tenzer C#+47 cents, while Sorrell suggests something between approximately C# and D#, thus for this music study D-D# is used as the starting pitch for pelog, and for slendro tuning - the measurement of tones have been set to accommodate tones slendro5/pelog4 and slendro6/pleog6 accordingly to Becker's intervallic proposition. It is important to address that the pitches suggested below are given in fixed note or in-between two notes, this has been done to simplify matters related to actual tones on all gamelan instruments independent on either island and tuning system.

Java

In Java, both slendro (five-tone) and pelog (seven-tone) tuning systems are actively used and appear to be the most common approach to measuring pitches on instruments (all authors on Javanese gamelan, besides Becker) only refers to specific tones within an unspecified octave (the system only gives indications of the tones on the instruments and ranges within one or in some cases two octaves), tuned in either of the two tuning systems; for example, tone 3 in the slendro scale, or tone 5 in the pelog scale simply referred to as slendro 3 and pelog 5, respectively. Sorrell is clear about not wanting to show fixed intervals and notes that proposes the relations between various notes for both slendro and pelog because states that "…Javanese attach great importance to embat, or intervallic structure" (Sorrell N. , 1990, p. 56). However, he suggests a visual impression showing the two tuning systems in relation to each other appears to be the most adequate approach to make it understandable for the reader. Further, he mentions that slendro 5 and pelog 4, as well as tones 6 for both tuning systems, are exchanging or coinciding notes (tumbuk nem gamelan) (Sorrell N. , 1990, p. 57)

slendro												
6.		1		2			3	5		6		i
pelog												
6.	7.		1		2	3		4	5	6	7	

Table 5.10. Sorrell's proposition for tuning relations between slendro and pelog intervals (Sorrell, 1990, p. 57)

Previously, Sorrell referred to the pitches on slendro roughly to fit with the black keys on a piano, which will suggest approximate pitches around C#-D#-F#-G#-A#-C# in slendro, by taking these pitches into consideration, the following pitches D-E-F-G#-A-A#-C-D should be somewhat in close approximation to those found in pelog.

Author's own tuning of instruments and explanation of compromises made to accommodate Javanese gamelan instruments

However, the major challenge with Javanese instruments is that no authors of Javanese gamelan has provided a full spectrum which shows us the full frequency range of every single instrument. This makes for a very big challenge calculating approximate (value of) pitches per each octave for both systems, the only author who proposes any model for how to calculate intervallic values for slendro and pelog, is Judith Becker. However, for singular instruments we need to rely on Sorrell as he appears to be the only author who provides us with specific slendro/pelog numbers for each Javanese gamelan instrument. If we take into account the staff notation proposed by Becker it suggests that the first tone in slendro appears at a lower pitch than that of the pelog - this appears to coincide with what we see from what Sorrell proposes as well. Further, Becker's proposition also suggests that both slendro5/pelog4 and slendro6/pelog6 coincide with each other, thus we can be assured that this is an appropriate model to use in order to calculate approximate pitches for Javanese instruments. Becker is clear about the staff notation for pelog not being entirely precise nor representing the exact pitches in pelog, but based on this we should take into account that the first note in pelog should appear above D with an intervallic value closer to E since this is where the first pelog note supposedly starts. If we take into account Sorrell's assessment about the slendro scale roughly to be played on the black keys on piano, and through his model the pelog1 note should appear between slendro1 and slendro2, (C# and D#) (we need to keep in mind Tenzer's proposition that the first tone would appear at C#+47 cents) – based on the intervallic values proposed by Becker, and in order to synchronize them so that the both coincided notes would match, pelog1 is likely to appear at approximately 260 cents (D-D#) – below is a model made particularly for this Music Study which incorporates and merges information from both Becker and Sorrell, thus the following suggestion for intervallic values for tones in gamelan sekar pethak have been proposed by me:

						slendro					
85		305			585	821		1063		1311 ≈ 1285	
≈C#		D#			≈F#	≈G#		A#-B		≈C#	
						pelog					
	260		370	524		821	938	1064	1219		1465 ≈1460
	D-D#		D#-E	≈F		≈G#	A-A#	A#-B	≈C		≈D-D#

Table 5.11. Encapsulated information based on Becker and Sorrell’s proposition for slendro and pelog tuning

For the sake of simplicity, all tables from now on, will show all of the pitches accordingly to their closest Western notes or “in-between” notes where applicable. In situations where there is no mentioning of any exact octave in relations to other instruments, I have tried to signify this in the best possible way, unfortunately in some cases assumptions of octaves has been required due to lack of firm information from any of the authors. The majority of information about pitches on Javanese instruments will be provided by Sorrell, with minor contribution from other authors. In addition, a chart proposed by gamelan.gs (https://gamelan.gs/booklet/a-javanese-gamelan-sound-library/) will be the only other tool to provide us with further insight about the frequency spectrum for all typical Javanese gamelan instruments (the chart suggests a total range of approximately five and a half octaves altogether), this will help us understand the frequency spectrum of each instrument, however, I will use the other authors of Javanese gamelan in order to verify whether the information appears valid or not, and what possible deviance in range if such occurs.

Javanese Instruments

In the process providing pitches for each instrument below, originally a lengthy discussion about validation and reasoning for tuning of each individual instrument was proposed and can be read in full in the appendices.

Gong ageng

The gong ageng has been tuned to approximately between 58.270 Hz and 61.735 Hz (A#1/Bb1-B1).

Gong suwukan

The first gong suwukan tuned at slendro 2 would oscillate at approximately 77.782 Hz (D#2/Eb2), while the second gong suwukan in slendro 1 at approximately 69.296 (C#2/Db2).

Kempul

The following order of pitches for the kempuls; slendro5 = 97.999 Hz (G#2/Ab2), pelog5 = 110.00-116.54 Hz (A2-A#2/Bb2), note 6 = 116.54-123.47 Hz (A#2/Bb2-B2), pelog7 = 130.61 Hz (C3), slendro1 = 138.59 Hz (C#3), pelog1 = 146.83-155.56 Hz (D3-D#3/Eb3. This suggest a ratio of three gongs for slendro tuning, and four for pelog tuning.

Kenong

Tables for tuning of Kenong instruments are shown below:

2	3	5	6 (tumbuk)	i
Hz	**Hz**	**Hz**	**Hz**	**Hz**
311.13	**369.99**	**415.30**	**466.16-493.88**	**554.37**
(D#4/Eb4)	(F#4/Gb4)	(G#4/Ab4)	(A#4/Bb4-B4)	(C#5)

Table 5.12. My proposition for tuning of intervals kenong in slendro

2	3	4 (slendro5)	5	6 (tumbuk)	7	i
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
311.13-329.63	**349.23**	**415.30**	**440.00-493.88**	**466.16-493.88**	**523.25**	**587.33-622.25**
(D#4/Eb4-E4)	(F4)	(G#4/Ab4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(C5)	(D5-D#5)

Table 5.13. My proposition for tuning of intervals kenong in pelog

Kethuk and Kempyang

For slendro tuning kethuk should appear at slendro2 311.13 Hz (D#4/Eb4) while kempyang in slendro1 should appear at 554.37 (C#5/Db5).

Bonang

Based on this information the following pitches should apply to the slendro tuning - bonang barung:

6 **Hz** **932.33-987.77** / **1864.7-1975.53** (A#5/Bb5-B5 / A#6/Bb6-B6)	5 **Hz** **830.61** / **1661.2** (G#5/Ab5 / G#6/Ab6)	3 **Hz** **739.99** / **1479.98** (F#5/Gb5 / F#6/Gb6)	2 **Hz** **622.25** / **1244.51** (D#5/Eb5 / D#6/Eb6)	1̇ **Hz** **1108.73** / **2217.46** (C#6/Db6 / C#7/Db7)	2̇ **Hz** **1244.51** / **2489.02** (D#6/Eb6 / D7#/Eb7)
1 **Hz** **554.37** / **1108.73** (C#5/Db5 / C#6/Db6)	2̣ **Hz** **311.13** / **587.33** (D#4/Eb4 / D#5/Eb5)	3̣ **Hz** **369.99** / **739.99** (F#4/Gb4 / F#5/Gb5)	5̣ **Hz** **415.3** / **830.61** (G#4/Ab4 / G#5/Ab5)	6̣ **Hz** **466.16-493.88** / **932.33-987.77** (A#4/Bb4-B4 / A#5/Bb5-B5)	1̣ **Hz** **277.18** / **554.37** (#C4/Db4 / C#5/Db5)

Table 5.14. My proposition for tuning of intervals bonang barung/panerus in slendro – table showcases actual player's position (superscript dot means higher octave, subscript dot means lower octave)

4 **Hz** **830.61** / **1661.2** (G#5/Ab5 / G#6/Ab6)	6 **Hz** **932.33-987.77** / **1864.7-** **1975.53** (A#5/Bb5-B5 / A#6/Bb6-B6)	5 **Hz** **880.00-932.33** / **1760.00-** **1864.66** (A5-A#5/Bb5 / A6-A#6/Bb6)	3 **Hz** **698.46** / **1396.91** (F5 / F6)	2 **Hz** **622.25-659.25** / **1244.51-1318.51** (D#5/Eb5-E5 / D#6/Eb6-E6)	7 **Hz** **1046.50** / **2093.00** (C6 / C7)	1̣ **Hz** **293.66-311.13** / **587.33-622.25** (D4-D#4/Eb4 / D5-D#5/Eb5)
1 **Hz** **587.33-622.25** / **1174.66-** **1244.51** (D5-D#5/Eb5 / D6-D#6/Eb6)	7̣ **Hz** **523.25** / **1046.50** (C5 / C6)	2̣ **Hz** **311.13-329.63** / **622.25-659.25** (D#4/Eb4-E4 / D#5/Eb5-E5)	3̣ **Hz** **349.23** / **698.46** (F4 / F5)	5̣ **Hz** **440.00-466.16** / **880.00-932.33** (A4-A#4/Bb4 / A5-A#5/Bb5)	6̣ **Hz** **466.16-493.88** / **932.33-987.77** (A#4/Bb4-B4 / A#5/Bb5-B5)	4̣ **Hz** **415.3** / **830.61** (G#4/Ab4 / G#5/Ab5)

Table 5.15. My proposition for tuning of intervals bonang barung/panerus in pelog – table showcases actual player's position (superscript dot means higher octave, subscript dot means lower octave)

Saron

Below is a calculation for all three categories of saron instruments both in slendro and pelog tuning:

6̣ **Hz** **233.08-246.94** / **466.16-493.88** / **932.33-987.77** (A#3/Bb3-B3 / A#4/Bb4-B4 / A#5/Bb5-B5)	1 **Hz** **277.18** / **554.37** / **1108.73** (C#4/Db4 / C#5/Db5 / C#6/Db6)	2 **Hz** **311.13** / **622.25** / **1244.51** (D#4/Eb4 / D#5/Eb5 / D#6/Eb6)	3 **Hz** **369.99** / **739.99** / **1479.98** (F#4/Gb4 / F#5/Gb5 / F#6/Gb6)	5 **Hz** **415.3** / **830.61** / **1661.20** (G#4/Ab4 / G#5/Ab5 / G#6/Ab6)	6 **Hz** **466.16-493.88** / **932.33-987.77** / **1864.70-1975.53** (A#4/Bb4-B4 / A#5/Bb5-B5 / A#6/Bb6-B6)	1̇ **Hz** **554.37** / **1108.73** / **2217.46** (C#5/Db5 / C#6/Db6 / C#7/Db6)

Table 5.16. My proposition for tuning of intervals saron demung/slendro/panerus in slendro (superscript dot means higher octave, subscript dot means lower octave)

1 **Hz** **293.66-311.13** / **587.33-622.25** / **1174.66-1244.51** (D4-D#4/Eb4 / D5-D#5/Eb5 / D6-D#6/Eb6)	2 **Hz** **311.13-329.63** / **622.25-659.25** / **1244.51-1318.51** (D#4/Eb4-E4 / D#5/Eb5-E5 / D#6/Eb6-E6)	3 **Hz** **349.23** / **698.46** / **1396.91** (F4 / F5 / F6)	4 **Hz** **415.3** / **830.61** / **1661.20** (G#4/Ab4 / G#5/Ab5 / G#6/Ab6)	5 **Hz** **440.00-466.16** / **880.00-932.33** / **1760.00-1864.66** (A4-A#4/Bb4 / A5-A#5/Bb5 / A6-A#6/Bb6)	6 **Hz** **466.16-493.88** / **932.33-987.77** / **1864.70-1975.53** (A#4/Bb4-B4 / A#5/Bb5-B5 / A#6/Bb6-B6)	7 **Hz** **523.25** / **1046.50** / **2093.00** (C5 / C6 / C7)

Table 5.17. My proposition for tuning of intervals saron demung/slendro/panerus in pelog (superscript dot means higher octave, subscript dot means lower octave)

Slenthem

Below is a calculation for slenthem instruments both in slendro and pelog tuning:

6̣ **Hz** **116.54-123.47** (A#2/Bb2-B2)	1 **Hz** **138.59** (C#3/Db3)	2 **Hz** **146.83** (D#3/Eb3)	3 **Hz** **185.00** (F#3/Gb3)	5 **Hz** **207.65** (G#3/Ab3)	6 **Hz** **233.08-246.94** (A#3/Bb3-B3)	1̇ **Hz** **277.18-293.66** (C#4-Db4)

Table 5.18. My proposition for tuning of intervals slenthem in slendro (superscript dot means higher octave, subscript dot means lower octave)

1 **Hz** **146.83-155.56** (D3-D#3/Eb3)	2 **Hz** **155.56-164.81** (D#3-Eb3-E3)	3 **Hz** **174.61** (F3)	4 **Hz** **207.65** (G#3/Ab3)	5 **Hz** **220.00-233.08** (A3-A#3/Bb3)	6 **Hz** **233.08-246.94** (A#3/Bb3-B3)	7 **Hz** **261.63** (C4)

Table 5.19. My proposition for tuning of intervals slenthem in pelog (superscript dot means higher octave, subscript dot means lower octave)

Gender

Below is a calculation of Gender instruments in slendro and pelog.

6̤	1̣ (7̤)	2̣	3̣	5̣	6̣	1 (7̣)	2	3	5	6	1̇ (7)	2̇	3̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
116.54-123.47	**138.59**	**155.56**	**185.00**	**207.65**	**233.08-246.94**	**277.18**	**311.13**	**369.99**	**415.3**	**466.16-493.88**	**554.37**	**622.25**	**739.99**
/	/	/	/	/	/	/	/	/	/	/	/	/	/
233.08-246.94	**277.18**	**311.13**	**369.99**	**415.30**	**466.16-493.88**	**554.37**	**622.25**	**739.99**	**830.61**	**932.33-987.77**	**1108.73**	**1244.51**	**1479.98**
(A#2/Bb2-B2	(C#3/Db3	(D#3/Eb3	(F#3/Gb3	(G#3/Ab3	(A#3/Bb3-B3	(C#4/Db4	(D#4/Eb4	(F#4/Gb4	(G#4/Ab4	(A#4/Bb4-B4	(C#5/Db5	(D#5/Eb5	(F#5/Gb5
/	/	/	/	/	/	/	/	/	/	/	/	/	/
A#3/Bb3-B3)	C#4/Db4)	D#4/Eb4)	F#4/Gb4)	G#4/Ab4)	A#4/Bb4-B4)	C#5/Db5	D#5/Eb5)	F#5/Gb5)	G#5/Ab5)	A#5/Bb5-B5)	C#6/Db6)	D#6/Eb6)	F#6/Gb6)

Table 5.21. My proposition for tuning of intervals gender barung/panerus in slendro (superscript dot means higher octave, subscript dot means lower octave)

6̤	1̣	2̣	3̣	5̣	6̣	1	2	3	5	6	1̇	2̇	3̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
116.54-123.47	**146.83-155.56**	**155.56-164.81**	**174.61**	**220.00-233.08**	**233.08-246.94**	**293.66-311.13**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**	**622.25-659.25**	**698.46**
/	/	/	/	/	/	/	/	/	/	/	/	/	/
233.08-246.94	**293.66-311.13**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**	**622.25-659.25**	**698.46**	**880.00-932.33**	**932.33-987.77**	**1174.66-1244.51**	**1244.51-1318.51**	**1396.91**
(A#2/Bb2-B2	(D3-D#3/Eb3	(D#3/Eb3-E3	(F3	(A3-A#3/Bb3	(A#3/Bb3-B3	(D4-D#4/Eb4	(D#4/Eb4-E4	(F4	(A4-A#4/Bb4	(A#4/Bb4-B4	(D5-D#5/Eb5	(D#5/Eb5-E5	(F5
/	/	/	/	/	/	/	/	/	/	/	/	/	/
A#3/Bb3-B3)	D4-D#4/Eb4)	D#4/Eb4-E4)	F4)	A4-A#4/Bb4)	A#4/Bb4-B4)	D5-D#5/Eb5)	D#5/Eb5-E5)	F5)	A5-A#5/Bb5)	A#5/Bb5-B5)	D6-D#6/Eb6)	D#6/Eb6-E6)	F6)

Table 5.22. My proposition for tuning of intervals gender barung/panerus (1) in pelog – note that this version uses pelog 1 (superscript dot means higher octave, subscript dot means lower octave)

6̤	7̤	2̣	3̣	5̣	6̣	7̣	2	3	5	6	7	2̇	3̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
116.54-123.47	**130.81**	**155.56-164.81**	**174.61**	**220.00-233.08**	**233.08-246.94**	**261.63**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**523.25**	**622.25-659.25**	**698.46**
/	/	/	/	/	/	/	/	/	/	/	/	/	/
233.08-246.94	**261.63**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**523.25**	**622.25-659.25**	**698.46**	**880.00-932.33**	**932.33-987.77**	**1046.50**	**1244.51-1318.51**	**1396.91**
(A#2/Bb2-B2	(C3	(D#3/Eb3-E3	(F3	(A3-A#3/Bb3	(A#3/Bb3-B3	(C4	(D#4/Eb4-E4	(F4	(A4-A#4/Bb4	(A#4/Bb4-B4	(C5	(D#5/Eb5-E5	(F5
/	/	/	/	/	/	/	/	/	/	/	/	/	/
A#3/Bb3-B3)	C4)	D#4/Eb4-E4)	F4)	A4-A#4/Bb4)	A#4/Bb4-B4)	C5)	D#5/Eb5-E5)	F5)	A5-A#5/Bb5)	A#5/Bb5-B5)	C6)	D#6/Eb6-E6)	F6)

Table 5.23. My proposition for tuning of intervals gender barung/panerus (2) in pelog – note that this version uses pelog 7 (superscript dot means higher octave, subscript dot means lower octave)

Gambang

Below is a calculation for gambang instruments both in slendro and pelog tuning:

6̤	1̤ (7̤)	2̣	3̣	5̣	6̣	1 (7̣)	2	3	5
Hz **116.54-** **123.47** (A#2/Bb2- B2)	**Hz** **146.83-** **155.56** (D3- D#3/Eb3)	**Hz** **155.56-** **164.81** (D#3-Eb3- E3)	**Hz** **174.61** (F3)	**Hz** **220.00-** **233.08** (A3- A#3/Bb3)	**Hz** **233.08-** **246.94** (A#3/Bb3- B3)	**Hz** **293.66-** **311.13** (D4- D#4/Eb4)	**Hz** **311.13-** **329.63** (D#4/Eb4- Eb4	**Hz** **349.23** (F4)	**Hz** **440.00-** **466.16** (A4- A#4/Bb4)

6	1̇ (7)	2̇	3̇	5̇	6̇	1̈ (7̇)	2̈	3̈
Hz **466.16-** **493.88** (A#4/Bb4- B4)	**Hz** **587.33-** **622.25** (D5- D#5/Eb5)	**Hz** **622.25-** **659.25** (D#5/Eb5- E5)	**Hz** **698.46** (F5)	**880.00-** **932.33** (A5- A#5/Bb5)	**Hz** **932.33-** **987.77** (A#5/Bb5- B5)	**1174.66-** **1244.51** (D6- D#6/Eb6)	**Hz** **1244.51-** **1318.51** (D#6/Eb6- E6)	**Hz** **1396.91** (F6)

Table 5.24. My proposition for tuning of intervals gambang in slendro – note that this table is broken into an upper bottom row to include all intervals on the instrument (superscript dot means higher octave, subscript dot means lower octave)

6̤	1̣	2̣	3̣	5̣	6̣	1	2	3	5
Hz **116.54-** **123.47** (A#2/Bb2- B2)	**Hz** **138.59** (C#3/Db3)	**Hz** **146.83** (D#3/Eb3)	**Hz** **185.00** (F#3/Gb3)	**Hz** **196.0-** **207.65** (G3- G#3/Ab3)	**Hz** **233.08-** **246.94** (A#3/Bb3- B3)	**Hz** **277.18-** **293.66** (C#4- Db4)	**Hz** **311.13** (D#4/Eb4)	**Hz** **369.99** (F#4/Gb4)	**Hz** **415.3** (G#4/Ab4)

6	1̇	2̇	3̇	5̇	6̇	1̈	2̈	3̈	5̈
Hz **466.16-** **493.88** (A#4/Bb4- B4)	**Hz** **554.37** (C#5/Db5)	**Hz** **622.25** (D#5/Eb5)	**739.99** (F#5/Gb5)	**Hz** **830.61** (G#5/Ab5)	**Hz** **932.33-** **987.77** (A#5/Bb5- B5)	**Hz** **1108.73** (C#6/Db6)	**Hz** **1244.51** (D#6/Eb6)	**Hz** **1479.98** (F#6/Gb6)	**Hz** **1661.20** (G#6/Ab6)

Table 5.25. My proposition for tuning of intervals gambang in pelog – note that this table is broken into an upper bottom row to include all intervals on the instrument (superscript dot means higher octave, subscript dot means lower octave)

Bali:

Pelog and slendro tuning systems tends to be executed quite differently between the two islands. While Java seems to regard both tuning systems equally or possibly show a slight preference for slendro, Bali practically never performs compositions specific for the slendro tuning system, instead favouring a five-tone pelog scale variant of the seven-tone pelog tuning system. Since the execution is different between the islands - Sorrell has suggested one way to decipher tones accordingly to the Javanese standard which we have discussed before, the tones are divided thus 1 2 3 5 6 (Sorrell N. , 1990, p. 25). This is we will primarily refer to tones in Bali.

Tenzer suggests that the frequency spectrum of all “key based” instruments ranges from approximately C3 or C#3 at about 130 Hz, and up to approximately C7 or C#7 2080 Hz, however, the lowest tuned gong appears at approximately 65 Hz, approximately an octave lower than the other instruments such as the two jegogans, the two jublags, ugal, the four pemades, the four kantilan, and the reyong/trompong (which altogether occupy the spectre of four octaves) (Tenzer, Balinese Music, 1991, p. 59), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 28).

Although the pelog system consists of unequally divided intervals and the perception of the intervallic distance between ensembles may appear a couple of semitones apart, especially in Bali. Thus, it would be difficult to precisely estimate all the tones accordingly to exact Western values, however, in order for simplicity and accessibility which would allow both Javanese and Balinese gamelan to be workable within one Virtual keyboard layout design interface for Gamelan, a compromise which incorporate and merges the propositions from Becker, Sorrell and Tenzer will apply for Bali too, despite an option that will allow the user to either select Javanese and Balinese instruments.

Concept behind tuning of Balinese gamelan instruments

The tuning of each instrument is mainly provided by Tenzer (unless otherwise noted), the tuning of all instruments are described separately, based on figures and staff notations from both books by Tenzer, which shows the range of tones and octaves between all groups of instruments (except the difference between pengumbang/pengisep variants – will discuss this shortly) (Tenzer, Balinese Music, 1991, p. 59), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 44). Tenzer states the following: “…a kebyar gamelan may simply be said to encompass four octaves of five tones each, plus the first note of the fifth octave, but it is also accurately described as a set of forty-two independent pitches, half tuned to pengumbang and half to pengisep” (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 33). Pengumbang and pengisep, provides a shimmering acoustic beating, or the effect of “unison between two instruments (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31). It applies to almost all of the instruments in gamelan gong kebyar, except for gongs – the pairing of same instruments is mainly divided into female (slightly larger) and male (slightly smaller) variants, the tones on these instruments are tuned approximately 100 cents apart, divided into a pengumbang and pengisep respectively (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31). It should be noted that giving a thorough explanation about the difference between these would be a complicated matter which involves a lot of compromises in terms of precise tuning of instruments. Because Tenzer does not provide a proposition for both pengumbang and pengisep variants of instruments, and since those ensembles who own one ugal instrument, appears to tune it to pengumbang, it is assumed that the tones on all of the Balinese metallophone instruments are referred to their pengumbang variants by Tenzer.

Large gong

The large gong in Balinese gamelan has been tuned to 87.31 Hz (F2).

Kempur

Thus, kempur should to be tuned approximately at 220.00-233.08 Hz (A3-A#3/Bb3).

Kemong

Thus, it should be tuned approximately at 880.00-932.33 Hz (A5-A#5/Bb5).

Kempli

According to Tenzer, kempli should coincide with the first tone of calung which is tuned to ding (pelog 1) at approximately 293.66-311.13 (D4-D#4/Eb4).

Gender

Jegogan instruments female/male

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
146.83-155.56	**155.56-164.81**	**174.61**	**220.00-233.08**	**233.08-246.94**
(D3-D#3/Eb3)	(D#3/Eb3-E3)	(F3)	(A3-A#3/Bb3)	(A#3/Bb3-B3)

Table 5.26. My proposition for tuning of intervals jegogan in pengumbang (female)

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
155.56-164.81	**164.81-174.61**	**185.00**	**233.08-246.94**	**246.94-261.63**
(D#3/Eb3-E3)	(E3-F3)	(F#3-Gb3)	(A#3/Bb3-B3)	(B3-C4)

Table 5.27. My proposition for tuning of intervals jegogan in pengisep (male)

A table with propositions of pitches for the jublag instrument is presented below:

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
293.66-311.13	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**
(D4-D#4/Eb4)	(D#4/Eb4-E4)	(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)

Table 5.28. My proposition for tuning of intervals jublag/calung in pengumbang (female)

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
311.13-329.63	**329.63-349.23**	**369.99**	**466.16-493.88**	**493.88-523.25**
(D#4/Eb4-E4)	(E4-F4)	(F#4/Gb4)	(A#4/Bb4-B4)	(B4-C5)

Table 5.29. My proposition for tuning of intervals jublag/calung in pengisep (male)

Gangsa

Thus, a figure with propositions of pitches for the ugal instrument is presented below:

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
155.56-164.81	**174.61**	**220.00-233.08**	**233.08-246.94**	**293.66-311.13**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**
(D#3/Eb3-E3)	(F3)	(A3-A#3/Bb3)	(A#3/Bb3-B3)	(D4-D#4/Eb4)	(D#4/Eb4-E4)	(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(D5-D#5/Eb5)

Table 5.30. My proposition for tuning of intervals ugal in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
164.81-174.61	**185.00**	**220.00-233.08**	**246.94-261.63**	**311.13-329.63**	**329.63-349.23**	**369.99**	**466.16-493.88**	**493.88-523.25**	**622.25-659.25**
(E3-F3)	(F#3/Gb3)	(A3-A#3/Bb3)	(B3-C4)	(D#4/Eb4-E4)	(E4-F4)	(F#4/Gb4)	(A#4/Bb4-B4)	(B4-C5)	(D#5/Eb5-E5)

Table 5.31. My proposition for tuning of intervals ugal in pengisep (male)

Pemade – female/male

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz **311.13-329.63** (D#4/Eb4-E4)	**Hz** **349.23** (F4)	**Hz** **440.00-466.16** (A4-A#4/Bb4)	**Hz** **466.16-493.88** (A#4/Bb4-B4)	**Hz** **587.33-622.25** (D5-D#5/Eb5)	**Hz** **622.25-659.25** (D#5/-E5)	**Hz** **698.46** (F5)	**Hz** **880.00-932.33** (A5-A#5/Bb5)	**Hz** **932.33-987.77** (A#5/Bb5-B5)	**Hz** **1174.66-1244-51** (D6-D#6/Eb6)

Table 5.32. My proposition for tuning of intervals pemade in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz **329.63-349.23** (E4-F4)	**Hz** **369.99** (F#4/Gb4)	**Hz** **466.16-493.88** (A#4/Bb4-B4)	**Hz** **493.88-523.25** (B4-C5)	**Hz** **622.25-659.25** (D#5/Eb5-E5)	**Hz** **659.25-698.46** (E5-F5)	**Hz** **739.99** (F#5/Gb5)	**Hz** **932.33-987.77** (A#5/Bb5-B5)	**Hz** **987.77-1046.50** (B5-C6)	**Hz** **1244-51-1318.51** (D#6/Eb6-E6)

Table 5.33. My proposition for tuning of intervals pemade in pengisep (male)

Kantilan – female/male

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz **622.25-659.25** (D#5/-E5)	**Hz** **698.46** (F5)	**Hz** **880.00-932.33** (A5-A#5/Bb5)	**Hz** **923.33-987.77** (A#5/Bb5-B5)	**Hz** **1174.66-1244.51** (D6-D#6/Eb6)	**Hz** **1244.51-1318.51** (D#6/Eb6-E6)	**Hz** **1396.91** (F6)	**Hz** **1760.00-1864.66** (A6-A#6/Bb6)	**Hz** **1864.66-1975.53** (A#6/Bb6-B6)	**Hz** **2349.32-2489.02** (D7-D#7/Eb7)

Table 5.34. My proposition for tuning of intervals kantilan in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz **659.25-698.46** (E5-F5)	**Hz** **739.99** (F#5/Gb5)	**Hz** **932.33-987.77** (A#5/Bb5-B5)	**Hz** **987.77-1046.50** (B5-C6)	**Hz** **1244-51-1318.51** (D#6/Eb6-E6)	**Hz** **1318.51-1396.91** (E6)	**Hz** **1479.98** (F#6/Gb5)	**Hz** **1864.66-1975.53** (A#6/Bb6-B6)	**Hz** **1975.53-2093.00** (B6-C7)	**Hz** **2489.02-2637.02** (D#7/Eb7-E7)

Table 5.35. My proposition for tuning of intervals kantilan in pengisep (male)

Reyong

This gives the following order of pitches for reyong:

3̤	5̤	6̤	1	2	3	5	6	1̇	2̇	3̇	5̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
349.23	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**	**622.25-659.25**	**698.46**	**880.00-932.33**	**1174.66-1244-51**	**1244.51-1318.51**	**1318.51-1318.51**	**1396.91**	**1760.00-1864.66**
(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(D5-D#5/Eb5)	(D#5/Eb5-E5)	(F5)	(A5-A#5/Bb5)	(A#5/Bb5-B5)	(D6-D#6/Eb6)	(D#6/Eb6-E6)	(F6)	(A6-A#6/Bb6)

Table 5.36. My proposition for tuning of intervals reyong

Trompong

According to what was stated above in regards to a pengisep tuning for this delicate instrument, proposes the following order of tones:

3̣	5̣	6̣	1	2	3	5	6	1̇	2̇	3̇	5̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
349.23	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**	**622.25-659.25**	**698.46**	**880.00-932.33**	**1174.66-1244-51**	**1244.51-1318.51**	**1318.51-1318.51**	**1396.91**	**1760.00-1864.66**
(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(D5-D#5/Eb5)	(D#5/Eb5-E5)	(F5)	(A5-A#5/Bb5)	(A#5/Bb5-B5)	(D6-D#6/Eb6)	(D#6/Eb6-E6)	(F6)	(A6-A#6/Bb6)

Table 5.37. My proposition for tuning of intervals trompong

Indian Rag

Among the three indigenous tuning systems examined within this research, a reasonable assertion is to suggest that there are a number of fundamentally commonalities between Indian musicks and the musical practices associated with the West. Similarly, commonalities between Indian and Arabic music exist too, however, this also applies to somewhat different aspects; due to a number of interactions between the cultures since ancient times (ranging from different incidents such as trading, wars, temporary/permanent employment, settlement *etc.*) – a number of musical instruments originating from either Persia and/or Arab World found their way into the music of India and through numerous transitions and adaptions over the course of centuries eventually developed into their current distinctive form and shape and were rendered as authentic Indian instruments as we know them today.

Further, apparent from the aforementioned information it is not unreasonable to assert that a number of different musical aspects in-between these three musical cultures (i.e. Western, Arabic and Indian) show similar traits although they may not always appear entirely the same or demonstrate similar/exact impact or significance in every respect within each of the three distinct cultures. A striking commonality to Western music, Indian music contains *svara*, which can be briefly described as a principle in Indian music which to some extent appears equivalent to the Western diatonic scale (i.e. do-re-mi-fa-sol-la-si/ti-do), however composed of a completely different set of syllables (i.e. *sa-re-ga-ma-pa-dha-ni-sa/sa-ri-ga-ma-pa-da-ni-sa in* Hindustani/Carnatic music, respectively). In addition to the above, *svara* also appears to be an integral part in order to construct and/or perform Indian classical music.

Further, a number of musical modes are also similar to the West; namely, Ionian mode (Indian: *Raga Bilawal)*, Dorian (Indian: *Raga Kafi*), Phrygian (Indian: Raga *Bhairavi*), Lydian (Indian: Raga *Yaman*), Mixo-lydian (Indian: Raga *Khamaj*), Aeolian (Indian: Raga *Asawari*), Locrian (Indian: Raga *Todi*). Although, the Indian tuning system comprises of a substantially larger number of intervals per octave, yet within this parameter up to 12 intervals appear within close approximation to the Western tuning and certainly conform to the Greek ideal of simple whole number tuning ratios.

Beyond this though, little to no resemblance can be detected between Western and Indian musical practices and any further comparison may present a number of problems leading to some potentially misleading assumptions yet simultaneously dismiss certain integral elements inherent in Indian music. One such example is evident in the musical execution practices which is vastly different; whereas the focus on Western music relies on harmony and distinctive sets of specific chord progressions which musicians are dependent on in their music, such practices are not common in Indian music. In Indian music no broad spectrum of harmony is common, neither are pronounced chord progressions, nor stable and fixed temperament which may be reflected in the somewhat meditative effect that Indian classical music appears to have on certain people. On the other hand, the significance of Indian classical music appears to be rooted in or emphasise other aspects such as pitch variations and maintaining constant sound for a certain number of cycles. Indian music is modal, it establishes a relationship between the fundamental, unchanging note-the tonic-and successive notes of the scale.

Another distinctive aspect about Indian music different to Western and Arabic music relates to the instrument making and fashioning process of Indian instruments. Despite no remote similarity to the aforementioned gamelan instruments, it should be noted that instruments of India showcase a higher level of complexity and expressive capability when compared to their Western and Arabic counterparts. Whereas

Western and Arabic instruments contain limited options to affect the overall timbre of the instruments, Indian instruments is a different matter. This is inherent in a few special features unique to Indian instruments which affects the reproduction of sounds/timbre on these delicate instruments; three distinct elements are central to the overall timbre and sound reproduction on Indian instruments, namely, 1) *jawari* bridges, a feature to a number of Indian instruments which render the shimmering and buzzing sounds uniquely associated with Indian music - through complex shaped bridges with a number of *jeeves* placed underneath while a number of main and sympathetic strings are entangled above, 2) sounds further enhanced through the addition of resonating gourds, 3) movable frets (however only applicable to a selected few instruments) and 4) fundamental notes forming a perfect fifth (C and G) reproduced through drone. These aspects are integral the creation of the Indian VMKLI.

All these unique features enable the performer more flexible playing overall; not only are they significant in shaping the timbre of the instruments whether this affects it only slightly or significantly, but also allow for advanced possibilities to bend notes past any capabilities of Western/Arabic instruments, and also offer more emphasis, and/or the possibility of embellishing specific/particular or nuances of tones/notes.

Traditionally, the most common practice teaching music in India has been taught through the ancient Indian practice of *Guru/Shishya* (master/disciple), where student *(shishya)* appoint the master *(guru)*.

In order to gather a clear understanding of Indian music, it is necessary to explain the dynamics of the integral principles which are fundamental in the construction of Indian music. The phenomenon of Indian classical music is designed/based on a five-principle model which comprises the following: *1) sruti, 2) svara, 3) raga, 4) tala,* and *5) drone*; it is important to address that all of the principles are interrelated with one another in some state or another – among others, it is not unusual to find the latter three elements/principles to be present in a composition at the same time. *Tala* is the rhythmic meter of a *raga*. Each of the five principles are not easily decipherable through expression of singular words, the meaning of each principle to some extent usually involves elements associated with another or some of the others principles. One example can be showcased through the distinction between *srutis* and *svara*;

whereas the aspect of *sruti* despite being integral to the understanding of intervals, is related more towards the passing notes - inflection, while *svara* relates to fixed standardized notes. Despite an obvious distinction between the two, they interrelate in the sense that both are used in all types of classical compositions.

A *raga* is governed by a set of rules that define a specific set of pitches which the musician is allowed to work around for a particular performance of the *raga*. *Ragas* differ from each other in terms of their pitch sets, and to an extent in terms of the relationships between them. The notes in question need to be performed in a particular order and the melodic style requires to be maintained within certain strict confinements - all comprising certain aspects expected to be mastered by the musician at an early stage during their musical training. The structure of every raga is based firmly on established principles in which it starts from a lower pitch (tonic), later to ascend (upper tonic) before it is finally descend back to its original pitch; the ascending order is called *arohana*, while the descending is referred to as *avarohana* (Shankar, My Music, My Life, 2007, p. 32).

The last principle of Indian music is drone; the tonic (i.e. the first tone in a diatonic scale, in this case equivalent to the *Sa* in Indian tuning) which establishes the foundation in any composition of Indian classical music. The drone is constantly audible throughout any composition and this tone usually remains the same throughout in any composition. The tanpura is the preferred instrument to execute this function, however the sitar may also be used for this purpose (we will further discuss this later on in this Music Study). The drone is exemplified as an octave below the tonic on the VMKLI.

The phenomenon of drone can also be found in Western music and most commonly through sounds/tones reproduced in association with bagpipe music, the drone found in Indian music does not resemble this particular timbre (or sound characteristic). For instance, Farrell suggests that the tonic note (Indian drone) can be heard throughout a performance while the tanpura also reproduces some type of ostinato that emphasize certain notes, most commonly this applies to the fifths; however, Farrell states that "…this spread of notes is not linked rhythmically to the melody of the composition, but rather provides a background wash of sound, rich in harmonics, due to the manner in which the strings vibrate on the bridge of the *tanpura* (Farrell, p. 38).

As we have witnessed so far, drone appears to affect the first tone in the diatonic scale, as such this applies to the C in the Western terminology, while it also appears to apply to the Fifths (i.e. G).

Indian Tuning

The concept of tuning in Indian music is based on the average human vocal range, thus the majority of Indian instruments commonly comprises a tonal range of 2½ octaves - although in some cases as much as 3 octaves – this is why the range of the Indian VMKLI is set to 2½ octaves. With the exception of *Sa* (or the tonic – which serves as the "home base" in a raga), every raga contains a predominant note called *vadi* (the sonant and also known as the "King of Notes" in India), which is the most commonly used and strongly emphasized note in a raga whose purpose is to set the mood of the raga (Shankar, My Music, My Life, 2007, p. 32). Similar to the two tetrachords (*purvanga/uttaranga*) which comprises the scale, *vadi* also has a corresponding note to it called *samvadi* and is considered to be the second most important note found in ragas; the intervallic distance between *samvadi* and *vadi* always appears to be a fourth or a fifth apart - the main purpose of *samvadi* is to strengthen the sonant (Shankar, My Music, My Life, 2007, p. 32).

Although Indian tuning system allows for a wider spectrum of intervals than Western musicians commonly are accustomed to, no true standardisation of fixed pitches appears to found. According to Bor, the exact position of semitones generally may be interpreted slightly different depending on the musician in question, although this does not commonly apply to natural fourth, natural fifth and octave (Bor, 2002, p. vii). Bor continues by suggesting that flat notes can be lowered by approximately 20 cents to make them appear flatter in tone and as such the notes will change and then become komal (flat), or ati komal (very flat), while augmented fourths may be sharpened (by approximately 20 cents) and then appear as tivrar (sharp); such microtonal variations are commonly referred to as *srutis* (Bor, 2002, p. vii). The last paragraph relates to added function on the Indian VMKLI called Pitch 'O' Meter, where each step is separated by a five cents increase/decrease.

According to Shankar, the primary ingredient in order to breathe life into a raga and make the tones come alive and provide the musical textures of a raga, is the system of ornamentation and embellishment. Often, these notes are described as grace notes (or gamakas, in Indian), Shankar describes these as "… subtle shadings of a tone, delicate nuances and inflictions around a none…" that please and inspire the listener" (Shankar, My Music, My Life, 2007, p. 33). The change from one note to another in Indian music is executed differently than the firm direct and clear transition between notes associated with Western music; on the other hand, Indian transitions are smooth and soft, like a glide, or ornament (Shankar, My Music, My Life, 2007, p. 33).

We will now briefly discuss two distinct instruments which have been integral to the development of timbre for the Indian VMKLI; however, it is important to address that the selected timbre is not singularly based – within the Indian VMKLI the quality of the timbre does not fully attempt to recreate sounds of Indian instruments but rather to retain some of the qualities associated with them.

Sitar

The sitar appears to be the most immediately recognisable Indian instrument from a Western perspective; similarly, it appears to be the most popular among the plucked lute instruments found in Hindustani music.

One of the most unique features found on the sitar appears to be moveable frets. The frets on the sitar are made of metal, and attached to the instrument by threads which are stretched across the underside of the neck; the threads are used to move the frets in accordance to particular modes and tuning of ragas; this function can be performed through the assistance of the aforementioned threads which are either made of gut or silk and tied to the respective frets.

When the sitar is tuned to a particular raga, the sympathetic strings vibrate in harmony with the main ones in order to reproduce a metallic, lush and shimmering effect (Wade, Music in Indian - The Classical Traditions, 2008, p. 96). In addition to the aforementioned strings, another important feature largely responsible for the shimmering and buzzing sounds is the bridge of the instrument – commonly referred to as a *Javari bridge*; Sorrel & Narayan suggests that the "… front of the bridge is filed into a smooth curve so that the string leaves it at a fine line angle…" which appears to be the main reason for reproducing these effects (Sorrell & Narayan, 1980, p. 44). Further, they state that "… the flat surface of the bridge and under each string is pulled a short length of thread. When it has been pulled to the correct part of the bridge the sound from the plucked string suddenly increase intensity and duration, and the instrument emit its special buzzing sound" (Sorrell & Narayan, 1980, p. 44).

Tanpura

Its position and stature in Indian classical music appears to have increased significantly in the past few hundred years and eventually it become a more prominent musical element of Indian music in modern times. Interestingly enough, despite being a large-sized instrument, the tanpura may appear to be the least complex lute instrument found in Indian classical music; unlike its closest tata vadya siblings, no sympathetic strings are found on the instrument. In addition, the tanpura contains no frets mainly because the instrument serves no other purpose than to reproduce the sound of drone (in other words the tonic) which remains constant and unchanged throughout a raga. Commonly, the tanpura player often appears to be a relative, friend or pupil of the main artist.

The phenomenon of the twenty-two *srutis* is the most fundamental aspect in the creation of the Indian VMKLI. The twenty-two *srutis* represent the entire spectre of possible intervals (or sometimes referred to as quartertones or microtones) available in the octave. All twenty-two srutis are never present within any particular *raga* and instead only a fraction of these intervals appear to be used. The numbers tend to vary and this based on the structure, and mood of the *raga* in question. Deva describes the phenomenon of *srutis* as a "… concept of immense practical and theoretical importance, it has generated the greatest discussion-more hot than sound", while he further addresses that it "… has deeply mathematical and occultic implication" and is considered "… a measure as well as an indicative number of intervals-the pitch relation of notes" (Deva, Indian Music, 1995, p. 29).

Despite that the intervals, in broad terms are described as quartertones, however this does not unambiguously suggest that the tones appear to be entirely equally divided; it should be noted that no standardization exists in which to determine exact values of each *sruti*, thus only approximations are provided in Indian music (Sorrell & Narayan, 1980, p. 101). Some scholars have argued that the Indian scale possibly may be divided further into notes past the regular division of srutis, mainly due to the possibility to further colour and bend notes in the subtlest ways possible. Deva provides an informing insight into the phenomenon of *srutis* by suggesting that: "… [*Sruti*] is a measure as well as an indicative number of intervals-the pitch relations of notes" (Deva, Indian Music, 1995, p. 29).

The phenomenon of srutis

Despite that the phenomenon of *srutis* are considered literally uncalculatable in Indian music, a number of Indian scholars have made attempts to come up with suggestions in which to offer approximate calculations of each *sruti*. While the divisions of *srutis* may often appear slightly fluctuating and executed with minor differences from one musician to another; this Music Study will take into account calculations of *srutis* proposed by a limited number of different scholars on Indian music.

Doctor Vivek Bansod and Professor Mohit Sharma both contributes with approximate frequency values in Hertz for each *sruti*, while Professor Dinesh Thakur proposes cents values and ratios for each sruti (Bansod & Sharma, 2019, pp. 249-250) (Thakur, 2015, pp. 519, 523). Despite that Popley only mentions the basic seven notes in the Indian scale, however all of these coincides with the exact same values as those proposed by Professor Thakur. When compiling all of these elements in addition to the information already provided by Popley, Wade and Deva, the following table should offer a somewhat thorough overview of all twenty-two srutis:

TABLE OF SRUTIS

Sruti Hindustani Name	Cents	Ratios	Frequencies	Western Note	Sign	Carnatic Name
22. SHADJA TARA …	1200	2:1	200 Hz	C	S	Shadja Tara
21. Tivra …	1110	243:128	189.84375 Hz	B	N+	
20. SUDDHA NI …	1088	15:8	187.5 Hz	B	N	Kakali Ni
19. Komal Ni …	1018	9:5	180 Hz	Bb	n	Kaisiki N
						Shatsruti Dha
18. Atikomal Ni …	996	16:9	177.777777 Hz	Bb	n-	
17. SUDDHA DHA …	906	27:16	168.75 Hz	A	D	Chatuhsruti Dha
						Suddha Ni
16. Trisruti Dha …	884	5:3	166.666666 Hz	A	D-	
15. Komal Dha …	814	8:5	160 Hz	Ab	d	Suddha Dha
14. Atikomal Dha …	792	128:81	158.0246913 Hz	Ab	d	
13. PANCHAMA …	702	3:2	150 Hz	G	p	Pa
12. Tivratara Ma …	612	729:512	142.3828125 Hz	F#	m+	
11. Tivra Ma …	590	45:32	140.625 Hz	F#	m	Prati Ma
10. Ekasruti Ma …	520	27:20	135 Hz	F	M+	
9. SUDDHA MA …	498	4:3	133.33333 Hz	F	M	Suddha Ma
8. Tivra Ga …	408	81:64	126.5625 Hz	E	G+	
7. SUDDHA GA …	386	5:4	125 Hz	E	G	Antara Ga
6. Komal Ga …	316	6:5	120 Hz	Eb	g	Sadharana Ga
						Shatsruti Ri
5. Atikomal Ga …	294	32:27	118.51851 Hz	Eb	g-	
4. SUDDHA RI …	204	9:8	112.5 Hz	D	R	Chatsruti Ri
						Suddha Ri
3. Madhya Ri …	182	10:9	111.111111 Hz	Db	R-	
2. Komal Ri …	112	16:15	106.666666 Hz	Db	r	Suddha Ri
1. Atikomal Ri …	90	256:243	105.3497942 Hz	Db	r-	
0. SHADJA …	0	1:1	100 Hz	C	S	Shadja madhya

Table 5.38. A complete overview of the 22 srutis containing Hindustani and Carnatic note names, ratios, frequencies and Western notes proposition – contributors of information: Popley, Wade, Deva, Doctor Vivek Bansod and Professor Mohit Sharma

Arabic maqam

Different from Indian music, music of the Arab World evidently displays an uneven history of documentation. It should be noted that the entire history of Arabic music comprises of periods lasting centuries which clearly evidences documentation regarding tuning while also showcasing a demonstrable number of sources written by contemporary scholars and/or to some capacity later writings based on these sources. However, we witness other similarly equivalent time-lapsed periods which offer little to no evidence of any extant sources or depict any apparent musical progression to occur in Arabic music. As a result, throughout the history of Arabic music; it is apparent that a significant body of information appears missing creating considerable obstacles to providing a continuous overview of changes in the Arab music – as such Arabic music appears to move away from one distinct conception of tuning system to another without providing sufficient documentation for these transitional phases and without offering any logical explanation to these changes.

Interestingly, the history of Arabic music appears to be somewhat intertwined with Indian music to some extent. Influence on musical instruments between the cultures appears to be traced back to ancient times, the earliest encounter between the cultures occurred when Aryans originating from the Arab World and current-day Persia invaded the majority of North India, although exact knowledge about the emergence of Arabic musical instruments in India does not appear to be sufficiently documented. However, the strongest evidences of Arabic/Persian instruments to appear in India may be attributed to Amir Khusrau/Khusrow in the 13th century; whose family appears to have brought a number of musical instruments originating from the Arab World and/or Persia (and even possibly Turkey) to India –which later would play a most significant role in the evolutional process of the Indian musical culture where these instruments would go through numerous changes, modifications and adaptions through centuries prior to becoming rendered fully authentic Indian instruments (one example is the Arabic instrument sehtar, which appears to be the forefather to the now infamous Indian sitar, yet the Arabic sehtar is literally considered an extinct instrument in current-day Arab world, though is still played within Persian culture in modern day Iran).

Further, the musical history of Arab World is not limited to the aforementioned interactions with India only; throughout history we may possibly witness an even stronger tie to occur between Western/European and Arabic musical cultures. Although, the extent of what can be separated by and legitimized either as Western and Arabic musical influences is a very difficult task to determine exactly. Conflicting information arises when discussing these subjects; modern discoveries through excavations of ancient instruments may contradict former beliefs about information previously believed to be considered fully established within the conformities of one/either/each respective culture. However, due to the complex nature of these subject matters, it is necessary to limit the extent by addressing that mutual influences likely would have affected the musical and cultural progression in each culture.

It should be noted that musical conceptions either theoretical/mathematical commonly accredited to philosophers/scholars of ancient Greek, such as the conceptions of Limmas (approximately 90.23 Cents) and Commas (approximately 23.5 Cents) evidently appears to be established in the Arab World as early as the 10th century through the 25-tones per octave tuning conception proposed by al-Farabi, although better exemplified through the subsequent 17-tones per octave tuning system proposed by Safi al-Din in the 13th century – the latter which is entirely conceptualized and composed through the phenomenon of Commas and Limmas. Unfortunately, a significant period lasting a number of centuries spanning from the 13th and 18th century indicates little to no development or progression to appear in Arabic music. Thus, little information appears to be known until the latter part of the 18th century until the work *Essai sur la Musique Ancienne et Moderne (1780)* published by French composer and writer on music, Jean Benjamin de Laborde. Laborde appears to be the first or possibly one of the first to propose a 24 equally divided intervals per octave tuning system in Arabic music. Through Laborde an apparent Western influence seeped through in an Arabic conception of a tuning system. However, this phenomenon is still widely debated in current-day Arab World; various nations are split between accepting two different conceptions of this 24-tones per octave system, where one is based on equally divided intervals while the other is based on roughly equally divided intervals. In order to settle this debate, a gathering of native Arab and foreign scholars and musicians was conducted in Cairo in 1932; (also known as the Cairo Congress 1932), however, no final conclusion to this problem appears to have resulted from this congress.

So far in this research project, an utmost meticulous concern and effort has been executed in order to offer/provide the best possible representations to yield authentic/faithful renditions of current-day conceptualizations of Indian and Indonesian tuning systems. However, once we encounter/embrace the current-day practices of Arabic tuning system it should be noted that a number of problems becomes apparent in relation to the contemporary musical executions of this particular tuning system; whereas all of the aforementioned evolved tuning systems clearly showcase maintenance of centuries long practices rendered fully authentic within their cultural contexts –such factors do not appear to be entirely evident in Arabic music. Although current-day Arab World operates with a 24-tones per octave system, the aim with this project is to create VMKLI's based on ancient and medieval 25-tones per octave and 17-tones per octave tuning systems.

Thus, the decision to further explore/pursue ancient/medieval history of Arabic music became an integral part in the search for authentic Arabic tuning systems, which were either mostly devoid of, or showed much less influence from Western music. In this search, however, two tuning systems provided sufficient insight into execution/practice of ancient/medieval Arabic music while simultaneously providing tables on how these tuning systems were divided into intervals within octave-based parameters, namely al-Farabi's 25-tones per octave tuning system proposed in the 10th century, and Safi al-Din's 17-tones per octave tuning system proposed in the 13th century. The exact extent of Western influences in these two tuning systems still remains unknown, and both Western and Arabic scholars may make claims as to what aspects to be rendered/considered inherent in either of these cultures – suffice it to say, these two propositions still remains more authentic than the current tuning system executed in the Arab World.

Another reason for choosing ancient/medieval Arabic tuning systems mainly relates to the level/extent of technical challenges associated with creating VMKLI's for Arabic music. In essence, the current 24-tones per tuning system would basically allow for two options; namely equally divided or a roughly equally divided tuning system. Thus, such an option would only double the number of intervals in comparison to the Western 12-EDO tuning system and separate spacing between each interval by a difference of 50 Cents per interval, or a difference within an approximate range in the upper part of 40 to 50 Cents per interval (exact numbers can be obtained by reading about Arabic Maqam in the Appendices section). The last reason for selecting these two ancient/medieval tuning systems has been to further add originality to this research project; by addressing previously abandoned tuning systems and bringing awareness of these again to any reader of this research either of Arabic origin or other again – perhaps can increase interest to further explore and expand on research of these past what will be dealt with in this research.

It should be noted that the inspiration for timbre on the Arabic VMKLI's was never a difficult process, among the instruments associated with traditional Arabic instruments very few instruments appears to be as distinguishable as the 'ud, it is also the most likely instrument known outside the Arab World; thus, the VMKLI's aimed to reproduce a similar hybrid of texture and timbre as to that of the 'ud.

Probably the most characteristic and most important instrument (often referred to as the "Sultan of Musical Instruments") to be found in Arab music. 'ud is a fretless plucked short-necked lute instrument with a pear-shaped body, the instrument is recognized for producing a sweet and tender sound, which by some individuals considered to be comparable to the sound of a nightingale (Touma, 1996, 2003, pp. 109-110). Farraj & Shumays describes the sound of the 'ud to represent a mellow and warm timbre due to the lack of frets on the instrument (Farraj & Shumays, 2019, p. 17). Racy also adds that the 'ud is praised for its affective sound qualities which occupies a relatively low register, thus the sonic characteristics revolves around a sonic definition rather than as a function of harmonic specialization (Racy, Making Music in the Arab World, 2003, p. 77). Throughout the course of history, from its initial emergence in Arabic music up until modern times, the 'ud has gone through a number of different changes before finally attaining its current shape and features. In the next few paragraphs we will provide further information about the aforementioned tuning systems.

Tuning

Al-Farabi's 25-tone tuning system from 10th century

Touma concurs with Farmer's assessment regarding Byzantine and Persian influences in Arabic music, however, he specifically emphasises the epoch between the 9th to 13th century as more significant by which these influences became a major part of Arabic music; this period witnessed a new set of challenges that questioned the identity of old Arabic music and appeared to be the first phase of opposing ideas since the emergence of Islam (Touma, 1996, 2003, p. 17). No fully conceptualized tuning system appears to be known prior to the twenty-five-tone tuning system proposed by philosopher, mathematician and musician Abu Nasr al-Farabi (ca. 872-950/951).

Al-Farabi's proposition

Touma states the following about al- Fârâbî's proposition: "… the octave, which comprises two tetrachords and a whole tone, contained twenty-five different tones, from which al-Fârâbî extracted the following intervals: octave, fifth, fourth, seventh, whole-tone, half-tone, and quarter-tone" (Touma, 1996, 2003, p. 19). The following table display ten possible intervals extracted from the division of the tetrachord:

Fraction	1/1	256/243	18/17	162/149	54/49	9/8	32/27	81/68	27/22	81/64	4/3
	c					d				e	f
Cents	0	90	98	145	168	204	294	303	355	408	498

Table 5.39. Displays the first tetrachord of al-Farabi's 25-tone tuning system – tetrachord + tetrachord + whole tone = 1200 cents (Touma, 1996, 2003, p. 19)

Al-Din's 17-tone tuning system from the 13th century

The next significant epoch occurred in the 13th century and strongly initiated by musician and theorist (quite possibly of Persian origin) Safi al-Din al-Urmawi (commonly referred to as al-Din) (d. 1294 A.D.). According to Touma, al-Din was the first person to propose a fully categorised system for the Arabic music scale; his treatise *"Kitab al-adwar"* (translated to Book of Modes) showcased a tone system based on seventeen tones per octave comprising of limmas and commas (Touma, 1996, 2003, p. 10).

In addition, the principle of a two-octave range, appears to have been adopted by Arab theorists at some point during medieval times and is still accepted (in some cases) in modern Arab theory; the idea appears to derive from the belief that this is the natural range of the human voice as well as the optimum range on a number of traditional Arabic instruments (such as the 'ud and the nay), Marcus suggests that the two-octave practice is considered to be a continuation of ancient Greek music theory; (Marcus, Arab Music Theory in the modern period, 1989, pp. 106-107).

Al-Din's proposition

As an apparent advocate of the Pythagorean school of ancient Greek music theory, al-Din's concept was based on a seventeen-tone system per octave principle and systemized into the following principles: the octave comprised two conjunct tetrachords in addition to one whole tone – while recognizing five whole-steps per octave the octave, each divided thus - two limmas (90.2 cents) and one comma (23.5

cents) (i.e. limma + limma + comma) all of which concerned fifteen out of the seventeen notes, while two undivided limma-sized half step intervals each between B-c and e-f (Marcus, Arab Music Theory in the modern period, 1989, p. 161). An illustration is shown below:

```
      1st tetrachord                 2nd tetrachord             whole tone
:------------------------------------:-------------------------------:--------------------:
G            A            B     c            d             e    f                  g
:____:____:__:____:___:__:____:____:____:__:____:___:__:___:____:____:___:
  L    L   c:  L   L   c:  L  :  L    L   c:  L   L   c:  L :  L    L    c:
:            :            :                  :          :   :                   :
```

Table 5.40. Displays the al-Din's 17-tone tuning system – including limmas and commas (Marcus, Arab Music Theory in the modern period, 1989, p. 161)

Marcus addresses that the tuning system originally proposed by al-Farabi's twenty-five tone system within a short period of approximately 200 years had been replaced by a seventeen-tone system proposed by Safi al-Din (13th century) a conceptual system which future scholars would embrace in the following centuries.

Conclusion

We have now provided sufficient information and overview about how each tuning system is conceptualized, measured and divided into intervals. The next chapter provides an overview of the current situation with regard to availability of software solutions for alternative solutions, and chapter seven will discuss the actual implementation of these tuning systems within the various VMKLIs.

6. AVAILABLE TUNING SOFTWARE AT THE INITIATION OF THE RESEARCH PROJECT

Why the need for new keyboard systems to accommodate these various tuning systems we have covered so far, and how will they affect - from a player's perspective?

In the following paragraphs we will discuss a variety of software and plug-ins that were available at the initiation of the research project during the period between 2018-2019, and examine their strengths and weaknesses. Many of the widely available tools/options for microtonal composing are provided through Virtual Studio Technology (from now on abbreviated as VST) plug-ins which enables the user to create microtonal music. VST is an abbreviation for audio plug-ins which combines/integrates software synthesizer and effects to be compatible with specific D.A.W's, and seems to be the easiest technology capable of translating tuning into non-Western/microtonal tuning systems. However, the major problem is that a significant number of these VSTs are not compatible with Macintosh OS X systems/computers, which forces mac users to seek other options when composing music.

Thus, as a result the next few paragraphs will explore and briefly examine a number of common VST plug-ins available. Among the most popular software for microtonal tuning is Scala. Scala is a software that enables digital calculations/translations of intervallic steps and/or tone frequencies into integer numbers allowing the possibilities to form tuning systems. Fortunately, Scala is a diverse software which allows compatibility with both Windows and Macintosh systems.

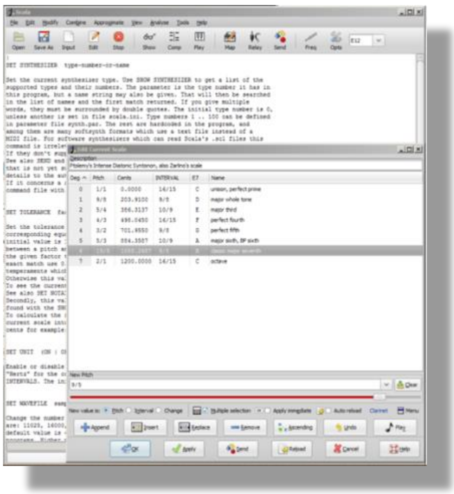

Figure 6.1. Image of the Scala Software

However, the downside with the Scala software is that it can be difficult to set it up; it requires the user to install the software correctly, in this case it involves a few additional software to be installed and each needs to be installed in a specific order for Scala to be able to run properly on any computer systems. Further, Scala does not appear to be the most user-friendly software to perform the aforementioned tasks and might require a brief period of trial and error before the user is capable of understanding the basics of the software properly. Scala enables the user to calculate intervallic steps between octaves, tritaves etc. or whatever may be desirable – further, this information requires to be saved to a separate Scala file and uploaded to a separate virtual keyboard software (sforzando or another) which then translates the stored info from the Scala file (i.e. selected tuning systems or customized intervallic values/divisions – octaves, tritaves etc.) onto to a keyboard layout software. For this demonstration the sforzando keyboard interface software was used.

Figure 6.2. Image of the Sforzando Keyboard Software

Initially this may appear to be an uncomplicated situation, however, a number of potential issues with the Scala/sforzando combination seems apparent. Although the sforzando software/plug-in allows for playback of any customized tuning system, among one of the major challenges is that the majority of such software are still limited to a traditional Western piano 12-semitone keyboard layout. Thus, for microtonal music/tuning systems not based on 12-tone steps nor 24-tone steps (for instance Arabic maqam music) makes it impracticable to use such keyboard layout for playability. However, the major issue with Scala/sforzando is that it appears to have some translation issues; when playing keys across a register of a number of octaves, occasionally singular keys appears to play incorrect pitches, in the wrong octave, or simply in the wrong key without any logical explanation.

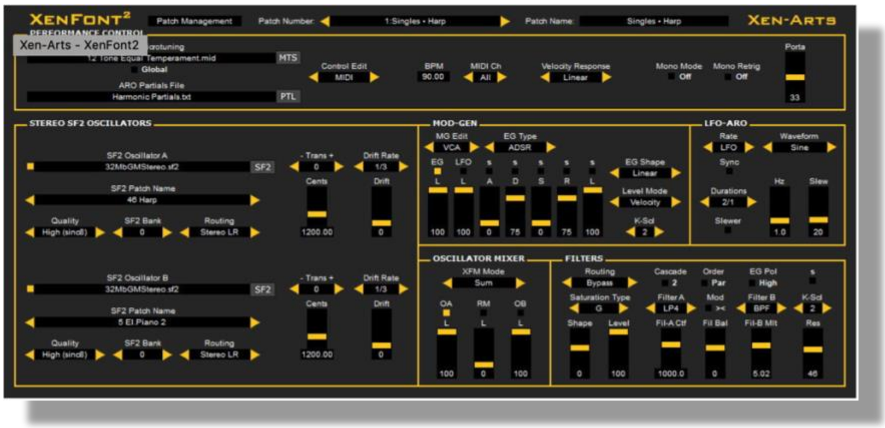

Figure 6.3. Image of a VST plugin from Xen-Arts

Another commonly used software for Microtonal tuning is Xen-Arts, however, this software is limited to Windows PC users due to the nature of being entirely based on VST, thus makes it difficult for Macintosh users to use it.

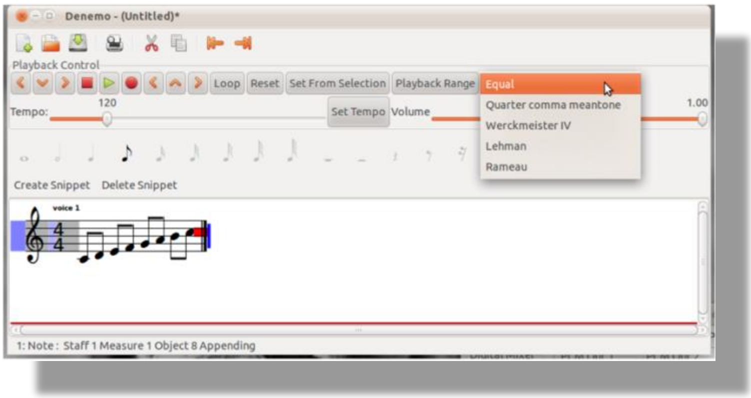

Figure 6.4. Image of the Denemo Software

In addition, there are a number of other options for microtonal tuning, among others Denemo, Mutabor, and Tall Kite's Alt-tuner. Denemo is a MIDI based music notation programming freeware software and allows the user to retune keys. According to the specifics on their website, their main area is classical music. However, it requires the user to download an additional freeware software called Lilypond in order to use it. The Denemo software allows the aesthetics of traditionally engraved music to computer printouts.

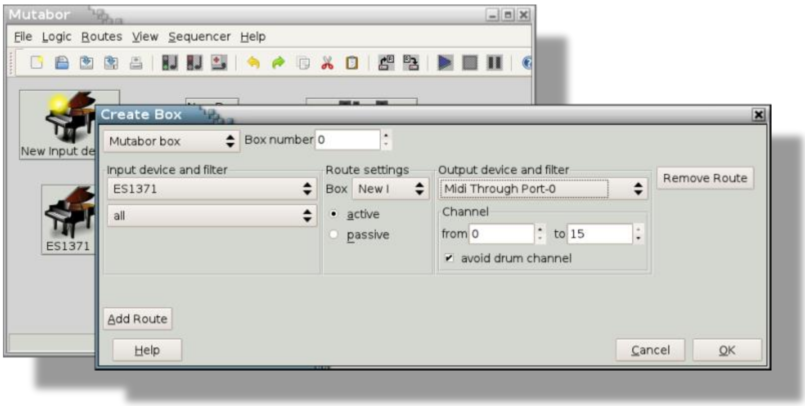

Figure 6.5. Image of the Mutabor Software

Similar to Denemo, Mutabor is another freeware software based on MIDI which similarly allows the user to retune intervals and contains a separate "just intonation" function. It supports live music with microtones. It uses its own musical language to describe pitches. Further MIDI ports, MIDI files, and GMN files can be used in the same manner, mixed and output. It provides easy access to static and mutating tunings and allows quick, easy and freely experimentation to switch between them. This software is particularly useful for those who seek and want to explore and compare ancient tunings, and useful tool for ear training in context of music theory and tonal experimental for composers etc.

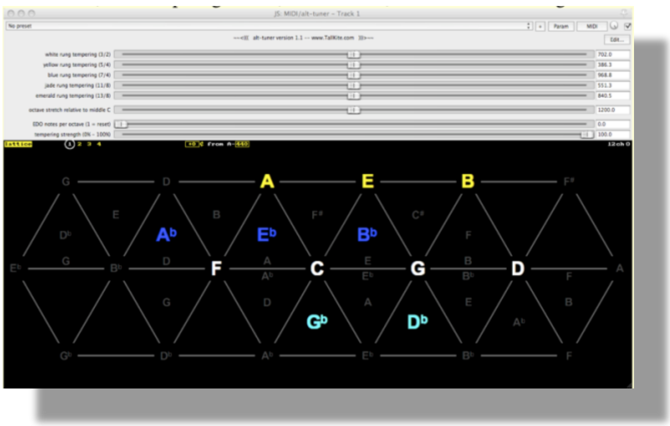

Figure 6.6. Image of the Alt-tuner Software

Tall Kite's Alt-tuner, appears to be the far most advanced amongst the software discussed so far, it contains a variety of different features, including setup of specific non-Western tuning systems (such as Turkish, Arabic, Persian, Indian and Indonesian tuning systems), different notations (Pythagorean, meantone, just intonation, and well-tempered), the possibility to stretch piano tuning, the ability to control and retune intervals as well as selecting different divisions to the octave. It should be noted that Alt-tuner is a MIDI-only effect, thus it alters the MIDI-keys prior to any signal to reach the hardware/software (softsynth) keyboards and converts it into audio. However, there are a few limitations to Alt-tuner; 1) Keyboards with limited timbrality, like most Nord keyboard which can only be played monophonically; 2) A few softsynths and some keyboard cannot be re-tuned because they do not respond to pitch bend messages; 3) Some low-end keyboard cannot be re-tuned because they do not let you turn off local control. Although, the software offers a lot of possibilities regarding tuning/retuning it should be noted that this software is not a freeware and priced $149 with possible discounts to students etc..

Interestingly, none of the aforementioned software above are specifically assigned to one singular tuning system and neither appears to apply specifically custom-made keyboard layouts for the user/player while playing intervals based on these tuning systems.

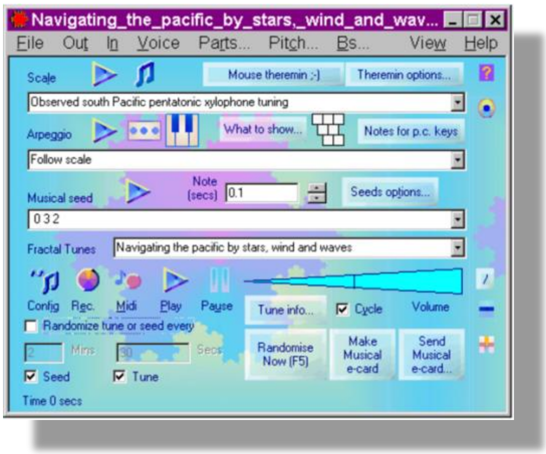

Figure 6.7. Image of the Fractal Tune Smithy Software

Another option available that offers microtonal tuning is Fractal Tune Smithy, developed by Robert Walker. This software operates with the same type of pitch-bend technology as the LMSO software, but is not entirely devoted to microtonal composing. However, it allows the user to use historical baroque tunings, Gamelan tunings, Indian music, tunings based on vertex patterns of 3D shapes, and other newly invented scales. It can also retune the keys that you are playing on your keyboard.

The software also offers a few additional features. For instance, the user can quantize, change note sizes, rhythms, just like with other familiar D.A.W's like Logic

Pro, ProTools etc. Apparently, the user does not require any necessarily compositional skills in order to create these sounds. The user can make music by moving mouse and PC keyboard, while an additional function allows for reproduction of the sound of Theremin, and play in Lambdoma tone array, both by using the mouse and PC keyboard. Another feature allows the user to calculate scales, by entering any sum, formula, etc., and it will calculate the cents, ratios, or whatever it is set out to do.

Other than the aforementioned software, there are Virtual Instruments available to use in relations to microtuning - some of them are Macintosh and PC compatible but not all. Virtual Instruments and VSTs are mainly made for Windows PC systems. In addition to these options, among others a number of .TUN and .SCL files can be used to calculate musical scales. However, both .TUN and .SCL comes with a set of pros and cons; both technologies offer the possibility to read the information using a text editor, as well as offering information of scale and MIDI Note mapping in cents. They also appear to share the similar types of issues. For instance, none of them offer dynamic, real-time microtuning, and requires the user to load a new file manually in order to change intonation system. Some VST systems will have problems with .SCL files when changing intonation systems. It should be noted that .SCL files have a technological aspect implemented into them called KBM, a technology which is not supported by some computer systems, thus may render such files useless on unsupportive computer systems.

Another approach for re-tuning intervals can be achieved by using a D.A.W. to customize/detune pitches to fit with a specific scale. In this occasion, one of the most versatile and user-friendly D.A.W.s to hold a professional Industry level is Logic Pro. Logic Pro offers a selection of many in-built tuning options ranging from various European tunings dating a few centuries ago, and a wide selection of tuning systems from various musical cultures throughout the world. Unfortunately, any tuning system that derives from a 5-tone, 7-tone or 12-tone division will be problematic to retune for the user, since these are the main divisions which Logic Pro are customized to operate easily. However, the other main challenge using Logic Pro is that any deviation of pitches which exceeds +/-120 cents (removed from their original 12-tone EDO setup) cannot be handled properly by the software.

Although there are several options of software or plug-ins widely available which enable musicians/composers to make music, the main and current problem revolves around possible solutions for a suitable keyboard layout system to accommodate each of these tuning systems (besides using the 12-tone equal temperament system). At the initiation of this research a selection of hardware keyboards that handle microtonal tuning appears to be very limited. Options available among hardware synthesizers that feature full MIDI pitch microtuning adjustment are KORG Monologue (approximately GBP £214-234, depending on colour, prices obtained from pmtonline.co.uk), Dave Smiths's Prophet 12 (approximately GBP £2,179.48, price obtained from Thomann UK (Thomann.de)), and Starr Labs MicroZone U-648 Generalized Keyboard (approximately US $ 3,495.00, price obtained from starrlabs.com). The first two offer a standard piano keyboard layout interface, respectively comprising 25 and 61 keys, while the latter contains a large Array Matrix Hex keyboard and up to 288 keys. Prices are likely to change; however, these are the actual prices per 12.07.2018. Pricewise, the only synthesizer that can be obtained for a reasonable amount of money is the KORG Monologue synthesizer, in addition it appears to be the most portable among the aforementioned examples.

Throughout this chapter we have examined available software and hardware options which offers microtonal tuning and retuning of intervals/pitches - and the majority of these have a significant cost. All to a greater or lesser extent require prior knowledge of alternative tuning possibility and some demand a significant mathematical understanding, and any options to offer unique musical keyboard layouts interfaces is rather limited. This means that all of the alternative tuning possibility is cast from the perspective of the traditional western keyboard layout, and even the most common alternative layouts still consider the problem from the perspective of 12 tones. This means that a user has both to be able to understand and input alternative tuning systems, and to understand exactly how this will manifest on a standard western keyboard layout. Among the aforementioned hardware synthesizers, only the MicroZone synthesizer by Starr Labs offers a flexible keyboard layout for microtonal tuning, but is a rather expensive synthesizer to acquire.

For years microtonal composers have commonly used the traditional piano keyboard layout in order to compose/perform music this particular type of music, however this leaves one main problem; both from a musician's and a composer's perspective the possibility to fully operate a tuning system with less or more intervals per octave compared to the Western 12-tone EDO makes it illogical to use this keyboard system. In this situation, the performer is forced to memorize the order of keys according to their divisions of intervals in order to navigate themselves on the keyboard and to know where each division begins/ends. This brings a lot of limitations for a musician to fully perform the segment of keys on the instrument. Further, this likely affect the way the performer approaches the instrument and the creative aspects through their logic when approaching the instrument as well as composing.

My own interface design, once perfected, offers a different possibility of user experience. Each has been developed through a painstaking journey in understanding the originating musical culture and tuning system in arriving at the particular interface design. However, the user will be able to experience this, if they wish to, from an entirely naïve perspective – they do not need specialized knowledge of either the musical culture or the underpinning tuning system because the interface is intuitive and will suggest possibility. In this way the interfaces at the heart of this project offer increased possibility of play, of simple experimentation and discovery of inherent potential and affordances.

Lastly, in addition to all the aforementioned options, a variety of different independent companies offers sample packs of instruments from other musical cultures either in synthesized or recorded forms. However, this also implicates its share of strengths and shortcomings. In the majority of cases, sample packs will be compatible with most D.A.W.s and either appears as VST plug-ins or as Wave/AIFF audio files which can be further customized and adopted within inherent built-in MIDI technology of D.A.W.s for easy use when composing music.

On the other hand, the general audio reproduction quality of such samples may vary significantly (dependent on the provider) in addition to other limitations inherent in built-in synthesized/recorded instruments, the economic implications which may further offer limitations in terms of the selections of available instruments within that particular musical culture and may or may not include instruments from other musical cultures.

7. THE CREATION OF THE FIVE VIRTUAL MUSICAL KEYBOARD LAYOUT INTERFACES (VMKLI)

Before we get deeper into the discussions about the VMKLI's, it is important to address that the following order for each VMKLI does not necessarily represent the exact order for initiation nor completion, but rather provides a gradual documentation of the development of these largely based on the gradual level of complexity.

In particular, during the extensive period of reading and thorough exploration of the various evolved tuning systems, it became apparent that the level of diversity and complexity turned out to be significantly more advanced and different than anticipated. Thus, this particular process was integral in order to acquire all sufficient aspects and to fully understand the inherent cultural approaches/methods/reasoning and mathematical dynamics of pitches in relation to configurations within measured divisions (i.e. octave, tritave, fifths etc.) for each respective culture.

With the exception of the modern tuning systems (which were mostly initiated during the early stages of the research project), the process creating keyboard designs for the evolved tuning systems occurred during the latter stage of the research project. The designing process and keyboard layout decision-making eventually emerged as a result after all three indigenous tuning systems had been deeply explored, although all of these VMKLI's would be subjected to a number of revisions, reconsiderations and editing to some extent before reaching their final state/configuration. The result of this extensive exploration allowed me greater perspective on indigenous cultures in general yet allowed me to understand the dynamics between musical instruments and their stature and relations between one another - not solely within their respective cultures but also from a greater musical perspective expanding past the singular cultures as well.

It should be noted that during the process creating the Virtual Keyboard Interfaces, no attempts were made to replicate exact sounds of musical instruments related to any of the respective musical cultures, however conscious decisions were made to respect/maintain particular musical flavours/aspects/characteristics and exact pitches/intervallic measurement (if applicable) associated with the respective culture. Interestingly, the invented tuning systems would offer entirely different set of challenges; mainly this is due to the lack of any invented musical instruments created to perform music nor any recognizable and characteristic timbre that would be representative of the respective tuning system. Both Alpha/Beta/Gamma Scales and Bohlen-Pierce Scale emerged as a result of experimentation on electronic keyboards/organs where intervals were re-tuned and measured through the usage of electronic devices. In the case of Alpha/Beta/Gamma Scales, the inventor Wendy Carlos originally appears to have made no attempts to invent nor re-arrange the order of keys on the keyboard used when she first demonstrated these tuning systems on her album *Beauty in the Beast (1986)*. As of the initiation of this research project still no examples of custom-made keyboard interfaces for Carlos' tuning systems appears to exist.

On the other hand, early on during the development of the Bohlen-Pierce Scale, the original inventor Heinz Bohlen appears to have had a conceptual idea for a keyboard design by rearranging the order of keys and other minor adjustments made to his own electronic keyboard/organ back in 1972. However, the idea of custom-made keyboard designs for this tuning system is not limited to Heinz Bohlen; in recent years musician Elaine Walker (the most pronounced advocate for Bohlen-Pierce Scale today) appears to be the most active innovator. Walker has proposed a number of different solutions for keyboard designs although the majority of these ideas mainly rely on re-arranging/re-imagining the order of white/black keys on a traditional piano keyboard setup with the sole exception of a singular case adapting the tuning system to a 64-key hexagonal/isomorphic keyboard. Besides these examples, no other keyboard propositions appear to have been made prior to the initiation of this research project.

Obviously, one of the more neglected facets on both of the aforementioned tuning systems is developing unique timbre and/or sound characteristics; similar to Wendy Carlos (the innovator of the Alpha/Beta/Gamma Scales), neither the innovators of Bohlen-Pierce Scale nor Elaine Walker have embraced this potential.

Thus, for this research, two of the most distinctive objectives involving (although not limited to) modern tuning systems have been to provide new solutions/innovation on keyboard designs through the creation of Virtual Musical Keyboard Interfaces, while the secondary objective has been to develop unique timbre for each Interface. In this occasion, it is possible to embrace this aspect with complete freedom due to the nonexistence of historical, cultural reference/significance, specific sound characteristic templates/contexts. This is largely what distinguishes invented tuning systems from evolved tuning systems.

It is common for traditional (evolved) musical cultures to contain one or a small selection of key/primary instruments that evokes the vibrancy (or reference point/guidance) or most representative of music associated with its respective culture. If we take basis solely on existing approaches to create sounds in the cases of Alpha/Beta/Gamma Scales and Bohlen-Pierce Scale, generally these have been limited to the sheer basics of electronically synthesized sound chips built into the respective hardware keyboard. In the case of the invented tuning systems, this means that the sounds would have been reproduced either on earlier analogue or later digital equipment up until more recent modern electronic keyboards used by Elaine Walker – all of which would yield similar yet very limited changes to the actual timbre of the instrument. Thus, both of the invented tuning systems primarily relates to basic electronically/synthetically created sounds rather than reproduction of natural sounds, specifically layered timbre created through various sound waves and filters or sounds reproduced through actual traditional instruments.

In essence, it seemed plausible to embrace more sophisticated and advanced programming tools to develop entirely unique timbre to allow for more complex sonic flavours. However, in this process it was integral to retain the preciseness of intervals thus the inclusion of additional effects/flavours would appear sparsely to prevent too much colorization eventually resulting in rendition of unrecognizable intervals. It should be noted that the timbre would be approached differently for each musical culture and respective tuning system. Thus, part of this research has been dedicated to explore new grounds in timbres as well as developing new innovative keyboard solutions for tuning systems. Both of these aspects will be discussed thoroughly in this chapter.

Brief information about the creation of the Interfaces

The initial process developing VMKLI’s for this research project began by experimenting on various technical ideas which would eventually turn into the development of the first prototype of a keyboard layout, namely the Alpha Scale. The initiation of this tuning system would be the trigger that eventually affected and forwarded the conceptual ideas and processes for the other two consecutive tuning systems by Carlos' – namely, Beta and Gamma Scales. These three tuning systems were the first to be leveraged in this research project.

In search for inspiration of a keyboard layout design that would complement a logical keyboard arrangement for intervals and divisions for Alpha Scale, the Novation Minipad hardware keyboard appeared to be the most ideal choice. Although this keyboard is commonly used for slightly different purposes than playing intervals and chords, among its most common uses is to trigger sounds/samples/functions in various D.A.W.s. It contains a total of 64 keys assigned into an 8X8 (i.e. 8 horizontal rows and 8 vertical rows) grid system which yield a symmetric keyboard layout and provide a logical yet distinct placement for all intervals for this particular tuning system.

Initially, in order to demonstrate the Alpha Scale in a musical setting, the original Max/MSP patcher was first adapted to a Novation Minipad hardware keyboard. The original prototype contained a set of novel features/options/settings which allowed for a limited number of interesting alterations to the timbre. The first musical contributions which features this early prototype of the Alpha Scale VMKLI was during an ACMG concert in November 2018 and included compositions by the guest performer for this occasion, renowned Romanian composer and double bassist Michael Cretu. This prototype of the Alpha Scale keyboard layout, (alongside the Beta/Gamma Scale keyboard layouts developed at a later stage of the research) was later featured on the composition called Twirl Dung Pa, a collaboration with Doctor Timothy Wise (and will be discussed thoroughly in the next chapter). This collaboration was originally planned as a commissioned composition for ACMG's concert at Manchester Museum in March 2020. Simultaneously, another composition was also planned for the same event, although for that particular composition a completely different tuning system was used, called Bohlen-Pierce Scale. This composition was originally planned to be a collaboration between my main supervisor Doctor Philip Brissenden and myself, however, the concert was cancelled due to COVID-19 pandemic, thus all these plans were postponed indefinitely.
Initially, the Alpha/Beta/Gamma Scale and Bohlen-Pierce Scale VMKLI's were developed using the Max/MSP software. However, approximately halfway during the research project it became apparent that no software compatible with Max/MSP

could possibly create fully independent VMKLI's operable on an iPad without access to a unique computer host and port. The main issues were the complexity of the technology, the required processing power inherent within the software and the advanced compounding of patches which rendered it impossible to use Max/MSP for its originally intended purposes. Thus, as a result in order to pursue with the planned research project the requirement of a more lower level programming software was necessary. After some exploration, it became apparent that the ideal choice of programming software was Pure Data (sometimes abbreviated as PD). It should be noted that this software requires a much steeper learning curve in comparison to Max/MSP before the user will be capable of comprehending the technology past basic knowledge, thus it can be perceived as a more complex and difficult software to manage.

Different from Max, Pure Data is a much lower level computer programming software, dealing with data processing on a far more elementary/basic level than the aforementioned software, however, additional compatible software exists which enables the creation of independently operable VMKLI's. During the exploration for compatible software with Pure Data, it appeared that MobMuPlat was the most compact/comprehensive software to allow for the creation of independently operable VMKLI apps for iPads. It should be noted that MobMuPlat does not allow for any programming itself and mainly appears as a designing software which enables information from Pure Data patches to be communicated through MobMuPlat (i.e. sound reproduction through suppressing keys or knobs and colorization of timbre through additional effects).

Prior to the final prototypes of all VMKLI's, all technical programming and designing conceptions were initiated in Pure Data, mainly due to its flexibility to perform both tasks; the main purpose behind this was to use Pure Data as a temporary solution to design and test out the functionality of my keyboard layout propositions prior to any further alterations and the eventual finalization of the VMKLI's to be created in MobMuPlat (a function which cannot be performed by using Pure Data).
Keyboard layout conceptions for the VMKLI's were sometimes somewhat (directly) related to actual instrumentations associated with the respective tuning systems and a conscious endeavour to recreate fundamental aspects of those instruments as closely as (i.e. Gamelan), while in other cases the VMKLI's were generally

encountered through more independently creative approaches either because of no apparent evidence of customized keyboards (i.e. Alpha, Beta, Gamma Scales) or conscious decisions to steer away from existing keyboard propositions (i.e. Bohlen-Pierce Scale). Further, in the latter situation the emphasis was more focused on singular instrumentations or simply approaching the VMKLI with firm and specific timbre characteristics (i.e. stringed instruments) to evoke a vibrancy closely associated with the respective indigenous music culture (see Arabic Tuning, and Indian Tuning).

All five tuning systems have been approached differently both from a designing and technical programming perspective, the number of keyboard layouts for each VMKLI is sometimes dependent on the complexity of the tuning system in question and approaches towards instrumentation; thus a range between one sole keyboard layout (Indian tuning) and a selection of up to six keyboard layouts (gamelan) can be found between each of the five VMKLI's. In the case where more than one keyboard layout appears, the user will be able to switch between the different keyboard layouts similarly to slides/pages on an iPhone and iPad simply by placing a finger on the touchscreen and move it either to the left or right in order to select the preferred keyboard layout.

As noted, prior, the Alpha/Beta/Gamma Scales and Bohlen-Pierce Scale VMKLI's were first initiated using the Max/MSP software before eventually adopted to Pure Data towards the latter stage of the research project. However, all indigenous tuning systems were originally created by using Pure Data. Further, all VMKLI's went through various stages of completion and development prior to eventually being created into the independently operable VMKLI apps in MobMuPlat. Each of the VMKLI's based on evolved tuning systems have been treated with a unique type of synthesis; namely, Frequency Modulated (abbreviated as FM) Synthesis (Indian tuning), Karplus Strong Algorithm (Arabic tuning) and Additive Synthesis (Gamelan tuning) – these will be discussed individually later on in this chapter. It should be noted that due to time-constraints, currently the VMKLI's based on invented tuning systems solely comprises of basic Waveform setups featuring Sine/Triangle/Sawtooth/Square waveforms and minimal additions to further shaping of the timbre. However, plans to integrate more unique timbre and additional or possibly different or combinations of wave shapes for these will be initiated and implemented either by the tail end or shortly after completion of this research project.

Invented Tuning Systems

Alpha Scale

The Alpha Scale is a modern tuning system invented by composer/musician Wendy Carlos, simultaneously along with this tuning system she also invented Beta and Gamma Scales (which will be discussed shortly). The initial demonstration/usage of this tuning system (as well as the two others) appeared on Carlos' album called Beauty in the Beast, released in 1986. The Alpha Scale is based on divisions of nine intervals per perfect fifth (3:2) (just intonation perfect fifths = 701.96 cents) with each interval divided equally into 77.965 cents; this tuning system derives from the common traditional Western octave based 12-tone equal temperament tuning system and matches Interestingly, this tuning system contains very few intervals which matches those or appear within close approximation of intervals derived from 12-tone EDO and independent on any range of division, the octave never appears to meet.

In terms on intervallic qualities, Alpha Scale appears to have a few advantages compared to the Western 12-EDO tuning system; in the rare occasions when we encounter intervals/notes within close approximation, intervals from the Alpha Scale produce purer tones; such as superior minor thirds, major thirds, yet also produces wonderful triads, perfect fifths (3:2), and excellent harmonic seventh chords. It should be noted that as we progress upwards the fifths the keys will appear slightly sharper – this is due to the difference between the evenness of 12-tone EDO (700 cents) Perfect Fifths and the justly tuned Perfect Fifths (approximately 702 cents) which allows an increase by 2 cents per Alpha Scale division thus will create a minor unevenness in intervallic values in the upper perfect fifths.

As previously addressed, Alpha Scale was the first tuning system to be adapted into a keyboard layout (and featured on the Alpha/Beta/Gamma Scales VMKLI); enclosed below, the two following figures show the progression from the initial protypes adapted to Novation Minipad and Max/MSP respectively. These two prototypes were created approximately at the same time thus should bear the same set of colour patterns. It should be noted that the round buttons on the top horizontal row and the far right vertical row from figure 1 does not feature any lit buttons, mainly this was a result of limitations of colour combinations to appear on the Novation Minipad (i.e. red, green, yellow, and amber in addition to dimly lit options of the exact same colour variations), thus separated to prevent confusion between the playable square-shaped buttons (i.e. playable intervals) and the round shaped buttons (i.e. additional effects/features).

Initially, the button system/arrangement on the Novation Minipad hardware interface appeared to be the ideal template and eventually turned out to be the basis of all of Wendy Carlos' tuning systems (i.e. Alpha/Beta/Gamma Scales). The button arrangement on both the Novation Minipad hardware keyboard and the virtual recreation of this keyboard interface made in Max/MSP both showcased a range of intervals which started from bottom left and moved progressively for each consecutive key to the right until it reached the next level of rows and then repeats the same pattern. Thus, the 8X8 grid system provided a symmetrical order of keys, showcasing every ninth and final interval per division to shape into a nice rightward diagonal and symmetrical sloped line of perfect fifths when moving upwards on the keyboard, eventually allowing for easy navigation between each perfect fifth independent on the basic note/interval to start from on the keyboard.

The colour coding for the most part has been consistent during the entire creational process although with some minor and/or significant adjustments. Evident in the two figures below, the majority of keys appear in green to indicate intervals which diverges significantly from Western 12-tone EDO intervals, while a limited number of yellow keys indicate intervals within close approximation or equivalent to the 12-tone EDO. These two specific colour patterns have appeared consistently throughout the entire creational process on all of Carlos' tuning systems. In addition to those, another unique colour (amber) was assigned to indicate the first interval for each division in order to aid for easy navigation on the keyboard. However, as the project progressed this colour would eventually change into red at some point as it proved to be more distinguishable and contrasting compared to the other colours used on the keyboard layout.

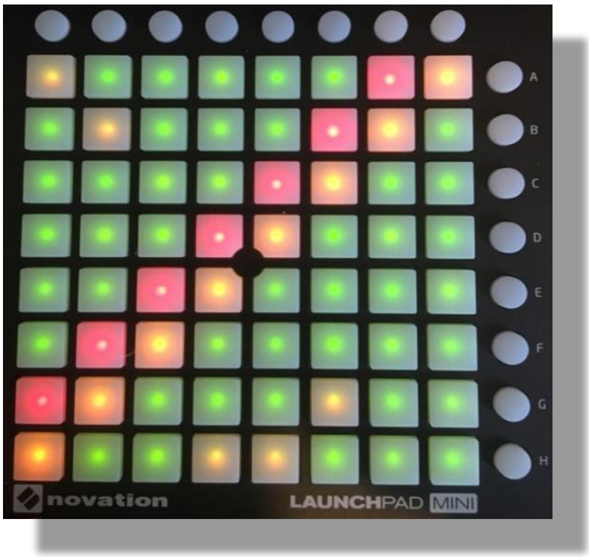

Figure 7.1. The earliest prototype of Alpha Scale – adapted to Novation Minipad hardware keyboard

Figure 7.2. The earliest prototype of Alpha Scale – digitally constructed using Max/MSP software

At some point during the research project, the original red buttons would later be changed into blue buttons (evident in the third and last virtual prototype (first created using Pure Data) and depicted in figure …), eventually were abandoned prior to the final fourth prototype (figure 4), one may notice that the keys in blue indicates where the previously perceived Perfect Fifths had occurred, these were soon changed into colours to accommodate the intervallic distance accordingly to Western intervals. Further, when a firm and thorough examination to establish and exact definitions of each interval, it became clear that a number of intervals previously perceived to be non-Western intervals eventually were changed into close approximation or Western tuning - this would also include configurations associated with other common alternative Western tunings such as Just Intonation, Meantone, and Well-tempered tuning. Vice versa, the intervallic values in two cases (previously depicted as yellow buttons) were re-examined and changed to green. In the fourth and final figure (and configuration) the perfect fifth intervals appear in red, while the addition of orange coloured buttons was introduced in order to provide the user with some indications of each consecutive approximated “octave” (may be subjected to change at a later point).

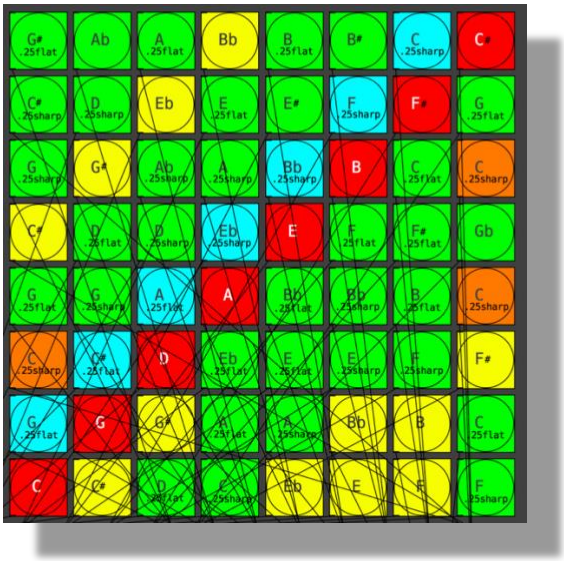

Figure 7.3. The second prototype of Alpha Scale - digitally constructed using Pure Data software (old photo with digital patching leads)

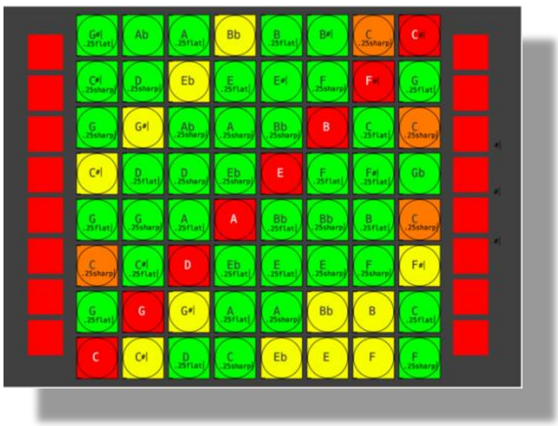

Figure 7.4. The final third prototype of Alpha Scale - digitally constructed using Pure Data software

It should be noted that the aforementioned information never affected the original calculation of intervals as it appeared to be correct from the beginning; the gradual changes from the initial prototype to the final prototype was solely related to the complex nature defining the exact colour coding for each interval and to evaluate whether these would be close enough or too distant to be assigned a Western definition (due to the large majority of them to appear in-between established Western intervals either slightly or significantly).

The initial demonstration of the Alpha Scale in a musical live context was used during the ACMG concert featuring guest musician Michael Cretu, in addition it was used during a number of other occasions and concerts with ACMG concerts in order to provide unusual textures, sounds and non-Western intervals/pitches, sometimes to add to what the rest of ACMG played (either scored or improvised music) and other times as a backdrop/soundscape that they could play against. It was also implemented in the collaborative composition called Twirl Dung Pa, which was also featured during the ACMG concert on 4th May 2022, where all other members played on top of a solo piece through the use of a graphic score arranged/composed by Doctor Tim Wise. This was later repeated for a recording session which was undertaken shortly after.

The intentions for the final prototype was to be used for a number of different purposes; invite musicians to try them out and provide feedback and opinions about the experience playing on it; describe the degree of user-friendliness, address what aspects they liked about them and provide suggestions for potential improvements etc. Another plan was to get the entirety of ACMG to use this VMKLI as an improvisational tool during a future ACMG concert.

Beta Scale

Similar to Alpha Scale, the Beta Scale comprises divisions based on perfect fifths (3:2 ≈ 701.995 cents), however the difference between the two is that this tuning system is divided into eleven equally measured intervals with intervallic value of 63.832 cents. Although, the Beta Scale keyboard layout also takes its basis in the same keyboard arrangement/set-up featured on the Novation Minipad keyboard, the intervals on the Beta Scale keyboard layout would require a slightly different arrangement of button/knobs system due to the increased number of intervals to appear. Unfortunately, because of this, the Beta Scale would not yield the same level of logical and symmetrical keyboard interface compared to the Alpha Scale keyboard layout, however it would still provide some symmetry between the order for each Perfect Fifth.

Similar to Alpha Scale, Beta Scale is also based on divisions of Perfect Fifths, however, differently this tuning system expands on the number of intervals per divisions by two. Largely, because of the same originator and the creation of both tuning systems appeared simultaneously, thus it appeared logical and respectable to the innovator to approach both with a similar conceptual treatment; however, this would lead to a number of designing challenges in order to pertain some of the fundamental similarities to the Alpha Scale. Despite that the sequence and order of intervals were approached similarly to the previous keyboard layout; the resulting Beta Scale keyboard layout would not provide similar symmetry for a number of reasons. However, it should be noted that some aspects of symmetry to the appearances of Perfect Fifths is obvious – as showcased in figure … the bottom row of intervals displays a space of two intervals and the consecutive Perfect Fifth to appear a row above between the first three Perfect Fifths and this is continued on to the following three Perfect Fifths on the keyboard layout. Similar to Alpha Scale the appearance of Western equivalent intervals and approximate octaves appear in a non-symmetrical order.

It should be addressed that for this research project, among the three tuning systems created by Wendy Carlos – the sole tuning system of interest originally was the Alpha Scale. However, as the project evolved, the following two tuning systems became integrated into the prospect. Thus, the inclusion of Beta and Gamma Scale were merely added to the equation as additional bonuses, to allow for further expansion and exploring the wonders of tuning systems based on Perfect Fifths. This is also evident why no previous prototypes and versions on keyboard layouts of Beta appears.

The Beta Scale was featured in the collaborative composition Twirl Dung Pa, during the ACMG concert on 4th May 2022, which involved members of ACMG who played on top of the pre-composed solo piece (Twirl Dung Pa) through the use of a graphic score arranged/composed by Doctor Tim Wise. This was later repeated for a recording session which was completed shortly after. The final prototype of the Beta

Scale keyboard layout will be used for the similar purposes as that of the Alpha Scale.

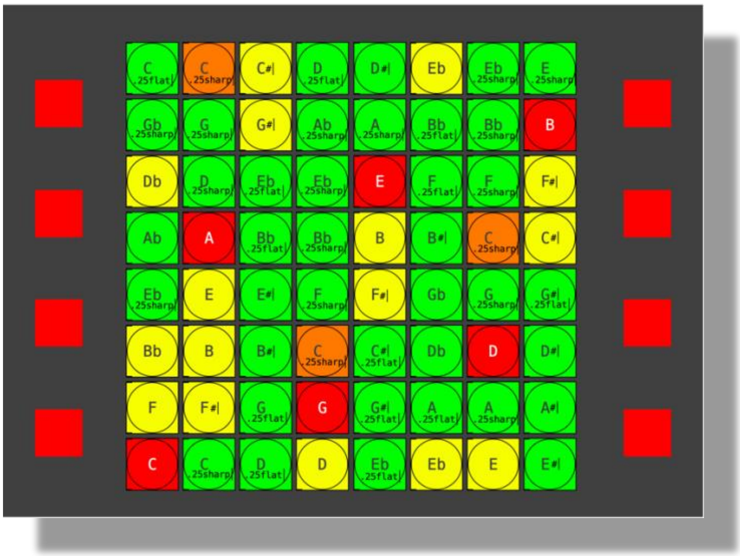

Figure 7.5. The final prototype of Beta Scale - digitally constructed using Pure Data software

Gamma Scale

Similar to the above, the Gamma Scale also comprise of divisions based on perfect fifths (3:2 ≈ 701.995 cents), however each division is divided into twenty equally measured intervals each with intervallic value of 35.098 cents. Further, similar to the two aforementioned tuning systems by Wendy Carlos, Gamma Scale also takes basis on divisions of Perfect Fifths in addition to the sharing similar button arrangement/set-up of the Novation Minipad hardware keyboard.

Although, Gamma Scale is also based on divisions of Perfect Fifths, the most significant difference between present tuning system and the other two aforementioned tuning systems is the number of intervals to be doubled and nearly doubled in the case of Alpha and Beta Scales, respectively. Thus, it provided a set of problems to be solved in terms of keyboard layout conceptions.

The major difference in this occasion revolved around significantly revising the appearance of this particular keyboard layout which would showcase very little similarities to both of the aforementioned Carlos' tuning systems. Evident in the example below, the number of Perfect Fifths is fairly limited – thus, this would lead to a number of designing challenges in order to pertain some of the fundamental similarities to among others the Alpha Scale keyboard layout. However, despite the sequence and appearance of intervals to not appear exactly the same the only symmetry apparent on this keyboard layout is the appearance of the first key in C at the bottom to the far left while every consecutive Perfect Fifth to appear to the far left and two rows above the previous Fifths. Similarly, to the two aforementioned tuning systems by Wendy Carlos, all Western equivalent intervals and approximate octaves appears in a non-symmetrical order on the keyboard layout.

However, as previously addressed, neither Beta nor Gamma Scales were considered the main objectives when developing VMKLI's thus included mainly as bonuses to the Alpha Scale. Beta Scale was also featured in the collaborative composition Twirl Dung Pa, featured during the ACMG concert on 4th May 2022.

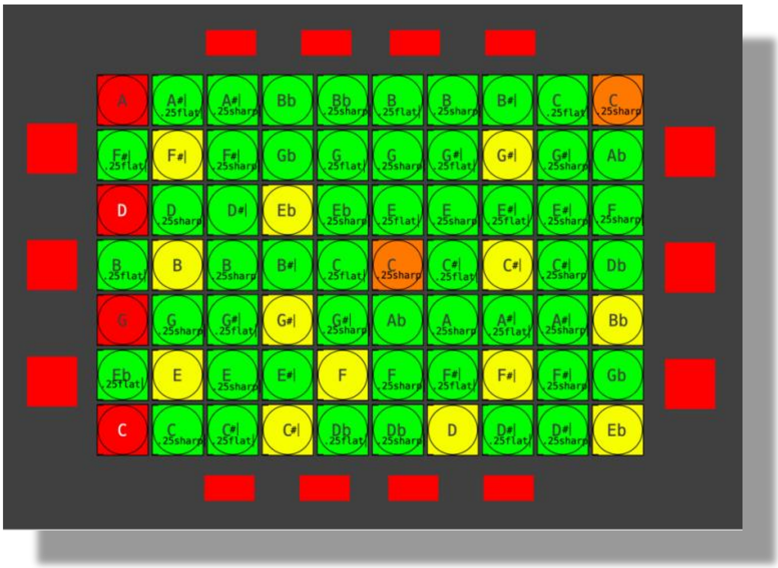

Figure 7.6. The final prototype of Gamma Scale - digitally constructed using Pure Data software

Bohlen-Pierce Scale

Despite that the aforementioned/previous collective entity of Alpha/Beta/Gamma Scales may easily be conceived as being one complete tuning system, however, this notion is not true; despite that each of these three tuning systems share in common division of intervals based on the perfect fifth (3:2), judiciously they appear to be conceived as an ideology that separate themselves from the common traditional octave based Western standardization. Similarly, this applies to Bohlen-Pierce Scale as well because this is a modern invention of a tuning system as well as an approach towards intervallic separation that derives from the traditional Western standardization. The initial development and creation of Bohlen-Pierce started in the early 1970s by German-born microwave engineer named Heinz Bohlen. A few years later another renowned microwave engineer named John R. Pierce also made similar discoveries. Interestingly, without the knowledge of nor awareness of one another, each of them believed they had invented a new tuning system only to discover later that the other had invented a similar tuning system, thus the name Bohlen-Pierce Scale. It should be noted that this tuning system possibly have involved important contemporary contributions by other significant individuals whom may not have gotten the rightful/justifiable recognition for their contributions among others the Dutch computer programmer Kees van Prooijen. However, the fundamental knowledge of this tuning system has been commonly attributed to the two aforementioned individuals, none of whom were primarily musicians and who by sheer coincidence shared the same profession and happened to be completely unaware of each other's contribution.

The commonality of profession and (necessarily) training naturally leads to speculation as to similar common factors which might have led each individual to such obscure, mirrored innovation, but if such exists there does not appear to be any documentation or even anecdotal evidence to suggest anything beyond coincidence.

Bohlen-Pierce scale does not contain any single interval which corresponds to the traditional 12-tone EDO Western tuning system and similarly to Alpha/Beta/Gamma Scale thus produces pitches that may appear out of tune to the casual listener. Bohlen-Pierce scale is based on a set of measurement called tritaves (3:1); essentially this involves a combination of an octave (2:1) and perfect fifth (3:2) to form one tritave resulting in a total ratio of 1901.96 Cents per division. Further, it should be noted that the perfect fifth in this case is based on Just Intonation ratios and not according to the Equal tempered version commonly found in traditional Western musical practices. The spectrum of tritaves consists of 13 intervals, and can be found in two different configurations 1) Equal Temperament with intervals approximately 146 Cents apart and 2) Justly tuned temperament (Just Intonation) containing unequally divided intervals within a register of approximately 140-146 cents each per interval. It should be noted that keyboard layouts for both of these configurations are present on the Bohlen-Pierce VMKLI created for this research.

It may be obvious to the reader at this point that the intervals in Bohlen-Pierce Scale are divided into noticeable wider intervals (nearly 1½ per intervallic step compared to each intervallic step within the 12-tone EDO) compared to the typical Western 12-tone EDO and similar to intervals (either microtonal or not) commonly associated with a number of other modern invented tuning systems including some indigenous musical cultures in the world. Different from Carlos' tuning systems, Bohlen-Pierce Scale has been subjected to numerous different ideas and propositions in search for ideal keyboard layouts. Interestingly, this experimentations on keyboard layout conception dates back to the originator Heinz Bohlen who himself bought a do-it-yourself electric organ which allowed him to custom-made the order of black/white piano keys and eventually rearrange the keys accordingly to his own preference. In order to make the electric organ play back the desired tuning he enlisted help from another fellow engineer/friend Bernd Seidel who created divider circuits to accomplish the desired retuning of what has later become known as Bohlen-Pierce scale.

It should be noted that Bohlen-Pierce is not solely limited to keyboard instruments but appears on a limited variety of instruments such as guitars, pan flutes, stredici (long 16 feet stringed instruments which can be plucked, bowed or beaten), clarinets, metallophones etc. The most renown/famous individual associated with keyboard layout propositions for this tuning system is Elaine Walker. A number of videos on YouTube demonstrates her propositions and allows the viewer some insight into how she custom-made and re-arranged key order to make them play Bohlen-Pierce Scale – these features different electric hardware keyboards with keys commonly found on traditional piano layouts as well as an example of a 64-key hexagonal/isomorphic keyboard.

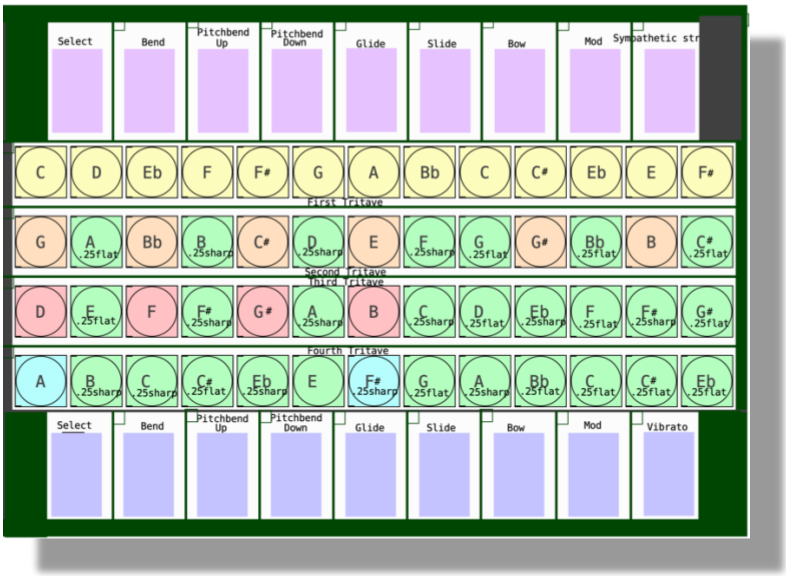

Figure 7.7. The final prototype of Bohlen-Pierce Scale for Equal Temperament - digitally constructed using Pure Data software

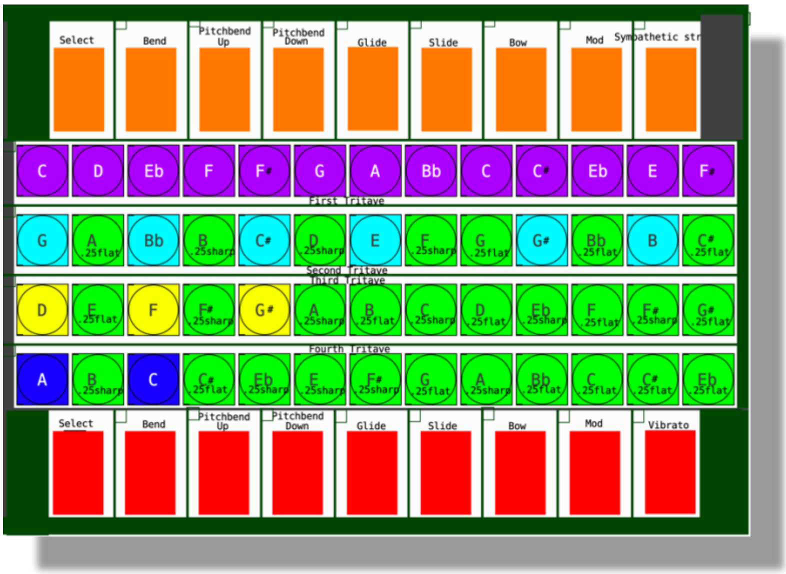

Figure 7.8. The final prototype of Bohlen-Pierce Scale for Just Intonation - digitally constructed using Pure Data software

Interestingly, at the initiation of this research it appears that these propositions were all limited to hardware instruments and no known examples which suggests the potential of keyboard layouts for Bohlen-Pierce Scale to be approached within the virtual/digital/computer programming domain.

Bohlen-Pierce VMKLI's

In total, two keyboard layouts have been created for the Bohlen-Pierce Scale VMKLI; the first is based on equally divided intervals per tritave (example …) while the other is based on Just Intonation intervals per tritave (example …). Both keyboard layouts are literally constructed in the same fashion except for different colour patterns in order to separate one from the other. However, one consistent colour to be found on both applies to the non-Western intervals represented in green. Further, as addressed above, no exact intervals appear accordingly to the Western 12-tone EDO. However, intervals within the lowest range on the keyboard layouts have been provided with a different colour due their close proximity and difference in Cents/Hz appear marginal to any traditional Western based intervals (i.e. either related to Just Intonation, Equal, Meantone, or Well-tempered tuning), but will appear otherwise in different colours for each consecutive tritave – this is mainly a designable attribution to accommodate the overall appearance for the keyboard layouts of both the Equal Temperament and Just Intonation versions featured in the Bohlen-Pierce VMKLI and further to distinguish each tritave rather than for this to have any other specific purpose.

The hexagonal 64-key Axiom keyboard is quite an interesting approach for Bohlen-Pierce Scale; however, this approach will also result in another challenge. Since a tritave based tuning system does not contain a repetitive pattern with the same order of keys (i.e the next division contains a completely different set of keys/intervals compared to the previous tritave), thus it will be difficult to make logic by using isomorphic configuration. On the other hand, this would not be problematic for an octave based tuning system with repeated sets of intervals per divisions thus this allows for a more logical navigation on an isomorphic keyboard layout.

Early on in the initial process developing the VMKLI for Bohlen-Pierce Scale, an apparent/conscious decision was made to stray away from any of the propositions made by Elaine Walker for the following reasons; 1) a desire to allow for separate rows for each tritave due to the nature of each division to appear in an entirely different key than the previous division (i.e. due to the non-octave relation and non-repetition keys to be found in tritaves) to make it easier for the player to navigate through each division and to combine finger navigation from one division to the other, thus no logical reason to repeat consecutive divisions on the same row. 2) Shorter rows of keys to allow for easier access to additional options for effects and changes of timbre etc. while playing the instrument, 3), a consistent arrangement of and shapes of keys due the tuning system to be non-octave based. 4) Since none of the intervals (except for C1, the starting key) completely matches intervals from the traditional Western 12-tone EDO, it is difficult to unlikely to create an unsymmetrical keyboard layout similar to the piano layout since no repeated patterns of same intervals per division appears. Further, there are also more complex interval variables compared to the 12-tone EDO (i.e. additional fractional, semi, half flats and sharp keys) which would force more variants/shapes of keys to be introduced and likely appear too confusing to the player - thus one consistent shape of keys has been chosen. 5) a consistent colour pattern for non-Western intervals - in accordance with Carlos' tuning systems and represented with green coloured keys in order to be distinguished from Western intervals, 6) a distinctive timbre for the VMKLI; similar to Carlos' tuning system, Bohlen-Pierce Scale appears to have no distinct timbre to be associated with the tuning system, it is mainly recognized for the unusual divisions of intervals/pitches, thus this allows for experimentation to create/shape unique timbre to enhance the quality of the intervals for this tuning system.

Evolved Tuning Systems

Gamelan

The phenomenon of Indonesian gamelan is quite possibly the hardest and most complex among the tuning systems explored for this research project, it should be noted that the overall focus/knowledge on gamelan in this occasion has been allowed significant portion of elements to encapsulate an overall understanding that possibly constitute the majority which comprises the phenomenon of gamelan. Despite that numerous gamelan ensembles are present on every island in Indonesia, opinions of individually created conceptions of tuning (although this appears within specific boundaries); this involves and affect the amount of instrumentations both for singular categories of instruments and the overall groups of instruments in the ensembles. Further, specific type of instrumentations appears to be mainly determined/accepted through personal preferences from key individuals/leaders for inclusion in gamelan ensemble, however in the vast majority of cases this is determined prior to any fashioning process including purchase of instruments (thus it does not affect already established gamelan ensembles).

It should be noted that the overall complexity which comprises the phenomenon of gamelan cannot be limited solely to the aspects included in this research as it stretches further beyond what has been covered and explored within the confinements of this research. All over Indonesia, it is estimated that more than 1000 different gamelan ensembles exist, yet each island contains different configurations and categories of gamelan ensembles which are further enhanced by numerous different variants of instrumentations (with a portion of instruments either similarly or distinguishably crafted from the practices of one island to any of the others). In addition to this, approaches and principles to the overall tuning conception including intervallic balance between general instruments within specific ensemble as well as singular instruments typically appears to be predetermined individually by the leader of the ensemble in accordance with the craftsman/maker in the initial stage of the existence of the gamelan ensemble.

Despite that Indonesian gamelan appears to be a very engaging yet interesting and fascinating topic and likely will reveal entirely new aspects the more one keeps exploring the aspects of its musics; however, due to severe time constraints this research is limited to focus on two standardised categorizations of gamelan ensembles situated in Java and Bali, namely the Javanese Gamelan Sekar Pethak and Balinese Gamelan Gong Kebyar ensembles, respectively. Although it has been addressed previously to some extent, both Javanese and Balinese gamelan generally encompasses a number of other different gamelan ensembles with slightly or significantly different configurations/standardization compared to the two categories dealt with in this research.

Gamelan VMKLI

Evident on what has been stated above, the process of developing VMKLI for gamelan appeared to be a slow yet gradual process largely informed due to the complex nature of the tuning system. In this occasion, a vast amount of information needed to be acquired through different stages of the research project; from the early stages up until the latter stages of the project. Thus, the approach conceptualizing and eventually creating a Gamelan VMKLI proved to be the most challenging software programming development undertaken during this project – however at the same time this work eventually yielded both a rewarding experience yet appeared to be one of the greatest achievements of the research. In particular, due to the vast number of gamelan instruments found in both of the two aforementioned standardized groups of gamelan ensembles, it was necessary to create several keyboard layouts to provide an overall overview which would cover and represent the most integral and characteristic instruments associated with both the Javanese Gamelan Sekar Pethak and Balinese Gamelan Gong Kebyar ensembles. In total this resulted in the creation of six different keyboard layouts for the Gamelan VMKLI where each of these keyboard layouts were subjected to a number of different designing and layout approaches and conceptualization. It should be noted that a few minor omissions of instruments have taken place, such as all melodic non-percussion instrumentations, in addition to barrel-shaped hand drums (associated with both islands) and cymbals (Bali only) – in the two latter cases the reason for omission is mainly due to none possessing any distinct pitch, unique nor uncharacteristic timbre which distinguishes them from any equivalent instruments associated with Western music and possibly other cultures.

The playable objects on each Gamelan keyboard layout appear with designated areas which are outlined and clearly separated by the differences of intervals from either the pelog or slendro tuning systems (indicated either through outlined rectangular or square-shaped areas surrounding the playable objects separated by the letter S or P) when applicable, in these cases as well as independent on either tuning system in general, octaves are signified by dots to appear subscript (dots below) or superscript (dots above) in order to indicate the octave/s (the more dots to appear – the more deviations in terms of octaves to be involved).

For the sake of simplicity and in order to address all the basic assets/properties of the Gamelan VMKLI to be understandable to and easily adaptable to any performer/musician with limited experience, understanding of intervals and overall awareness of the tuning systems - thus a number of compromises have been made in order to incorporate different terms and ideas which in turn have resulted in a melting pot of various expressions invariably used between the islands as well as by Western based authors and Scholars. Further, each interval from either of the aforementioned Javanese/Balinese gamelan standardizations are represented either in red (Gamelan Sekar Pethak) and blue (Gamelan Gong Kebyar) colours, respectively.

In terms of providing sound design conceptions for each keyboard layout on the Gamelan VMKLI, early on in this process a meticulous effort was made to recreate sounds that retain and preserve the integrity of distinctive timbre, aural qualities and vibrancies associated with authentic Indonesian percussive gamelan instruments.

Independent of the nature/natural timbre associated with each and every gamelan instrument - these were all encapsulated into distinct group of instruments for each of the six keyboard layouts on the Gamelan VMKLI, as a result the following categories of instruments were made; gong instruments, gong-chime kettle instruments (one keyboard layout each for Javanese instruments and Balinese instruments), metallophone instruments (one each for Javanese instruments and Balinese instruments) and bamboo xylophone instrument. In order to achieve the desired sounds while simultaneously endeavouring the metallic qualities associated with Gamelan percussion instruments, the technical methods for each keyboard layout was approached by the use of additive synthesis; this turned out to yield the most satisfying results from a technical programming perspective. It should be noted that the playable objects for each keyboard layout have been shaped with unique distinctive timbral characteristics.

In this process, a search for additive synthesis that would imitate bell-like/embellishment was absolutely necessary; in the end, Risset's Bells, a conceptual idea based on additive synthesis by software developer and music composer Jean-Claude Risset (1938-2016) turned out to be the ideal basis for replicating timbre that would evoke the sounds of Indonesian gamelan percussion instruments.

The reason why additive synthesis turned out to be the most satisfying choice can be attributed through the use of a bank of oscillators which enabled the possibility to stack numerous synthesis (or partials) of increasingly higher frequencies on top of each other and further allowed adjustment to the amplitude, frequency, duration of each specific partial. Although this turned out to be a significantly time-consuming process, this was integral to the final outcome which enabled the desired shaping and fine-tuning of timbre for each Gamelan keyboard layout.
Further, concepts for playable objects on each keyboard layout are divided between two distinguishable configurations; all gong and gong-chime kettle instruments are represented by circular/round shaped playable objects while all metallophone and bamboo xylophone instruments are represented by rectangular shaped keys.

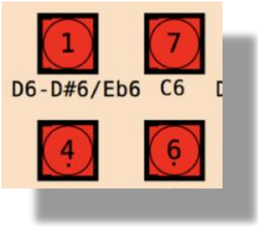

Figure 7.9. Example of circular/round playable objects

It should be noted that the circular/round playable objects mainly appear in the same size on all keyboard layouts except for the gong keyboard layout where they are represented in different sizes in order to signify the difference in size and pitch between the various gong instruments. Different from all the other keyboard layouts, the gong keyboard layout combines all gong instruments according to the standardization found in Gamelan Sekar Pethak and Gamelan Gong Kebyar ensembles; the main reasons for including all gong instruments onto one keyboard layout was to limit the total number of layouts yet also to provide some flexibility since the total number of gong instruments are relatively few in numbers.

Interestingly, the playable circular/round shaped objects found on the Javanese gong-chime kettle instrument keyboard layout provides different aspects of playability. The distinctive order and placement of these mainly appear according to the actual order found on the bonang instruments (i.e. kettles placed in center or close to center are frequently played while those placed on either side are played far less), however due to the inclusion of the kenong instrument (larger and lower tuned gong-chime kettles) to this particular keyboard layout some minor alterations to the overall placement of playable objects was completely necessary.

Differently, the Balinese gong-chime kettle instruments keyboard layout displays intervals placed in an ascending order from left to right according to the actual order found on Balinese gong-chime instruments; although a number of intervals appear in-between in the row beneath/above one another in order to showcase intervals which appear in-between.

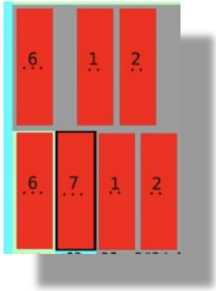

Figure 7.10. Examples of rectangular shaped playable keys

The only other configuration of playable objects is represented through rectangularly shaped keys to appear reminiscent of keys associated with actual metallophone instruments - although this resemblance may not be limited to these types of instruments, they may as well evoke the vibrancy of white keys associated with traditional pianos. This type of configuration solely applies to the metallophone and bamboo xylophone instruments of Indonesian gamelan.

On every metallophone keyboard layout independent whether related to equivalent instruments found on Gamelan Sekar Pethak or Gamelan Gong Kebyar ensembles, the size of rectangular keys/playable objects appears in the same size and are represented according to the ascending order of intervals beginning from the lowest (left) and progressively to the highest (right). Each of these keyboard layouts encapsulated a number of different yet distinct features commonly found on the various tuning systems in Java and Bali. Whereas Java operates with two different tuning systems; namely slendro (five tones per octave) and pelog (seven tones per octave) these are represented by an upper and bottom row, respectively. On the other hand, the Balinese metallophone keyboard layout solely operates with a five-tone customization of the original seven tone tuning system commonly associated with Javanese gamelan. Commonly, Bali operates with female and male (i.e. larger and smaller counterparts – further descriptions will be provided in the chapter about gamelan) variants/counterparts of the same instruments which are approximately tuned one semitone apart from one another, thus the upper row separates the female (lower tuned) apart from the male (higher tuned) counterparts. It should be noted that the Javanese designations which have been applied to the Balinese intervals do not actually exist in Balinese gamelan, however have been introduced mainly to simplify and make their appearance more intelligible to Western musicians by using a numeric value instead of using the common Balinese expressions such as ding, deng, dang, dong etc.. The Gamelan VMKLI will be represented through a total selection of six keyboard layouts which can be selected literally by using a finger to slide the screen from right to left in order to select the preferred keyboard layout and instrument.

Briefly about the design and conceptualization of each VMKLI

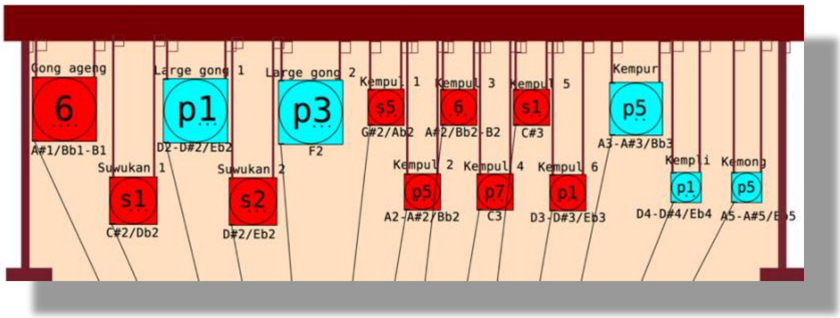

Figure 7.11. Gamelan keyboard layout 1 – Incorporates all gong instruments for both Javanese and Balinese gamelan

For the Gong keyboard layout (layout 1), I decided to create a layout which would replicate a broad gong stand which would encapsulate all the gong instruments. As indicated previously, this keyboard layout comprises of gongs associated with both Gamelan Sekar Pethak and Gamelan Gong Kebyar. Despite, that no such thing is to be found in actual Indonesian gamelan, it is however somewhat common for gong stands to contain more than one type of gong instruments.

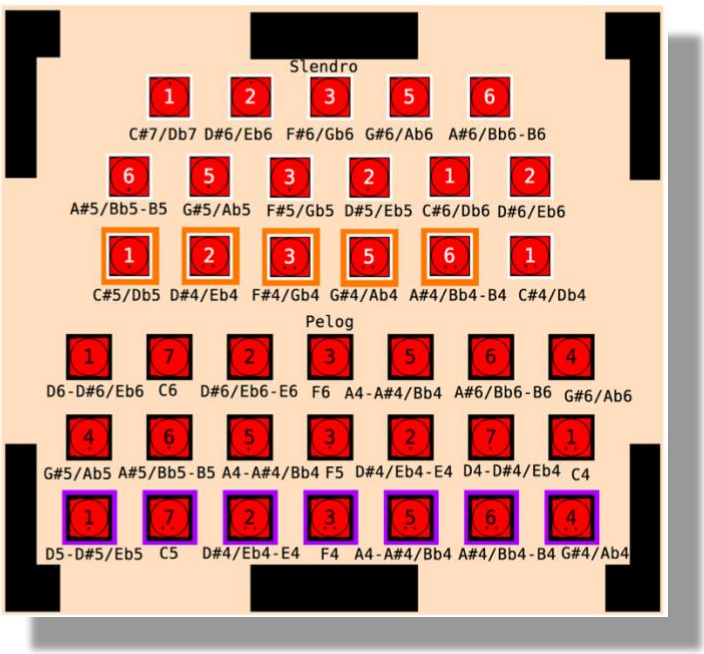

Figure 7.12. Gamelan keyboard layout 2 – Incorporates all gong-chime kettle instruments of Javanese gamelan featuring both slendro/pelog tuning (upper/bottom sections)

The Javanese gong-chime kettle keyboard layout (keyboard layout 2) encapsulates all gong-chime kettle instruments found in Javanese Gamelan Sekar Pethak and comprises all intervals and the full range of two different yet distinctively similar types of instruments, namely kenong and bonang. As previously addressed, a great extent of endeavour was undertaken to preserve, retain and possibly allow a sympathetic logic of order of gong-chime kettles to be remotely representative within close proximity of expected appearance associated with the bonang instruments. However, slight adjustments were completely necessary in order to make the necessary compromises to accommodate both instruments to appear on the same keyboard layout. The actual appearance and order of kettles on bonang instruments are separated into two rows of six (slendro) and seven (pelog) rows where pitches 1, 4, 6, and 7 in pelog and pitches 1, 2 and 6 appear the least significant when played in pelog and slendro, respectively, thus the intention with this keyboard layout seeks to preserve the playing position accordingly to the actual instruments for both tuning systems although it removes the common row featured in the lower/higher octave versions (bonang barung/bonang panerus) of the instrument.

Further, bonang and kenong instruments are separated through specific colour coding; evidentially the bottom row for both slendro and pelog tuning on keyboard layout 2 depicts additional squares marked (kenong instruments) with a distinct colour different from all the other knobs (bonang instruments) and represented through orange and purple colour patterns, for slendro and pelog respectively. This decision was made to separate and make these two different instruments distinguishable from one another to the player/performer. Interestingly, the bonang instruments suggests yet another conceptual dilemma due to both comprising two set of the same instruments with 12 and 14 gong-chime kettles on each instrument (i.e. combined these comprises 18 and 21 kettles with one shared octave in common for slendro and pelog tuning, respectively). Instead of incorporating a common/parallel octave of intervals onto the keyboard layout; a decision was made to conceptualize a keyboard layout comprising solely individual unique pitches (not repeated twice), thus omitting the extra common/parallel row of intervals. Also, worth pointing out is that the kenong instrument tuned to slendro only comprises five kettles (in comparison to the fixed six row setup of the bonang instrument) which affects the general placement of gong-chime kettles on the keyboard layout, mainly this is showcased by substituting one kettle from the common setup of the bonang instrument in order to leave a non-symmetric upper row of five kettles only.

The concept of the general design for keyboard layout 2 was the result of a logic yet also somewhat unconventional process; the initial idea largely sprung out of spontaneity and occurred primarily as a result of sheer instinct - although the order and shape of playable objects on the original instrument/s obviously played an important factor in the final decision-making process. It should be noted that due to the extensive number of gong-chime kettles and further because of their round-shaped appearance would eventually trigger the idea to create a layout which sought to recreate the appearance of a chess board. This idea fitted perfectly with the necessary segmentation of two different tuning systems to be represented on the same keyboard layout, thus the playable objects would evoke the vibrancies of white and black pieces on a chess board, to indicate slendro and pelog tuning, respectively. As evident in the example above, slendro and pelog tuning are separated between an upper and bottom area of gong-chime kettles.

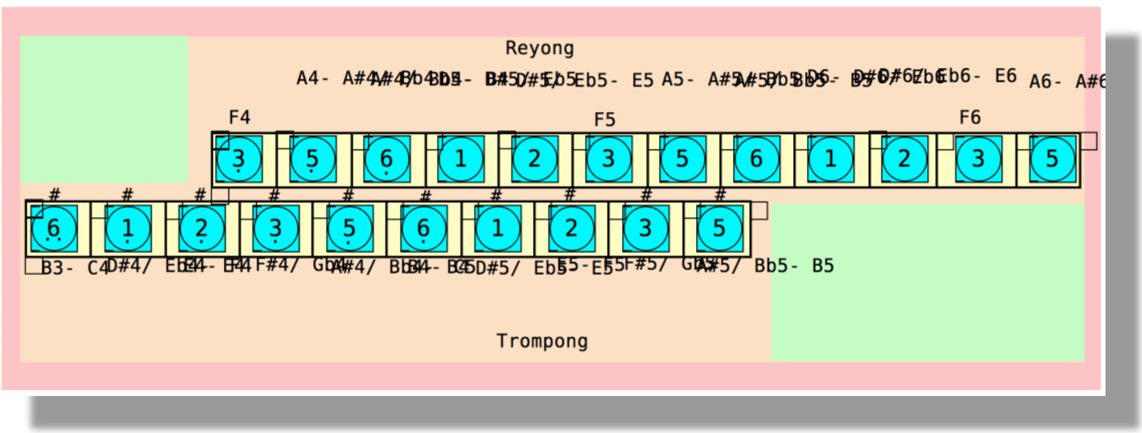

Figure 7.13. Gamelan keyboard layout 3 – Incorporates all gong-chime kettle instruments of Balinese Gamelan

Keyboard layout 3 represents Balinese gong-chime kettle instruments. Similar to its Javanese counterpart it comprises two different instruments within a mostly similar categorization of instruments, namely Reyong (comprises of 12 gong-chime kettles) and Trompong (comprises of 10 gong-chime kettles).

Conceptually, keyboard layout 3 appear truer to the actual physical appearances of the original instruments. There are a few obvious reasons for this; the Balinese counterpart solely contains only one each of these two categories of instruments, thus leaving no coinciding pitches nor shared octave to appear on either instrument and far less kettles in total. Further, the pitches are placed accordingly to the order on the actual instruments - ascending from left to right (low to high), this is due to the actual placement of gong-chime kettles on the instruments. As evident in the example above, one may notice that the playable objects on the bottom row are not entirely synchronized with the objects in the upper row; the reason for this is that Trompong kettles appears as male equivalent pengumbang (higher pitched) to the female Reyong counterpart pengisep (lower pitched), thus a deviation of one semitone (i.e. 100 cents) between each. Different from keyboard layout 2, keyboard layout 3 to a large extent seeks to recreate the physicality of the actual instruments although with some minor modifications; the long rectangular yellow areas are supposed to resemble the elongated shape of both Reyong and Trompong instruments in which the kettles are attached to, any other details added are purely for artistic/decorative purposes.

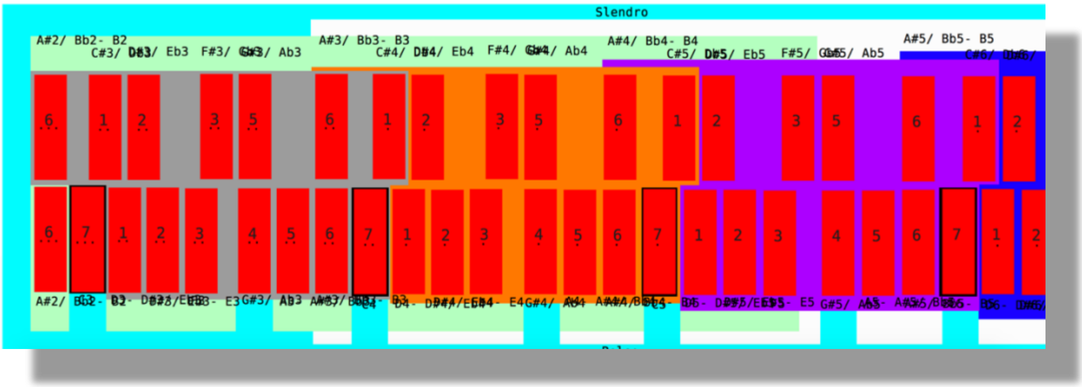

Figure 7.14. Gamelan keyboard layout 4 – Incorporates all metallophone instruments of Javanese Gamelan featuring both slendro/pelog tuning (upper/bottom row)

Common for both metallophone keyboard layouts (independent on the island they represent) is that they are represented by an upper and bottom row of keys; in most cases a set of keys appear in-between the keys found on the upper and bottom row in order to indicate pitches/intervals to appear in-between those pitches/intervals. Despite that both keyboard layout 4 and 5 shares an upper and bottom row of keys, it should be noted that these are operated differently between Java and Bali largely due to the different conceptions and executions of tuning systems between the respective islands. Both keyboard layouts seek to encapsulate the entirety of all and to represent the full range of metallophone instruments (independent of all tuning systems) for Gamelan Sekar Pethak and Gamelan Gong Kebyar.

As such, keyboard layout 4 (based on Javanese metallophone instruments) contains a setup of keys arranged to accommodate the intervallic appearance and differences between the slendro and pelog tuning system, where the upper row applies to slendro and the bottom row for pelog tuning. In the rare instances when keys are positioned at the exact same position on the upper and bottom row - this indicates coinciding pitch to appear in two occasions, namely interval 6 for both tuning systems while interval 4 in slendro coincides with interval 5 in pelog.

It should be noted that the colour coding on keyboard layout 4 serves a few different purposes; the colours surrounding the actual keys mainly relates to the total range of slenthem and saron instruments (please read Appendix 1 for further information, reference and characteristics of those specific instruments) - grey signifies the range of the slenthem instruments and further similar to the saron instruments through the appearance of seven keys for both slendro and pelog tuning – however, each instrument include two coinciding pitches which are indicated through an overlap between two different colours (i.e. grey and orange colours, orange and purple etc.).

Thus, orange colour signifies the range of saron demung instruments, purple for saron barung and blue for saron panerus, while outer colours signifies the range of gender instruments such as gender barung which appear in light green and gender panerus in white - any gaps between keys suggest that there are no specific pitches to appear in either gender nor saron. The main target with this keyboard layout was to create one unifying timbre to encapsulate which to apply for the entire range of Javanese metallophone instruments and for different purposes; 1) to create an entirely original keyboard layout without any similarity to any other options available in the world and 2) to develop and create one distinct timbre which applies to all metallophone instruments in order to evoke sounds similar to those associated with actual Javanese metallophone instruments. Similar to the Gong keyboard layout, intervals/pitches are indicated both through their Indonesian designation as well as Western approximation of intervals in order to make these keyboard layouts appear more user-friendly to Western musicians.

In comparison to the saron instruments, the gender instruments comprise twice the number of keys (14 keys per instrument) while being further juxtaposed through two different configurations of pitches which applies to these instruments; thus, the setup of the keyboard layout have been customized to enable the user/player the possibility to perform both options if desired; one which includes every interval across a span besides intervals 1 and 4 (i.e. interval 7 is outlined by a black rectangle), while the other option (the most common approach) contains every interval besides 7 and 4, (i.e. indicated by the green colour which does not cover the area of intervals 7 and 4).

On the other hand, conceptually the intervals on keyboard layout 5 (based on Balinese metallophone instruments) are distinguished by an upper row which represent the lower pitched female equivalent (pengumbang) to the higher pitched male (pengisep) counterparts of same category of instruments, where each key between the rows is tuned one semitone (i.e. 100 cents) apart from the other – this is signified by the symbol # (i.e. sharper pitched) present on each key on the bottom row of keyboard layout 5.

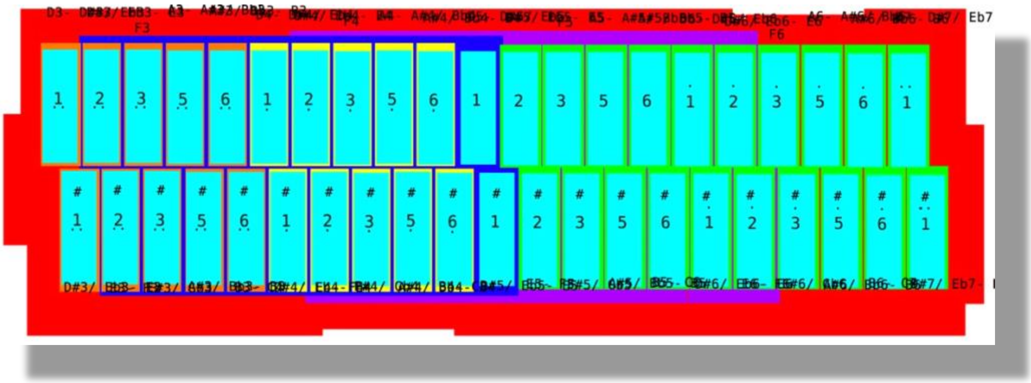

Figure 7.15. Gamelan keyboard layout 5 – Incorporates all metallophone instruments of Balinese Gamelan featuring both pengumbang and pengisep tuning

In total, Balinese metallophone instruments contains a similar number of keys in comparison to Javanese metallophone instruments although they comprise a few more different types of instruments. Similar to keyboard layout 4, a number of different colour coding signifies the different types of metallophone instruments in order to indicate the range and intervals and appear as follows; the first five keys surrounded in orange indicate the range and pitches of the lowest tuned metallophone instrument called jegogan, followed by another five keys instrument called jublag in yellow (which appears in the octave above jegogan). The consecutive instrument is the ten key instrument ugal (which comprises two octaves) in blue –

which almost parallels the range of both jegogan and jublag except for starting key from interval 2 and ending at interval 1 almost two octaves above, and then followed by another ten key instrument named pemade in purple starting one octave above ugal, and finally the ten key instrument kantilan in green.

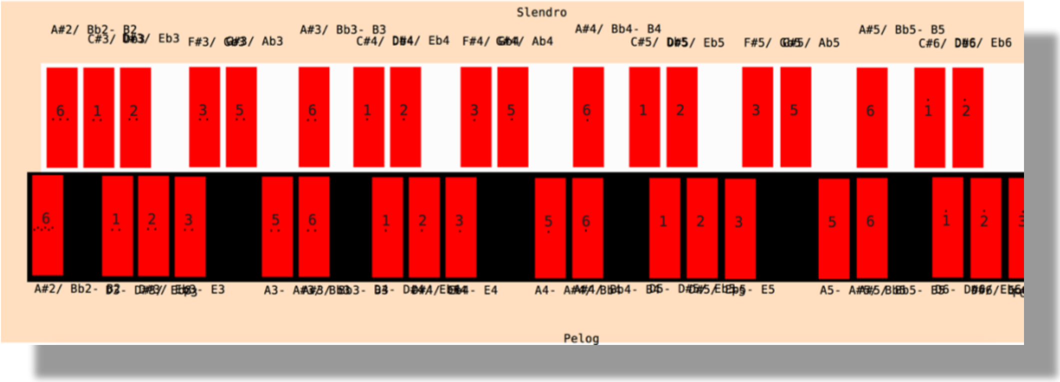

Figure 7.16. Gamelan keyboard layout 6 – comprises the gambang instrument featuring both slendro/pelog tuning (upper/bottom row)

Keyboard layout 6 distinguishes itself from all of the other Gamelan keyboard layouts, largely due to being based on one single Gamelan instrument, namely the Javanese bamboo xylophone instruments called Gambang. Further, this instrument is the sole Gamelan instrument dealt with in this research with a playing surface which is not made of any metallic material. This keyboard layout showcases the instrument by dividing it into an upper row (tuned to slendro tuning) and a bottom row (tuned to pelog tuning). Evident with this keyboard layout is that it proposes a rather simple design and replicates a similar pattern to that found on keyboard layout 2 instruments where slendro and pelog tuning has been distinguished into white and black colours, respectively.

Indian tuning system

Indian tuning system is possibly among the oldest in the world, further its conception appears to have been consistent and distinguishable throughout its history with its concept firmly rooted back to ancient times and no known alternative approach to tuning appears to have been proposed in modern times. The significance of Indian classical music appears to be rooted in or emphasise other aspects such as pitch variations and maintaining constant sound for a certain number of cycles. Thus, the conception of precisely calculated correct pitch and intonation appears differently in

Indian music compared to Western music, although a set of twelve notes may appear in Indian scale, these will not be equidistant (Deva, Indian Music, 1995, p. 29).

Integral to the history of tuning in Indian music is the usage of whole tones in its inherent musics – this has been evident since ancient times through the musical treatise called Rikpratisakhya (approximately 600-400 B.C.), in this source it appears the earliest known execution of Indian music to comprise a register of three voices and seven notes of the gamut (Popley, 1921, p. 9). This would later be extended into seven-toned chant.

Currently, Indian tuning is basically rooted on 22 srutis, which means 22 possible tones to appear per each octave. All twenty-two srutis are never used in any particular compositions and instead only a fraction of these intervals appears to be used, although the numbers tend to vary and mainly based on the structure of the musical composition in question. Srutis is considered "… a measure as well as an indicative number of intervals-the pitch relation of notes" (Deva, Indian Music, 1995, p. 29). Despite that the intervals, in broadly terms are described as quartertones, however this does not unambiguously suggest that the tones appear to be entirely equally divided; it should be noted that no standardization exist in which to determine exact values of each sruti, thus only approximations are provided in Indian music (Sorrell & Narayan, 1980, p. 101).

The Western diatonic scale works similarly in Indian classical music. While the West has long-since established a scale system commonly known as solfège (Do, re, mi etc.), similarly Indians also operates with a similar system called svara which relates to the same tones although with different names and sets of abbreviations: Sa, Re, Ga, Ma, Pa, Dha, Ni, Sa (next octave). It should be noted that Indian compositions rarely exceed more than five tones, thus they appear to encompass certain rules which limits a tonal periphery – which mainly revolves around a limited number of tones; commonly these appears to consist of a fixed tonic (Sa), and at least the fourth (Ma) or fifth (Pa) as a second tone (Bor, 2002, p. 1). In order to make a comparable distinction between srutis and svara understandable; the aspect of sruti; despite obviously pointing towards the intervals, it related more towards the in-between notes, while svara relates to fixed standardized notes. These works suggest the following distribution for the twenty-two srutis:

Sa	Ri	Ga	Ma	Pa	Dha	Ni	
4	4	3	2	4	3	2	= 22

Table 7.1. The 22 Srutis as explained by Popley (Popley, 1921, p. 32)

In order to calculate a set of 22 srutis, the Cents and Hertz values were based on findings/discoveries made by Doctor Vivek Bansod, Professor Mohit Sharma and Professor Dinesh Thakur (Bansod & Sharma, 2019, pp. 249-250) (Thakur, 2015, pp. 519, 523).

Largely due to the firmly documented history of Indian music and lack of significant changes over the course of history, the process creating the Indian VMKLI was a much easier task compared to both Gamelan and Arabic thus one sole keyboard layout was sufficient to the creation of the Indian VMKLI.

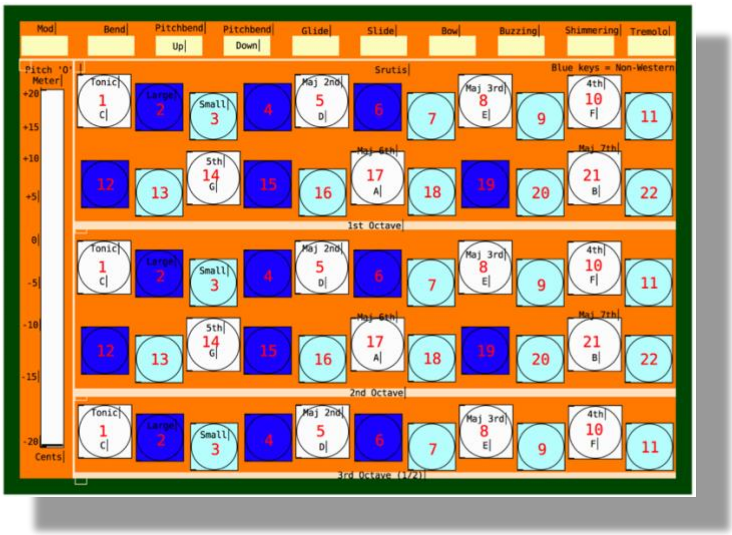

Figure 7.17. Indian VMKLI

The range of the Indian VMKLI is based on the typical range of instruments which comprises a range of two and a half octaves. Evident to the left on the VMKLI is a long vertical bar/slider which allows for detuning intervals by an increase/decrease of +/- 5 cents per step with the possibility to detune every interval up to +/- 20 cents of original key. This feature was added primarily due to the moveable frets on the sitar which allows musicians to slightly detune their instruments by a maximum of 20 cents from one composition to another during live performances.

Each interval on the Indian VMKLI has been separated through unique colour coding to signify their distance apart from its neighbouring interval; white keys indicate intervals in compliance with Western 12-tone EDO intervals, while both dark blue and light blue indicates non-Western intervals whereas dark blue indicates a significantly wider gap in cents (although less than 100 cents) apart from the previous interval/key and light blue indicates smaller gap in cents. Any additional features are marked in yellow, among others this includes techniques to reproduce bowing sounds and fundamental tones/drones both in the key of C and G approximately one octave below the register on the playable knobs on the VMKLI.

Conception for sounds and timbre on the Indian VMKLI was to evoke the vibrancy of Indian stringed instruments despite that the Sitar and similar qualities to timbre was considered to be a central instrument to emulate early on, eventually this notion shifted slightly as the work progressed and in the end the idea to steer slightly away from recreating exact timbre of a sitar occurred. The purpose by doing this was to create an original timbre which would retain some of the qualities evoked by stringed Indian instruments although adding a creative twist to make it distinguishable from the most common Indian instruments.

Ancient/medieval Arabic tuning system

Exploring different Arabic tuning systems throughout history was a quite interesting yet difficult process; the current Arabic tuning system comprises 24-tones per octave, however the exact execution has been subjected to heated debates among its inhabitants for the past 100 years or so – and currently subjected to heated debates and arguments among Arab musicians and scholars whether the intervals to be tuned roughly equal or equally (i.e. 50 cents) divided. Upon exploring Arabic music history for this research, it became obvious that approaching either of these two configurations would yield somewhat predictable results and allow for an unchallenging process and limit the originality of this aspect of the research project. Further, another reason for rejecting the notion to create keyboard layouts for the Arabic VMKLI based on contemporary conceptions of the 24-tone tuning systems system is largely due its highly Westernized conception through influences from numerous Western (or specifically French) scholars who by late 18th century were the first sources to address the current execution of a 24-tone Arabic tuning system. Thus, it is believed that this tuning conception derives from the West – interestingly, no Arab source appears to mention this phenomenon prior to these sources. Thirdly, although this also relates to the above, the 24-tone system configuration solely doubles the number of intervals (adding another 12 intervals to appear in-between) found on the 12-tone EDO Western tuning system without providing much difference in execution otherwise.

After these revelations it appeared to be integral for this research to further explore the history of Arab music as far back in time as possible with the intention to uncover another tuning conception/s which would be deemed more authentically Arabic. Thus, upon extensive examination of ancient/medieval Arab music history in search for previous Arabic tuning systems (either forgotten or discarded and not executed in Arab music of today) some important discoveries were made which would offer tuning principles that showcased less/little influence from the Western world while still retaining some aspects associated with contemporary Arab music. In total, two ancient/medieval tuning systems were discovered and would eventually become the basis for both of the keyboard layouts to appear on the Arabic VMKLI created for this research project. Although, they both still bear some resemblance to Western music through potential influence from Greek musical theory through their principal incorporation of commas/limmas (i.e. 23.5/90.2 cents) to divide intervals (please read section about Arabic music in Appendix for further information). In general, both of these tuning systems undoubtedly can be considered more distinguishable and authentic than the current conception of Arabic tuning system.

The two tuning systems which each keyboard layout has been based on is the 25-tones per octave and the 17-tones per octave proposed by al-Farabi and Safi al-Din in the 10th and 13th century, respectively. These two tuning systems would eventually allow for far more intricate, unique and surprising/unexpected results than any anticipated preconceptions expected if this research would pursue the contemporary Arabic 24-tones per octave tuning system. As of the initiation of this particular research it appears that the most common approaches among computer software programmers (independent of any cultural origin) has pursued the modern/contemporary 24-tones per octave Arabic tuning system; however, whether this is due to a lack of preconceptions or knowledge of any of these two former Arabic tuning systems or not is difficult to verify without any direct interaction/contact with these individuals.

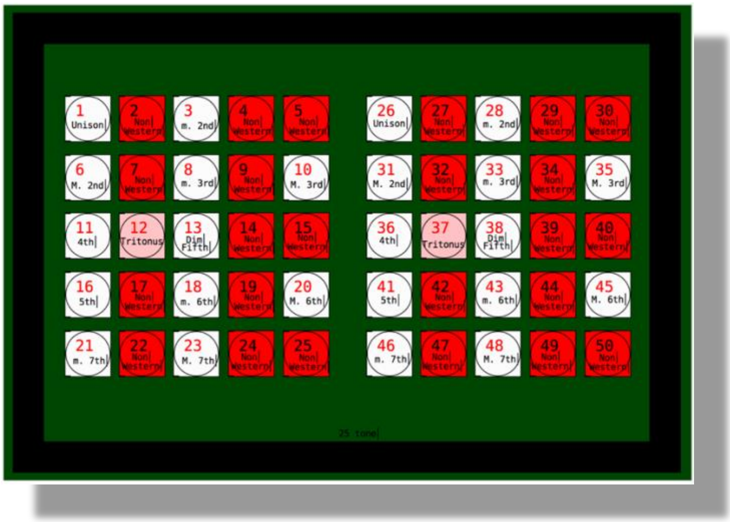

Figure 7.18. Arabic 25-tone per octave keyboard layout

The example above displays the proposition of a keyboard layout for the 25-tones per octave tuning system (originally proposed by al-Farabi in the 10th century) which was created specifically for this research project by present author. It should be noted that the musical range of this keyboard appears in accordance with the two-octave range found on the most typical Arabic musical instruments. Currently, this keyboard layout provides a total number of three different colour codes (although there is a possibility that this may change in the future post completion of this research project) in order to distinguish separate types/categories of intervals on this keyboard layout. In terms of the selection of colours, the usage of white knobs was a determined decision and intended to relate beyond the sole use of one single keyboard layout - this colour has been used consistently on other VMKLI's based on evolved indigenous music culture, at least in the context where intervals have been based on Western ideologies. However, this phenomenon is predominantly limited to the Arabic and Indian tuning system only, thus no such situation occurs on any of the intervals related to any of the instruments on the Gamelan VMKLI.

It should be noted that the major distinction between the Arabic VMKLI and the Indian VMKLI mainly relies on a number of ideas based on factual information derived from the respective cultures although the conceptual implementation of colour coding on the various VMKLI's was entirely predetermined by myself. As a result, the Arabic VMKLI contains one distinct difference apart from any other VMKLI created for this research project. The Indian VMKLI clearly showcase a clear distinction between intervals through a selection of three different colours, namely white, light and dark blue knobs in order to distinguish intervals between Western intervals from the uniquely inherent Indian pitches. However, different from the Indian VMKLI, except for the white knobs, the Arabic VMKLI mostly proposes a different set of colour scheme to distinguish the different types of intervals associated with its inherent culture.

The Arabic keyboard layout designed for al-Farabi's 25-tone tuning system comprises a colour scheme which is mainly divided between white and red knobs – whereas red indicates unique Arabic intervals, while a third colour (pink) has been used to signify the Tritones (Western phenomenon). Currently, the 17-tone keyboard layout incorporates different sets of colours. It should be noted that these keyboard layouts were the last to be developed during the research project and the concept of colours and design will likely undergo further development past the completion of this research project. Thus, ideas for the Arabic VMKLI is still under development and will continue to be so past completion of this research – currently the most distinct feature added is the possibility to reproduce sounds that simulate bowing sounds.

The second keyboard layout is based on the 17-tone per octave system proposed by Safi al-Din from the 13th century. Interestingly, this tuning system shows some significant influences from Greek/Western tuning terminology due to the usage of commas and limmas. Evident by the example below, a number of Western intervals or at least within the notion of equivalent intervals appears on this keyboard layout, thus it seemed sensible to apply additional colours (compared to previous keyboard layout) to signify the impact of these; thus white has been chosen for 2nd's, yellow for thirds, light blue for 4ths and darker blue for 5ths, green for 6ths, while pink for 7ths. Largely, due to the vast difference in execution and divisions of intervals, designing conceptions between the two Arabic tuning system resulted in entirely different approaches and set of colour schemes to accommodate the user.

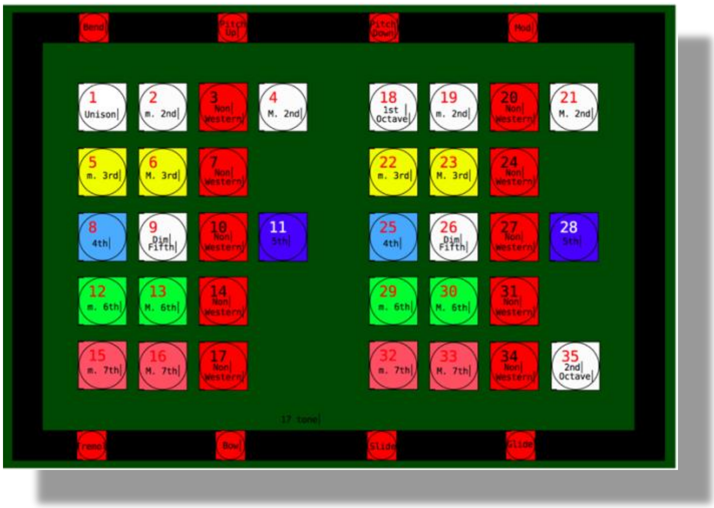

Figure 7.19. Arabic 17-tone per octave keyboard layout

Conceptual ideas for sound reproduction on the Arabic VMKLI was to approach programming through a technical programming named Karplus Strong Algorithm. In this occasion the purpose was to seek a characteristic sound in which to evoke a timbre commonly associated with the traditional Arabic ‘ud.

Implementation of VMKLI’s into each composition

With the exception of one composition, each VMKLI turned out to be the initial trigger for approaching every composition in this research project. By this, no compositional work was initiated prior to any significant progress undertaken to complete each VMKLI. The purpose of this was to approach musical composing through entirely unique and different approaches compared to any previously known songwriting/compositional styles/approaches. Thus, each and every composition presented in this research appears to be the first demonstration of how each of the five VMKLI’s were implemented into separate compositions in order to demonstrate both their advanced programming aspects as well as their potentials for implementation in contemporary musical compositions.

Interestingly, each VMKLI would gradually become more dominant as the work became completed. The first compositions to be created for this research project were the modern/invented tuning systems. The first composition to feature any of VMKLI was *Twirl Dung Pa*. Differently from all other composition, the Alpha/Beta/Gamma Scale VMKLI was incorporated after the intended solo piece was composed. Its purpose was to serve and add additional flavours randomly throughout the composition, although they were intended to appear dominant during passages when piano appears to be the predominant parts of the composition. Further, it should be noted that *Twirl Dung Pa* was the first solo piece completed for the research project.

The second composition created for this research project is called *In Search Of Enchanted Soundscapes*. This composition features Bohlen-Pierce Scale (Equally Tempered version) and appears to be an integral part of the compositional process. The intention with the solo piece was to construct a backdrop or soundscape to allow musicians to play along to this. The purpose with the soundscape was to create and combine a 50/50 blend of non-musical sounds from numerous field recordings with sounds from the respective tuning system in order to create an interesting musical blend through composition either completely on its own or through the accompaniment of other musicians (in this occasion with the accompaniment of ACMG).

The third composition, *Alien Transparagus & Seven Dead Minions* features both configurations which comprises the Arabic VMKLI. The concept was to create a solo piece entirely made up of sounds from the VMKLI, although with some additional audio processing – although no alteration of timbre is present in the composition. The composition mainly relies on and around the key of C, although with some additional variations added to it. What is unique about this composition is that it incorporates both of the Arabic tuning systems, yet seeks to juxtapose and make both interact with one another in order to shape the composition. It is very likely that these tuning systems have not been used for composing music in modern times, and unlikely combined for the same composition.

The fourth composition, *Music For People Who Doesn't Have Any Real Friends*, showcases a combination of random field recordings and the Indian VMKLI. The purpose was taking these elements to the extreme. No apparent melodic nor harmonic characteristics of Indian music has been retained in this composition. Although, the intervals implanted in this solo piece retains their distinctive intervallic nature – in combination with the field recordings and the addition of ACMG – thus, these qualities may be rendered slightly indecipherably/underachieved/unrecognizably in the final outcome of the composition.

And finally, the fifth composition, *The Esoteric 666-Type Of Dance* – may eventually appear as the most dominant use of a VMKLI in this research project. Not only does it appear dominantly throughout the composition, it may also be the closest exemplification in which to evoke the vibrancies of its respective culture. However, surprisingly, the composition blends both the meditative nature in terms of padded beating of Javanese gamelan in combination with the excessive and aggressive nature of hammer based Balinese gamelan. The result of this provides an amalgam of two distinctive playing techniques between the islands which occasionally from one distinct type of approach to the other while occasionally combining the two. It should be noted that a combination of the two categories most likely have never occurred in one single composition before.

8. THE IMPLEMENTATION OF THE FIVE VIRTUAL MUSICAL KEYBOARD LAYOUT INTERFACES (VMKLI)

The composition component of this PhD consists of five pieces. Each reflects a different collaborative process and involves different collaborators, and each implements a different tuning system and interface that I have designed as its foundation. The order below represents the actual order of completion for each composition.

CASE STUDY 1

Composition 1: In Search of Enchanted Soundscapes

COLLABORATION MANCHESTER MUSEUM PRESENTED AT FESTIVAL OF RESEARCH IN SALFORD/MANCHESTER

Collaborating partners/performers: Philip Brissenden on RAPH; Eirik Dyroy Field Recordings Soundscape and Bohlen-Pierce Scale Virtual Musical Keyboard Interface; Alan Williams on Accordion; Timothy Wise on Guitar.

This piece was commissioned as part of a collaboration between the Adelphi Contemporary Music Group at the University of Salford, and the *Beauty and the Beasts; Falling in love with Insects* exhibition at the Manchester Museum for a concert planned for late March of 2020. For this event, this composition (originally intended to be a duo collaboration between Doctor Philip Brissenden and myself), a variety of other ambitious experimental compositions simple folk song fragments were prepared to be performed live in their entirety. However, this planning was all derailed by the UK, COVID-19 national lockdown which began in March 2020 and the event was cancelled. Despite the lockdown conditions, frequent meetings were conducted through Microsoft Teams/Zoom and further plans to resume the collaboration was discussed. Originally, my collaborating partner Doctor Brissenden planned for this piece mainly as a solo piece which featured his own invented instrument (the reverse action piano harp) which would then be subjected to live signal processing and playing against a prepared electronic canvas featuring field recordings that he recorded in a nature reserve on the Costa Blanca in Spain during summer of 2015. Planning for the piece had reached a sufficiently advanced stage that we both had put forward intended outcomes and solved various technical problems as to methodology before lockdown commenced.

In our discussion about our desired conceptual ideas for the composition, Doctor Brissenden's demand for the collaboration was for me to create a soundscape by using his aforementioned field recordings in order to recapture/evoke the vibrancy of summer, warmth and exotic landscapes (i.e. through the advancement of audio artefacts capture the essence of dry sparsely/minimally vegetated areas of land, sunny weather and clear blue skies, (sandy) dunes, stepping barefoot on hot sand, beaches and clear blue seas/oceans – swimming in salty water etc.) and further complemented by equally exotic insect sounds from same area of land (i.e. crickets, grasshoppers etc.). My demand for this collaboration was to deploy an alternative tuning system by applying one of the aforementioned VMKLI's, and in the end the highly unusual Bohlen-Pierce scale was chosen.

Lockdown introduced a set of problems which rendered the original ideas of the composition unfeasible - isolation and social distancing prevented any face-to-face interaction to take place in any conventional rehearsal space or possibilities for a real-time live performance to be operated simultaneously with live signal processing of the RAPH. Thus, this plan was slightly altered and forced us to rethink and compromise the original idea both from a technical and musical perspective in order to complete the composition yet figure out ways to evoke similar effects.

With the advent of emerging Video communication tools in the following months, Professor Alan Williams decided to contact members from ACMG in late May of 2020 requesting musical contributions to be commissioned for the annual Festival of Research (entirely Video based due to situational circumstances) conducted by University of Salford in 2020. Among the musical material composed/rehearsed/prepared by ACMG prior to lockdown - it was generally agreed upon that this composition had the best potential to represent the artistic/musical palette/merits of ACMG in recorded form, thus this would be the perfect opportunity to present this piece as a finished musical composition - and different from the originally intended purpose ended up becoming more of a two-way collaboration. The process that we devised would be a series of individual responses rather than an *in the moment* collaborative endeavour but all work would follow extensive discussion. The solo piece would work as a template for all other participants to interact with and/or respond to and they were given complete freedom to approach and play it as they desired.

It was decided that everybody involved in this project would have to record their instrument themselves using whatever technical equipment available to them (whether primitive or advanced) and submit their recordings to me – this approach allowed for a more collaborative effort and opened up the possibilities for more participants to be involved in the project. Altogether four members of ACMG made musical contributions, namely Doctor Philip Brissenden on RAPH, Eirik Dyroy creator of the soundscape, Professor Alan Williams on accordion, and Doctor Timothy Wise on electric guitar.

Remarkably, we completed this process in time to both present a completed composition and live paper at Festival of Research. We had to do some interesting preparation in order to execute this. Teams or Collaborate were acceptable presentation media for voices and discussion, but we wanted to present the highest possible quality musical audio to our audience. So, we devised a presentation with embedded audio for the conference attendees to download. That way we could tell them when to listen to the embedded audio from their version of the presentation on their sound systems.

For this composition I would not use pitches besides those limited to the Bohlen-Pierce scale – however, this was only limited to my contributions, the other participants were allowed to come up with whatever gestures they desired, whether atonal or melodic.

Decision making process and composition methods – collecting the data/methods

During the process of creating the soundscape approximately four hours of field recordings were to be meticulously examined, I would listen through each and every recording in order to search for a combination of timbres and sounds that evoked a sense of summer/exotic landscapes. Secondly, I would select and edit out shorter and longer segments of audio (samples) from these recordings and favour moments that evoked or triggered reactions in me rendered distinguishable, accidental, interesting or somewhat served a bigger purpose in the composition. The intent for these was to complement and add to the general character/mood of the piece. These segments of sampled audio would then be shuffled around in the composition and seemingly placed where they would appear adequate to my liking/taste – this was a process which occurred both spontaneous and gradual through rational/irrational decision making.

Prior to this, Doctor Brissenden arranged a meeting where he would have a lengthy discussion guiding me through all these recordings (i.e. in regards to recording methods and the content of what was recorded and specific/noticeable aspects of these recordings that he particularly enjoyed/favoured etc.) and then eventually allow me full access to use all of these for our collaboration. The soundscape was completed by me by early March 2020; it should be noted that the soundscape in itself forms a finished piece that integrates field recordings, signal processing and the novel Bohlen-Pierce scale performances.

The majority of the soundscape is dominated by theses field recordings which were partly kept originally as recorded and partly processed using various digital effects and processing tools. At times this combination of processed and natural sounds of insects and environments are interlaced so that they go from being entirely natural as recorded and gradually processed and vice versa. Lastly, the Bohlen-Pierce Scale VMKLI was embedded into the soundscape in order to allow Doctor Brissenden, and subsequently everyone else involved to be set for a musical challenge not to feature any Western pitches thus forcing an approach and interaction based on instinct and interpretation of the sounds from the soundscape. The purpose with the Bohlen-Pierce VMKLI was to juxtapose and sometimes complement sonic qualities from the field recordings.

The aforementioned soundscape in its mixed and produced form would then form a stimulus for ACMG members to perform their instruments against this so-called sonic canvas. Interestingly, this allowed the musicians to come up with some truly original and unorthodox musical gestures as well as approach their instrument in an unconventional non-musical way by scratching strings, create sudden bursts of sounds, or hitting their instruments with their fists in random areas etc. It should be noted that most of the participants had little to no knowledge nor previous experience of the Bohlen-Pierce scale beforehand. Each performer relied entirely on the sounds from the soundscape only and was not aware of anyone else’s contributions to the composition when they submitted their own performances/recordings. Without the advantage of hearing what any fellow musician would contribute to the solo piece, it forced them to think entirely creative instead of adding new layers on top of or to complement existing musical content to any of the other contributions. This process would demand repeated listens to the soundscape in order to become familiarized with the structure, then work out ideas and interact against the sounds they heard or believed they heard – whether pursuing it by providing surprising sounds past the expected Western tones inherent in their instrument and/or whether they would push forward past their instruments natural boundaries or limitations.

By mid-June all participants finally submitted their recordings and this allowed me the freedom to incorporate all performances into the composition and make the final artistic decisions. It should be noted that each and every recording provided by the participants have been used in the piece although the extent from each take varies from near complete to only a fraction.

Auditioning process

Intensions with the solo piece was to allow very little use of harmony and melody to be present in the piece and further avoid rhythmic instruments and provide limited rhythmic structures. When auditioning Doctor Brissenden's field recordings, various considerations were taken into account, in particular a mutual respect for his concerns about the overall expectations of the collaboration as well as the eventual procedure of how the soundscape would be integrated into the solo piece by myself.

The implementation of Bohlen-Pierce Scale VMKLI played an integral part in terms of how the composition eventually turned out in the end. This tuning system was introduced after all of the field recordings had been implemented, the uniqueness, advantages and limitations inherent in this VMKLI played a significant part in how the other participants/performers would approach and perform their parts in this piece. Further, pitches from Bohlen-Pierce may not appear obvious at a noticeable audible level for the majority of the time during the composition, they serve a few different purposes upon which all are not intended to be entirely melodic; when they appear, the pitches serve as counterpoint against the natural and processed sounds from the aforementioned field recordings; they appear more as an *undercurrent* that barely scratches the surface in order to enhance and add additional character to the soundscape. Integrating all of the participant's recorded performance would each serve very different purposes in the composition and provide different harmonious/harmonic/melodic and timbral nuances in addition to varying degrees of density and textures.

Initially when decisions were made to include other participants to interact with this composition, we were still determined to capture the essence and feeling of a solo piece playing against a pre-composed electronic soundscape; thus, it seemed apparent to me to start integrating/implementing Doctor Brissenden's takes/recordings into the solo piece first. This decision would shape and define the musical flow of the composition (as an indicator for further integration of recordings provided by the other participants) and maintain the vibrancy of the originally intended solo performance, thus it was necessary to keep any editing to a minimum, and respect the integrity of the timing and flow from each of his takes and performances.

This was the only obvious decision made beforehand. By doing this, decisions on integrating all the remaining recordings/takes from the two other participants would be triggered and embedded accordingly to the flow of contributions made by Doctor Brissenden and myself. Interestingly, when the following recordings were integrated into the composition, those performances would be subjected to much more editing and fragments of their performances would be occasionally shuffled around in the composition where seemed fit. Doctor Brissenden submitted three takes, it turned out that each take complemented one another perfectly due to slight variations in playing, yet each provided an additional layer of density and offered different gestures noticeably different from the other takes.

In terms of artistic as well as mixing decisions, each of Doctor Brissendens takes were subjected to minimal editing (only when all three takes would occupy too much musical space and/or appear too dense). Different from all other instruments present, the timbre of the RAPH was further processed using various real-time graining and delays techniques in order to add some extra textures to complement Doctor Brissenden's performance. The effects were added to the RAPH after mixing and editing all of the recordings as it made more sense to make these creative decisions after all of the other takes had been implemented into the composition.

The next instrument integrated into the piece was the accordion played by Professor Williams – these were approached quite differently than Doctor Brissenden´s recordings. Professor Williams provided two takes each which were quite different from one another; whereas the first take focused on rather dense gestures and the occasional loud bursts of sound, the second focused more on long mellow melodic and beautiful gestures both of which seemed to complement the RAPH really well. I decided to construct a combination of each to provide both softer and denser passages of accordion and occasionally juxtaposing - mainly these decisions were determined and affected by the gestures played on the RAPH. Artistically, the accordion would command a more complementary role in this composition and while it appears frequent and is significant throughout the composition, simultaneously it provides some additional textures necessary to complement the RAPH. It should be noted that some of Professor Williams' parts were shuffled around to produce an atonal flavour at the beginning of composition. Different from Doctor Brissenden's recordings, these recordings were trimmed and altered to a much greater extent, however some passages were retained as performed in real-time, in particular this applies to the dense playing towards the end of the composition.

Lastly, Doctor Timothy Wise's guitar recordings were treated in a similar fashion to those of Professor Alan Williams' accordion recordings. Although no parts were shuffled around in this case, some segments were time adjusted slightly to enhance and make certain musical moments more effective in terms of the flow of the musical gesture. To a greater extent these takes were edited down to smaller audio samples. Doctor Wise's made various experimental sounds on the guitar by applying a variety of effects to create an interesting wash of sounds. At times he made certain sounds that had similar timbre to that of the Bohlen-Pierce scale tuning system, which complemented both the RAPH and accordion really well.

Once the auditioning process, assemblage and positioning of audio/audio samples had been completed, the next stage was to mix the composition. Interestingly, up until this point the composition would remain unpanned and appear in mono; while this may appear as an unorthodox method towards mixing - I firmly believe that if the composition provides me with an artistic and "musical" cohesive/coherent satisfaction without use of any panning, then it will sound much better once it is subjected to panning. In terms of placement of sounds to dominate or to be complementary, this happened largely to be by spontaneous intuition and instinct to produce the most desirable results – it should be noted that these decisions came about after some trial and error.

Decisions on panning was worked out in a similar fashion to what has been stated above. When it came down to the final mixing decisions, it should be noted that this turned out quite differently than originally planned. Originally, I intended to let the soundscape appear rather low in the mix but clearly audible, yet emphasizing the effects added to the RAPH and make them more pronounced than in the final mix. With the addition of accordion and electric guitar there were suddenly more instruments competing for space, and I came to the conclusion not to approach the original plan as intended. I could really envision the potential of a really good yet original composition if all instruments were to be allowed equal space in the composition. By this I would also allow the soundscape to have equal space compared to all of the musical instruments, and maintain a noticeable loud but warm atmosphere. The mixing was completed the last week of June just in time for the presentation at Festival of Research, and in line with everybody else's contributing to this composition mixing occurred on less than desirable equipment and monitors.

The composition itself ended up showcasing a conscious artistic decision to stray away from common compositional approach based on repetition and common western musical structures. This approach may be sufficiently described as a progressive composition - meaning that the structure of the composition always moves forward, and present a consistent flow containing several peaks and valleys in terms of amplitude and density, evoking aspects of Stockhausen's Moment From (find reference!). The advancement of this was that it allowed for a wider hybrid/palette of distinctive sounds to form a unique music listening experience – like story telling that potentially could simulate (or replace) a cinematic experience through audio artefacts (like a story containing a beginning eventually leading to an ending/conclusion). In addition, the composition provided a number of transitions, dramatic moments that signal different sections of the piece to enhance the vibrancy of storytelling and at times to surprise, and disorient the listener. Conceptually, aesthetically and artistically, we all agreed that the final mix and production was to be completed at my home using budget monitors, and no further mixes to be completed later by using any of the studio facilities at the University of Salford. This allowed the composition to be a fully authentic experience and the result of limitations accelerated by the COVID-19 lockdown and isolation.

Conclusion for outcome of composition

This composition turned out somewhat different than anticipated both in terms of musical content, style, direction and involved more musical participants than originally planned. Initially, when Doctor Brissenden and I met up to discuss and establish common grounds, set individual goals and predetermined demands for the collaboration – part of the original collaboration was for me to construct a soundscape (comprising of field recordings combined with pitches from the Bohlen-Pierce Scale VMKLI) as a means for Doctor Brissenden to interact with as a singular real-time musical performance. In addition to this, audio signal through the XLR output of Doctor Brissenden's RAPH instrument would then be connected to an audio interface and run through Ableton Live D:A.W. in order for me to control all audio processing and feed the processed signal back to a set of monitors.

The main intention using the Bohlen-Pierce Scale VMKLI was at first to test it out in a musical context, since this was the first VMKLI to be used on any of the planned compositions for the research project, the initial anticipation was impossible to predict, and generally a big risk that could have turned this collaboration into a maligned experience. Considering that no pitches within this tuning system matches any pitches found on typical Western instruments, there were some uncertainties about how it would interact with the usage of field recordings and eventually the addition of Western musical instruments based on 12-tone EDO.It should be noted that this combination or "experiment" of elements embedded in the soundscape could easily have resulted in sounds and/or timbres that would not have blended easily nor well together.

However, in the end the addition of Bohlen-Pierce Scale not only produced very refreshing and unusual sounds in a positive way, yet added another exciting musical dimension which complemented both the processed/unprocessed field recordings and made the insect sounds appear more prominent in the composition. In addition, another important aspect which we were eagerly anticipating was how the different harmonic intent of the equal temperament harp would blend with the Bohlen-Pierce pitches. We were both positively surprised by how well this implementation of sounds which included a combination of the soundscape, Bohlen-Pierce scale and the harp - overall seemed to work really well together.

The soundscape was completed and prepared prior to the Manchester Museum exhibition and remains the only conceptual aspect of the composition which was kept entirely as planned. Initially, the collaboration between Doctor Brissenden and I was less ambitious than it ended up; the composition turned out to be significantly more complex and densely layered than expected. Although, in essence much of the core idea, which involved the combination of soundscape and the RAPH remained intact throughout this process – the execution was somewhat altered.

When the plan to present a composition for the Festival of Research was unveiled, the collaboration was expanded to include another two musical participants and this altered much of the original focus for the original collaboration. Despite that every musical instrument was recorded at home and by each participant themselves, the general capture of instruments and quality was surprisingly satisfying - especially considering the various quality of equipment used; from low-level recording possibilities by Video meeting software such as Zoom or Teams to higher level recording possibilities such as Logic Pro and ProTools D.A.W.s.

Integral to the success of the composition was constructive communication/discussions between Doctor Brissenden and myself throughout this musical collaboration. Although, when the direction of the original collaboration was altered, we were still able to work things out together and Doctor Brissenden would show continuous support for any new musical addition to the composition. Despite, that a significant artistic change occurred in the latter stages of the mixing process, all participants were satisfied with the produced outcome of the composition. There are various reasons for this; the original intended approach for mixing appears to be very typical for this type and style of music, thus in the end when all elements had come together, I decided to create something that would sound more unique and original.

It should also be noted that the involvement of more or less participants in this composition could have greatly affected the outcome of the mix and turned this composition into something that could have sounded quite different.

CASE STUDY 2

Composition 2: Alien Transparagus And Seven Dead Minions
COLLABORATION WITH ACMG

Collaborating partners/performers from ACMG: Philip Brissenden on RAPH; David Crawley on Acoustic Guitar; Eirik Dyroy on Arabic Virtual Musical Keyboard Interface; Michael Elliot on Acoustic Guitar; Anthony Farrell on Grand Piano; Justine Loubser on Cello; Ashley McAulay on Flute; Hossein Soleymanineshat on Real-Time Audio Signal Processing; Alan Williams on Accordion; Timothy Wise on Saxophone.

This composition was proposed as a musical collaboration with ACMG. It began with the creation of a pre-composed "solo" composition which was entirely recorded, performed, mixed and produced by myself. One of the main purposes with this composition was to derive somewhat from the atypical compositional aesthetics of my previous compositional leanings and allow myself to embrace a more minimalist approach by composing a significantly softer and sparser type of music than before; thus, as a result this solo piece may showcase the most minimalistic composition within the confinement of this research project.

The main concept for this particular solo composition was to utilize the Arabic VMKLI's created for this research. One artistic feature which is distinguished from this solo piece compared to all others is that it solely relied on pitches from this Interface with no further accompaniment of additional instruments neither programmed nor recorded. Central to the creation of the solo piece was the implementation of two ancient/medieval Arabic Tuning Systems based on a 25-tone per octave system and a 17-tone per octave system, respectively. Interestingly, neither of these are based on the Westernized conception of 24-tone (either equally or roughly divided intervals per octave) tuning system, and focuses instead on ancient/medieval tuning conceptions proposed in the 10th and 13th centuries divided into 25-tones and 17-tones per octave, respectively.

While exploring the phenomenon of Arabic music and its history, I found myself more compelled to embrace the earlier tuning conceptions which are precursors to the commonly used approaches of today, although these are apparently different from the 24-tone conceptions, yet they appear as distinctly Arabic.

The idea was to produce a minimalist solo composition which showcased limited harmonic and melodic progression throughout yet would evoke uniquely Arabic musical flavors, sounds and timbre deeply associated with the Arabic World. Further, by creating a soothing and relaxing composition, this would eventually allow a distinctive juxtaposition to any of the other compositions presented in this research.

In the discussion of musical structure of the solo composition; the piece starts rather quietly through the introduction of shimmering sounds to evoke Arabic (and possibly Indian) musical flavors/nuances, shortly after the first appearances of Arab pitches occurs the piece gradually builds up and become denser up until the first half when it reaches its apex. At this point in the composition a sudden shift in density appears and the general ambience of the solo piece immediately becomes quiet and largely dominated by various shimmering textures and flavors with only the slightest appearance of the occasional Arab pitch. Despite that the general essence of the piece is meant to evoke a sense of relaxation or meditating mood, bursts of sounds appear occasionally to disrupt the flow and has been added as an element of surprise for the listener (listener expectations).

The solo piece was presented to ACMG in rehearsals during autumn 2021 by running it through the PA system in the Bandroom (New Adelphi Building) at the University of Salford. The purpose was to let the members of ACMG get accustomed to the structure and progression of the piece before allowing them any interaction musically. They were allowed complete freedom to interact with the sounds and pitches that they heard or thought they heard, in this occasion they were provided the opportunity to collectively approach and/or work out independent approaches, figure out whether they wanted to get as close as possible to the pitches heard, interact/interlock with another individual or simply adding different musical gestures to compliment already implemented sounds in the composition.

The piece was rehearsed during two extensive rehearsals and to my surprise the process went surprisingly fast and successful. All performers were easily adjustable to the piece and seemed to somewhat understand my artistic and musical visions almost effortlessly. Their interaction with the piece was immediately satisfying, in particular their capability to immerse into the musical landscape, flow and transitions inherent in the composition without showcasing much profound effort already from the start. It was interesting to follow the development from the initial musical interaction and witness the eventual development into the final product. The combination of introducing interesting gestures in line with the atmosphere and feeling of the piece provided a desirable blend of melodic and experimental sounds/gesticulations according to my expectations. All the musical gestures played by ACMG were completely improvised and for the most part occurred spontaneously.

At first, full permission was granted to ACMG to approach this without any kind of intrusion at first, as I am a firm believer that in certain occasions and with a certain type of musicians it is possible to create magic if one allows and provides them with the comfort and complete freedom to improvise and express themselves musically without any confinements. Initially, the only instruction given to them was to simply accompany what they heard in the piece. The purpose was to provide a relaxed environment to establish trust and comfort and allow them to perform without feeling any constraints or pressure – I believed that this could be a useful strategy to trigger some unusual musical phrases/gestures/ideas (a key component of what I wanted from ACMG) that might not have emerged naturally under more forced, fixed and/or demanding musical circumstances/confinements.

During these rehearsals I would listen carefully, examine and focus on the musical content and interaction collective played by ACMG. Initially, the intent with this process was to test out and observe how ACMG's immediate musical reactions/responses as a collective group would work out in compliance with the musical nature of the original solo piece – the process was integral to the preparation to figure out what elements would work or not work that well in the end. Once I had examined and evaluated their actual performance, then I started to provide minor instructions and addressing particular personal preferences for how I wanted them to pursue the composition musically.

My immediate reaction to ACMG's musical response was highly satisfactory and required only minimal suggestions for improvements prior to the eventual recording session by the end of the semester. However, as the recording session was fast approaching I started to reflect deeper about ACMG's contribution to the piece and concluded with two minor issues: 1) my only criticism in terms of their general performance was a desire for slightly sparser playing due to too many musical ideas which seemed to dominate over the pace of the original solo piece and 2) minor changes to the dynamics of their playing – I wanted ACMG to play gradually denser up until halfway through the original solo piece when the density reaches its apex and then ask them to play much sparser in the latter half in accordance with the dynamics of the solo piece.

The recording session for ACMG's performance took place in the Band Room on 1st December 2021. Their performance was recorded as a collective live ensemble with all members situated to form a semi-circle – centered around a Decca Tree Stereo Room Microphone which was set-up in front of the performers.

Data collection

The initial work on the "solo" piece started early November 2021 and despite no appearance of other instruments, a limited amount of the recordings was subjected to various audio processing either separate or plug-ins within a D.A.W. to provide additional effects and layers of sounds/timbre in order to complement the Arabic pitches. The main purpose with audio processing was to create various harmonic nuances in addition to shimmering and timbral effects to further enrich the ambience of the piece. However, it should be noted that none of the audio processing detuned any of the actual Arabic pitches in the piece.

The "solo" piece comprises solely of recordings of the two aforementioned Arabic VMKLI's created for the research project, namely the ancient/medieval Arabic 25-tones and 17-tones tuning systems. As an interesting twist to the compositional challenge both the 25-tone and 17-tone systems have been implemented mainly to test and explore the effect of using these simultaneously and evaluate how successfully these have blended together in the solo piece. Similar to the previous solo piece, every recording would be edited out into smaller audio samples and shuffled around.

The recordings of ACMG was engineered by staff member Samuel Jones, accompanied by two Master students; William Cotton and Edsel Hampson. Due to unforeseen commitments, Doctor Brissenden was unable to attend this recording session and needed to record his parts afterwards and as a result his parts were mixed into the composition at a later stage. For this particular piece he re-tuned his RAPH accordingly to the Arabic intervals. This was achieved by providing Dr

Brissenden with a cents deviation from 12-tone EDO for each pitch, he could then input these into logic and tune the RAPH accordingly. My main task during the recording session was to “conduct” ACMG and direct and/or clarify any necessary musical or conceptual changes to occur where applicable. For this particular piece I had only one request (which also was my sole criticism) from my previous experience when we rehearsed the piece - I wanted the performers to play their parts a tendency sparser, and suggested that they rather hold back their playing a little bit. In the end, two takes of ACMG was recorded.

Similar to the previous composition, an audition process took place once the recordings of ACMG were completed. However, the auditioning approach for this composition would be quite different. While this applied to selecting different aspects and parts from each of the two takes, it mainly revolved around adjusting a satisfying amplitude/audio level balance to enhance the overall presence of the instrumentations. In other words, the auditioning process was largely based on emphasizing and ducking/burying each of ACMG’s instruments throughout the entire composition. Preserving the integrity of the original performance by ACMG was a crucial part of the conception of this piece, thus no performances were edited out or edited into smaller audio samples nor shuffled around.

Results

Largely due to ACMG’s performance being a live recording in a studio, obviously a few challenges were obvious in terms of mixing/production; as a result of recording a somewhat large ensemble of musicians in the same room and at the same time (with the exception of the RAPH), naturally this would cause audible/noticeable microphone bleed from other musical instruments in most/if not all other microphones, this was further affected by the playback of the original “solo” piece. It should be noted that the Bandroom (the actual recording space) is designed to be a space for orchestral recitals/rehearsals/recordings, thus to some extent it was bound to capture some natural reverberance of a somewhat larger live room although not on the same level as a typical concert hall. The microphone bleeds would introduce a set of challenges when the ACMG recordings were later integrated into the same recording project together with the “solo” piece recordings, in particular this became very apparent when the mixing process started.

The original “solo” piece retained a somewhat dry production aesthetic with minimal usage of reverb and I wanted to create a similar ambience when blending/combining these recordings together with the ACMG recordings. Because of the apparent bleed in each audio track it was necessary to handle each track with the utmost attention by exhaustively listen through the take/s separately and through editing be able to enhance every little musical gesture, idea and/or sound captured by that particular performer in that particular recording – and then adjust the volume so that the entire performance would retain more or less the same volume throughout. In essence, this process can be described as a “digging up” process, where sections/parts of the original recording appear somewhat buried and once “dug up” then becomes significantly amplified (due to increase in volume) and equally audible with the rest of the performance. This was a recurring procedure and applied to each performer; once this was completed, ACMG’s performance became very dense, overly busy and very reverberant before any mixing started. Interestingly enough, the “digging up” process allowed me to discover a number of different sounds and gestures that would otherwise have been buried in the mix –some of these provided a nice hybrid of melodically/harmonically sounds with purely experimental sounds.

When the proper mixing of this composition was initiated, yet another audition process began; by listening to the entire composition and pay close attention to the dynamics of every performer including the original “solo” piece, I was now able to make final artistic decisions. At this stage in the mix, ACMG would sound somewhat unpolished and edgy in addition to occupying too much musical space (largely due to the “digging up” process which I described earlier). It should be noted that this process somewhat compensated the usage of compression as I believed that would not be ideal for the production aesthetic aimed for in this composition. Still, production wise at this stage it did not feel quite like ACMG appeared in the same musical space as the original “solo” piece. Thus, the audition process was required to make the instruments blend together smoothly and to enhance a vibrancy of being created in the same musical space.

Essentially this process can be described as an approach where each aspect in every performance (in this process all audio tracks are enabled while listening) is auditioned and simultaneously either emphasized or buried in the mix. The reason for this process was to bury; 1) parts that possibly distracted or strayed too far away from the dynamics of what others were playing, 2) elements either musical/audible which contained too many ideas at inadequate times, or 3) in cases where gestures for some reason did not sound or blend well with the flow of the composition. The selection of takes was based on moments in the performance which yielded most satisfying, best interaction between all performers, or selected part from the other take whenever it was necessary to change the dynamics in their playing (i.e. playing too dense/soft for too long). Every performer would be subjected to burying by some extent.

Once the latter auditioning process was done, the production of the composition was nearly complete, at this stage the ACMG recordings appeared much drier in the mix (due to editing and volume adjustment in each take – less bleed from microphones were apparent), and all instruments seemed to flow and overlap with one another much smoother and provided a sombre/soothing almost meditating atmosphere/listening experience. It should be noted that it was necessary to adjust the volume level of the Decca Tree setup rather low in the mix to make these recordings appear as dry as possible – I did not aim for a “live sound” or live presence for this composition. The recordings of ACMG was engineered really well and literally required very little use of additional effects or equalization applied to make each instrument sound good in the end, thus the latter stage of the production largely dealt with tweaking volume adjustment/balancing so that both the “solo” piece and the ACMG recordings would blend together perfectly.

The final mix contained approximately 50/50 percent musical content from each recorded take, and panning decisions were affixed accordingly to the actual audible appearance of each performer/instrument as captured in the room by the “Decca Tree” stereo microphone technique. Thus, ACMG was subjected to fixed panning, while all elements from solo piece were subjected to extreme stereo panning (i.e. sounds moving from left to right speaker and vice versa). It should be noted that the occasional microphone bleed from other instruments and sounds from the “solo” piece may cause instruments to occasionally appear in other positions within the stereo field/spectrum.

Conclusion:

The final outcome of the composition showcased an equal audible/mixing balance (both elements given equal space) of the solo piece and a complete performance by ACMG played in real-time, although it alternates between selected parts from take 1 and take 2. Each member of ACMG would approach their instrument in a different manner to one another. Thus, three distinctive considerations were crucial in auditioning process altogether; 1) the level of conventional/unconventional approaches to playing instrument (producing sounds not usually associated with the natural timbre of instrument) - some performers would combine or play either of these two extremes. In addition to the above, 2) the level of density from each performer varied significantly, some performers made musical contributions constantly throughout the composition, others made minimal and only sporadic contributions, while some would appear somewhere in-between these two polar opposites. Lastly, although related to the previous two markers, 3) the overall cohesion and blend of instrumentation throughout the composition (i.e. how each instrument interrelates/complements with one another and the solo piece) also played a significant part in the auditioning process.

The main importance prior to any mixing was to decide which parts from each performer to be emphasized or buried by listening for an overall musical cohesion – then to evaluate the extent of complementation between particular instruments and others, and finally implement level balancing (i.e. emphasizing interesting gestures that complemented and captured special audible/musical moments, while burying others which would overplay or distracted somewhat from the overall performance). In this process sacrifices were necessary; in particular there were moments when contributions from singular performers needed to be underplayed or simply buried in order to provide more room/space for other instruments to be enhanced for the sake of the overall quality of performance, while other times certain instruments were layered to be barely audible in order provide an additional layer of bass or treble to the composition.

Another important aspect to mention is the concept behind the usage of stereo panning in the composition. There is an obvious difference between how the Arabic pitches and other sounds associated with the original “solo” piece were treated compared to the ACMG recordings. Whereas the placement of Arabic pitches in the “solo” piece has been exposed to wide usage of stereo panning – where pitches and sound effects have been panned accordingly to fill in open spaces within the stereo field and allow for movement of sounds to appear from left to right and vice versa, yet also to allow dynamics of sounds (softer/louder) to emerge in order to enhance/bring a sense of cohesion within the artistic/musical structure of the piece.

Interestingly enough, this is the second to last “solo” piece composed for this research project, however a few significant occurrences made the completion as a collaborative effort/composition feasible within a shorter time span than some of the other compositions created for this research project. Firstly, the composition was far more minimalistic and already contained less audible artefacts than any the other compositions. Because there was much audible space for other instruments to be implemented, it turned out to be much more easily process to integrate the recordings of ACMG quickly and with limited use of equalization or other added effects.

Despite what is stated above, it should be addressed that mixing and producing such an ambitious composition still ended up being a very time-consuming process although proved to yield very satisfying results in the end, and I feel content that I managed to achieve my main goal which was to provide a perfect blend of the “solo” piece and the ACMG recordings – to make them appear as if they had been recorded in the same space and at the same time.

CASE STUDY 3

Composition 3: Music For People Who Doesn’t Have Any Real Friends

COLLABORATION WITH ACMG

Collaborating partners/performers from ACMG: Philip Brissenden on RAPH; David Crawley on Acoustic Guitar; Eirik Dyroy on Electric Guitar, Drums, Indian Virtual Musical Keyboard Interface and Field Recordings; Michael Elliot on Acoustic Guitar; Anthony Farrell on Grand Piano; Justine Loubser on Cello; Ashley McAulay on Flute; Hossein Soleymanineshat on Real-Time Audio Signal Processing; Alan Williams on Accordion; Timothy Wise on Saxophone.

Similar to the previous composition, this composition was originally intended as a collaboration between ACMG and myself and was initiated by the creation of a precomposed solo piece. Similarly, to the previous composition (and case study) discussed, every recording and musical instrument contained within the solo piece was done entirely by myself. The “solo” composition comprised of three musical instruments; drums, electric guitar and the Indian VMKLI.

There were two main reasons for composing this solo piece was 1) to demonstrate the palette of the 22 Srutis (i.e. the amount of possible Indian intervals within the span of an octave) inherent in Indian Tuning System, in order to evaluate the extent of success implementing the Indian VMKLI within the context and concept of experimental music composition. The other reason was 2) to create a reactionary composition to act as a contrast to the stylistic leanings of my last few compositions which have become increasingly more musical and stylistically cohesive in comparison to any music made prior to the research project. Thus, the concept was to create a composition which strayed away from these principles; conceptually the present solo composition is dominated by block of sounds, field recordings which appears completely random, with the overall mood and atmosphere to appear chaotic, as artistically/musically fragmented as possible and provide the widest contrast between the utmost absurd/humorous and violent/dark themed musical expressions. The composition seeks to challenge the outer boundaries between the latter two opposite extremes.

The “solo” piece contains many layers of sounds stacked on top of each other, including music concrete/blocks of sounds, a wide usage of the 22 Srutis of Indian Tuning System (at times stacked on top each other in order to produce big and complex chords), various grooves and experimental approaches performed on drums, processed electric guitar, and numerous different field recordings that switches between being quite random/fragmented at times yet focused and sensible at other times (i.e. a combination of sounds from nature (bird songs, rain, bonfires, ducks, footsteps in snow, cars, cats etc.) and fragmented bits of random noise and unintelligible conversations presented either at normal speed or sped up or a combination of the two - and randomly edited and pieced together), all of these artefacts are meant to provide the listener with a very wild and confounding musical experience/journey.

The structure of the “solo” composition approaches a number of different musical directions throughout. The first half of the composition is mostly dominated by field recordings with the occasional appearance of Indian pitches. From the second half towards the end, drums and rhythmic structure takes a more dominating role, with the occasional section juxtaposing between sudden shifts of dense and quiet passages. Finally, the remaining last two minutes or so is literally dominated by audible madness, frenzy, fast and violent playing.

Conceptually, the inclusion of ACMG plays a few different roles in this composition; 1) to add random audible/musical texture to the solo piece (at times minimal while dense in others passages), 2) to juxtapose any audible/musical sounds from the solo piece, 3) to be the sole performers in one section and 4) to complement other musical instruments heard in the solo piece

During the first half of the composition, ACMG's role was to start playing by providing only very sparse/minimal atonal gestures and gradually as the composition progressed to the first half, they were granted more musical space and in accordance with this their musical approaches to become denser and more musical. Content wise, the first half is mainly dominated by sounds from the solo piece with minimal contribution from ACMG. From the second half to the end of the composition, ACMG takes up more musical space and the solo piece appear less prominent in the mix, at times ACMG takes up all musical space. Apart from their atonal playing, some sections may evoke vibrancies similar to classical music while the musical style during the latter two minutes can be described as free jazz.

Similar, to the previous composition, the present solo piece was presented to ACMG in rehearsals during autumn 2021. The purpose was to let the members of ACMG get accustomed to the structure and progression of the piece before granting them any interaction musically. Initially, they were allowed complete freedom to interact with the sounds and pitches that they heard or thought they heard, in this occasion they were provided the opportunity to collectively approach and/or work out independent approaches, figure out whether they wanted to get as close as possible to the pitches heard, interact/interlock with another individual or simply adding different musical gestures to compliment already implemented sounds in the composition.

In-between the time after the last rehearsal and the eventual recording session of ACMG, I spent some time to reflect on how to make ACMG provide the right balance/blend of interactions with the "solo" piece and - managed to provide a set of instructions on how ACMG should approach specific parts of the piece. I wanted ACMG to start off by providing atonal sounds on their instruments during the first part of the composition predominantly comprising field recordings and then make them gradually provide more musical sounds as the piece progresses towards the first half. For the next section of the piece, comprising 30 seconds of silence where ACMG was allowed musical space all to themselves, I requested them to play as melodic as possible until sounds from the original piece reappeared; and for the final part of the composition I asked them to go completely mad by playing at their utmost intense, loud and harrowingly/violently to the best of their abilities. Generally, during the recording of the composition, it was not necessary to guide ACMG through too much physical conducting, however, I realized that for the final part the performers needed to be put out of their comfort zone by signifying/applying wildly intense physical gestures and some type of "conducting" to make them play more intensely, energetic, wild and louder accordingly to my satisfaction and past what they may have been capable without such direction.

Despite that both present and previous composition were presented in the same rehearsals, recorded during the same recording session and approached somewhat similarly by ACMG - the present composition would require more specified instructions, work and focus from ACMG before the musical structure was deemed satisfactory. This is mainly due to the present composition being a much more complex composition with numerous sudden shifts in density and musical styles.

Data collection

The drum recordings were recorded in the Band Room at the University of Salford 1. February 2019, with no other purpose than to be potentially used in any future recording projects. During this session, I played a variety of different styles of music, such as jazzy grooves by using brushes, while others were played with sticks for rock grooves and finally an extended experimental "solo" jam where the goal was to play in the fastest tempo possible. These recordings comprised of approximately 1-1:30 hours of drumming and were eventually edited down into what can be heard in the composition; the passage between 1:11-1:32 was exposed to much editing, while the other sections were kept almost entirely intact (last section of the piece contain approximately 5 minutes of drumming edited down to 2-2:30 minutes) – it should be noted that all drum parts were shuffled around in the composition.

The field recordings contained within this composition were recorded in Norway between December 2020-August 2021, by using a 2 XY Microphone (with an additional two optional microphone inputs) Zoom Digital Audio Recorder - the result of spontaneous and random recordings of objects done either inside my home and around my hometown during sound walks (i.e. bringing my zoom recorder for a walk and record everything/every sound that I would come across/encounter during this walk). Recordings comprises birds singing, dialogue, animal noises, cars, raining, thunder, walking in snow etc.

In this context, I recorded whatever sounds that I found interesting, both from a perspective of being unusual, just by random accident, purely interesting and/or pleasant to the ear. At first I made recordings of conversations between family members mainly as means to become acquainted with the technicalities of the Zoom Recorder, then later I realized that some of these recordings could add some interesting texture to this particular composition although most of them were later altered, processed and sped up to make the actual dialogues unintelligible (partly out of respect to the individuals who appear in these recordings).

As previously addressed, numerous recordings of various bird songs/chirping and seagulls crying etc. were made and can be frequently heard in the composition (it should be noted that I resided in a smaller town with little interference of traffic noise which made Field recordings quite feasible), random recordings of outdoor activities were also captured, and a 30-40 minutes recorded “soundwalk” where I walked alongside a water (pond) connected via a roaring river and recorded every single audible object encountered along the way (i.e. various animal sounds, footsteps in the snow, river flowing, cars passing etc.), located in my neighbourhood. Later the soundwalk recordings were edited down to smaller sections of audio and shuffled around mainly in the beginning of the piece and simultaneously combined with other aspects recorded during this soundwalk. This also applied to the other field recordings used in this composition and in both cases the audio samples were placed where they felt natural/applicable to other recorded artefacts, served a particular purpose, accommodated other details/sounds and/or to evoke reactions/to signal transitions/confuse/surprise the listener etc. Originally, none of these recordings were recorded for any particular purpose other than to be implemented into future compositions. These recordings were the result of having to travel back to Norway due to circumstances related to the COVID-19 lockdown.

The electric guitar and Virtual Interface were recorded in October 2021 and recorded specifically for present composition. Both the Indian Virtual Musical Keyboard Interface and Electric Guitar recordings were done simultaneously and recorded particularly for this composition in mind. The novel Indian pitches heard throughout the piece were recorded first and comprise separate recordings of clean pitches without any added effects and pitches accompanied by added drones (fundamental key either in C or G an octave below the lowest register), and lastly slight pitch variances of each of the original 22 Srutis with an increase/decrease of 5 Cents across a register of +/- 20 Cents in total (which appears to be a common practice when tuning instruments in Indian music). Each of these pitches were edited and shuffled around in the piece where they felt most natural or complemented other audible aspects/artefacts in the piece – sometimes placed alone to produce one singular pitch, while sometimes two-three or even several pitches stacked on top of each other to create interesting chords or unique flavours of sounds.

The intension with the Electric Guitar was solely to add sonic textures and “flavours” to the piece. The Guitar was recorded straight into Ableton Live D.A.W. and subjected to real-time processing through various delay/filtering effects (similarly to how the Field Recordings were processed in *In Search For An Enchanted Soundscape*). The playing is completely random and experimental containing sections played either densely or sparsely and occasionally moving rapidly from one to the other simply to explore how the real-time processing would react to these changes. Further, no obvious attempt was made to play chords in any “traditional” sense (although it may occur occasionally throughout the piece) or proposing any melodic structures. it should be mentioned that an obvious decision was made not to properly tune the guitar (which had not been played on since the beginning of COVID-19 pandemic in March 2020) purely as an experiment, basically to explore what sounds the guitar combined with real-live processing would possibly produce – and whether these could possibly emulate or accommodate some of the non-Western pitches among the 22 Srutis of Indian Tuning.

These recordings were the first to be implemented into the “solo” piece and eventually became integral to how I placed/positioned the Indian pitches throughout in the piece and whether it was decided to add simple pitches or a stack of pitches to be shaped into chords. Similar to all other recordings included in the “solo” piece, the Guitar recordings were also subjected to editing and shuffling around, although larger sections have been retained as they were because some of them eventually ended up dictating the progression of the piece.

When the “solo” piece was completed it was eventually presented for ACMG.
In the end ACMG provided two different takes which both showcased an interesting blend of atonal, experimental sounds, intensity and musicality that accommodated the original “solo” piece in a perfect way and managed to further enhance and surpass the listening experience of the original “solo” piece.

Results:
The work on the “solo” piece was initiated and completed over the course of two weeks during October 2021, with some additional mixing to occur on and off up until 30. November 2021 (until the evening/night before the collaborative recording session occurred).

It should be noted that there are a few similarities between present and the previous composition *Alien Transparagus And Seven Dead Minions*, in particular this applies to some of the mixing aesthetics both for both the content in the solo piece as well as ACMG. As such, one of the main goals was to achieve a mix that could provide a perfect blend of the “solo” piece and the ACMG recordings – to make them appear as if everything had been recorded in the same space and at the same time. The “solo” piece and the final collaborative composition also shared a similar progressive non-repetitive musical structure, with stereo panning decisions retained somewhat identical to the previous composition, namely wide usage/movement of stereo field solely for audible effects/content and occasional Indian/Arabic pitch while all musical instruments were subjected to fixed positions accordingly to actual instrument placement during the recording session.

All of the audible/musical content in the “solo” piece was subjected to extreme stereo panning with sounds/instruments moving from left to right, with samples filled in to cover the entire range of stereo field/spectrum, however, the drum recording was panned accordingly to the placement of every drum/cymbal on the kit, and panned across the entire stereo - from a listener perspective.

Similar to *Alien Transparagus And Seven Dead Minions*, where each instrument played by ACMG was subjected to the same types of “digging up” and auditioning processes discussed in previous composition/Case Study and the final mix contains approximately 50/50 percent of real-time performances from each of the two takes. The goal was to make the ACMG recordings to sound as dry as possible in the final mix (i.e. “Decca Tree” stereo microphones very low in the mix) to accommodate the vibrancy of the “solo” piece.

Interestingly, after the “digging up” process, I realized that ACMG ended up occupying too much musical space during specific parts of the composition; further their performance/playing appeared constant throughout - thus leaving little room for the audible/musical content of the “solo” piece to be emphasized and present in the final production. It was inevitable that ACMG became subjected to at least some slight adjustments upon which a fraction/s of each instrument to be altered/buried in the mix occasionally in order for the eventual collaborate composition to be more artistically divisive and retain satisfying musical dynamics. Vice versa, content from the “solo” piece also required some adjustments; except for all drum parts and Indian pitches, a significant number of audible/musical content in the “solo” piece ended up being muted or buried in the mix to allow more musical space for ACMG.

However, in terms of approach to mixing, this is where the similarities between present and previous compositions end. Due the general density and experimental/adventurous nature of the music combined with the occasional sudden yet confounding changes/transitions and sometimes fragmented pace of the present composition – a specific mixing/production style was pursued to accommodate all of these divergent/fragmented musical directions. Whereas I intended *Alien Transparagus And Seven Dead Minions* to sound as smooth as possible with all instruments gently overlapped one another to create an almost meditative listening experience - for *Music For People Who Doesn’t Have Any Real Friends*, my goal was to mix/produce ACMG in a fashion where their performance would sound as jagged and edgy as possible. For the present composition I would allow the instruments to produce sudden bursts of sounds and provide greater dynamics between soft and loud performances in the mix, either during the same section of the piece and/or at times switching from loud to soft and vice versa including in-between transitional phases (of the composition). In essence, I wanted the production of the composition to sound somewhat underproduced, to evoke the vibrancy of Underground Music which would further encompass a somewhat punk/garage rock element to the overall production - a style entirely in keeping with the nature of the subject matter.

In order to implement all the aforementioned aspects to create a satisfying final mix, I realized that a number of challenges would complicate matters further. Different from the rather sparse and minimal sounding *Alien Transparagus And Seven Dead Minions* “solo” piece, the present “solo” piece ended up being far more intense, densely layered and detailed through a wide usage of stereo panning. In retrospect, the challenge to blend the recordings of the “solo” piece and the ACMG recordings in order to achieve a satisfactory mix and production turned out to be quite difficult. The issue was that was too much audible and musical content altogether and required yet an additional period doing further extensive editing/muting and/or burying of musical and/or audible elements in order to justify musical space for both the original “solo” piece and the recording of ACMG was necessary.

In the end, most of the elements from the “solo” piece appears to be predominant at the beginning of the composition with the occasional yet sparse musical contribution/instrumentation from members of ACMG. Gradually, as the composition progresses towards the first half of the composition, ACMG is mixed as to appear increasingly denser in accordance with their gradual melodic performance/playing - in reality ACMG played noticeable denser during this section of the composition.

The only other parts of the composition where ACMG becomes somewhat buried in the mix (although for very brief moments) occurs during significant yet brief transitions or other similarly brief parts where the significance of elements from the “solo” piece requires to be emphasized/signified more than ACMG’s contributions. The second to last section of the composition is almost exclusively reserved for ACMG and this continues throughout to the end (with the exception of all Indian pitches and drum recordings which were kept intact from the “solo” piece). The rest of the composition retains a blend of approximately 50/50 between the “solo” piece and the recordings of ACMG, although occasional audible elements from the “solo” piece became muted. This combination of and mixing balance of audible/musical elements from both the solo piece and ACMG yielded the most satisfactory results. As an interesting footnote – the recordings of ACMG were least prominent in the mix at the beginning of the composition while the majority of elements from the original “solo” piece were least prominent at the end of the composition.

Conclusion:

Among the selection of compositions, this appears to be the most complex and densest to be submitted for this research project; the uniqueness of timbre, technical advantages and limitations plays an important part in how the final composition eventually turned out. The present composition required more attention to how the general performance of ACMG was to be executed from start to finish; mainly due to a number of sudden/rapid changes of density/complexity in the present composition as well as a greater variation of musical styles – ACMG’s performance required to be adjusted accordingly in the end. Thus, some experimentation with a few different approaches in mixing was required in order to find the right blend of the original piece and ACMG. ACMG’s performance would end up being slightly more compromised than anticipated, however, the finished mix provided a nice balance between the solo piece and ACMG and succeeded in making both elements to sound as if recorded in the same room and at the same time.

Another reason for composing this piece was to add variation to my portfolio by showcasing my diversity as a composer, enabling me to incorporate pitches from an indigenous Tuning System into an experimental composition without approaching nor attempting to recreate the musics associated with that particular culture. Further, this enabled me to explore and experiment entirely without dealing with any boundaries, either rhythmically/melodically/harmonically, playing patterns and other expected traditional “rules” that are commonly associated with classical Indian music. Thus, in essence this composition ended up showcasing little resemblance to Indian music, and at the same time it is the composition least relatable and evocative of its inherent musical culture. However, it should be noted that the timbre of the pitches from the Indian VMKLI comprises distinctive nuances of drones and shimmering qualities – although the overall density and extreme audible/musical details inherent in the composition may camouflage and colour these timbres to some extent.

CASE STUDY 4

Composition 4: The Esoteric 666-type Of Dance

JOINT COMPOSITION With Doctor Philip Brissenden featuring ACMG

Collaborating partners/performers from ACMG: Philip Brissenden on RAPH; David Crawley on Acoustic Guitar; Eirik Dyroy on Arabic Virtual Musical Keyboard Interface; Michael Elliot on Acoustic Guitar; Justine Loubser on Cello; Ashley McAulay on Flute; Alan Williams on Accordion; Timothy Wise on Saxophone.

This composition was originally intended to be a collaboration between Professor Alan Williams, Doctor Philip Brissenden and myself. However, in the end Professor Williams was not able to commit due to time constraints. Similar to the previous compositions/Case Studies, this collaboration was initiated by the creation of a precomposed solo piece. The “solo” composition comprised solely of pitches from the Gamelan VMKLI’s created for this research project, and were recorded and played entirely by myself. The intention with this composition was to work closely with an additional musical arranger to provide an additional graphic score for ACMG to play. As a “solo” piece, it appears to be the most melodically rich among the selections of compositions presented in this research.

The Gamelan VMKLI’s are the most complex and advanced among the VMKLI’s created for this research project. They comprise of seven VMKLI’s which encapsulates a total number of approximately 155 metallophone/bamboo keys and gong-chime kettles across 26 different gamelan instruments. In essence it appears as a customized and complete faux gamelan ensemble (for more details please read section about the Gamelan VMKLI’s in chapter 1). For this solo piece all variances of tuning, instrumentations and “playing tools” (i.e. padded mallets/hammers) associated with both Java and Bali have been implemented.

The main purpose with this composition was to demonstrate the implementation of Gamelan VMKLI’s in order to approach it from an experimental musical angle rather than to approach it from the perspective of traditional Indonesian gamelan music. An obvious decision was made prior to the initiation of this composition to make a solo piece which was literally based on Gamelan pitches and for the solo piece to take a pre-dominant role in the overall constitution of the “final” composition. In this context, the pitches literally form the skeletal framework of the composition. The purpose with the pitches was to shape a complex musical landscape that would simulate and evoke an imaginary sense/idea of a gamelan ensemble playing in front of an audience.

The specific idea for this solo piece was to provide a composition that would evoke certain aspects or sound characteristics deeply rooted within and associated with the culture of Indonesian gamelan. However, it should be noted that no consideration was given to provide a composition based on any firm/fixed compositional form associated with Indonesian gamelan. Thus, the intent and purpose of the piece is to stray away from such approaches (i.e. musical structures as in fixed rhythmic meter and melodic progression related to Indonesian gamelan). A number of times during the composition, there are sections of performance which starts and then stops at certain points – during these sections the performances will gradually decline and leading to an eventual collapse before starting again. Thus, the compositional intent is to capture the sense of “struggle” as a recurring theme for this composition.

What mainly distinguished this solo piece from any of the others was that the composition seeks to explore the vibrancy of its respective culture to a further extent than previously and to appear as the most integral element of the composition. Different from some of the other solo pieces where the usage of pitches from (their respectable) VMKLI which mainly intends to accommodate other musical/audible content and appear as an additional musical element pushed into the background rather than being the central aspect of the piece itself. In this composition, however, the solo piece also plays a more integral part in the overall production, whereas in some of the other compositions – where the solo piece and musical contributions from ACMG is given a 50/50 blend in mixing – it should be noted that the musical contributions/responses from ACMG only plays an accommodating part and appears significantly lower in the overall mix.

The structure of the solo composition was divided into different sections. The piece is initiated by the sound of a large gong, similar to how authentic Indonesian compositions are started. The first part is very sombre, with a relaxed meditative feeling yet melancholy mood and gradually builds up with the appearance of increasing sonic textures as the piece progresses. In some ways it showcases some aspects that may evoke the sound of or resemblance of Javanese gamelan. In this section, there are no rhythmic structures to be heard, only the occasional timbre of singular gamelan pitches. I wanted the solo piece to evoke a beautiful feeling of a river flowing.

Then the next section introduces rhythmic structures for the duration of 2-3 minutes, this is where the “musical theme” of the piece is first introduced. This section is marked by a number of occasions where the performance gradually collapses and starts all over again. This continues until the next section of the piece when it arrives at a crossroad - the piece suddenly becomes quiet and only accompanied by sparse, atmospheric non-musical sounds. This section then gradually builds up to become increasingly dense until it reaches the final section of the piece which is complex, loud and dense. Once the piece becomes quiet again, the earlier “musical theme” is revisited again, however this time it is distorted and eventually the composition ends abruptly. Interestingly, in contrast to the earlier section of the solo piece where musical textures and flavours resembling Javanese gamelan, the densely layered aspects of the last section may be more representative of Balinese gamelan.

Once the solo piece was completed, a proposition was made to collaborate with two musical arrangers, namely Professor Williams and Doctor Brissenden. I conducted a few meetings with each of them separately, as I wanted them to have no interaction with each other prior to the planned collaboration. During these meetings they each brought the typical instrument which they play when rehearsing with ACMG and improvised/practiced along with the solo piece. These meetings would eventually result in a live performance with the ACMG concert in 2nd May 2022, which comprised on playback of the solo piece accompanied by accordion and RAPH, respectively.

Shortly after, I decided to work with a musical arranger to arrange a graphic score to accompany the musical content of the solo piece. As mentioned before, it was originally intended to be a collaboration between Professor Alan Williams, Doctor Philip Brissenden and myself. When Professor Williams was unable to do this collaboration, I approached Doctor Brissenden to schedule some meetings where we discussed the approach of the collaboration. In this occasion, Doctor Brissenden was then provided with an audio file comprising the original solo composition and asked to compose a graphic score to complement the musical/audible content of the original solo piece.

In these meetings Doctor Brissenden and I discussed possible musical approaches/directions and elaborate how we could possibly enhance and improve the overall musical experience (extend the musical merits inherent in the original solo piece). The purpose with these meetings was to enable both (of us) to establish a common ground [platform] for constructive brainstorming where each of us would settle specific demands and discuss various propositions for the collaboration. Prior to us meeting up and partly because the collaboration first occurred within limited time prior to the recording session, it was decided that I would initiate this collaboration by coming up with a set of demands as a template for Doctor Brissenden to work around although I would allow him freedom to change or alter some of these ideas on his own terms. The graphic score would then be proposed for ACMG during a number of rehearsals between March and May 2022, and eventually recorded during a recording session scheduled in 13th of June 2022.

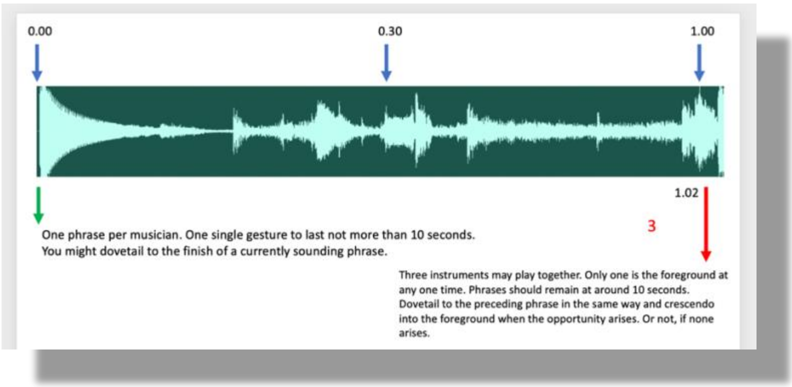

Figure 8.1. Excerpt from Doctor Brissenden's Graphic Score for The Esoteric 666-Type Of Dance

Dr Brissenden's intent in producing this score was in fact voiced as distilling my own compositional intent. In discussion he would question me in order to seek very precise definitions of the type of playing that I wanted in response to the fixed media. He then sought to distill these as instructions to the players and to place them at an appropriate timing reference.

Data Collection

Work on the composition started in mid-late November 2021 simultaneously while mixing the two previous compositions/Case Studies. The solo piece, was approached similar to the composition/Case Study 2, it comprises entirely of pitches from the VMKLI's based on its respective musical culture. In the end, a few hours of recordings of each Gamelan VMKLI's was done containing all different instruments possible variants, adjustments to timbre and tuning which the VMKLI's would allow. Then these recordings were edited down into small audio samples and shuffled around in the solo piece, sometimes these were placed singularly and other times stacked on top of each other to produce more complex chords or rhythmic structure. In this occasion, some of these recordings were also processed through various effects in order to add musical texture to the solo piece. However, it should be noted that in no case were the original pitches altered. Due to the vast number of recordings, it took approximately one month to compose current solo piece, work stopped in mid-December 2021 and commenced in mid-January 2022.

A recording session was scheduled on 13. June 2022 in order to implement musical contributions from ACMG into the solo piece, these recordings were engineered by myself and accompanied by assisting engineer Greg Davies. In total, three different takes of ACMG's performance was recorded during this session. Shortly after the session, the plan was for Doctor Brissenden and myself to meet up for a listening session to discuss the outcome of this recording session and figure out which takes that would represent the most accurate performance according to the visual representation in the graphic score, and select the specific sections/parts where this applied the most. However, Doctor Brissenden decided to allow me complete control to implement the takes according to my own preference, that included all technical approaches/decisions for mixing, production and any additional creative twists/ideas to my liking (i.e. best exemplified by the abrupt ending of the composition).

Results

Much of the solo piece had been completed up until mid-December 2021, however, I was not entirely satisfied with the current state of the piece. At that stage, I felt that it was too straight forward and more musical than I wanted it to be and it also lacked a proper ending.

When work on the solo piece commenced in mid-late January 2022, I realized that it was necessary to add some sort of chaos into the piece in order to mess it up slightly. In this occasion, I went through a library of previously recorded sounds and added them to random places with no other purpose than to add surprising elements and a more jagged and edgy energy to the piece. These sounds were recordings of found sounds from various objects (among others sounds of different kitchen utensils) at a previous residency. The intention was to add additional loud and surprising non-musical sounds to appear in the piece.

Shortly after, I came up with what I considered a suitable, although unorthodox ending. In essence, when work was nearly finished I reflected on the idea that this composition was to be the last during my tenure as a student at the University of Salford, thus I wanted to do something completely opposite of what someone would expect of such an ambitious composition – rather than to end it with a big fanfare with majestic proportions, I decided that I would like to it to end sudden and abrupt. Thus, this may be described as a somewhat symbolic ending, yet it felt absolutely right and I thoroughly feel that it complements the overall composition. The ending coincides with a recurring musical theme which can been heard twice before; however, when this musical theme reappears it appears distorted and when the section finally builds up to a climax the composition suddenly ends abruptly.

As addressed previously, the recording of ACMG was done in three takes, and a similar approach to the past two compositions was undertaken. In the end, segments from all three takes were implemented throughout the composition although it should be noted that transitions between takes appear quite frequently on this composition (i.e. each take often occupy only a number of seconds before transitioning into the next). The main reason for this was to seek/favour specific moments from ACMG's performance that would evoke immediate musical stimulation/satisfaction yet also accommodate the musical content in the solo piece rather than to employ longer sections of performance from each take which would signify the most accurate performances according to the visual representation of the graphic score. However, while transitions between different takes would occur quite frequently throughout the composition, the next step in the auditioning process would be to deal with more delicate aspects of ACMG's overall performance; namely focus on the separate/singular contribution by each performer and to create the most satisfying balance/blend to accommodate the overall musical performance and the audible/musical content of the solo piece. In general, this process dealt with the mixing aspect of the composition and to various extent during the composition each performer’s musical contribution would be either emphasized or buried in the mix to create overall cohesion in the composition.

Conceptually, the mixing balance between the solo piece and ACMG was approached quite differently compared to any of the previous compositions/Case Studies. Early on I decided to let the solo piece appear loud in the mix and be the main dominant aspect of the overall composition, while making ACMG appear low in the mix – I wanted their performance to barely “scratch the surface” yet appear noticeable throughout.

Conclusion

One of the most integral ambitions for my research project was to present a palette of compositions where each consecutive piece would display a gradual progression/enhancement of musical elements or to evoke vibrancies associated with its respective culture. In this case, present composition may resemble the essence of its indigenous music culture the most.

The process completing the solo piece was really difficult, in particularly due to the COVID-19 pandemic and lockdown period postponed the practical aspects of my research for approximately 1.5 years, this forced me to work excessively for a number of months and all compositions created up until this point was to a large extent forced to be completed in quick succession. Because of all the work done prior, it was necessary to take a break away from any composing during the Christmas holiday 2021.

Interestingly, although the intention to include all or some of ACMG in this collaboration was always apparent from the initiation of the solo piece. The direction for further musical accompaniment did change in the last couple of months before the recording of ACMG took place. When ACMG did a concert at the University of Salford, on the 2nd May 2022, one of my two contributions to this event was the solo piece accompanied by Professor Williams and Doctor Brissenden, on accordion and RAPH, respectively.

One of the plans early on was to offer two different approaches of the Gamelan composition for my portfolio, as a means to demonstrate juxtaposition by enabling the listener to compare the solo piece with the entirely of ACMG, and solo piece only accompanied by Professor Williams and Doctor Brissenden. Both configurations were planned to be recorded during the recording session in June 2022, however, due to time constraints I decided only to record the entirety of ACMG instead.

CASE STUDY 5

Composition 5: Twirl Dung Pa

<u>JOINT COMPOSITION With Doctor Timothy Wise featuring ACMG</u>

Collaborating partners/performers from ACMG: Philip Brissenden on RAPH; David Crawley on Acoustic Guitar; Eirik Dyroy on Arabic Virtual Musical Keyboard Interface; Michael Elliot on Acoustic Guitar; Justine Loubser on Cello; Ashley McAulay on Flute; Alan Williams on Accordion; Timothy Wise on Saxophone.

The musical aspiration for this composition was to create a composition which mainly relied on timbre and blocks of sound with a strong emphasis on atonal musical qualities rather than to focus on melody and harmony. The general aim was to create a solo piece which encapsulated a serious yet chaotic atmosphere with dark/mysterious/melancholic undertones that would manifest sudden changes in dynamics and amplitude. In essence, I wanted the solo piece to evoke or possibly recreate the sense of a cinematic experience to the listener.

Further, another significant intention for creating this composition was to initiate a musical collaboration with Doctor Wise. Despite another collaboration which included musical contribution through the use of a graphic score; the scope and anticipation for different outcomes to encompass significant emphasis on different musical characteristics and generally different arrangement style was to be expected. Similar to all other compositions, this solo piece would also pursue the concept of maintaining the authentic nature of recorded sounds, thus allowing no programming sounds nor involvement of any midi to be part of the creation.

Early on during the planning of the solo piece, two influential factors were apparent; 1) inspiration from two compositions created by Doctor Wise which were presented to ACMG prior to our collaboration (both of which I participated in as a musician), namely *Norber Erratics* and *Requiem for Insects* - in which Doctor Wise further developed a means of notation first presented in an ACMG collaborative concert where the score was projected onto a large screen in order for the audience to partake/view:

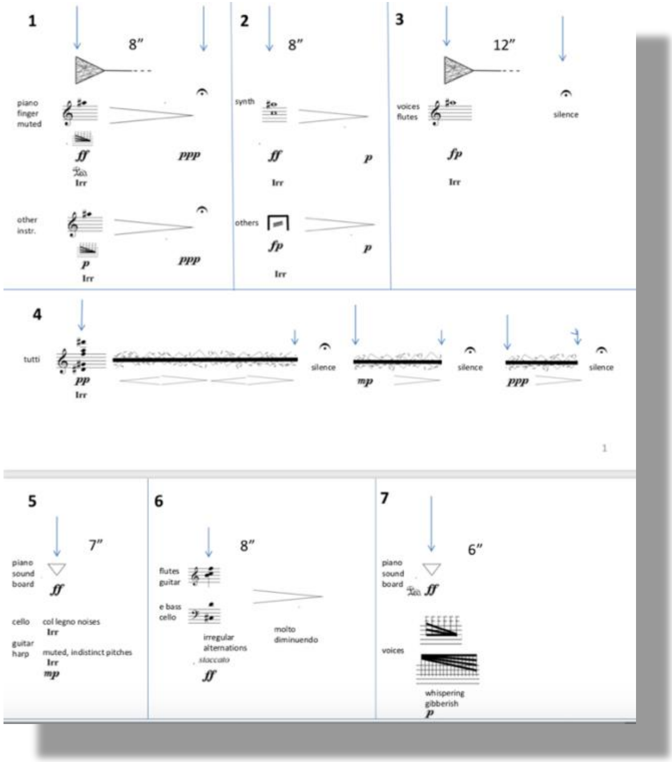

Figure 8.2. Excerpt from Doctor Wise's Graphic Score of Norber Erratics

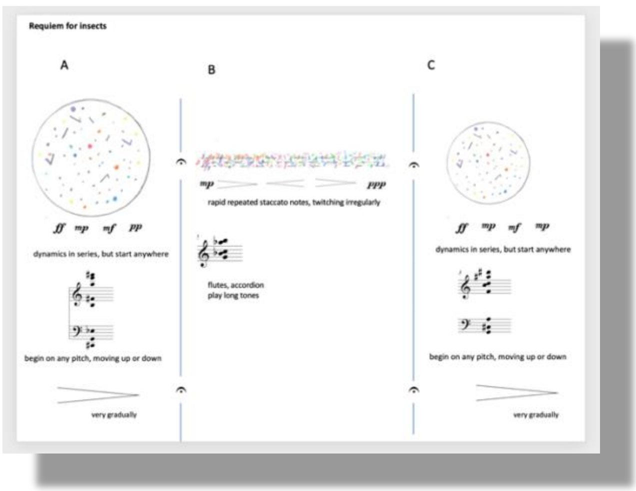

Figure 8.3. Excerpt from Doctor Wise's Graphic Score of Requiem For Insects

(https://salford.figshare.com/articles/dataset/Designing_Notation_from_Screen/7957613) (Brissenden 2019) – needs to go into bibliography.

The other key influence, 2) was cinematic qualities greatly inspired by watching numerous movies made by filmmaker David Lynch. In this instance, the compositional approach of the solo piece allows for a wider hybrid/palette of distinctive sounds to form a unique music listening experience – through the advancement of music to evoke a cinematic experience through audio artefacts (similar to a story containing a beginning and eventually leading to a conclusion/ending). In addition to this, the listener will be subjected to a number of abrupt and sudden transitions and dramatic moments, which are meant to; 1) to disorient the listener, 2) at times to bring the element of surprise, 3) signal different sections of the piece and 4) to further enhance the vibrancy of storytelling.

When initially listening to Doctor Wise's compositions, I immediately recognized that we both share similar artistic qualities in our approach to composing; in particular this applies to the overall moods of his compositions which often portrays dark, melancholy and mysterious qualities to them, a similar focus on block of sounds and similar approach to elements of surprise (i.e. used as a means to trigger a jump scare, sounds that just appear out of nowhere without any logical reason – or by emphasizing sounds that do not necessary follow any logical melodic/harmonic progression). Further, both of us create long compositions with firm transitions to signal a change in the piece or moving to the next section, similar compositional structures with sudden changes in dynamics both musical and/or audible and a similar sense of dark humour and playfulness.

Commonly, Doctor Wise approaches his musical compositions through the use of graphic scores (i.e. giving the performers a set of notated instructions while at the same time allowing them the freedom to improvise around these parameters) which is quite different from mine and entirely created through the use of D.A.W.'s. Prior to any composing taking place, I use the studios to record potential material for my pieces and/or in some cases use previously recorded material – these recordings may both involve just myself and/or other musicians. Then I use the D.A.W.'s to compile all these recordings together and usually comprises of complete/partial performances and/or heavily edited down audio samples (or either) to turn these into fully-fledged musical compositions. Despite these compositional differences, I believed that Doctor Wise and myself would be capable of finding common grounds for a very fruitful and interesting collaboration. Besides the collaborative aspect, the other intention with this composition was to demonstrate the implementations of the Alpha/Beta/Gamma Scale Tuning Systems into an experimental composition which mainly relied on blocks of sounds instead of a melodically structured composition with a somewhat predictable progression. The most common demonstration of these tuning systems previously was used by Wendy Carlos in order to create music which leaned heavily on classical music structures with firm melodic progressions to retain the main focal point of the music.

Differently from any of the other solo pieces, the pitches from the Alpha/Beta/Gamma Scale VMKLI's were implemented just prior to the solo piece being completed – thus their purpose was 1) to play a secondary role in the composition, 2) to appear sporadic and mainly provide an additional complementary layer of musical textures to the solo piece and 3) only audible at a sufficiently noticeable level. In particular, the appearance of Alpha/Beta/Gamma pitches are most apparent during the various passages when the piano is present and when it appears to be a dominant element in the composition (it should be noted that some of the piano parts were rendered through audio processing which involves alteration in pitch, either slowed down or sped up). Beside these occurrences, these pitches appear sporadic and where seemed suited to my own intuition. Occasionally, pitches from all three tuning systems appear simultaneously to create a wider palette of sounds and/or timbre, while at other times pitches from either one or two of them appear.

The solo piece was completed at the beginning of December 2019 and shortly after I contacted Doctor Wise to schedule a meeting in order to discuss and elaborate artistic/creative ideas to possibly enhance on the musical ideas already inherent in the solo piece. Prior to this meeting, Doctor Wise received an audio file of the solo piece and was granted complete freedom to approach his musical contributions according to his own eligibility/preference and use whoever musicians at his exposal. Supplemented in Doctor Wise's graphic score was a visual representation of the entire piece depicting the visualization of the audible file (showing the audible dynamics in terms peaks and valleys etc.). This depiction would aid Doctor Wise in order to separate different sections of the piece and to quantify specific durations (in seconds or minute/s) when to instruct ACMG to play (or not) accordingly to the notations and directions provided in the graphic score.

This graphic score was first introduced to ACMG at the beginning of 2020. Before any attempts were made to interact with the graphic score, the original "solo" piece was played back to the members of ACMG a few times. The main idea from Doctor

Wise was to test out the score as a means of trial and error in order for him to listen and observe how ACMG would approach and interact with the audible/musical artefacts of the solo piece – initially the purpose was to measure the success of the graphic score and ACMG, and from there on potentially draw further inspiration from ACMG's playing in order to make changes or come up with other/new ideas. Unfortunately, due to the COVID-19 lockdown, this collaboration would be postponed indefinitely.

However, Doctor Wise and myself decided to resume the intended collaboration during the first half of 2022. During this period Doctor Wise (in collaboration with myself and Doctor Brissenden) completed the first working version of the graphic score and introduced it to ACMG.

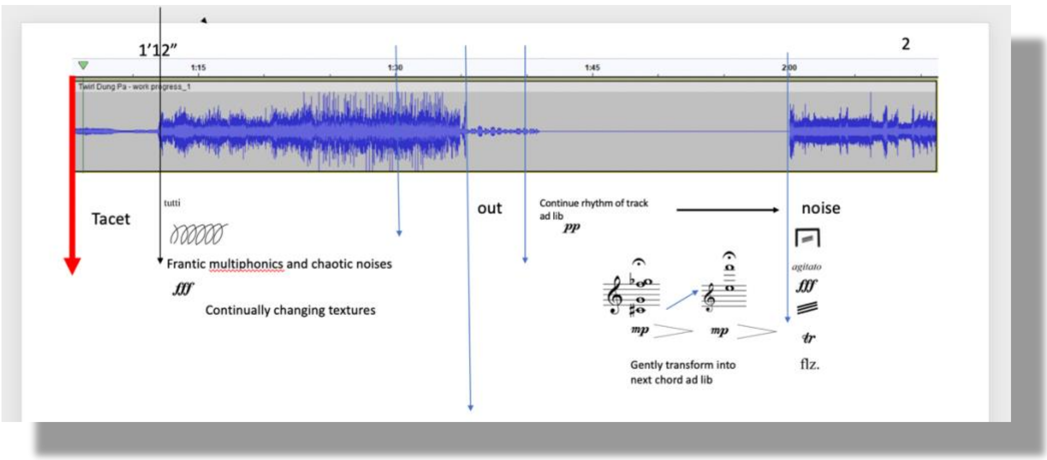

Figure 8.4. Excerpt from Doctor Wise's Graphic Score for Twirl Dung Pa

This piece ended up being performed during the ACMG concert on 2nd May 2022. On June 13th a recording session was scheduled to record Doctor Wise's contributions. This recording session was set up in a similar manner to the recordings undertaken in December the previous year - all members were situated to form a semi-circle and centered in front of a Decca Tree Stereo microphone Room Microphone set-up. The graphic score had been prepared for visual presentation on a big screen TV enabling the performers to perform by observing instructions and follow the progression through additional timings and different dynamics of the original solo piece.

Data Collection

When I first started to assemble recordings for the solo piece I intended to use previously made (recycled) recordings (recorded either by myself or with Doctor Brissenden as co-engineer) rather than start anew by recording entirely new material. A significant part of the solo piece comprises recordings from one recording session in the Band Room dating back to 2017 (during my tenure as a Masters student). During this recording session four of then-current members of ACMG performed sets of improvised music, both as collective performances and later solo improvisations/performances recorded entirely on their own - recordings of the latter was utilized for this solo piece. In addition to Doctor Brissenden's RAPH, two other experimental instruments feature in these recordings; Doctor Adam Hart's experimental theremin and Aden Peet's modified udu – both of these instruments create unusual and indeterminate pitch content.

https://salford.figshare.com/articles/media/SPARC_2017_-_Experimental_Instrument_Ensemble/7929995

In addition to these recordings, a number of other recordings engineered and played entirely by myself were eventually integrated into the "solo" piece; this includes various drum recordings derived from the same recording session as *Music For People Who Doesn't Have Any Real Friends* (dating back to 1. February 2019), and recordings of myself playing Grand Piano (in Studio 1, dating back to 2017). In addition to the aforementioned recordings, recordings of a MS-20 synthesizer (mainly to create audible effects) and pitches from the Alpha/Beta/Gamma Scale Virtual Musical Keyboard Interfaces (created specifically for this research project) were recorded during the creation of the solo piece and the last remaining elements implemented. As previously mentioned, on June 13th a recording session was scheduled to record ACMG's contributions to the collaboration between Doctor Wise and myself - in the end three different takes of ACMG were made.

Results

Conceptually and artistically, I wanted to create a musical composition which would challenge commonly accepted norms within music production by intentionally "sabotaging" certain aspects of the production. Thus, an exercise which sought to challenge common mixing/production values/practices/principles through emphasizing a set of audible artefacts which would be considered unacceptable within the realm of commercial music production. This is already evident at the beginning of the composition – it starts abruptly with an audible click which suggests that the first two or three seconds of the composition was cut out by mistake; in addition, numerous digital clicks are audible throughout the composition as a result of not adding fades to the numerous audio samples implemented in the solo piece.

Further, occasionally the composition is also rendered with digital clipping as a result of pushing the volume past the threshold of the digital domain while lastly, during certain sections audible hiss can be detected in the recordings of ACMG. All these artefacts were intentional to provide an edgy listening experience to accommodate the chaotic atmosphere of the original solo piece and eventually the overall listening experience of the composition.

As previously mentioned, the musical contributions by ACMG were captured in a total of three takes and shortly after the recording session, Doctor Wise and myself scheduled a meeting to listen through each of the takes in order to figure out which sections from each take that would represent the graphic score most accurately. In this process, the majority of take three ended up being the primary take used for most of the duration in the final mix, although one section from each of the other two takes were used as well. Thus, the approach of editing different takes of ACMG in this composition was quite different from all the other collaborations with ACMG - transitions between takes in present composition were minimal and sparse (i.e. three minutes of one take kept intact etc.).

Despite that Doctor Wise had the final voice selecting aspects of each takes to be in the final mix of the composition, still certain aspects of the production were left up to me. It should be noted that all mixing and panning of the solo piece was given similar treatment to any of the previous compositions presented in this research project, namely similar usage of extreme left-to-right panning and panning/layering of sounds to fill audible gaps within the stereo field where applicable – resulting in a densely layered and complex composition.

One major importance when mixing this composition was to conceptualize the idea for individual space of each instrument from the musical contributions provided by ACMG. The purpose of this session was for ACMG to provide a complementary/supporting yet significant role to the overall mix/production in the composition; my original idea was to share musical space equally between the original solo piece and ACMG (approximately 50/50) although, in effect the solo piece may have taken up slightly more musical space in the finishing mix than initially planned. It should be noted that ACMG's musical responses mainly derived from instructions provided in the graphic score created by Doctor Wise, thus certain artistic decisions in ACMG's performance would require specific attention to detail when it came to mixing together these two different entities. This process was initiated through meetings with Doctor Wise and by listening and analyzing the overall quality of each take/performance by ACMG; as an arranger I would allow Doctor Wise complete freedom to select and decide the takes as well as the duration from each separate take to be retained in the final mix/production (i.e. this would involve takes/segments which would represent the notation of the score most accurately or according to Doctor Wise's artistic vision). Once these decisions were made, the next step was to figure out mixing aesthetics that would complement both the solo piece and the additional musical contributions provided by ACMG in order to make both entities/elements blend together properly in the final mix. Despite that an entirely different direction of mixing aesthetics was approached initially – ACMG's contributions would be treated similarly to traditional live recordings where the main focal point would rely on the overall fidelity of the recordings while a secondary aim would emphasize an equally balanced/weighted instrumental balance within the stereo field without too much concern as to how each singular instrument would interact with the overall quality of the solo piece; however in the end I realized that this approach did not complement the overall mix/production of the composition. During the recording, in addition to setting up microphone for each individual instrument I also used a Stereo recording setup technique for live recordings commonly known as Decca Tree. All of these recordings were retained in the final mix of the composition, although the volume on the Decca Tree was mixed lower than the individual microphones.

The final mix of this composition proved to be the most difficult among the ones presented in this research project. The result of the initial merging of the solo piece and ACMG would require some rethinking in the aftermath; thus, emphasis on certain aspects of the overall composition would require a few reconsiderations when the composition was remixed. It was obvious when relistening and re-evaluating the first mix it seemed apparent that ACMG did not entirely accommodate the musical aesthetics and nature of the solo piece as anticipated. Thus, the consensus of approaching the mixing by showcasing a fairly natural and accurately balance of instrumentation in accordance to what was captured in the original recordings of ACMG's musical contributions proved to not yield the best results.

Upon revisiting the mix, an unorthodox approach was pursued, at least in comparison to the mixing approach of all previous compositions which included ACMG's performances; in particular, one idea came to mind when listening to the original solo piece – it was to approach ACMG's contribution in a similar way to how certain key elements of the solo piece was mixed. Thus, the remix, would eventually showcase similar aesthetics in accordance to the jagged/edgy and fragmented nature of the solo piece. In order to achieve this, some experimentation was required in order to provide a satisfying blend between the solo piece and ACMG. In the current mix (remix), both the appearance of the solo piece and instrumental balance of ACMG appear significantly fragmented with sudden shifts in focus and with wide dynamics of amplitude and positioning within the stereo field (although ACMG's performance is not affected by the original panning position of each instrument in the mix). In order to describe this more precisely; the loudness level on each instrument (from each individual ACMG performer) would be adjusted in an unconventional fashion to excel an audible balance between quiet and loud simultaneously accelerated through spontaneity and unpredictability. Secondarily, this type of unconventional mixing was meant to fill in missing frequency gaps where any potential of audible content required presence within the stereo field (to fill in void/audible gaps not preoccupied in the original solo piece). This involved a mixing concept completely removed from any conventional approach; among others the importance to incorporate audible flaws (such as editing out the first two seconds of the composition, pushing the audio tracks to such high levels that they would render audible hiss, digital clicks and digital clipping) into the composition and make them integral to the overall listening experience, which may be perceived as provocative by itself to a number of listeners with a more conventional listening preference. ACMG's contributions would also serve other purposes in the composition – such as providing different harmonious/harmonic/melodic and timbral nuances/content and adding varying degrees of density to the musical textures in the composition. In the end, the audible space and presence of the solo piece may appear more dominant and maintain more impact on the overall decisions in the final mix than initially planned; originally my aim was to provide a mix which intended to allow and share approximately 50/50 musical space between the solo piece and ACMG, although as previously mentioned this combination turned out to not yield the most satisfying/desirable results.

Conclusion

Interestingly, Twirl Dung Pa was the first "solo" composition to be composed for my research project. Work began mid-late November 2019 and was completed at the beginning of the following month. Due to complications as a result of the lockdown situations in the UK, this collaboration was postponed indefinitely. The work on this collaboration resumed in mid-late April 2022, and eventually became a commissioned contribution for the ACMG concert at the University of Salford, on the 2^{nd} May 2022.

Similar to all preceding compositions, the present composition also provides a number of distinctive yet unconventional compositional strategies which may render it immediately recognizable in the context of set artistic "trademarks" – or musical traits which also seeps through in all other compositions enclosed in this research. Further (similar to all of the other compositions), the composition also showcase a number of distinctive divergencies; in this case three very distinctive features needs to be addressed; one relates to the overall style and approach of the solo piece itself, while a secondary element to this approach is the implementation of Alpha, Beta, Gamma Scales tuning systems, while a third feature relates to the mixing/production aesthetics of the composition.

9. CONCLUSIONS AND CRITICAL EVALUATION

This section of the Thesis will present the outcomes of the research project including the key findings and measurement of success for each of the objectives in relation to the research questions. The following research questions were presented at the initiation of the PhD research:

- *How can I make both user-friendly Interfaces and at the same (time) include components that will make them capable of reproducing sounds (characteristics which can be associated with) which relates to the actual tuning systems?*
- *How shall I recreate the instruments that are most associated with each tuning system in appearances or in what way to feel natural to play on the Interface?*
- *What sacrifices/compromises do I have to make in order to succeed?*
- *Develop personal composition and production practice which integrates the interfaces in collaborative endeavour*
- *Which musical communities would be interested in the interfaces and what sort of concepts shall I have in mind for each musical Interface to make composers/performers more interested in them/ favour them instead of compared to the options already available?*
- *How will composers respond to my invention, will they easily adapt to the functionalities and the additional features of the Interfaces?*
- *What kind of playing positions? Deployment of existing technique, such as (but not limited to) keyboard technique will be most appropriate for each Tuning system? And are there general principles that can be drawn from specific case studies as to how to work out layouts that will seem logical for a performer/musician/composer to understand?*
- *What kind of issues do I need to be aware of when I customize the Interfaces to make them compatible with a Tablet such as iPad?*

Key findings and measurement of success

In the following pages I will provide answers to the proposed research questions which were prepared at the initiation of the research project and then critically evaluate the extent of successes, limitations, and recommendation for further research in situations where it may be required.

How can I make both user-friendly Interfaces and at the same (time) include components that will make them capable of reproducing sounds (characteristics which can be associated with) which relates to the actual tuning systems?

This process would be initiated and eventually achieved through the aid of three integral components/factors; obviously, integral to this process - acquisition and compilation of all necessary technical and theoretical components prior to implementing and eventually transmitting this information onto the five VMKLI's through a practical process. The research project would then enter a stage of transition largely based on a series of testing, evaluations, re-testing, re-evaluations, further tweaking, reconsiderations etc., until the final outcome would be assessed as successful by myself as a primary user.

Technical/Practice-based factors

The technical/practice-based factors of the VMKLI's has been discussed at length throughout chapter 7. The initial stage of the research project would be dedicated to searching for and approaching available programming software to properly explore and weigh the various advantages against a number of other available existing alternatives – of which the entirety of chapter 6 is based on. This was integral to validate the overall potential for realization of the PhD research project. However, the majority of technical/practice-based factors of the project would not occur prior to compiling and processing/absorbing all sufficient theoretical sources in order to create a theoretical framework for all five VMKLI's (with the exception of the two invented tuning systems where all integral information could be absorbed within a short period of time), this is sufficiently summarized in chapter 5, including three separate Music Studies for each evolved indigenous tuning systems which provides an expanded overview of all integral aspects of each tuning system, musical instruments and the respective culture in great detail - and appears in the Appendices.

The sound characteristics/timbre of the VMKLI's took as their basis, a few distinct and clear purposes; the primary target was to evoke timbre with a strong connection/association closely related to instruments from each respective culture, yet simultaneously allowing each of the evolved indigenous tuning systems to be based on one particular type of synthesis which was unique from each of the others (i.e. frequency modulation synthesis for Indian VMKLI, Karplus strong algorithm synthesis for Arabic VMKLI, and additive synthesis for Gamelan VMKLI). Further, once the sound/timbre would start to appear similar to key instruments, I wanted to blend the authenticity of respective instruments with my own creative input by altering and adding minor nuances to the timbre – to make a distinguished yet recognizable timbre (i.e. no exact recreation of specific instruments), this was achieved after an extensive period of exploration tweaking the sound on each VMKLI. It should be noted that sounds on some VMKLI's will appear more closely relatable to instruments of their respective culture than others and may contain more or less creative input from me, the same applies to the number of instruments which have been encapsulated to create the various timbre on VMKLI's.

Theoretical factors

The theoretical framework for the research project was achieved by compiling special in-depth information about tuning systems through a large number of academic sources. Across a period of approximately 1 ½ years (i.e. from initiation and up to the first half of the research project), these sources would be compiled through extensive reading of up to 90 different books, and due to the complexity of the topic matter only selected aspects from the sources and sometimes limited to a fraction of key information to be selected from singular authors, requiring much processing of various literature to provide a sufficient overview about the theoretical framework limited to the respective tuning systems and instruments.

One of the main challenges in this process was that several authors would emphasize and dedicate the majority of their book to the subject of musical notation and how to play various instruments while aspects on tuning to would be limited to a few pages (in particular this would apply to Indonesian gamelan). All three evolved indigenous tuning systems would show various level of complexity, which dictated various timescales for completion, the following perspective is provided thus: gamelan would require up to nine months for completion, Indian music two months while Arabic music six months. In addition, minor corrections would be applied at a later stage of the project.

The theory commentary of the three evolved indigenous tuning systems was made into separate studies that appear in the Appendix. This theoretical research was integral to the process of integrating all significant components to fully acquire and sufficiently understand all “dynamics” of instruments and the tuning system for each music culture. As indicated above, this process would turn out to be very complicated and time consuming, however it was completely necessary in order to initiate the technical, developmental aspects and completion of the VMKLI’s. Mainly, the creations of the VMKLI’s would require many considerations both interrelated to design and technical matters. Authenticity with respect to historical aspects of tuning and instruments were taken into consideration in order to understand validate various aspects.

Through extensive reading many different key aspects were discovered which would not have been encountered through a perfunctory search. Among others, the authenticity of current 24-tone Arab tuning system which is highly Westernized and mentioned first by Western scholars, and through reading several sources I finally discovered the ancient/medieval Arab tuning systems dating from 10th and 13th century, respectively. Further, no specific guidance would enable clearly divided intervals for gamelan – thus, through compiling many different sources and comparing the different information I arrived atmy own intervallic and frequency numbers. The quest for acquiring information about the intervallic values of the 22 srutis of Indian music would require similar attention, and extensive reading from various sources would eventually provide a perspective of and enable me to divided and calculate each and every sruti – with the intent to be respectful towards the culture, despite that various sources would suggest that some are incalculable. During the research I realized that there are a number of disputes about the origin of infamous historical instruments and may be subjected to reconsiderations in terms of age and origin, in particular, excavations have revealed instruments formerly known to originate from Greek may in fact possibly originate from the Arab World - on this occasion, such discoveries would pre-date the existence of ancient-Greek. All this aforementioned information would not have been discovered through perfunctory exploration of more obvious sources.

Another reason for building such an extensive theoretical framework was to pay proper respect to the music of each respective musical culture. In this process, I would explore all core instruments thoroughly and establish an overview of the most typical instruments, recognizing key instruments, and singular instruments which would represent and possess the strongest vibrancies of music associated with the respective culture from both historical and contemporary contexts – then weigh the importance of various regional variants or unique instrumentations and their significance/effect on contemporary traditional music related to that particular culture. Features such as *Jawari* bridges that affect specific aspects of the timbre were a strong part of this exploration; thorough research on specific details regarding additional functions on numerous instruments and how this/these would affect timbre on instruments. Further, historical documentation would aid in an understanding of the origin of the respective instruments and suggestions on how instruments have evolved, other possible tuning arrangements or amount of strings *etc*. over the course of centuries. All of this was taken into account when the development of each VMKLI was undertaken.

Tester as a primary user

The majority of development of VMKLI's would be undertaken towards the end of the research project, a number of different layouts, usage of keys and knobs were considered, tried and accepted or rejected. One of the main purposes with the VMKLI's was that users encountered straightforward, even simplified instruments which possessed the key elements of the music culture and tuning systems. The interfaces would demonstrate progressive degrees of complexity through the number of keyboard layouts featured within the respective VMKLI. The basics of the VMKLI's should be easy to learn for any user largely due to fixed intervals to appear on the Interfaces and no complicated finger techniques or long processes to learn actual instruments. Purchasing and learning actual instruments would of course be severely expensive thus these VMKLI's will offer a compromise both in terms of economical budgets and comprehensive approach for playing/performing.

Once the VMKLI's reached a satisfactory level of completion, they were incorporated into the music compositions made specifically for this research project. The purpose with these compositions was to measure the level of success for each VMKLI's. The Music Studies in the Appendices were used as guidelines throughout this process and provided numerous minor yet important details which were integral to the process of finalizing the VMKLI prototypes.

How shall I recreate the instruments that are most associated with each tuning system in appearances or in what way to feel natural to play on the Interface?

I have accomplished this through the multi-disciplinary approach dictated through the methodology which is clearly elaborated in chapter 2; this process is mainly demonstrated through Lewin's renowned method of action research and systematically approached through the other aspects of methods which are discussed within this chapter. The approach can be further understood through successive cycles of practice integrated with reflection and research. It is the case that as my knowledge of tuning practice within individual cultures deepened through the research the resulting interfaces thus became more sophisticated in their design.

It should be noted that chapter two solely provides the various methods required to reach conclusions, however the inherent designing decisions of the VMKLI's are clearly elaborated throughout the entirety of chapter seven. Despite apparent similarities to the previous research question, it is important to address that these two questions seek different answers for the development of the VMKLI's; whereas the previous question seek answers for technical programming approaches, the current seeks answers related to the "external" visible designing aspects.

Apparent during the process from initial ideas to the eventual creation of the VMKLI's - besides the overall musical aspects of the respective culture through processing the theoretical framework/practices, the most important factor was undertaken by absorbing the fundamental aspects in the construction of singular instruments and also to seek the common denominator between different instruments within the same culture. Thus, finding ways to incorporate and encapsulate inherent qualities within the respective cultural phenomenon of music through the advancement of tuning appeared to be integral during the construction of and process turning these ideas into singular user-friendly keyboard layouts/VMKLI's.

In terms of designing digitally constructed instruments, another set of challenges needs to be addressed. A potential problem turning actual physical instruments (whether it applies to singular or an encapsulation of a number of different instruments) is the obvious aspect of executing a non-hardware instrument where the ability to control natural sensitivity by operating keys/knobs would not provide the exact same preciseness as in handling an actual music instrument. Digitally constructed keyboard layouts (or VMKLI's) may lose that particular directness of physical interaction and force the user to re-think or become accustomed to a new set of exact finger and playing positions which may not replicate the logic or be somewhat different from the intended purposes of the original instrument.

This change may result in both positive and negative outcomes; the aspect of simplification may allow or persuade more musicians to engage with music previously considered too alien and difficult to embrace due to the complex construction and nature of the instruments which is further followed by a long-lasting steep and difficult learning curve to properly execute and master the instruments. Within certain musical cultures it may take many years if not decades to master specific instruments before the pupil/student can be considered a master him/herself (sometimes with the requirement of long-lasting teacher/student practices – i.e. the Indian guru/shishya practice) – this applies to the majority of the indigenous music cultures which were approached for this research project. Understandably, this challenge may discourage a number of Western musicians to become familiarized with musics from other cultures.

Thus, distinguishable from this overlong process to master all aspects of playing and comprehension of all other specifications related to the respective instruments - the intentions with the VMKLI's always was to provide entirely new alternatives for playing and engaging with non-Western tuning systems by offering simplifications yet unique approaches of interacting with user-friendly keyboard layout solutions. However, these considerations resulted in a number of apparent compromises; whereas I was able to retain the natural playing positions of gamelan instruments (more or less), both the Arabic and Indian VMKLI's were approached from completely different angles. It should be noted that both the Indian and Arabic VMKLI's were based on instruments which are categorised as stringed lute instruments. Although, the idea of recreating the instruments by applying *StringTouch* technology (digitally constructed strings which will vibrate once triggered/played) seemed appealing during the early stages of the project, when conceptualizing the overall design of these two VMKLI's, a number of potential obstacles seemed apparent in terms of turning complex stringed instruments into user-friendly VMKLI's which intend to provide a product that can be comprehended through a fast learning curve yet retain easy and logical playing for uninitiated users. Presenting a Keyboard Interface containing a total of 50+ strings within close approximation may have brought confusion to the uninitiated user and rendered it difficult to locate and separate exact strings. This would also affect the marking/colour coding on the specific strings. Also, the aspect of providing an element of originality and easily adoptable Interfaces was apparent in the development of these VMKLI's.

Largely due to the inherent complex nature which involves the construction of numerous non-Western instruments – several considerations regarding various features to affect nuances of timbre and/or pitch were taken into consideration during the development of the VMKLI's. Eventually, after considerable time dedicated to brainstorming, knob-based keyboard systems appeared to be the most ideal approach – despite that such a concept diverges significantly from the actual key instruments associated with the respective cultures.

This would enable a significantly quicker learning curve for the uninitiated user – and no longer require acquisition of a deeper understanding on how and where to suppress fingers on their left hand (if right-handed) to execute chords on the neck of the instrument in order to achieve the desired/exact tones/chords on the instrument. Largely these parameters have been incorporated by being assigned to separate knobs which perform the exact same functions without involvement of other finger orientations. For example, in the case of the Indian VMKLI, the uninitiated user is presented with an interface which displays three different colour coding on the playable knobs – white indicates Western equivalent tones, light blue indicates slight variation of pitch apart from the previous pitch, while dark blue indicates significant variation of pitch. In addition, the Indian VMKLI allows the user to select an additional set of detuning through the addition of the *"Pitch "O" Meter",* this allows the user to select and adjust the exact amount of detuning instead of pulling threads on a sitar which requires expert knowledge to execute properly.

Another major challenge was to construct the gamelan VMKLI. Inherent in the Indonesian culture as well as being the exact meaning of the word: the composite of the word *gamelan* in the Indonesian language means “to strike”. Purely through this definition, the gamelan VMKLI will *not* provide the exact meaning and purpose inherent within the cultural context. However, the VMKLI provides a lot of potential possibilities which will not be apparent on actual gamelan instruments. The gamelan VMKLI offers an encapsulation of gamelan instruments by providing all possible intervals/pitches to be found on both Gamelan Sekar Pethak (Java) and Gamelan Gong Kebyar (Bali), these may sometimes appear on the same keyboard layout while sometimes separated into distinct keyboards which separates the island, all of this is elaborated in chapter 7, as well in chapter 5. Thus, a number of instruments have been merged in order to realize the gamelan VMKLI.

What sacrifices/compromises do I have to make in order to succeed?

This information covers a multifaceted topic which does not apply to one single chapter but has had significant impact on the entire process of the research project in itself, thus have taken effect in numerous chapters. Aspects of this can be found in chapter 1, 5, 7, 8 and in all appendices. In order to succeed the first half of the research project required dedication to gather/collect theoretical material/sources. This would occupy a significant amount of time and would be further affected by the COVID-19 pandemic which delayed the technical developments. My original goal was to transfer the keyboards to become playable Apps. In the process, requirement of a period of testing, evaluation, re-testing and re-evaluation – eventually proved that the initial two softwares (Max MSP and Touch OSC) would not produce the final outcome according to the intended specification. Without this period of trial and error, I would not have figured out these problems. However, once the ideal programming software had been agreed, and the VMKLI’s would have reached a sufficiently advanced level of development, it would finally allow the compositional aspect of the research to be initiated. Thus, several chains of information and development needed to be completed before triggering initiation of the next stage of development for the research project.

In the end, after an overlong process, the keyboards appear completely developed and ready for use. The measurement of success of these can be documented through the creation of the musical compositions. I also have further plans to develop new functions on all keyboards. Since all the paths to implementation have been established this process will be uncomplicated but will take some time to accomplish.

Develop personal composition and production practice which integrates the interfaces in collaborative endeavour

The majority of this information has been described in detail throughout chapter 8, however that chapter mainly provides description of the process, creating five musical compositions discussed as five different cases studies. This includes the various artistic and creative purposes and conceptions distinguished between individually created solo pieces in conjunction/combination with improvised real-time performances through collaboration with an experimental/contemporary music ensemble. Eventually, each case study is concluded with a section which specifies the mixing/production aesthetics/practices/conceptions for each composition.

On the other hand, another set of personal goals should be addressed in this occasion; I wanted to develop my capacity as a musical composer by demonstrating the diversity of my musical palette, creating musical compositions taking as a basis different non-Western tuning systems and deploying the VMKLIs.
I developed diverse, highly experimental musical compositions providing a palette ranging from sparsely arranged pieces to the extreme opposite; densely layered pieces. On this occasion, my intent was to develop my current state of knowledge in regards to music theory, as well as developing closer working relationships through collaborations with other similarly minded musicians. I found that through this methodology I was able to coalesce my strengths as an experimental composer whose preferred composing method is to work with composite of blocks of sounds, field recordings with little or no focus/emphasis on traditional melodic progressions. I worked with musicians demonstrating more performance-based skills than myself and incorporated other musical dimensions - sets of performance qualities which I would not be capable of creating through real-time live performances in my own solo pieces/compositions.

Prior to this research project, the majority of my compositions have been achieved independently with very limited inclusion of other musical participants. I believe the eventual outcome of the compositions created and presented for this research project provided a strong evidence of success for the intended developments as a composer and of the success of the VMKLI interfaces as a whole. Based on these experiences, a number of other fellow musicians and composers have shown interests in pursuing collaborative efforts with me in the future.

During the research project, the general experience to be part of one particular musical ensemble has enabled me to interact musically with other musicians to a greater extent than previously and this has been an overall stimulating experience – which I believe is mutually shared with my musical collaborators. This includes the musical partners who have provided musical scores/arrangements for my compositions as well as the participating musicians. Another important aspect of these collaborations has been to combine musical sounds of non-Western tuning systems and fuse these with Western based instruments to create compositions based on total experimentation without any particular branded style of music. Further, the majority of audible/musical elements of the solo pieces would be rendered through a process of editing and shuffling – different from their actual real time appearance. Differently, the additional performances provided by ACMG would retain the authenticity of a real time performance – with the sole exempt being alterations which involved transitions from one recorded take (of a graphically notated/improvised performance) to another one and vice versa. Besides this, the only alteration would be during the stage of mixing the compositions where the occasional emphasis on certain parts of performance/instrument while ducking others - this approach was done to allow every performer some audible space throughout the composition in addition to provide a consistent finished product.

The only exception to this rule was *In search of Enchanted Soundscapes*, which involved a completely different approach; in this case each musical participant ended up recorded themselves playing their instrument at home and would allow me to decide whether to keep their performance in real time or be edited/shuffled where I felt was desirable – either intuitively or instinctively.

Also, another important concept in terms of compositional approach has been to retain production aesthetics within the realm of recorded sounds (i.e. without the interference of programmed sounds). Further, none of the compositions intend to meet any criteria in terms of firmly established production styles, although an exercise in total experimentation or aesthetics within contemporary classical music may be traceable in these conceptions.

Which musical communities would be interested in the interfaces and what sort of concepts shall I have in mind for each musical Interface to make composers/performers more interested in them/ favour them instead of compared to the options already available?

The VMKLIs will be relevant as compositional resources to musicians with some prior knowledge of non-western tuning, and to the completely initiated alike. At the outset of the research project, the main target group was Western musicians who seek new approaches towards music making - to experiment with established Western or non-Western conformities of music compositions, groundbreaking/inventive or simply approach unknown musical territories. The potential style of music where the VMKLI's could be deployed was not defined and could range from a similar context to the compositions created for this research project, to far more discrete integration within more traditional compositon. The planned test group was young musicians/composers at the start of their musical career or any age group interested to experiment with the aforementioned style of music.

Interestingly, as the project progressed and particularly during the completion of the VMKLI's, this perception changed slightly. At this stage I finally recognized the potential to target musicians originating from the respective cultures explored for the research as well (useful from both the Western and non-Western perspectives). Obviously, from encountering various sources on the subject, a significant Westernization also have played a large part in the shaping of modern music making within these musical conformities resulting in numerous musicians steering away from their centuries-long traditional practices or at least fused their own music with common Western musical styles. Although, the VMKLI's cannot constitute/replace the exact qualities of their native instruments, it may allow them to become enchanted with, think anew/inventive and create anew – by using them in musical contexts within their native music.

Thus, a potential aspect is not to limit the VMKLI's purely for Western-based (or not) experimental/contemporary musicians, but also seek the potential for fusing the VMKLI's within styles of popular music from all over the world (yet, including them in commercial Western pop hits, seems quite unlikely due to the "alien" sounds that they produce). Further, they may be seen as useful assets – for further learning of non-Western music and musicians to seek and engage with actual music instruments from these cultures – since the VMKLI's will readily show the basics of what the various tuning systems (comprises) are composed of.

In terms of actual responses from musical communities, particularly one case should be addressed, namely the musical collaboration with ACMG. This aspect of the research has been partially elaborated in the answer to the previous question and has been described in chapter 8. Through this collaboration, the fusion between Western based instrument within the context of improvised experimental and/or contemporary music combined with the inclusion of the VMKLI's (incorporated in experimental solo pieces) has proven to be successful and musicians from such communities have shown deep interest for collaborations in the near future.

To sum up the most likely candidates to embrace the VMKLI's a brief list is provided below:

1. Musicians (who wishes to further develop their musical palette as musicians)
2. Composers
3. Music producers
4. Young talents who sees the value/potential in cultural music/contemporary music
5. Those who wishes to be groundbreaking/inventive
6. Underground music
7. Other cultures who are not so resourceful
8. Worldwide

How will composers respond to my invention, will they easily adapt to the functionalities and the additional features of the Interfaces?

The work transforming the VMKLI’s into playable Apps was initiated but not entirely completed by the time of submission of this Thesis due to time-constraints, the process of developing the VMKLI’s is thoroughly described in chapter 7. These will be fully developed into playable Apps at a later point in time – and finalized once the planned case study interviews have been completed. It should be noted that they are all fully functional at the present time and can be used for their original purposes (as evidenced in chapter 8) and for further audible excerpts/references all five compositions will be enclosed in the further material section.

With the exception of interaction with ACMG and other additional musicians who took part in informal meeting during the development of the VMKLI’s, limited amount of information was assembled regarding this aspect of the research project. The initial plan (with the project) was to establish case studies through interviews/meetings with musicians in order for them to test out the keyboards. In these meetings I was supposed to make notes about every single response (positively/negatively) and take this into account for further potential improvements on the keyboards. Because of the pandemic it became impossible to achieve this during the research project largely due to the significant delay developing the keyboards/VMKLI’s – thus in the end I would become the primary tester.

Since the eventual implementation of these case studies during the creation of the VMKLI’s would likely have some effect on the final result; it is important to look at a number of potential pros and cons to likely influence this process. Potential advantages by incorporating feedback from case studies early in the developmental stages of the VMKLI’s will be elaborated in the following paragraphs. In general, the effect of input from outside “parties” would definitely provide creativity, and most likely provide important additions to any research projects. The significance of critical feedback should not be dismissed even if it strays away slightly from planned ideas, but it is important to properly evaluate and validate the significance of this feedback - further filter and weigh this against other potential alternatives.

On this occasion, it would have been expected that the majority of feedback from these case studies would be related to the actual appearance of the keyboard layouts, and more specifically setup and arrangement of the respective keys/knobs systems chosen. The potential criticism would thus likely be related to slight alterations and/or implementation of other keyboard systems (i.e. usage of other objects besides knobs and keys) - whether closely relatable to the ones applied or completely. Further, it likely that suggestions for closer or more distantly spaced playable objects, change of order/structure for arrangement of keys/knobs (vertically/horizontally) and/or the additional functions/options, or proposing a potentially simpler or more complex navigation. In terms other aspects regarding design, more colours, adding pictures either of actual instruments or purely for decorative purposes or usage of colours that may be more closely associable to the actual culture than current. And lastly, critical feedback on timbre whether this to be positive or negative.

Another important aspect of feedback would be the significance of including feedback from both Western-based musicians with background solely on Western music and musicians from the respective cultures or from nearby countries with similar/closely related musical approach – and weigh these opinions against one another. Critical feedback from musicians from the respective cultures may also have fast-forwarded both designing and technical aspects of the VMKLI's.

However, providing critical feedback at an earlier stage of development may also have provided a set of potential disadvantages; one obvious reason is that to include uninitiated Western-based musicians (whose knowledge about the cultures are limited) would risk undue influence from creative input and opinions that lacked the necessary understanding of tuning conceptions (outside of Western music). These voices may well be most critical at a stage when not every aspect of the respective culture/tuning system had been incorporated into the technology of the VMKLI's – thus potentially disrupting or causing distortions on the development and providing an unwanted Westernization effect on the final outcome. It is a potential problem to conduct these at a stage when the development is still pending and decisions as how to finalise the design of the VMKLI's, and particularly how to integrate aspects of the evolved tuning system and musical culture are yet undetermined – this may have influences me negatively and made me steer away from closely following and examining the specialized literature/sources which were assembled at the initiation of the research project.

Lastly, gathering additional participants for case studies and to profile the types of participants most likely would have been demanding and time-consuming process. Although, it may not have been difficult to gather musicians associated with the University or various Universities based in Manchester, seeking out a number of locally based Arabic/Indian/Indonesian musicians with expert knowledge may have proven to be an impossible task – in particular for a project which was fast approaching the final end date. Bringing in participants also means that meetings would be scheduled and dependent on availability of the respective participant – potentially causing further delays, on the other hand as the primary user/tester I was allowed to work on the VMKLI's whenever I wanted/needed to.

In retrospect, the decision to not proceed with case studies during the course of the research project probably yielded the most ideal outcome. This decision would allow completion of all VMKLI prior to any interference from outside parties and/or opinions and allowed me to be true to the literature findings and information absorbed through the three Music Studies which appear in the Appendices.

Despite this, I did conduct informal meetings with a limited number of musicians and staff at the University of Salford - who tested some of the VMKLI's and provided feedback on them. I would not dismiss the potential positive outcomes of involving more participants to enhance the creative aspects of the VMKLI's and allow for further brainstorming during that phase of the project. However, I do consider it necessary to proceed with the planned case studies after completion of the research. It will be easier to make slight changes or additions to the VMKLI's since all integral aspects from the theoretical framework have been incorporated/implemented. The plan is to further fine-tune and make slight changes to the Interfaces and possibly add a few new features that will affect timbre or enhance the user-experience – these changes are very likely to take effect as a result of conducting and transcribing the planned case studies, however I am determined to complete these prior to any eventual commercial distribution of the VMKLI's. Plans with these VMKLI's is to sell them "in" to companies who develop music plugins or other potential developers. The selected target group/s and communities that I approach may be different depending on the city I will be situated/based in when these are conducted and can affect accessibility to different types of musicians vs. styles and/or interest for this type of technology and music.

What kind of playing positions? Deployment of existing technique, such as (but not limited to) keyboard technique will be most appropriate for each Tuning system? And are there general principles that can be drawn from specific case studies as to how to work out layouts that will seem logical for a performer/musician/composer to understand?

This has been covered more in detail in the answer to the previous question, although this aspect of the research solely relates to the facets elaborated in chapter 7. On this occasion, there are different approaches for the various conceptions of playing positions, they can be described as a combination of logical playing positions according similarities to their inherent execution within the respective cultural context (gamelan), or string-based instruments turned into keyboards with knob-based systems (Indian and Arabic tuning systems). Further, Alpha/Beta/Gamma Scales were taken into an entirely creative path since no previous unique keyboard system (besides a Western based 12-tone electric keyboard which allowed for retuning the keys) has been proposed, while Bohlen-Pierce Scale offers a re-arranged/imagined keyboard system of playable keys – with the intention of taking inspiration from previous proposition provided by Heinz Bohlen and Elaine Walker yet provide something unique and distinguished which somewhat steer away from their propositions.

A keyboard system for the Gamelan VMKLI which relates to actual gamelan instruments - may seem as an obvious decision to most readers, but the keyboard solutions on the two latter cases may appear confounding. It should be noted that there is a firm reason for implementing these keyboard systems; mainly the immediate difficulties to provide user-friendly keyboard systems based on strings such as StringTouch which has been previously explained. The deployment of knob-based keyboard systems in these cases was determined with the intention to provide the user with a fast induction/inception to learn the basics of the tuning system and categorization of intervallic differences (i.e. Western equivalents, slight/large deviations from previous intervals and distinctively non-Western etc.). However, since my keyboard systems are not based on any predetermined/established conception/setup/foundation developed by native musicians – thus, this transition would require some considerations (including a process of trial and error) in terms of deciding the eventual selection of keyboard systems, including the level of symmetry (symmetry versus asymmetry) and arrangement of knobs which appeared to be rendered logical and intelligible to the unexperienced/uninitiated user.

Another challenge with the VMKLI's is the general disadvantage of playing on digital interfaces which does not allow direct "feelable" interaction with the physicality of actual instruments and provides some extent of sterility (i.e. does not allow for exact/natural sensitivity/velocity to reproduce the expected effect on playable objects and requires another level of finger precision to touch exact spots in order to enable reproduction of sounds). While making comparisons and measuring/weighing the advantages/disadvantages between the VMKLI's against one another, can be challenging; in conception the VMKLI which may be least beneficial for this type of transformation is likely the gamelan VMKLI. In principle, the nature of execution on gamelan instruments can be traced in the exact meaning of the word gamelan which means "to strike". During the development of the Gamelan VMKLI, considerations were made for creating an Interface which would allow for playable objects to be struck with stick type objects; however this idea would be dismissed early on, mainly due to a set of technological challenges related to providing the accurate touch screen sensitivity when struck by physical objects, as well as finding suitable sizes for sticks to strike – while the most apparent issue concerned was the potential risk/danger of causing physical damage to iPads (i.e. which would require a certain level of force when struck).

Despite that this compromise may take away some level of authenticity while playing Indonesian gamelan instruments, the Gamelan VMKLI encapsulates all categorisations of instruments and all possible intervallic values of Gamelan Sekar Pethak and Gamelan Gong Kebyar to be performed on a limited amount of keyboard layouts. The benefits of this VMKLI, is that it will allow the user a quick learning process to absorb the basics of Indonesian Gamelan – and of course to implement it within composition work.

Further benefit is that this VMKLI will be an affordable package in comparison to access and acquisition of a full gamelan ensemble which will be significantly expensive are quite rare besides Indonesia, and for the most part appears available solely at selected Universities around the world – meaning that it is difficult for everyday people outside of academia to have access to actual gamelan instruments. One thing in common for actual instruments from all of the evolved indigenous musical cultures dealt with in this research is that they are difficult to master and it may take decades to become a fully accomplished master performer of these instruments.

Unfortunately, as indicated in the previous question, none of the planned case studies were completed and with the exception of my own findings as a primary user/tester – answers to general principles of logical hand orientation from selected participants will be conducted and completed in the aftermath of this research project.

What kind of issues do I need to be aware of when I customize the Interfaces to make them compatible with a Tablet such as iPad?

This has been briefly addressed in question 3, one of the major problems with the technical development of the VMKLI's was to establish the most suitable software to yield/produce digital artefacts according to the specifics of the research project. Below a summary of the issues that I went through before reaching the satisfactory outcomes.

As a result of compiling and absorbing literature to build a comprehensive theoretical framework, a number of technical challenges would lead to further problem solving. In the search for fully established set of exact intervallic values in Indonesian gamelan it turned out that no standardization existed - any author would provide approximations of intervals and some would state that no two gamelans will tune the instruments 100% exactly like any other ensemble. In the end I developed my own intervallic numbers to be present on the Gamelan VMKLI, in this process I would make compromises which would enable approximate pitches of Javanese gamelan and to be somewhat correlated with those on Balinese gamelan – all intervallic numbers are mine. All other tuning systems offer precise mathematic calculation which I have retained on all the VMKLI's – yet in some cases it would force me to browse through dozens of academic books and sources before acquiring this information thus further delayed the process somewhat.

At the outset of the research project, it seemed apparent that the combination of two programming software Max/MSP and TouchOSC would produce the planned VMKLI Apps. The primary reason for approaching Max/MSP as the target programming software for development of the VMKLI's was largely due to the high level of programming skills (using this software) which I possessed at the initiation of the project - which would have allowed me to work largely independently from an early stage in order to completely develop the VMKLI's. Thus, at the beginning it seemed obvious that Max/MSP would appear as the most ideal software in order to achieve the expected final programming artefacts/outcome (i.e. VMKLI's).

However, nearly halfway through the research project after a significant amount of time was spent on the development and near completion of the first VMKLI (Alpha/Beta/Gamma scale), this VMKLI was used to test the correlation (by transforming/transmitting this technology through the creation of Apps) between Max/MSP and TouchOSC. Although, TouchOSC would successfully recreate the VMKLI's and turn them into playable Apps - unfortunately, during this process I finally realized that these two software were not capable of producing the final outcomes/artefacts according to the originally intended purposes. The main issue with TouchOSC is that it would not produce independently working VMKLI's for widely commercial distribution - TouchOSC would only allow any interaction of the technology to be performed through the use of a Host computer and a specified computer port for the users of the VMKLI's; thus, rendering the VMKLI's completely unusable when the host computer would be turned off or disconnected.

In order to pursue further with the project, search for an alternative programming software for Apps was necessary to complete the research project as originally intended. During this instance, another software called MobMuPlat (which had been considered early on during the initial stages of the project, but rejected due to not being compatible with Max/MSP) was chosen as the new software for creating Apps. However, largely due to the aforementioned experience, it was important to dedicate a significant amount of time to ensure that this software would be capable of creating the VMKLI's according to the predetermined specifications of the research project.

This change would eventually force me to learn a new programming software in order to pursue with the research project – largely due to the fact that MobMuPlat could not correlate with Max/MSP patches due to the advanced and complex nature of the software, this required the more low-level and basic programming software Pure Data for the eventual development of the VMKLI's. Pure Data patches would allow creation of significantly smaller file sizes and less requirement of CPU capacity/processing power – however Pure Data eventually would prove to be even more complex in execution than Max/MSP and the necessity for a limited number of tutorials prior to acquire the necessary skills for me pursue and work independently to fulfil the VMKLI's. Despite my previous skills as a programmer, in order to acquire a similar level of programming skills using this software, Pure Data would prove a significantly steeper learning curve (across the timespan of a few months) than anticipated.

Unfortunately, this process was affected by another setback; this occurred at the beginning of the COVID-19 pandemic and would have significant impact on and further delay the process acquiring the necessary programming skills in order to properly finalize of all VMKLI's. Face-to-face interaction appears to be the most beneficial approach for this type of teaching and learning and this did not transfer well to video tutorials. As a result, the majority of work developing the VMKLI's would be postponed for approximately one and a half years and enforce the eventual development to occur during latter stages of the research project.

In the end the correlation between Pure Data and MobMuPlat would turn out to be a success and would allow for the creations of the VMKLI's according to the predetermined specifications. In addition, it became apparent that Pure Data would feature a number of additional technical/designing possibilities and allow it to be used as a designing platform (this also applies to Max/MSP). Pure Data enabled important designing possibilities to be achieved with accuracy and precision (rather than drawing all of these using pen and paper) as well as numerous other technical tasks all within the software itself (i.e. colour coding and decorating other aspects of the keyboard layouts), this allowed for a much faster trial and error period largely due to any editing, correct and changes to be performed quickly without starting all over again.

Throughout the duration of the project and for these past five years of my life, a number of challenges both from technical perspectives as well as external circumstances have made significant impact on the development of the research project as well as the final outcome, both positively and negatively. The past three years have been difficult for every human citizen worldwide due to the COVID-19 pandemic and enforced entirely new different approaches and working methods for communications which may be permanent incorporated and standardized in most if not every type of profession and educational institution in coming years.

In many ways working under extreme pressure and with limited access to required resources and facilities enabled me to approach both the technical programming and compositions to be performed at a spontaneous (if not desperate) pace, in particular although to varying degrees - the musical compositions would showcase this immediate abrasive musical direction through their very distinct artistic experimental nature which would likely not have been achieved as success without the same amount of pressure. It should be noted that plans for future career paths will be difficult to pinpoint at this stage, however the immediate idea is to complete the remaining aspects of the research as planned and then approach various software developer companies in order to sell my ideas, thus allow other musicians out there to make similar or different types of music by using these VMKLI's (although in an updated form).

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APPENDIX 1

Before proceeding any further, it should be noted that the purpose and logic by including the following three Appendices is mainly to showcase the importance of the complex nature which revolves around the general phenomenon of evolved tuning systems. As evident in chapter 4, we examined our own Western tuning system and explored the various transitions throughout the course of the history beginning with ancient Greece (considered as the origin of Western music) and tracing numerous remarkable transitions to have occurred up until modern times; and on this occasion we witnessed many different aspects of history and origin of instruments which to be disputed in current times – and similarly this applies to other musical cultures as well. Thus, in order to approach, complete and transform information established through the significance of extensive music studies on indigenous evolved tuning systems and apply this knowledge transmittable to the creation of VMKLI's - in order to obtain and respectfully preserve all integral aspects applicable to and comprising the advancement of relatable tuning systems obviously is a significantly complicated and difficult task to resolve.

It should be noted that the purpose with chapter 5 was to provide the uninitiated reader solely with the most integral if not superficial information and overview in order to describe the most crucial aspects of tuning related to each of the five tuning systems. In that chapter we only witnessed the most integral musical instruments involved as influences to as well as divisions of intervals and not all of the other important aspects of significance which were crucial in the development and creation the VMKLI's.

One of the most integral factors in the creation of the VMKLI's (and of which should appear somewhat lacking in the overall review of all tuning systems in chapter 5) was the ability to pay overall respect to all integral aspects in relation to the execution of each tuning system in addition to significant emphasis and focus on characteristics found on a number of singular aspects of key and additional musical instruments – logically none of which should appear similarly assessed for in chapter 5.

MUSIC STUDY OF JAVANESE GAMELAN SEKAR PETHAK AND BALINESE GAMELAN GONG KEBYAR ENSEMBLES

This Music Study will deal with the standard percussive instrumentation found in Indonesian gamelan music. The instruments taken into account here are commonly found in ensembles found in or outside Indonesia going by the names *Gamelan Sekar Pethak* (Java), and *Gamelan Gong Kebyar* (Bali); thus, any typical melodical gamelan instruments according to Western terminology related to woodwind and stringed instruments such as *suling* (air reed) and *rebab* (bowed string instrument) will be omitted in this Music Study. The majority of instruments found in gamelan orchestras are based on percussion instruments; the tuning systems (*laras*) in Indonesia, *pelog* (seven-tone) and *slendro* (five-tone), are deeply rooted in these instruments while the melodic instruments primarily functions as a secondary asset to the ensembles. The main focus on this subject revolves around tuning of Javanese and Balinese gamelan instruments thus any other aspects of gamelan will be omitted from this research.

The names *Gamelan Sekar Pethak* and *Gamelan Gong Kebyar* derive from actual categories of Indonesian ensembles in Java and Bali, respectively. Interestingly, while such ensembles may be found in different continents all over the world, in the majority of cases these have been manufactured in Indonesia. Further, it is important to establish the fact that there are other types of gamelan ensembles to be found all over Indonesia (including Java and Bali) and contains numerous different categorisations of percussion instruments which are either similar, partially and/or dissimilar and names relatable or non-relatable to those found in the aforementioned category of ensembles dealt with in this Music Study.

Interestingly enough, Indonesia music is mainly composed with its basis on timbral relation between percussion instruments and somewhat executed in the complete opposite way of how Western music is approached; where the melodic instruments are commonly known to be the main focal point of music composing (besides singing), while drums and percussion instruments take a secondary more supporting position in the music.

Gamelan is a musical style originating from Indonesia. According to Sorrell "…the word gamelan is usually translated as the action (-an) of a hammer (gamel) (Sorrell

N. , 1990, p. 20). The two most infamous islands, Java and Bali, are recognized for their gamelan music all over the world, each known for their own particular blend and uniquely distinguishable style of gamelan music.

Javanese and Balinese Music

Evidences of Indonesian culture can be traced back to ancient times in the shape of reliefs carved in stone which can still be found in old Hindu temples such as Prambanan and the Buddhist temple of Borobudor (both erected during the 9th century) in Java; these carvings provide evidence of several musical instruments derived from India and presumably played by local musicians, none of which are commonly found in any modern gamelan ensemble today (Sorrell N. , 1990, p. 23). The instruments depicted are almost exclusively Indian and displays side-blown flutes, bottle-shaped drums, and plucked string instruments; however, according to Lindsay, Javanese tradition "… claims that gamelan music existed long before Prambanan and Borobudor, although the same tradition attributes the creation of gamelan instruments to Hindu gods" (Lindsay, 1979/1992, p. 4).

The earliest known evidence of Indonesian gamelan musical activities was documented on ancient palm leaf manuscripts (called lontar in the Indonesian language) dating back to an unknown period in ancient times, in addition evidences found on bas-relief (mainly found at Borobudor dating back to the 9th century) suggests existence of basic gamelan instruments such as gongs, bells, and hand drums although no metallophone instruments to appear in ancient times – according to Tenzer ancient gamelan ensembles contained fewer and larger instruments than current gamelan ensembles (Tenzer, Balinese Music, 1991, p. 20). Sorrel and Lindsay concurs that the appearance of gamelan instruments were larger sized in ancient gamelan ensembles, while Lindsay suggests that these can be possibly dated back to the 12th century (found in palaces in Yogyakarta and Surakarta which features instruments from Gamelan Kodokngorek and Gamelan Munggang ensembles), and tuned to a three-tone scale system including a number of quite large gongs (up to 125 cm wide in diameter) (Lindsay, 1979/1992, pp. 7-8) (Sorrell N. , 1990, p. 36). Further, Sorrell suggests that the original intent with gongs were to be used as a type of signalling system (Sorrell N. , 1990, p. 19).

Similar to a number of other ancient musical traditions (among others, the Indian tradition), Gamelan music has mainly relied on an oral tradition in order to retain its musical tradition from one generation to the next. Both Indonesian and Indian musical principles is commonly taught based on a guru-disciple relationship, where each student appoint the guru themselves (Tenzer, Balinese Music, 1991, p. 20).

Conceptions on tuning

Although, firm documentation on the earliest traces of tuning systems cannot be accounted for with certainty, it is possible that the slendro scale is the earliest tuning system to appear, at least among contemporary tuning propositions. Both Tenzer and Lindsay concur that the slendro scale quite possibly emerged between 5th century and the Islamic and Dutch rule in Java (Tenzer, Balinese Music, 1991, p. 20) (Lindsay, 1979/1992, p. 38). On the other hand, the exact emergence of the pelog tuning system is less apparent, the earliest known instruments to be tuned to pelog are Sekaten gamelan instruments possibly dating back to the 16th century; similar to other medieval/ancient gamelan instruments are larger in appearance and extremely low in pitch (Lindsay, 1979/1992, p. 8).

Differences between Javanese and Balinese gamelan music

Javanese gamelan music is generally considered to be soft and slow which may possibly yield a profound meditating effect on certain people due to its relaxing, calm and shock-less resonant sound; on the other hand, Balinese gamelan music is characterized as challenging, loud, hard and fast and more dynamic than its Javanese counterpart – with strong influences from Western music, and in particular jazz.

Classification of instruments

Many of the instruments still found in modern gamelan ensemble have existed for at least one millennium, while others only for a number of centuries. Since the evolution of most instruments have not been properly documented during the majority of their existence, most likely we will never be fully capable knowing the exact emergence and/or when/how they eventually were integrated into gamelan ensembles, thus any later additions, adaptions, and potential modifications to any instruments prior to the past few centuries most likely will still remain completely unknown to us.

An interesting case about Indonesian gamelan is that all current instruments appears to have been firmly recognized and established within their musical culture long before any written ideas or documentations about their musical classification. The oldest known written document mentioning gamelan instruments or at least to provide any indication of sound reproduction dates back to the seventeenth century, and appears to have been written in a court genealogy (Babad Buleleng, in Indonesia) (Hood M. M., Gamelan Gong Gede: Negotiating Musical Diversity in Bali's Highlands, 2010, p. 72). Approximately a century later, another historical manuscript called Prakempa appears to document a five-tone scale (presumably believed to be pelog), although the time period when this scale emerged in gamelan is not entirely known (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 33).

Pa yin, Mandala and Greek classification systems

It is worth mentioning that Indonesia borders other significant musical cultures which were among the earliest and most significant innovators proposing classifications on musical instruments while simultaneously capable of preserving and documenting significant aspects of their ancient musical culture (such as India and China). For instance, the Chinese *pa yin* classification, which is the oldest still existing classification system of instruments, dates back approximately 3000 B.C. (Kartomi, 1990, p. 34). Further, India provided the *Mandala* classification system which is mentioned in the ancient writings of Sanskrit dating back to the second millennium B.C. (Sorrell & Narayan, 1980, p. 94). However, despite the long Hindu rule and influence across the Indonesian archipelago appears to never have inspired Indonesians to ever document anything about their musical heritage beyond depicting instruments in ancient times. Whether as a consequence to the above or completely coincidental, no firm and widely acceptable classification system of gamelan instruments exists; thus, in the following paragraphs we will address a number of propositions provided by either Indonesians or Westerners in more recent times, prior to proposing my own suggestion of a classification system which has been exclusively developed/proposed for this research project.

Jaap Kunst's classification system for gamelan instruments

One of the most significant Western scholars to propose a classification system for gamelan instruments in the 20th century was the Dutch scholar Jaap Kunst who termed it as “the nuclear theme (Kartomi, 1990, p. 7). He divided the instruments into five categories; a) cantus firmus (nuclear theme) instruments, b) interpunctuating (colotomic) instruments, c) instruments playing a more or less independent counter-melody, d) paraphrasing instruments and e) agogic instruments (Sumarsam, 1995, p. 145).

Hornbostel-Sachs classification system

Despite the close and amicable correspondence between Kunst and the famous ethnomusicologist Erich Moritz von Hornbostel, their approach towards classifying instruments appears slightly different. Von Hornbostel, together with Curt Sachs established what is now regarded as the renowned Hornbostel-Sachs classification system commonly used in Western music culture - a system which divides grouping of instruments as follows: 1) Struck Idiophones, 2) Plucked Idiophones, 3) Friction Idiophones, 4) Blown Idiophones; all of which will not be further described (Von Hornbostel & Sachs, Classification of Musical Instruments: Translated from the Original German bu Anthony Baines and Klaus P. Wachsmann, 1961, p. 14). Further, the Italian composer and theorist Gioseffo Zarlino came up with a classification mainly based on the types of mallets/hammers used to play particular instruments (Kartomi, 1990, p. 149). It should be noted that current Javanese musicians most likely would find any of these propositions for classification systems to be inferior and incorrect compared to their own native interpretations.

Ancient Javanese classification system

Suggestions for classification system proposed by Indonesian musicians

The Javanese musician Sindoesawarno provides a completely different classification system which takes its basis on a different categorification of instruments compared to any of the above; according to him instruments are supposed to be divided into a group of two – which is entirely based on the physical placement of instrument to appear in an ensemble and distinguished thus; 1) instruments placed in the front of the performing area, and 2) instruments placed in the back. His argument is that instruments such as gender, rebab, kendhang, slenthem and bonang will be placed at the front due to their high status, while instruments such as saron and various gongs (i.e. instruments not responsible for producing embellishment) should be placed in the back (Kartomi, 1990, p. 89).

In addition to any of the aforementioned classification systems, an entirely different categorisation/classification exists which mainly distinguishes between female and male type of instruments (i.e. the same or same type of instrument, but distinguished between a larger or smaller versions of it), such as bonang barung (female) and bonang panerus (male) (Kartomi, 1990, p. 89). Kartomi states the distinction between female and male instruments as follows: "… female instruments are larger because the size of the womb is larger than the penis" (Kartomi 1990, 89). There are also other classification systems applied in Javanese gamelan, however we will not discuss this subject any further.

1. ricikan dijagur/ditabuh:	"instruments beaten with a padded hammer," e.g., the suspended gongs
2. ricikan dithuthuk:/ditabuh:	"instruments knocked with a hard or a semihard hammer," e.g., the saron (keyed metallophones) and the bonang (gong-chimes)
3. ricikan dikebuh/ditabuh:	"hand-beaten instruments," e.g., the kendhang (drum)
4. ricikan dipethuk/ditabuh:	"plucked instruments," e.g., zithers
5. ricikan disendal/ditabuh:	"pulled instruments," e.g., jew's-harp with string mechanism
6. ricikan dikosok/ditabuh:	"bowed instruments," e.g., the rebab
7. ricikan disebul/ditabuh:	"blown instruments," e.g., suling (flute)
8. ricikan dikocok/ditabuh:	"shaken instruments," e.g., the angklung (bamboo idiophone)

Table A1.1. Javanese classification system supposedly dating back the ages of oral tradition in Indonesia (Kartomi, 1990, p. 85)

Author's Classification of instruments

Before reading any further, it is important to state that my own creation of a classification system serves a few purposes; the original purpose of this undertaking intended to display overview of a classification system which encompasses the ensemble as a whole unit and provide clarity decipherable and understandable to any uninitiated reader with a Western background, while it further sought to emphasize the relationship between fashioning processes and tuning in relation to both Gamelan Sekar Pethak and Gamelan Gong Kebyar ensembles – an aspect which appears somewhat neglected in any of the other propositions addressed previously in this research.

To a great extent the process creating a classification system was initiated through hinspiration by examining several different propositions of classification systems provided by scholars from both Western and Indonesian perspectives (including the ones already described). However, in the process of developing my own classification, the main inspiration and impact on this creation derived from a model provided by Sorrell, which showcased a relation between instrumental groups and their musical position in Javanese gamelan ensembles. Further, this model had similar impact on the creation of a classification system for Balinese instruments.

My own classification system is based thusly; each category of instruments have been confined to four different categories: 1) the kendhang drums are the closest connotation to rhythmic leaders of every gamelan ensemble (Sorrell N. , 1990, pp. 39, 105). 2) The gong-chime (all besides the bonang) instruments and gongs closely follow the kendhang, and provide the ‘colotomic’ (phrasing and punctuating) function that support the rhythm (Sorrell N. , 1990, pp. 34, 85). The Bonang (barung and panerus) instruments functions as the main embellishing (or melodic) leaders among the louder instruments in the ensemble (Sorrell N. , 1990, pp. 87-88). 3) Below the Bonang instruments, we find the three Saron instruments and slenthem which work as the melodic skeleton which the entire musical structure is based around, and lastly 4) the Gender and Gambang whose purpose is to elaborate on the melodic lines and provide with the softer sounds/texture in the ensemble instruments (Sorrell N. , 1990, pp. 31,79, 97-98).

Thus, the classification of instruments is largely based on their physical appearance and type of material used in order to construct the instruments, since this appears to initiate the manufacturing and ultimately the tuning strategies (from a Western standpoint) of found instruments. For instance, the bonang, kenong and reyong/tromping instruments may contain similar traits to metallophone instrument as they both consist of a range (or register) of different objects (keys or kettles) which are each tuned to produce different pitches, while other gong-chime kettle instruments entirely rely on one individual object in order to produce sounds (akin to the gongs).

It should be noted that I have a Western background, thus it is quite possible that the following propositions may bear striking resemblance to, strong influences of or pertain strong ties to a Western point of view - despite that the exploration of Indonesian gamelan was the result of a 12-month period dedicated to extensive research (i.e. this Music Study) absorbing all integral aspects of the musical culture and as such any Western influences in this process should be considered purely unintentional. Other musicians or scholars from the Western culture might concur or reject on the following ideals and principles if they were to propose similar classification systems themselves. A Javanese or Balinese musician and/or scholar might interpret the relation between purpose and relation of instruments entirely different, and might consider this classification to appear completely incorrect or inferior to a system proposed by an Indonesian scholar.

Classification of instruments in Java

The instruments discussed in the classification system of Java are based on instruments commonly found in current Gamelan Sekar Pethak.

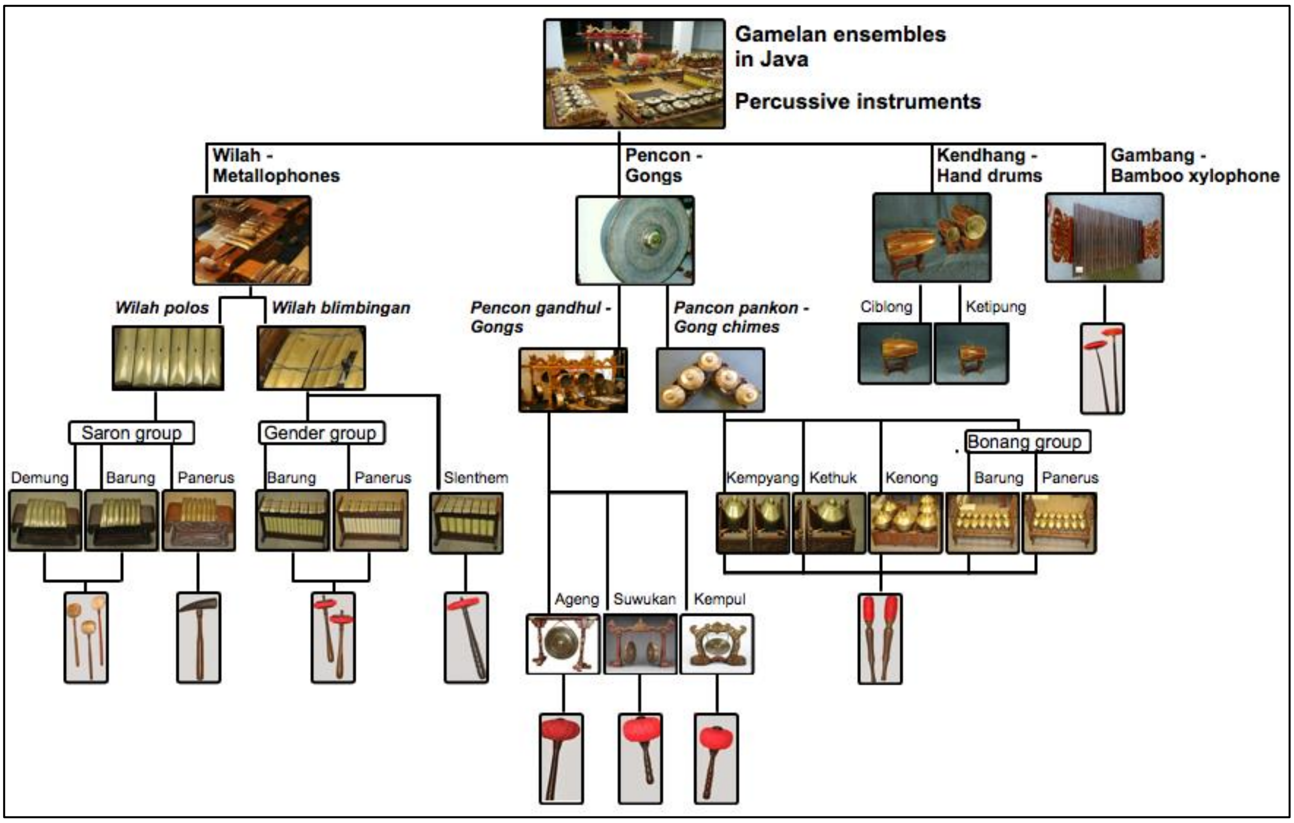

Figure A1.0-1. Classification system of Javanese instruments based on my proposition

As implied above, among the aims for developing this classification system was to retain the inherent stature in which each instrument possesses and further categorizing these into separate groups in order to represent their current musical position within the respective ensembles. However, based on this alone, such a classification system will not be completely possible or even logical, thus minor compromises have been taken into consideration. For instance, instead of grouping the gender instruments together with the gambang instrument (as per their instrumental relation within a gamelan ensemble), it appears more logical to place the gender instruments into a wilah category of instruments and further distinguish them by creating a wilah blimbingan subgroup (which also includes the slenthem instrument), and separate this from another subgroup, wilah polos group (which comprises solely of saron instruments) – thus, as a result the wilah category of instruments will comprise all metallophone instruments (whereas the purpose of the subgroups is to distinguish the two different physically shaped metallophone keys).

Further, the physical appearance of the keys on gender instruments neither resemble the ones found on saron nor gambang instruments, thus a reasonable excuse to exempt it from being grouped together with the gambang instrument. Another potential categorisation for the gender instruments would be to place them into a fifth category of instruments, although this may not necessarily seem very plausible. Interestingly enough, the physical shape of keys found on Gambang instrument relate to Wilah polos, except that they are made of bamboo instead of bronze or iron, thus the decision to assign this instrument into an entirely separate category seems logical.

Indonesian gamelan instruments

Both Javanese and Balinese gamelan ensembles share similar types of percussion instruments, such as gongs, gong-chimes, metallophone instruments, and wooden drums. Despite these similarities, they seldom share the same name and similar on both islands - with the exception of Reyong (exclusively for Balinese ensembles) all gamelan instruments are commonly played solely by one performer per instrument.

Gamelan instruments are mainly grouped into two dominant categories; pencon, which is the name most commonly associated with both gongs and gong-chimes kettle instruments; and wilah/bilah (Java/Bali), all of which are metallophone instruments (one wilah/bilah is equivalent to one key on a metallophone instrument) (Sorrell N. , 1990, p. 28). It is important to address that the terms wilah and pencon are solely used for Javanese gamelan ensembles only, however the decision to use the latter term for both Javanese and Balinese gong-chime kettle instruments was made in order to simplify matters for the uninitiated reader, since no proper word to describe this group of instruments appears to exist in Bali.

The pencon and wilah instrument groups are further divided into subgroups; the pencon is divided into suspended/hanged (pencon gandhul) and cradled gongs (pencon pangkon), the latter will be referred to as gong-chime kettles from now on (Sorrell N. , 1990, p. 29). In compliance with what has been briefly indicated previously, keys on Javanese wilah instruments are mainly categorized by two distinctive shapes; namely wilah polos and wilah blimbingan (which we will discuss later) (Sorrell N. , 1990, pp. 28-29). Differently, keys on all Balinese metallophone instruments appears to comprise only one distinctive shape, which are distinctively different in comparison to their Javanese counterparts. It should be noted that both pencon and wilah instruments come in a variety of different sizes.

Javanese gamelan ensembles usually contain approximately 156 wilahs and 75 pencons altogether; this constitutes a complete gamelan ensemble and is also known as double gamelan (i.e. gamelan seprangkat - sepangkon for slendro instruments only) in order to fully accommodate either tuning system (i.e. pelog and slendro) (Sorrell N. , 1990, pp. 28, 56). Due to the different number of notes and divisions between intervals in each tuning system this may affect the number of keys and gong-chime kettles found on each complete set of instruments, although deviations in size/thickness/number of instruments may be more significant in other types of gamelan ensembles independent of region and island in Indonesia. However, a thorough elaboration on pelog and slendro tuning systems will be presented later in this Music Study.

Brief descriptions and history of instruments

Suspended gongs

Gong instruments found in South-Eastern Asia dates back at least a thousand years and the word/term gong can be traced back to Java, Indonesia (Tenzer, Balinese Music, 1991, p. 19). Suspended gongs are always stored vertically on wooden stands and the appearance of typical Indonesian gongs are generally flat except the area around the protruding boss (in the shape of a circular knob) which is located at the centre of the instrument. Different to some types of gongs which are used in certain different continents and similar to the majority of cymbals, the outer rim of Indonesian gongs has a thicker diameter (usually between 5-10 cm), while the rear part of the instrument is hollow.

Commonly, gongs comes with two holes drilled at the top where ropes are pulled through and looped together, although some gongs may also appear with “T” shaped “handles” affixed to them which allows ropes to be twirled around the points and tightened - in both cases, they are commonly attached to a wooden stand or a number of wooden stands. Gongs are normally suspended by either a thick piece of rope or two separate pieces of rope (attached to either side of the gong) and then attached and tightened to a hook on the wooden stand. It is common for gamelan ensembles to have separate stands for slendro and pelog tuning.

Gong-Chime kettles

The origin of gong-chime kettle instruments is not entirely clear, however, it is quite possible that they have been part of the Indonesian music culture as far back as the Bronze Age and possibly emerged around the same time as suspended gongs (Hood K. M., 2000, p. 365). Gong-chime kettle instruments usually are carried and stored in wooden cases (called rancak in Indonesia) and comes in different sizes depending on the size of the kettles.

Metallophone instruments

Similar to gong-chime kettles, the initial emergence of metallophone instruments in Indonesia appears equally difficult to trace. However, among the earliest extant evidence is a relief found in the Borobudor temple and depicts something that resembles a single-octave saron instrument. Based on this, it appears that Javanese xylophone or metallophone instruments have been in existence since at least the 9th century. Whether this was the initial type of such an instrument, or whether it was mainly a solo instrument without accompaniment of any other instruments (or a part of any gamelan ensembles) at that point, remains unclear (Hood M. , The Nuclear Theme as a Determinant of Patet in Javanese Music, 1977, pp. 240-242).

Further, according to Tenzer, it appears that metallophone instruments were not an integrated part of gamelan ensembles around the 9th century since the instrument does not appear on any depictions of ancient gamelan ensembles (Tenzer, Balinese Music, 1991, p. 20). McPhee concurs to this claim and adds that there is also a relief at the Borobudur temple which depicts an archaic xylophone instrument and a small gong, however no stone reliefs of ensembles which features both gongs and metallophones (McPhee, 1976, p. 24). In addition, he mentions occasional reference to literature dating back to the 11th century (which has been discovered in Bali), which describes bamboo tube xylophone instruments as the only tuned percussion to be found in contemporary ensembles of the time and otherwise accompanied by instruments associated with Indian music (lute instruments, flutes, hand drums etc.). Thus, most likely the emergence of metallophone instruments made of bronze would appear at a later point in time (McPhee, 1976, p. 24).

In this context, the oldest extant proof of any metallophone instruments in Indonesia, are a number of saron instruments found in ancient Sekaten gamelan ensembles dating back to the 16th century – these comprises noticeably thicker keys than contemporary instruments and played with large hammers containing beaters made of buffalo horn (Lindsay, 1979/1992, p. 8). According to Lindsay, peking appears to be the latest addition among the saron instruments (Lindsay, 1979/1992, p. 16). Further, she does not mention any metallophone instruments to be part of Gamelan Kodokngorek and Gamelan Munggang ensembles, both of which possibly dates back to the 12th century (Lindsay, 1979/1992, pp. 7-8) Thus, we can assume that saron instruments occurred in gamelan ensembles somewhere between the 12th to the 16th century, possibly emerging at some point during the Majapahit Empire.

Interestingly enough, no information or firm evidence about Gender instruments appears in any of the gamelan ensembles mentioned above. McPhee suggests that the gender instruments may be a later development which took its basis from saron instruments (McPhee, 1976, p. 30). However, due to their popularity and the strong Hindu connotations in Bali, it is likely that these instruments possibly emerged prior to the establishment of the Muslim rule in Java.

Hand drums

Drums appears to be found in practically every musical culture in the world in one form or another, and Indonesian gamelan is no exception. It is quite possible that drums were part of Indonesian gamelan music since the emergence of gongs and gong-chime kettles, if not further back in time. Carvings found in the temples of Prambanan and Borobudor depicts drums, although these appears to be bottle-shaped and might suggests that different types of drums appeared in Indonesian music back then (Lindsay, 1979/1992, p. 4). Thus, the emergence of kendhang/kendang wooden hand drums is not entirely clear, however, a possible theory is that it could possibly be a descendant of the similarly shaped ancient Balinese pejeng drum. These drums were approximately 2 m large “hour-glass shaped” drum originally cast in bronze or iron, and were produced approximately in the first few centuries of the Christian era (Ooi, 2004, p. 430). In older gamelan ensemble the kendhang hand drum used to come in more varied sizes with a general emphasis on larger drums than contemporary ensembles, nowadays there are usually only two distinct sizes to be found on both Islands.

Bamboo xylophone

The bamboo xylophone instrument appears to be non-existent in Bali, and rarely used in contemporary Javanese gamelan ensembles, thus very little information about its emergence altogether. It appears that Gambang used to be found in various sizes and ranges at some point in history, however commonly appears to be found in one size only within current Gamelan Sekar Pethak ensembles. The musicologist Jaap Kunst suggested that an older variant of gambang, called gambang gangsa (containing bronze keys) was the prototype to the entire group of saron instruments (Sorrell N. , 1990, p. 41). This may suggest that the gambang instrument emerged prior to the saron instruments.

Cymbals

Similar to numerous other gamelan instruments it is also difficult to trace the origin of cymbals in Indonesian music, in particular since no evidence of such instruments appears to exist in the 9th century. Lindsay states that the aforementioned Gamelan Kodokngorek and Gamelan Munggang ensembles most definitely contained cymbals (called *rojeh* in Indonesia) (Lindsay, 1979/1992, p. 7). Thus, it appears that they were part of gamelan music and can be dated back to at least the 12th century. Cymbals may possibly have emerged simultaneously in both Bali and Java at the same time; while another theory may suggest that the royal entourage brought them when they fled to Bali in the 15th century. It should be noted that cymbals are not a common feature in contemporary Javanese gamelan ensembles yet are still an important aspect of current Balinese gamelan music.

Mallets

Mallets for gamelan ensembles come in different shapes and lengths, and primarily based on the task and purpose of the supposed sound reproduction expected of an instrument in addition to the approach and execution of playing the instrument (this will be discussed in detail later). All percussion instruments come with specific mallets assigned for each type of instrument (besides the Javanese kendhang, which is played by hands). Mallets are completely integral to gamelan music; commonly performers on metallophone instruments combines the usage of mallets and additional finger/hand orientation to dampen keys in order to reproduce the expected or required effects from the keys, this approach affects the timbre, tuning, dampening, attack, decay and sustain of the instrument. These decisions are completely necessary in order to utilize the full range/capacity of the instruments in order to reproduce/create sounds which will blend perfectly with the rest of gamelan ensemble and sonically contribute to the wholeness of the ensemble.

It is important to address that Javanese and Balinese gamelan ensembles quite often use completely different types of mallets when performing similar/identical types of wilah and gong instruments, although suspended gongs on both islands are struck by heavily padded mallets with wooden discs in order to produce heavy yet smooth sounds when striking the gongs. One such mallet is normally used per gong, a practice commonly found on both islands.

In Javanese ensembles padded mallets are used almost exclusively on percussion instruments with the exception on saron demung and saron barung, which are played using mallets containing oval shaped wooden strikers. The saron panerus is played using a mallet containing a buffalo horn hammer. Contrary to Javanese gamelan ensembles, only a small selection of instruments such as the Jegogan, the largest gong and gong kempur uses padded mallets, while all other Balinese percussive instruments are played with mallets containing either hammers or stick shaped beaters.

Both islands offer completely different set of characteristics in their music, whereas contemporary Javanese gamelan music mainly focuses on softer sounding compositions, this is quite contrary to the current practices of Balinese ensembles where focus is to produce loud and bright sounds in order to make more adventurous and artistically challenging music. To a large extent this division can be attributed to the usage of mallets between the islands; as such, the gender instruments in Java are played with soft padded mallets, while they are played with beaters made of wood or hammers, in Bali (Sorrell N. , 1990, p. 25).

Categories of Javanese instruments

The Javanese gamelan instruments have been grouped into four main categories; 1) Wilah (metallophone instruments), 2) Pencon (gong instruments) 3) Kendhang (hand drums) and 4) Gambang (bamboo instrument). In terms of categorizing, the Gambang and Kendhang have been given less space than metallophone and gong-chime kettle instruments, for quite natural and obvious reasons. A fourth category, with the sole contribution of one singular instrument, namely the bamboo xylophones (Gambang), the reasoning for this inclusion is because it appears to be integral in current Gamelan Sekar Pethak ensembles. Most group of instruments are further divided into subgroups, which comprises of a female (the larger sized and lowest pitched of the pair) barung, and male (the smallest and highest pitched of the pair) panerus counterparts. It should be noted that barung/panerus usually appears to be reserved for kendhang and saron instruments only, but used here to simplify matters for the uninitiated reader.

1. Wilah instruments

The Wilah instruments (metallophone key instruments) are divided into two categories due to distinguishable physical shapes; 1) Wilah polos, contains convex shaped keys with a curved arch top – their appearance can be described as slightly flatter than a semi-circle, while the bottom of the keys are commonly completely flat (at least the ones found in contemporary gamelan ensembles) and the overall physical appearance are commonly smooth. 2) Wilah blimbingan, contains concave shaped keys, where each side appears in acute angles which are curve shaped, while the top is u-shaped (instead of straight), similar to its counterpart the bottom of the keys is commonly flat and the overall appearance of the keys are generally jagged. Further, the metal found on wilah polos keys are generally thicker than that of the rather thin wilah blimbingan. Because of its fragile and delicate shape, the wilah blimbingan are played with mallets containing beaters (in the shape of flat discs) with heavy padding encircled around them.

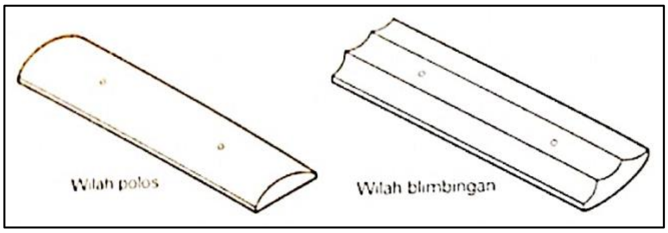

Figure A1.2. Depicts the difference between Wilah polos and Wilah Blimbingan ((Sorrell N. , 1990, p. 30)

1.1 Wilah polos

Wilah polos instruments are grouped into a subcategory described as a Saron Group (see Figure A1.2.), the instruments within this group comes in three different sizes as follows; saron demung (also known as demung) which is the largest and comprises the lowest range (i.e. the lowest pitched keys), saron barung (also known simply as saron) is the medium sized, and saron panerus (also known as peking), is the smallest within this group and contains the highest pitched keys (exact tuning on these instruments will be discussed later on in this chapter).

Lindsay claims that there is no uniformly accepted approach to play this instrument (Lindsay, 1979/1992, p. 16). This claim is substantiated by the fact that the instrument is played with a hammer instead of mallets with wooden beaters similar to the other types of saron instruments. Commonly, all Javanese saron instruments contain seven wilahs per instrument independent on the tuning system, however since there is no standardized system for metallophone instruments, some ensembles may be found with more or less amount of wilahs (most commonly a deviation of one or two).

Saron instruments are commonly rather low in height, approximately at 15-20 cm, which makes the most adequate playing position while seating and in compliance to how a variety of other gamelan instruments are performed ideally. The performer plays the instrument using only one mallet (usually in the right hand), while the other hand allows for different dampening techniques primarily by pinching the key between thumb and forefinger in order to affect the timbre (Sorrell N. , 1990, p. 32). The size of the smallest wilah on saron panerus approximately 35.5 cm long and 9 cm wide, and gets progressively bigger towards the left (Sorrell N. , 1990, p. 31).

The thickness at the centre on the smallest wilah is approximately 1 cm (i.e. distance between the top of the arch and bottom of the key) (Sorrell N. , 1990, p. 31). The wilahs rest on trough resonators and are fitted through holes, the troughs are attached on the edge on each side of the case, while the keys rest on cushioned cloth padding attached to the rim of the wooden case (in order to add a natural dampening effect not affected by any further action made by the performer), (please see Figure … for more details). The area beneath the keys is mostly hollow.

Figure A1.3. Showing the hollow insides of saron instruments

The saron instruments are played with mallets comprising hard wooden strikers mainly due to the intention of reproducing hard and piercing sounds; however, the keys are never struck with much force, although the player may proceed the instrument by striking the keys either softly or loud. The most appropriate method is to hit the keys with the beater facing straight down and hitting the centre on each wilah. The only major difference between the saron instruments (besides size and tuning) is that the saron panerus instrument appears to be the most important and dominating - largely due to reproducing the most distinctive and piercing sounds among the three. Most commonly gamelan ensembles contain one set (i.e. two) of each saron instrument per tuning system (pelog and slendro).

1.2 Wilah Blimbingan

The Wilah blimbingan instruments consist of one subcategory called Gender Group and one additional instrument called slenthem. The Gender group is further divided into two; Gender barung (female) and Gender panerus (male), both of which usually contain 14 wilahs (although they may appear with 12 or 13 wilahs within certain gamelan ensembles). All wilah blimbingan instruments are played with mallets containing padded disc shaped beaters which are encircled by a thick ring of felt. Different from saron instruments, the gender instruments are played with two mallets (thus allowing for minimal or no dampening possibilities) due to the high requirement of precision in order to accentuate very complex sounds.

Despite that slenthem shares the majority of physical traits found on Gender instruments, its functionality and appearance within the gamelan ensemble appears to be somewhat stuck in the middle between saron and gender instruments (Sorrell N. , 1990, p. 32). Melodically, slenthem relates more towards saron instruments, largely due to the same range of pitches and the same amount of wilahs. However, slethem comes with tube resonators and comprises of larger keys which are similar to that of the Gender instruments. Further, slenthem is played with only one mallet (similar to the saron instruments) in order to allow the performer to play while simultaneously dampen keys, the handles on the mallets are noticeable longer than those found on genders instruments. Besides these obvious differences, slenthem is practically identical to the gender instruments.

Figure A1.4. Showing the tube resonators found inside Gender (and Slenthem) instruments

Common to all Wilah blimbingan instruments is that the wilahs are suspended over tuned cylindrical tube resonators (instead of resting on trough resonators); these are commonly made of galvanized sheet metal or zinc (Sorrell N. , 1990, p. 33). On this occasion, each wilah is assigned to its own specific tube resonator and tuned to the exact same pitch. Commonly, tube resonators on the lowest tuned wilah blimbingan keys usually appears with almost entirely plastered top parts, thus only leaving room for a tiny round hole (although progressively larger on the next two to three keys) - while the top part on the remaining tube resonators are usually completely open (please see picture for reference). About halfway in the row, the tubes appear with less depth and get progressively smaller in accordance with the higher pitches (McPhee, 1976, p. 31). Any additional plastering is primarily done in order to precisely tune and compensate for any possible mistuning between each particular key/resonator (see Figure …).

Since there are no troughs (nor nails) on wilah blimbingan instruments, the keys are attached by the aid of a long single length of cord. All gender and slenthem instruments come with wooden crates containing bed stools (or handles) on each end of the instrument and commonly found with two drill-holes on each side. The cord only passes through one of the sides (see Figure), and is locked on the other bed-stool, thus allowing further possibilities to tightening or loosening the tension of the cord (see Figure … for reference).

Figure A1.5. and Figure A1.6. Showing how the cords are attached to the Gender and Slenthem bed stools

In order to retain the wilahs firmly in place (i.e. prevent them from falling out of their positions), sets of "*metal hooks*" (or knobs) are mounted next to (almost) every wilahs on either side of the rim on the wooden case and affixed through a single length of cord which passes through each of these. Similarly, the Wilah blimbingan also contain drill-holes although these serves a slightly different purpose; since these contains no trough resonators, the keys are suspended while the cord is looped from above and tied into knots by a piece of wood or branch (through the aid of a small knot to keep each key in place and prevent the knots from detaching) underneath each key (see Figure …) (McPhee, 1976, p. 31). Usually a complete gamelan ensemble (gamelan seprangkat) contains one of each gender barung/panerus instrument in slendro, while two of each in pelog (in total six gender instruments) (Sorrell N. , 1990, p. 33).

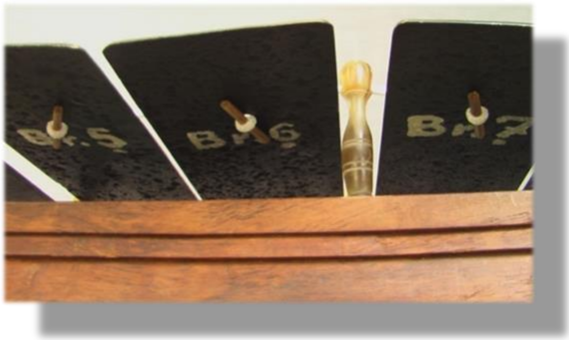

Figure A1.7. Displays the underneath of Wilah blimbingan metallophone keys

2. Pencon instruments

The pencon classification of instruments appears to be entirely in accordance with the model shown by Sorrell earlier in this Music Study, thus no deviations occur in this categorization of instruments.

The Pencon instruments have been divided into two distinctive types of instruments, 1) Pencon gandhul (suspended gong instruments), and 2) Pencon Pangkon (cradled gongs and also commonly known as gong-chime kettles). Both terms derive from the Indonesian language; gandhul means 'hanging', while pangkon means 'cradled' (Sorrell N. , 1990, p. 29). Both types of instruments are characterized by very distinctive shapes; the surface on the pencon gandhul can be described as rather flat around the central protruding boss and concave shaped near the edges, while the surface of the pencon pangkon resemble the shape of a round (rather than an oval shaped) urn. Each gong-chime kettle is relatively round, while flat on the bottom and hollow inside – the bottom part of its "body" appears convex shaped and becomes wider halfway to the top, while the upper part of slopes up to the protruding boss (see Figure A1.5. and A1.6) (Sorrell N. , 1990, p. 29). Further, none of the instruments within the pencon group require any type of resonators.

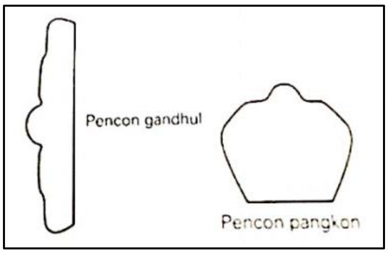

Figure A1.8. Depicts the difference between Pencon gandhul and Pencon pangkon (Sorrell N. , 1990, p. 30)

2.1) Pencon gandhul

Pencon gandhul (suspended gongs) always appear in a vertical position - the appearance of the instrument is circular shaped with the protruding boss at the centre of the instrument. Further, pencon gandhul is usually grouped into three categories; gong ageng (the largest and lowest pitched gong), gong suwukan (the medium sized gong), and a collective group of different smaller sized gongs, called kempul (the smallest and highest pitched categories of gongs).

Gong ageng is the most important instrument found in any Javanese gamelan ensemble (Sorrell N. , 1990, p. 49). In addition, it maintains a somewhat holy position and is the heart and soul among instruments found in any gamelan ensemble (Lindsay, 1979/1992, pp. 10-11). Gong ageng is approximately 85 cm in diameter and tuned to the coincided note 6 (for both slendro/pelog), thus requires only one instrument to accommodate both tuning systems (Sorrell N. , 1990, p. 35). Lindsay, suggests that there are usually only one or two gong ageng found in a typical modern Javanese gamelan, while old Javanese gamelan ensembles often had three or possibly more (Lindsay, 1979/1992, p. 10). In accordance with the musical examples provided in this Music Study, it is likely that the sound of gong ageng, due its very deep, calm and long sustained sounds possibly evoke a profound meditative effect on certain people.

Gong suwukan is the second largest gong found in gamelan ensembles. A typical gong suwukan is slightly smaller than the gong ageng with a diameter of approximately 63 cm; and in some cases used as the main gong for certain types of compositions that do not require any gong ageng (Sorrell N. , 1990, p. 35). Further, it is rather common to find gong suwukan as a substitute for gong ageng in smaller, less privileged gamelan ensembles, due to the high cost of acquiring a gong ageng. Most commonly there are two gong suwukan found in a typical gamelan ensemble, except for ensembles which do not contain any gong ageng instruments.

Kempul is the collective name of gongs that are smaller in size than the gong suwukan; up to six kempul gongs are usually found in contemporary ensembles although these are usually found in a range of different sizes and pitches which are specifically assigned to either of the two tuning systems, although the smallest one is approximately 45 cm in diameter (Sorrell N. , 1990, p. 35). No standardization is commonly associated among gong instruments on either island; however, sizes between gong ageng and gong suwukan usually appear to be within close approximation to each other.

2.2) The Pencon pangkon

The Pencon pangkon subcategory is divided into two; the first of these comprises three instruments called Kempyang, Kethuk and Kenong while the other comprises a bonang barung (female) and a bonang panerus (male) instrument and collectively termed as a Bonang Group. Further, all pencon pangkon instruments are positioned with the protruding boss facing upwards, instead of horizontal.

Gong-chime kettles may appear with slightly different physical appearances, in particular this applies to the kenong and bonang instruments whose shapes usually ranges somewhere between pencon pangkon (a shape that slopes upwards to the protruding boss), or in near approximation to those of pencon gandhul instruments (where the top appears entirely flat around the protruding boss). Obviously, this is dependent on the size and pitch of each gong-chime kettle found on the respective instrument.

All gong-chime kettles are placed separately in wooden crates and contain open boxes inside the crates and hollow at the bottom (see figure A1.9. for reference). Further, each gong-chime kettle rests on top of two or four sets of cords (depending on the size and instrument) in order to retain them firmly in place to the allotted space inside the wooden crate. The cords on kenong, kethuk and kempyang are attached to four knobs or small handles affixed to each edge on the wooden crate (see Figure …), while bonang instruments contains two lines of cords for each row of kettles (bonang instruments usually contain two rows of kettles) tied to resting points affixed to the wooden frame between every kettle - this secures each kettle to be firmly in place. Similar to gongs, the gong-chime kettles are hollow on the rear (i.e. opposite side of the pencu - protruding boss). All of the pencon pangkon instruments are played with a pair of mallets similar to drumsticks and comprises beaters which are encircled by coiled string padding.

Figure A1.9. Displays the Kempyang instrument and shows how the cords are attached to the knobs on the wooden case

The wooden crate for the Kempyang instrument is elongated, and contains two boxes with one common side. Interestingly enough, Kempyang and Kethuk could refer to two different things; they can refer to the name on one particular kettle on a Kempyang instrument, while it can also refer to two completely different instruments. The Kempyang instrument contains two similar sized gong-chime kettles; 1) kethuk, the largest and lowest pitched of the pair (commonly recognized by a flat surface around the pencu), and 2) kempyang, the smallest and higher pitched (recognized by a surface that slopes up around the pencu) (see figure A1.9.). However, the instrument can also be found with two gong-chime kettles with similar shapes as well (both either with a flat or sloping up appearance around pencu), although in this case one would appear smaller in size than the other. The instrument is limited to specific types of compositions only.

Figure A1.10. Displays a single Kethuk instrument with one gong-chime kettle, and a mallet next to it

The Kethuk (as a separate instrument) comprises one sole gong-chime kettle mounted onto a square-shaped wooden crate. Commonly, the size of the kettle appears to be slightly larger than the ones commonly found on Kempyang instruments. Similar to the Kethuk gong-chime kettle found on the Kempyang instrument, this also appears flat around the pencu. Most commonly, every gamelan ensemble contains one set of Kempyang and Kethuk instruments for each tuning system. Further, the Kethuk appears more frequently in gamelan compositions than the Kempyang instrument. The instrument is played with a mallet shaped like a stick and beater is encircled by light padding.

The Kenong instrument usually comprises up to 10 gong-chime kettles (Sorrell N. , 1990, p. 36). Different to the bonang instrument, the Kenong instrument is divided into separate wooden crates which often appears with either one or two boxes (twin crates) and similarly the same number of kettles stored in them. During performances, the kenong crates are assembled and arranged together, most commonly to form a U-shaped position although some ensembles might prefer to arrange them differently (i.e. meaning two twin crates positioned on the left side of the performer, two twin crates on the right side, and one twin crate in front - in line with the final kettle on both its left and right side). All of the kettles are pengcon pangkon shaped, although the degree in which the edges slope up to the pencu can vary somewhat. The pitches of the kettles usually start with the largest and lowest tuned kettle from the far left and progressively gets higher to the smallest and highest pitched on the far right. The sizes of the kettles appear rather similar as they are mostly all approximately 32 cm high while the diameter ranges from 34-37 cm (Sorrell N. , 1990, p. 36). Kenong is commonly used in all gamelan compositions and every ensemble contains one set of Kenong instruments for each tuning system, although commonly share the same kettle for slendro 5/pelog 4 and for tone 6.
The gong-chime kettles found on the Bonang instruments are placed on a very long elongated wooden crate which may resemble a bedframe and applies to both bonang barung (the largest and lowest pitched of the two) and the bonang panerus (the smallest and highest pitched). The Bonang bedframe is separated into two rows of seven; the row in front of the performer consists of pencon gandhul shaped kettles, while the other row progressively appears more towards pencon pangkon shaped kettles the further one moves to the right (Sorrell N. , 1990, p. 37). Interestingly

enough, the number of gong-chime kettles differ between the tuning systems; bonang barung and bonang panerus is commonly found with 14 kettles in pelog, while only 12 in slendro. Contemporary gamelan ensembles commonly contain one set each of bonang barung and bonang panerus per tuning system (Sorrell N. , 1990, p. 37).

Figure A1.11. The Bonang instrument shown from above

3. Kendhang instruments

There are commonly two types of kendhang hand drums found in contemporary gamelan compositions, kendhang ciblong (female) and kendhang ketipung (male). The kendhang hand drums contain two playing surfaces, the barrel (oval) shape of the drums makes one side slightly larger (female) than the other (male) and can produce up to as much as 14 different sounds. The largest (and lowest pitched) surface is positioned to the performer’s right side, while the smaller is to the player’s left side. The drumheads are often made of goat or buffalo skin and contains sets of ropes visible on both sides of the drums and tightened by sliding rings which binds the pairs of ropes into Y-shaped patterns - the ropes are further used to aid with the tuning of the drums and can be either tightened (by doing so, the pattern of ropes will gradually appear more towards V-shapes) or slacked (McPhee, 1976, p. 33).

Figure A1.12. Displays the shape of the Kendhang instrument

During performances, the drums are positioned in a rather horizontally position with each head pointing to either side of the performer and the drums are either placed in the lap of the performers or played while mounted on small separate wooden stands. Further, kendhang drums may contain a handle or a strap (attached around the performers neck) which allows the performer to play the instrument while standing. The typical gamelan ensemble contains one kendhang ciblong and one kendhang ketipung for each tuning system.

4. Gambang instrument

The gambang instrument shares some similarities to the saron instruments. For instance, the instruments appear in similar height (although the Gambang is slightly higher) and both shares wilah polos shaped keys resting on trough resonators (although these are noticeably longer and thinner than the ones found on saron instruments) with light padding on the edges of the wooden crates (Sorrell N. , 1990, p. 41). However, there are a few noticeable differences between the two; the keys on gambang are made of hard bamboo wood (called berlian in Indonesian) and the instrument usually comprises a large number of keys which covers the approximate range on both gender instruments altogether. Each ensemble commonly comprises two gambang instruments; one which contains 20 keys and tuned to slendro, while the other comprises 19 keys and tuned to pelog (Sorrell N. , 1990, p. 41). Further, the instrument is played with two mallets similar to those found on the gender instrument although comprising longer handles and narrower beaters.

Classification of instruments in Bali

Because of distinct and obvious differences between instruments and approaches to musical performances between Javanese and Balinese gamelan ensembles, thus the necessity to include an additional classification system entirely dedicated to Balinese gamelan instruments for this Music Study. On this occasion, the creational process proved to be similarly challenging. The instruments classified here are based on the instruments commonly found in Gamelan Gong Kebyar ensembles.

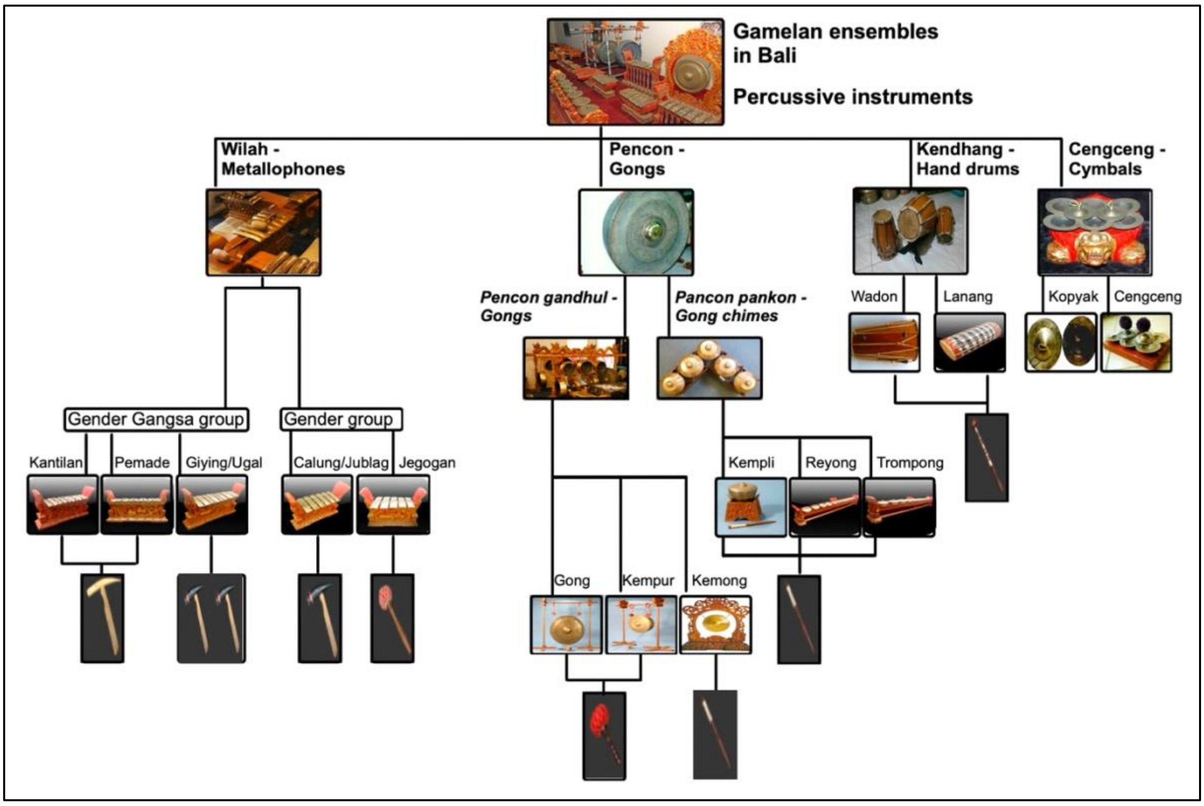

Figure A1.13. Classification system of Balinese instruments based on my proposition

The difference between instruments found between both islands is an important matter to discuss. For instance, cymbals are still commonly found in Bali and integral to contemporary Balinese gamelan compositions, while the instrument is literally absent in current Javanese gamelan ensembles. All Balinese metallophone instruments (for Gamelan Gong Kebyar) appears to contain one singularly distinct and characteristic shape which differs from the shapes on Javanese metallophone keys. Further, Bali more or less abandoned their saron instruments at some point during the past few decades, with the exception of some types of saron instruments which are featured in some Balinese ensembles, such as Gangsa Jongkok (5 keys), Angklung (4 keys), bamboo instruments such as Tingklik, Granting and Rindik, however, these instruments are only used in occasional ceremonies thus omitted from this Music study. Also, another Gangsa instrument called Penyacah is worth mentioning, although due to its uncertain stature in the past few decades, thus omitted from the classification system. In essence, this means that basically every metallophone instrument used in current Balinese compositions are gender instruments.

Besides the obvious aforementioned differences, Balinese gamelan instruments still shares a number of commonalities with their Javanese counterpart. The majority of the core instruments associated with Javanese gamelan ensembles (i.e. metallophone instruments with tube resonators, gongs, gong-chime instruments, and hand drums) also appears to be integral to Balinese gamelan ensembles, in some form or another. However, all of these instruments contain minor or major differences compared to their neighbouring counterparts. Similar to Java, Balinese gamelan ensembles in certain cases also tends to omit firm standardization - which means that the exact number of instruments, as well as number of keys, gongs, or gong-chime kettles to appear on various instruments may thus be quite unpredictable.

Similar to the Javanese classification system, the categorisation of Balinese instruments has treated in a similar fashion. Quite possibly to a greater extent than the Javanese counterparts, Balinese ensembles tend to seperate instruments between a female - pengumbang (the larger sized and lowest pitched of the pair) and a male - pengisep (the smallest and highest pitched of the pair) counterpart.
As previously addressed, the keys on all metallophone instruments found in Bali contain one distinct physical shape thus no further subcategory has been appointed to the bilah (Balinese equivalent to wilah) category of instruments. Further, all of the metallophone instruments commonly used in Gamelan Gong Kebyar are technically gender instruments due to all containing a set of tube resonators (Tenzer, Balinese Music, 1991, p. 33). However, there is one significant distinction between these and Javanese gender instruments, thus the distinction between two Gender categories appear in the aforementioned Balinese classification system (these will be discussed shortly).

In addition to the distinct shapes of metallophone keys, gong-chime kettles also appear to be slightly different in Bali. The physical shapes of Javanese gong-chime kettles (in particular those associated with instruments such as bonang and kenong) commonly appears in similar sizes and width dependent on the different pitches on each individual kettle, and further largely affected by various degrees of flatness and roundness around the pencu. In Bali, all kettles basically have one particular physical shape and will vary significantly more on the basis of the sizes compared to their Javanese counterparts; on this occasion, their shapes may best be described as appearing somewhere between the shapes of pencon penkon and pencon gandhul around the area of the pencu, in particular this applies to the trompong and reyong instruments.

Categories of instruments

The Balinese instruments are grouped into four main categories; 1) Bilah (or Daun (i.e. metallophone instruments)), 2) Pencon (gong instruments) 3) Kendang (hand drums) and 4) Cengceng (cymbals). THe Balinese terms for metallophone keys are either Bilah or Daun, although for the sake of simplicity (and for its close resemblance to the Javanese word wilah), from now on bilah will be used to refer to keys on Balinese metallophone instruments. Also, worth mentioning, the terms Pencon gandhul/pangkon has been applied to classify between Balinese gong/gong-chime instruments, as no proper word is used in order to describe these instruments in Bali. No Western scholars appears to have any particular Balinese terms to describe these instruments (thus only refers to these instruments by using variations of words such as gongs, gong-chime or simply kettles), thus simplified these have been simplified in order to make it more understandable for the uninitiated reader.

Instruments of Bali

1. Bilah instruments

As previously mentioned, the shapes on metallophone keys are fairly unique to Balinese gamelan, although some resemblance to the Javanese wilah blimbingan is apparent, except that the edges are square-shaped rather than U-shaped. Further, the physical appearance can be described as cuboid with the left/right sides containing acute angles from the bottom to the top, while the upper/bottom sides of the keys are straight/right angled and the top is flat.

Besides the shapes of the keys, all other aspects of the bilah instruments shares physical similarities to the gender instruments found in Java, among the most apparent of these features is that the keys are suspended over tube resonators (for further reference please read the instruments section of Javanese gender instruments above). However, in addition to being strung over leather cords, the Balinese tube resonators are commonly made of bamboo (McPhee, 1976, p. 31). Further, the grouping of gender instruments always comes in groups of two, which always refer to female/male counterparts, although the Balinese terms for these are pengumbang/pengisep instead of the common Javanese terms barung/panerus.

Figure A1.14. Displays the shapes on Bilah metallophone instruments

1.1) Gangsa group

For this particular group of instruments, the name Gangsa has been selected. Among others, Michael Tenzer (1991), (2000) refers to the Kantilan, Pemade and Ugal instruments as part of a category referred to as Gangsa (or Gangsa gantung), while the other metallophone instruments such as Jublag and Jegogan are categorised simply as gender instruments; although structurally and physically all of these fit the technical term gender instruments - thus the reason for separating these into two categories is due to distinguishable number of metallophone keys which applies to instruments in either categorisation (Tenzer, Balinese Music, 1991, pp. 33, 36), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, pp. 41, 45).

As addressed above, the Gangsa subcategory is grouped into three different instruments; Kantilan, Pemade, and Ugal (sometimes referred to a giying) and commonly contain 7 to 12 bilah per instrument, although most commonly these instruments contain 10 bilah per instrument (Tenzer, Balinese Music, 1991, p. 36), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41). Common for all of these instruments is that they are played with one mallet, which allows the performer to use the other hand in order to dampen the keys either by using the thumb or the knuckle on the index finger. There are three common playing techniques used on Gangsa instruments; 1) no dampening (reproducing a natural albeit long resonating sound) 2) immediate dampening after key has been struck (resulting in a quick attack and short decay although retaining the natural timbre of the key) 3) dampening the key at the same time as it is struck (reproducing a muted sound which resembles the sound of a click, leading to a change in timbre) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41).

Kantilan is the smallest metallophone and highest pitched instruments found in Balinese gamelan ensembles (Tenzer, Balinese Music, 1991, p. 36). Most commonly, there are four kantilans in every ensemble and divided into two female and two male instruments (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41). The instrument commonly comprises 10 keys over a range of two octaves and is played with one mallet featuring a wooden beater which resembles a buffalo horn (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41).

The Pemade instruments are the closest relatives to the Kantilan both physically and musically. Similarly, Pemade contains 10 keys across a range of two octaves albeit appears one octave below the Kantilan, thus the second highest pitched instruments among the Gangsa instruments (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41). Further, there are usually four Pemade instruments grouped into two male and two female categories, and played with the exact same type of mallets as the Kantilans (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 41). Both type of instruments is known for producing piercing sounds and sticks out from the rest of the gamelan ensemble by elaborating ornamentations.

Ugal (also known as giying) is the largest and lowest pitched Gangsa instrument found in Balinese gamelan ensemble (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). Different to the two other types of Gangsa instruments, there is usually only one Ugal instrument thus it holds a very special position in every gamelan ensemble (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). However, in the case where two Ugal instruments may occur, the second Ugal will be a male counterpart to the first Ugal (which will be considered a female version of the instrument), the instrument is commonly positioned at the centre of the ensemble in order to serve as the musical leader of the entire Gangsa instrumental section (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). Only the most prominent gamelan performers are allowed to perform on this instrument during concerts and most commonly this task is assigned to the leader/master of a particular ensemble (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45).

Ugal is characterized for its “bassy” timbre, which appears in a similar register (and sizes) to that of the Jegogan and Jublag. Probably due to the derivations from other Gangsa instruments and similarities to Gender instruments, the ugal instrument may not always be referred to as a Gangsa instrument (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). However, the number of keys present firmly makes it a Gangsa instrument. Commonly, like the other Gangsa instruments there are 10 bilah over a range of two octaves, and is tuned an octave lower than the pemade (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). The Ugal is played with a mallet similar to the pemade.

1.2) Gender Group

As a rule of thumb, the main distinction between Gangsa and Gender instruments is that Gender instruments commonly contains half the amount of bilah keys, thus logically these instruments only comprises a range of one octave (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). The Gender instruments in Balinese Gamelan most commonly appear with five bilah, although in some ensembles there may be up to six or seven keys per instrument. The main purpose of the Balinese Gender instruments is to play the core tones, which forms the basis for the melodic palette in every gamelan ensemble, thus the size of bilah on these instruments are considerably larger than those commonly found on Gangsa instruments (Tenzer, Balinese Music, 1991, p. 42). Most commonly the more accomplished metallophone performers are assigned to play Gender instruments.

Jublag (also known as Calung) is the smallest and highest pitched among the Gender instruments. Commonly, there are two Jublag instruments in every gamelan ensemble and divided into a female and a male counterpart (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). In terms of tonal spectre, the range of the Jublag instruments appears between Pemade and Ugal (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). The instrument is played with one spherical mallet featuring a heavily padded beater and known for producing long characteristic ringing tones.

Jegogan is the largest and lowest pitched among the Gender instruments and appears an octave below the jublag (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). Similar to Jublag, Jegogan also consists of two instruments and similarly distinguishable by a male and a female counterpart (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). The instrument is played with one single mallet similar to the one used on jublag instruments.

2. Pencon instruments

Similar to Java, Balinese ensembles also divide their pencon instruments into two groups, namely gongs and gong-chime instruments. Interestingly enough, most gongs are manufactured in Java, in particular this applies to the *large gong* which is the largest gong found in Balinese gamelan ensembles (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Similar to Java, gongs and gong-chime kettles are mainly struck on the protruding boss in the center of the instrument.

2.1) Pencon gandhul

The most obvious difference between the gongs found in Bali is that they are generally slightly smaller than their Javanese counterpart, the main reason for this is that Balinese performers prefer higher pitched and more resonant sounding gongs (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Similar to Java, Balinese gongs are divided into three groups of instruments comprising Gong (large), Kempur (medium sized) and Kemong (the smallest). According to Tenzer, the most important significance of gong instruments in Balinese gamelan ensembles is that "… the sound pulsates enough on its own to blend in well with the beating of the metallophones", however different from metallophone instruments, gongs are not tuned in pairs (Tenzer, Balinese Music, 1991, p. 37).

The large gong is approximately 85 cm and shares equal respect within the context of Gamelan music on both islands (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Different from Java, it is more common to find two Gongs in Balinese gamelan ensembles rather than one (although one is slightly bigger than the other), further it is important to address that these are always played for completely different purposes and never played simultaneously (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, pp. 46-47). The main purpose of the large gong is solely to mark beginnings and endings in gamelan compositions; it is struck with a large padded mallet similar to the one used on the Javanese Gong ageng (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46).

Kempur is the medium sized gong and the Balinese equivalent to Gong suwukan, except that it appears slightly smaller than a large gong (approximately 70 cm in diameter) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). The main purpose of the Kempur is to emphasize important structural points in gamelan melodies (Tenzer, Balinese Music, 1991, p. 135). Similar to the large gong, the instrument is struck with a large padded mallet.

Kemong is the smallest of the suspended gongs found in Balinese gamelan ensembles. Whereas the Javanese gong suwukan and kempli appears slightly different in size, the Kemong is noticeable smaller than its Javanese Kempli (width approximately 45 cm in diameter) counterpart, at approximately 26 cm width in diameter (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46) (Sorrell N. , 1990, p. 35). In essence, Kemong could possibly be viewed as a slightly oversized gong-chime kettle suspended on a separate wooden stand.

Interestingly enough, there is usually only one kemong (commonly mounted on a separate wooden stand) in Balinese gamelan ensembles, which is quite in contrast to the Javanese equivalent (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). The instrument commonly emphasizes less noticeable musical parts than the Kempur, such as midpoints of melodies in gamelan compositions (Tenzer, Balinese Music, 1991, p. 135). Further, Kemong is performed with a mallet similar to a stick featuring a beater which is padded into a ball of twirled string.

2.2) Pencon pangkon

As previously mentioned, the appearance of Balinese gong-chime kettle instruments generally looks slightly different than their Javanese counterparts. Only three instruments appear within this category, namely Kempli, Trompong, and Reyong.

Kempli is a single gong-chime kettle mounted onto a wooden crate with “railings” affixed to the top of the frame and hooks attached to the kettle; the instrument is either played while mounted or placed in the performer’s lap (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). The instrument can be roughly described as an equivalent to the Javanese Kethuk instrument. Kempli is the largest single gong-chime kettle found within Balinese gamelan ensemble and similar to its Javanese counterpart played with one single mallet, which is shaped like a stick with light padding around the beater (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46).

Similar to some of the Javanese bonang instruments, both Trompong and Reyong includes several gong-chime kettles to be placed in long elongated wooden crates which are enabled across several open spaces for placements of numerous kettles (which commonly features up to four drill-holes on the bottom) to be suspended with cords. At first glance, Trompong and Reyong may appear to be the same instrument, although there appears to be insinuations/objections for this point of view, while simultaneously certain instances would justify such claims to be perceived as such. Whether the aforementioned statement is entirely correct can be up for debate, however for the sake of simplicity as well as for the respect of one the main contributors to Balinese gamelan in this research - we will side with Tenzer’s definition of it as one instrument although called trompong when performed by one musician and reyong when performed by four musicians (Tenzer, Balinese Music, 1991, p. 37). Further, quite often the size of the instrument and the number of kettles appears to match one another, although they might also deviate slightly between different ensembles. Despite the opposing views about the instruments, the smallest kettle and the highest pitch range associated with either (or both) instrument appears to be similar to the Gangsa instruments which comprises a range of two octaves (although reyong contains an additional two tones) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 57). All of the Pencon pangkon instruments, besides Kempli are played with two sticks featuring a beater with padding shaped into a ball of twirled string.

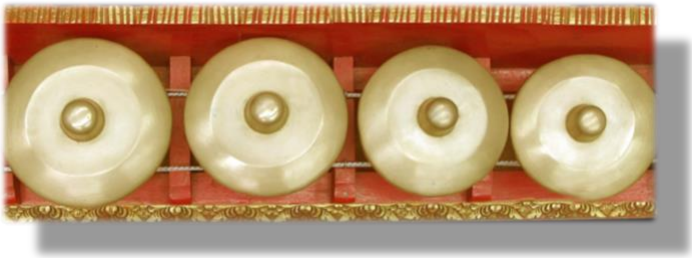

Figure A1.15. Displays how gong-chime kettles are mounted onto the wooden cases on Trompong/Reyong

On this occasion, it is important to address that the term Reyong first appeared in more recent times, thus considered to be of a more contemporary phenomenon within contemporary practices of Balinese gamelan. It became common in the early 20th century although firmly established and integrated into Balinese gamelan music within a short time span of a few decades (Tenzer, Balinese Music, 1991, p. 38). The Reyong instrument commonly associated with Gamelan Gong Kebyar usually contains 12 kettles (although in some ensembles it may appear with up to 14 kettles) (Tenzer, Balinese Music, 1991, p. 59).

One may suggest that the Reyong/Trompong instrument shows resemblances to metallophone instruments in terms of the physical arrangement of one single row of playable objects where the lowest tuned kettle appears to the far left and progressively builds up to the highest on the far-right side of the instrument. However, the musical approach is definitely different from the execution of a metallophone instrument; the performers on a Reyong instrument is divided into two groups comprising four performers whose responsibility applies to playing a total of three kettles each (all of which are next to one another), the first group of two - plays the first three kettles (1) in addition to kettles seven-nine (2), while the second group plays kettles four-six (3), and kettles ten-twelve (4) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 57). The purpose with this grouping is that both performers - plays the same part with a deviation of one octave apart from the other (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 57).

It should be noted that trompong is not commonly present in contemporary Balinese gamelan ensembles and appears to be mainly associated with elder court music and compositions dating back approximately one century. Despite that the instrument may appear with 12, or even 14 gong-chime kettles, it is rather common to find it with

10 kettles in a configuration of kettles which sometimes appear slightly bigger than those commonly associated with Reyong instrument (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). Interestingly enough, the reyong instruments found on the older Gamelan Gong Gde ensembles (which appears to have been popular in Bali prior to the 20th century) came with fewer gong-chime kettles per instrument, either with eight or four kettles (Tenzer, Balinese Music, 1991, p. 38).

3. Kendang instruments

Kendang instruments are usually found as a set of two. It comes in two specific sizes, one called wadon (larger) and the other lanang (smaller) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Even though the kendang drums can be described as barrel shaped, they are noticeably flatter in appearance compared to their Javanese counterparts. Commonly, the lower pitched (female) side of the drum is positioned to the right side of the performer and the higher pitched (male) side on the left. The Kendang hand drums, similar to their Javanese counterpart are also known for producing a variety of sounds. Both wadon and lanang are usually held across the lap and played with both hands by using either finger and hand techniques and sometimes played using a mallet in the right hand (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 48).

4. Cengceng instruments

Unlike Java, cymbals are still more commonly present in compositions found in Balinese gamelan ensembles. They come in two different sizes, one called cengceng kopyak (largest) and cengceng (smallest) and usually comprises four pairs in every gamelan ensemble (Tenzer, Balinese Music, 1991, p. 38). The size of the cengceng kopyak is similar to Western crash cymbals and always come in pairs which are similarly played according to traditional Western big bands, brass bands etc. by being clashed against each other (Tenzer, Balinese Music, 1991, p. 38).

Differently to the above, the smaller cengceng instruments often comes in pairs of six; commonly one half of each pair is mounted on a small wooden base with the inside of the cymbals facing upwards, while the other half of the pair is executed by a performer and used to clash against the other cymbal (Tenzer, Balinese Music, 1991,

p. 38). Although it may appear obvious by the information provided above, most often one performer each handles one pair of two cymbals each, and the appearance of these instruments is much more commonly found in ceremonial music than any other styles of music (Tenzer, Balinese Music, 1991, p. 38).

The process of fashioning Javanese instruments

"To see a gong slowly taking shape from a small black disc through patient and skilled hammering is truly an amazing experience, verging on an optical illusion!" (Sorrell N. , 1990, p. 45).

The following section is largely based on information provided from books written by Neil Sorrell (1990) (Javanese instruments) and Michael Tenzer (1991), (2000) (Balinese instruments), with additional contributions from other authors where noted (Sorrell N. , 1990, pp. 44-53) (Tenzer, Balinese Music, 1991, pp. 29-31). Primarily, since these instruments are manufactured in Indonesia and the accessibility of Balinese gamelan instruments (in the UK) seems far less approachable than their neighbouring counterparts, these books have been a complete necessity for any reference in order to establish a thorough overview of gamelan instruments.
The initially period when musical instruments were created out of metal in the Indonesian archipelago can be traced back to the Copper Age (also known as the Chalcolithic Age somewhere around 4500-3500 BC) with the discovery of copper on the islands. Further, the earliest stages of the Bronze Age (approximately 3500-1200 BC) with the discovery of lead and tin in addition to the aforementioned copper allowed a mixture of all these metals to create bronze (Hood K. M., 2000, p. 365). Gradually, the next few centuries would further instigate advancement in casting techniques and forward significant developments within hand forging skills, and it is quite likely that bronze gongs and gong-chime kettles (similar to modern gamelan ensembles) might have emerged sometime during this period (Hood K. M., 2000, p. 366).

Similarly, due to the different fashioning processes of instruments which appears on both islands, it is also quite obvious that this will affect the craftmanship through different conceptions and approaches of fashioning instruments among gamelan makers. This may not be limited to different parts within one particular island, but may also affect other ensembles within the same region, community, region whether small or large. Thus, the tuning of instruments made by one manufacturer most likely may not be compatible with the tuning conceptions of instruments made by another; this particular uniqueness in crafting techniques is responsible for giving each and every gamelan ensemble across Indonesia a unique and special tonal personality (or quality) which affects the characteristics of the overall sound of the ensemble. Thus, the process crafting instruments according to fixed ideas on pitches or frequencies, a process commonly associated with Western instrument fashioning and possibly similar to certain other musical cultures will be not representative nor considered desirable to either Javanese or Balinese musicians - whose tuning principles may render Western tuning approaches (i.e. instruments to be completely in tune to fixed meters) completely unjustifiable to or completely unexciting according to Indonesian tuning principles.

However, the significance of contemporary fashioning processes of Indonesian gamelan instruments should not be entirely dismissed, and likely appears somewhat different compared to practices of ancient times. Sorrell describes contemporary fashioning processes as a four-step process: 1) Mixing the Bronze; 2) Forging; 3) Filing; and 4) Tuning (Sorrell N. , 1990, pp. 47-52). Lindsay concurs with this fashioning approach, although simultaneously pointing out the significance of the necessary supervision and presence of the actual instrument-maker to always appear during this particular stage the of instrument making, while later stages may require the involvement and presence of fellow assisting craftsmen prior to the actual initiation of the consecutive forging process (Lindsay, 1979/1992, p. 35).

The following sections will describe the manufacturing process according to the Javanese Gamelan instruments maker Pak Tentrem. It should be noted that his approach toward instrument making dates back to 1981, thus there is a possibility that his method of fashioning gamelan instruments may have been modified since then. Further, it is important to address that this approach is uniquely attributed to Pak Tentrem, thus it might not coincide entirely with the fashioning processes of any other gamelan manufacturers whether it relates to practices on the same or on a different island.

The creational process is done without interference of machinery and none of the instruments are entirely finished by the time they are being casted and would require additional hammering and filing before the instruments appear entirely satisfactory to the instrument makers. The task commonly involves a total group of approximately ten craftsmen and the duration of the work usually takes up to two-three weeks before completion although due to the unpredictable notion of the creational process creating gamelan instruments - in some situations it might take longer. Most of the work is done inside a smithy hut, with a charcoal fire in the ground which is placed in the middle of the hut – thus requires a hole in the middle of the roof to accommodate smoke from the fire. The process crafting instruments is mostly affected by different seasons to occur in Indonesia, as both rain and sun appears to affect this process in different ways. Especially, rainy seasons are the most challenging due to the negative effect it has on bronze, making the instruments much more prone to breaking if significantly exposed to rain over an extended period of time.

In terms of forging the metal into the expected physical shapes two different types of hammering tools are used; iron hammers are used when forging wilah instruments while stone tools are applied when forging pencon instruments. Prior to this process, the metal is being melted in clay cups.

Mixing the bronze

According to Sorrell, in order to create bronze, the appropriate ratio of copper/tin ideally should be 10:3, a balance which Lindsay appears to completely concur with (Lindsay, 1979/1992, p. 35). The acquisition of metals used for instrument making are commonly weighted separately from one another prior to being mixed together. Before the proper casting process occurs, commonly two small pieces of bronze are made in order to test the overall quality of this blending and to be assured that the balance of copper and tin has been properly sustained and suitable for instrument making. Thus, one piece is left cooled before any hammering is done while the other is being hammered despite being still hot, however if the piece breaks during this process then the balance of copper and tin is considered inadequate (Sorrell N. , 1990, p. 48). In addition to pertaining a smoothening effect on the bronze, tin also plays a significant part in order to give the instruments a great sound.

Forging

Eventually, when the bronze has been approved of, it is poured into moulds which appears in two basic shapes; one for the creation of wilahs (oblong shaped) and the other for pencons (circular shape). Lindsay states that bonang and kenong kettles are not moulded, but instead beaten into their final shape (Lindsay, 1979/1992, p. 36). After the wilahs have been cast they appear similar to the final shape although slightly smaller and higher pitched than the final product (Lindsay, 1979/1992, p. 36). On the other hand, the molten metal used in order to create pencon instruments is poured to make round shaped discs (Lindsay, 1979/1992, p. 36). The next step of the fashioning process involves hammering; at this stage the wilah keys emerge almost in their final expected shapes, although approximately two hours of additional work is usually required in order to finalize these. This also includes pencon instruments which requires very little additional work past the forging stage.

Different from metallophone keys and gong-chime kettles the process of forging the larger gongs appears to be a significantly more complex and time-consuming process. Prior to any hammering, it is worth addressing that the larger gongs appear in similar shapes compared to the smallest gongs (i.e. small round discs). The process hammering these into noticeable larger objects and into the final shape requires as much as up to two days and requires the assistance of several craftsmen to fashion such objects into a gong. The bronze object is placed into the charcoal fire in order to maintain a hot temperature during the entire hammering process – which starts around the centre of the (disc shaped) object and gradually moves towards the edge. Lindsay adds that the smithy hut is always kept dark in order to make the red metal more visible and enables the craftsmen to determine which parts of the hot pencon to be thin or thick and to differentiate between the parts which require hammering and the one which does not (Lindsay, 1979/1992, p. 36). Simultaneously, the craftsmen double-check the tuning several times by using a tuning hammer in order to verify that the gong is within the appropriate range of tuning in relation to the level of completion which is expected at that stage of the forging process.

As soon as the craftsmen are satisfied and content with the sound of the gong, it is immediately put into a cold-water bath. It is important to address, that this process is a very critical phase of the instrument making due to a reasonably high risk of breakage when it gets in contact with cold water; however, if it remains intact the forging process can be considered successful.

Filing

When the filing process is initiated, gongs (as well as wilah keys) will always appear in a higher pitch than finally intended, however the larger the size of the gong and the further apart from the originally intended pitch (of which the gong may appears at that stage), thus the significance of additional work to file them into their final shape and pitch is required. At this stage of the process, the bronze will still appear black and in a rough appearance. Thus, all of the pencon instruments usually will be smoothed in order to make them appear glossy and within their natural colour, with the exception of the gong ageng which is commonly left untouched at this point.

The filing stage is considered among the most time-consuming processes of instrument making and sometimes may take twice as long in comparison to the forging process. Further, filing is never executed inside the smithy hut, but always occurs outside in a nearby open space which is large enough to store all the instruments applicable for filing. However, the most significant challenge which will affect the final outcome of instrument making is the weather and in particular the type of season occurring under the filing process, as this will greatly affect how the instruments eventually turns out.

Tuning

Tuning is the last stage of instrument making and eventually occurs when each and every instrument of the ensemble have been completed. The wilahs and tube resonators appears to be easy to tune, while pencon instrument may often require additional hammering at this stage. It should be noted that any hammering at stage involves a high risk due to the delicacy of bronze being hammered in normal (room) temperature which is much more susceptible to and prone to damage or worst-case scenario breakage - thus only an expert will be assigned to this particular task. It is during the tuning process when two holes are bored into the centre of each wilah key – the precision of this technique is important as inaccuracies will greatly affect the overall sound quality on each key - thus the utmost precision is completely necessary (Lindsay, 1979/1992, p. 36).

The decision on the general tuning of an entire gamelan ensemble and tuning relation between each individual instrument is decided by the maker of the instruments while sometimes in consultancy with the client (in case the client may possess sufficient knowledge about tuning of gamelan ensembles and/or have specific preferences for the tuning of the entire ensemble and/or each individual instrument). At this stage, the initial instruments to be roughly in tune are wilahs, partly because the effort of filing them into their final proper shape requires little effort and is done rather quickly; however, their pitch is eventually more a means of reference in order to enable tuning of the rest of the gamelan ensemble (Sorrell N. , 1990, p. 50). Thus, their importance to be merely a reference point to initiate the tuning process, while tuning of all instruments happens in accordance with the pitch of the gong ageng when the tuning process reaches its final stage (Sorrell N., 1990, p. 35). The most efficient approach to lower the pitch of wilah polos is by filing the surface underneath the wilah near the middle between both holes, or underneath near the end of the upper or bottom part of the key. McPhee concurs to this method of lowering pitches although suggests that the object is scraped instead of filed, and further adds that filing the end of the keys will raise the pitch (McPhee, 1976, p. 30). The approach tuning each separate wilah blimbingan (due to their rather thin appearances) appears most convenient by filing the top of the key in case it has been filed too much underneath already. Tube resonators (for genders and slenthem) can be tuned by closing the aperture on the top with sticky tape in order to further lower the pitch, while the possibility of raising the pitch can be achieved by enlarging additional filings. It should be noted that the process of tuning the resonators is considered a relatively quick and easy process.

Commonly, the last instruments to be tuned are pencon instruments, although before this process is initiated, the craftsmen need to understand which sections of the respective gong to appear thick and thin prior to any tuning to occur, this is most commonly achieved by hitting random areas on and around the pencon. The craftsmen will then measure beat frequencies by placing fingers in order to interpret the areas of the gong which contains more or less vibrations (i.e. the desirable effects when hit), and then be able to understand which areas requires filing or needs to be left as is.

In order to tune the pitches on pencon pangkong instruments, any hammering on the outside around the area around pencu (boss) will lower the pitch of the instrument, while any hammering on the exact opposite side (i.e. the inside) of the pencu will raise the pitch. This also applies to pencon gandhul instruments, however, hammering on these instruments needs to be done nearer the rim on the inside of the gong in order to raise the pitch. Among all instruments, pencon gandhul proves to be the most difficult to tune, because shaping the sound requires significantly more attention than any other gamelan instruments. A common practice when determining the parts of pencon gandhul which requires hammering is achieved by adding clay to various parts of the gong – this allows the craftsmen to determine the parts which requires to be hammered in order to appear in the correct pitch. The hammering tools will never be in direct contact with the bronze and always supported by using iron or wood.

Interestingly enough, when the gamelan instruments are finished and ready to be delivered to the client, the instruments will requires additional - sufficient time to be ‘played in’, a process which may take up to a few years and involve frequent performances on the instruments before allowing the bronze and the eventual tuning of the instruments to be properly settled and stabilized. However, prior to handing over the instruments to the client, the instrument maker usually arranges a concert comprising these newly crafted instruments in order to verify whether the tuning relation between the instruments is satisfactory. However, from the perspective of the instrument maker determination of the perfect balance between instruments is difficult mainly because higher and lower pitched instruments tend to change in slightly different ways over time; lower pitched instruments often tends to rise more in pitch after their initial finished state compared to high pitched instruments which to a greater extent manages to retain their original pitch over time, before they eventually appear slightly lower in pitch gradually over an extended period of time.

In total, however, it is common for the instrument maker to accept that the relation between instruments to appear lower in pitch than commonly found in an ensemble where the instruments already have been properly ‘played in’, this is generally accepted as a means to compensate for the difference in tuning which is bound to occur at a later point in time (Sorrell N. , 1990, p. 52). The final process of instrument making is dedicated to the creation of wooden crates for all bronze instruments which are usually made of teak and containing various hand carved decorations of floral or serpent motifs.

The fashioning process of Balinese instruments

The fashioning methods of Balinese gamelan instruments appear quite similar to Java. Similarly, the common procedure to determine tuning of a gamelan ensemble and the respective instruments is done by instrument maker in accordance with its client, if applicable. The following information about fashioning of Balinese instruments are based on the fashioning principles according to Pande Made Gableran (whose conceptions appear similar to the aforementioned maker Pak Tentrem), whose approach appear entirely by personal preference, or going with already established approaches (or a “family recipe” carried over through a long family lineage of gamelan craftsmen) unless specific preferences or requirements are made by the client. Tenzer concurs with the mixing relation (between tin and copper) in order to create bronze (or kerrawang as he describes it) appears the same as previously described by Sorrell; although suggests that raw materials are used and mixed despite the possibility of recycling old bronze derived from damaged instruments (damaged beyond repair) since this is preferable compared to create bronze from bottom on up (Tenzer, Balinese Music, 1991, p. 29).

It is important to address that the instrument making process according to Pak Tentrem appears quite similar to Pande Made Gableran’s approach with only the slightest of deviation between the two, thus it appears more adequate to provide a summary of the fashioning process of Balinese gamelan instrument making rather than present a similarly detailed overview as above. The initial stage of the instrument making process starts with determining the sizes of instrument to be created, since each specific size is integral to the amount of bronze required to make them, on this occasion between one and two kg of bronze is used per key or gong. Further, the charcoal fire inside the smithy hut is prepared and the bronze then ready to be melted for a significant amount of time before the mixture of bronze is properly blended. When this process is fulfilled, the bronze is poured into moulds and then the next stage involves hammering bronze key or gong into shapes and finally placed in cold water. When the bronze has cooled down, the next stage involves filing, scraping and polishing and the appearance of the instrument (whether wilah or pencon) should by now appear as recognizable instruments. In the final stage, the instruments are assembled and the final tuning process starts.

Only Pande Made Gableran or one of his sons is entrusted with this task and requires the aid of sensitive ears to detect precise and accurate tuning of all instruments. Similar to the aforementioned information suggested by Sorrell, the pitch of a metallophone key can be lowered if the underside is filed, thus resulting in longer shaped keys which allows for slower vibration while filing the ends of the keys will achieve the opposite effect (Tenzer, Balinese Music, 1991, p. 30). When the entire gamelan set is finally in tune, the keys are then strung up with cords attached to the wooden cases of the instruments and the tube (bamboo) resonators will be tuned according to the vibration rate of the keys. The section of bamboo found below the node has no proper musical function at all and are merely for decorative purposes. However, the nodes resemble the shape of a staircase when seen in front of the instrument, ascending from left to right.

The crafting of wooden crates is made at the same place as the bronze instruments; the crates are commonly made of jackfruit tree due to its heavy and durable semi-hard-wood. The carved decorations found on Balinese wooden crates usually depicts gods or serpents.

We have now examined two different yet similar fashioning approaches of gamelan instruments. Thus, we can now conclude that there are many similarities between these two distinctive instrument makers despite operating on a different island. For instance, tuning of instruments in both cases may support the involvement from both the manufacturer and client. Both processes involve the same principles of mixing Bronze, forging, filing and tuning and is done in that particular order.

However, the only main difference between the two gamelan manufacturers seems to deal with the attention to detail; Pak Temtrem seems concerned about getting the mixture of bronze completely correct before the initial manufacturing process starts, since this will eventually affect the robustness of the instruments (i.e. inconsistent ratio of tin and copper will eventually lead to instruments breaking during the hammering stages). Also, he does not appear content that the fashioning process can be entirely deemed finished unless a test performance is arranged to verify that the tuning of and between the instruments appears appropriate. However, there is no information provided whether Pande Gableran tests the quality of the mixed bronze before he initiate the creation of instruments nor any mentioning of a test performance in the final stage of the manufacturing process – further no details was provided whether the instruments would be tuned lower intentionally, according the Pak Tentrem's tuning practices.

Sorrell did point out that the fashioning process in which he witnessed, was Pak Tentrem's first task ever overseeing the manufacturing of an entire gamelan ensemble. It is quite possible that this might have affected a more protecting, cautious and accurate attention to details in the manufacturing process due to lack of same level of confidence. However, Sorrell does not give any further description on Pak Tentrem's background nor exact profession, thus difficult to determine whether he comes from a long family line of gamelan instrument makers or his degree of knowledge and expertise prior to undertaking this task.

Tenzer, on the other hand provides sufficient information about Pande Made Gableran's background and it is apparent that he comes from a long family line of gamelan instruments makers, thus maintaining a long expertise of manufacturing gamelan instruments. However, we can only speculate whether his attention to detail on certain aspects of the fashion process might be attributed to a higher confidence due to years of experience – and may allow him to ignore certain aspects of the manufacturing process which someone with less experience would pay much more attention to or be more concerned with. Further, it is not entirely impossible that Pande Made Gableran put similar care and attention into the same aspects which concerned Pak Tentrem, however, this would mean that this would not have been observed by and/or documented by Tenzer.

Tuning and different conceptions in order to generally understand tuning in Indonesian gamelan

Indonesian gamelan music does not rely on standardized systems such as our own widely accepted Western twelve-tone equal temperament tuning system (comprising fixed intervallic values). No such concept exists in Indonesian gamelan independent on the island in question; there is no such thing as two gamelan ensembles which will sound exactly the same, whether including the exact same types of instruments, the same amounts of wilah/bilah or gong-chime kettles per instrument – every ensemble either in Java or Bali appears to have their own unique distinctive sound.

Before we go any further, it is important to address that there is an additional selection of tuning systems to be found across Indonesia beyond the slendro and pelog tuning which we have discussed up until this point of the research. Although, the sheer majority of additional tuning systems to be found in Indonesia are rather obscure (such as degung and madenda), thus solely found in certain regions in the minority of ensembles around Sunda or West Java.

Slendro

The generally accepted tuning systems used across Indonesia is slendro; it can be described as a pentatonic system which comprises five approximately equidistant tones per octave. The five-tone slendro system shows similarities to the pentatonic scale found in many cultures all over the world despite its anhemitonic nature - which means that none of the five tones are semitones despite that they are spaced with fairly close approximation to each other. The concept of slendro is difficult to understand, thus a statement provided by Sorrell appears adequate to include in order to provide some clarity:

> (Slendro does not contain any semitones) … which would also describe the scale obtained on the black notes of the piano. The crucial difference is that the five of slendro are more or less equally spaced, while the black notes have clear differences between whole tones and minor thirds. The problem for the Western ear is relating the pitches of such a subdivision. Divisions of the octave into twelve equal intervals (semitones), six (whole tones), four (minor thirds: the dimished seventh chord), three (major thirds: the augmented triad) and two (tritons) are familiar, but the ‘missing’ division between one and six is not used in Western music, and this is the territory of slendro. If the octave is divided into five equal parts, the resultant interval will lie between a whole tone and a minor third. The somewhat elusive quality of slendro is that we cannot say exactly where, because in practice the octave is not divided into five precisely equal steps. (Sorrell N. , 1990, p. 56).

Pelog

The pelog scale is based on a seven-tone system and can be described as heptatonic. In order to give some rough estimation about the tones in pelog, it is fair to say that the seconds and thirds are the most distinguishable among the intervals, while the others appear within a closer approximation. The combination of very wide with comparatively narrow intervals is widely responsible for the very distinctive tonal character of gamelan music. Contrary to pelog, slendro is generally characterized to reproduce a smooth and harmonious progression. It is further important to address that the two tuning systems are never performed at the same time nor will instruments from one tuning system be combined with instruments from the other during a performance entirely based on one single tuning system.

To further complicate matters, neither slendro nor pelog entirely resemble the five-tone nor the seven-tone systems (commonly found in most parts of the world), since the tones are neither divided exactly into either whole tones nor half tones. No such thing exists in the world of Indonesian gamelan music. The closest resemblance comparable to a Western based tuning system, however, can be attributed to the slendro scale, which deals with nearly equally divided intervals per octave. The concept of tuning in Indonesia is mainly based on approximation of tones since there is no fixed arrangement nor system in order to make tones accommodate precisely established or firmly given pitches in accordance with Western terminologies. Tuning of instruments ranges from many different concepts, although an emphasis on regional if not individually based ideas appears to be valid if not the most common approach. In the end, no instruments are tuned to exact cent or frequency/Hz values due to lack of a firm standardization thus (as previously addressed) tuning is based solely by the instrument maker or through an agreement between the manufacturer and the client.

It should be noted that the emergence of either tuning system is difficult to trace due to the fact that very scant information appears to exist at all. The interest of documenting any ancient music appears to be little or possibly neglected in historical sources thus any information past the last couple of centuries makes it particularly difficult to trace any accuracy when significant events occurred in Indonesia and as such we need to rely on actual extant artefacts or depictions of carved relief in order to substantiate such evidences. It appears that the most common practice for transmitting musical knowledge and preserving the historical legacy for the most part appears to be retained through oral tradition (from one generation to the next) and has been maintained as such for numerous centuries. The lack of historical documentations through literature obviously is a disadvantage when exploring different musical cultures - as this arises significant possibility of numerous factual errors, and lack of documentations which can validate various information to be factual or as myths.

Among the few extant evidences, the written document named Prakempa which dates back to approximately 1750 appears to be the earliest known evidence which mentions any tuning systems in Bali and deals with the slendro tuning system

(Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 33). However, it is not unlikely that the pelog tuning system may have emerged first since the period prior to any Hindu influence to be swept across the Indonesian archipelago has been suggested to be a potential period for when the pelog tuning system first appeared, despite that no exact time period has been properly proposed.

In current times gamelan music has been transcribed into a notation system called kepatihan. It was developed by Western missionaries who arrived in Indonesia at some point during the 19th century. All authors and sources used for this Music Study agree that the execution of tones on both tuning systems are divided as follows: slendro (1 2 3 5 6), and pelog (1 2 3 4 5 6 7), while tones 4 and 7 are left out in slendro. Further, it is more common to use only five or six tones for compositions in pelog. Subscript dots are used in order to display the lower octave on instruments while superscript dots are used for higher octave. Most Javanese ensembles commonly use both tuning systems, while Bali prefers pelog and applies a modification of this tuning system which comprises solely of either four or five tones per octave (slendro is rarely ever used in Balinese compositions, but may appear as a four or five intervals per octave scale configuration).

Complications related to tuning of specific gamelan instruments and general discussion about the subject among scholars

Tenzer states the following: “Each of the five tones are labelled with one of the Balinese solfa names (similar to our do, re, mi, etc.) ding, dong, deng, dung, and dang, with ding considered to be the starting note of the mode” (Tenzer, Balinese Music, 1991, p. 32). The pitch for the tone ding can vary as much as approximately 300 cents; most commonly ding appears fairly close to the Western C or C#, but may appear as high as D# or slightly more (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 28). As previously addressed, the difference between intervals will always be described as either greater or narrower to each other, although we will provide more specific information about pitches, ranges and general tuning by the tail end of this chapter.

Proposing a comprehensive and understandable concept for tuning of Indonesian gamelan instruments have proven to be a very difficult process in this Music Study. Different authors/scholars, who spent many years of research may propose slightly different ways on how to interpret Indonesian tuning systems and general tuning of instruments. However, it appears to be divided into two distinctive groups of ideas; the authors who deals with Javanese gamelan instruments, Sorrell and Anderson Sutton seems to favour the idea describing tones by assigning numbers to a slendro and pelog tuning (i.e. slendro6, pelog2 etc.), but they do not provide exact information to make these numbers understandable in terms approximate tone (intervallic) values. Sorrell provides some rough estimation about this by referring to the black keys on the piano in order to show an approximate order of intervals to be performed for slendro, thus; C# - D# - F# - G# - A#. However, any suggestion for tones in pelog appears less clear, other than that the seconds and thirds are the most distinguishable among the intervals, although others should appear within a closer approximation.

It should be understandable to the uninitiated reader that pelog1, slendro1 refers to the first tone within the range of a specific octave independent on either of the tuning systems in question. However, this information cannot be fully intelligible to a musician whose understanding is limited to Western music. The slendro/pelog system might make complete sense to an Indonesian musician or scholar who have been accustomed to these systems throughout their entire life, but how would it be possible for a Western musician or scholar to completely understand tuning systems where plain numbers are the only indication provided in order to explain narrow or wide intervals, or roughly equal distant tones not based on semitones?

It should be noted that McPhee, Becker and Tenzer all share in common a specific approach towards conception of tuning which distinguishes itself from Sorrell and Anderson Sutton. The authors on Balinese gamelan describe tuning in terms of beating (called penjorog in Bali - i.e. beat frequencies commonly associated with sounds produced by striking keys/chords on pianos) and pulsations. Tenzer further states that:

> … most gamelans vibrate, or beat, at a rate of somewhere between 5 and 8 times per second, depending on the preference of the gamelan's tuner and the type of gamelan involved. In the case of a 7 vibration difference, every pair of instruments from the lowest to the highest must be tuned so that the one vibrates 7 fewer times per second than the other. This is no mean feat, because while that difference can account for a big discrepancy in pitch on the deep bass instrument, it may be barely discernable in the piercing upper registers. This is where the acute sensitivity of the tuner's ear really comes into play. Furthermore, in order to keep the rate of beating constant throughout the gamelan, octaves and other intervals within the scale must sometimes be comprised. (Tenzer 1991, p. 33)

Interestingly enough, the distinction between opinions seems to be limited to and relatable solely to the island which each author investigated; Sorrell and Anderson Sutton discuss Javanese gamelan while McPhee, Becker and Tenzer discusses Balinese gamelan. McPhee, Becker and Tenzer each provide a fraction of unique aspects of the phenomenon of Balinese gamelan not mention by any other author; however, when all this information was compiled and put into context - the concept of Indonesian tuning became significantly clearer.

Generally, all authors on Indonesian gamelan (who contributed information to this Music Study) agrees that Indonesian musicians do not favour a Westernized standardization of tuning. Despite that intervals on tuning systems rarely or never appears to match those of another gamelan ensemble, there are generally accepted ideas/ideologies for the extent of deviation allowed between intervals. It is important to address that Balinese ensembles prefer instruments to be more out of tune with one another in comparison to Javanese ensembles – in addition Balinese ensembles shows a higher preference of music performances which accentuate shimmering sounds of the beat from their instruments.

According to Sorrell, gamelan ensembles are regarded as one unit rather than an ensemble thus one complete gamelan (called seprangkat in Java) comprises one set of instruments each for slendro and pelog tuning (sometimes also addressed as a “double gamelan”) (Sorrell N. , 1990, pp. 55-56). Whether “one unit” can be interpreted as a categorization of an entire gamelan ensemble to be one instrument or not, is debatable. However, this opinion has had a strong impact on the approach taken in order to create a VMKLI for an entire gamelan ensemble. However, none of the authors or scholars on Balinese gamelan have expresses the idea of an entire gamelan ensemble to appear as one instrument.

Colin McPhee (among the first Western Scholars outside of Dutch influence to take an interest in Balinese gamelan music) have proposed a few examples which may make it easier to understand how Balinese tuning works. In order to make it understandable to a Western musician or scholar, the first table displays a straight-forward chart comprises frequency and cents values according to 12-EDO.

277.18	293.66	311.13	329.62	349.23	369.99	392.00	415.30	440.00	466.16	493.88	523.25	554.40
100	100	100	100	100	100	100	100	100	100	100	100	
C#	D	D#	E	F	F#	G	G#	A	Ab	B	C	C#

Table A1.2. Frequencies (in Hz) & Cents values in Western 12-tone equal temperament:

Further, McPhee proposed a comparison of the slendro and pelog scales (both shown as five tone systems) in order to provide some clue in order to make approximate differences between intervals on these two scales easier for interpretation and to appear more understandable for Western readers; pelog rarely (if ever) uses more than five tones, thus only displayed with five intervals here (McPhee, 1976, p. 52). Evident from both of examples shown below is that the intervals rarely ever match those found in the Western 12-EDO tuning system, however, it is important to note, that the exact values shown here unlikely would match the intevals/tones found on instruments in any other gamelan ensemble.

Slendro

195	205	272	259	269		
C#	D#	E#	G#	A#	C#	(12-EDO)

Table A1.3. McPhee's proposition for slendro tuning (McPhee, 1976, p. 52)

Pelog

134	172	412	82	400		
C#	D	E	G#	A	C#	(12-EDO)

Table A1.4. McPhee's proposition for pelog tuning (McPhee, 1976, p. 52)

Judith Becker has proposed a chart similarly to McPhee's; although in Becker's chart all of the intervals for the pelog scale are displayed and evident from the example below, there are no longer any gaps of approximately 400 Cents between intervals (Becker, 1980, p. xvi). It is important to address that McPhee's example dealt with the Balinese five tone variant instead of the entire seven tone pelog scale, thus two intervals/tones were omitted in his chart.

Despite that both McPhee and Becker have proposed similar models for tuning of slendro and pelog scales, one interesting observation is that neither model/chart contains approximate intervallic values which appears to match, and one particular situation a deviation of up to 53 cents is apparent. However, the most distinguishable contribution from Becker is a clearer perspective on how to possibly divide all tones on the pelog tuning system. Collectively, contribution from all authors manage to provide a clearer concept on measurement of intervals and enables to make Sorrel and Anderson Sutton's description of tuning more understandable. The addition of McPhee and Becker enables us to establish a reference in order to understand the process assigning intervallic values to both slendro and pelog scales. Becker also explains that it is impossible to show exact notes on staff accurately, thus these will appear within the region of nearest key according to Western 12-tone EDO tuning.

Slendro

1		2		3		5		6		i (upper octave)
	220		280		236		242		248	
Staff notation proposed for slendro as C-D-E-G-A										

Table A1.5. Becker's proposition for slendro tuning (Becker, 1980, p. xvi)

Pelog

1		2		3		4		5		6		7		i (upper octave)
	120		144		297		117		126		155		246	
Staff notation proposed for pelog as E-F-G-A-B-C-D														

Table A1.6. Becker's proposition for slendro tuning (Becker, 1980, p. xvi)

In addition to the above, Tenzer shows yet another proposition for intervals in pelog, in which he describes the intervals as scale-tones (i.e. ding, dong, deng, dung, dang). Despite similarities between intervallic values proposed by McPhee, Tenzer suggests that a number of authors (which also includes McPhee) appears to have ignored additional aspects of tuning when they have proposed measurement of intervals for the pelog scale (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 30). Further, he suggests that *"a rough pelog sample"* (a description he uses in order to simplify the actual intervallic differences on the pelog scale and make it seem adaptable to Western tuning) can be played on the following white keys on the piano E-F-G-B-C (Tenzer, Balinese Music, 1991, p. 32).

Among the authors on Balinese gamelan which has provided an adequate overview of intervals (which appears to be approved by Tenzer), is Andrew Toth, whose research dealt with investigation of forty-nine kebyar instruments, upon which he discovered two "polarities," known by the terms begbeg and tirus, and an "in-between" type called sedeng. Tenzer states that … "They refer to interval widths and the degree of contrast between intervals within a given octave, and are used to describe the full ensemble's laras as well (1993:102). Begbeg means straight or lined up, tirus means narrow and converged, and sedeng means moderate or average" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 30). The division between these are; tirus (preferable for old repertoire), begbeg for the discontinuities in modern music such as kebyar, while sedeng retains some the character of each.

(a) begbeg

Intervals		120	114	432	81	453 (oct)
Cents	0	120	234	666	747	1200
Tone	ding	dong	deng	dung	dang	ding

(b) sedeng

Intervals		136	155	379	134	396 (oct)
Cents	0	136	291	670	804	1200
Tone	ding	dong	deng	dung	dang	ding

(c) tirus

Intervals		197	180	347	104	372 (oct)
Cents	0	197	377	724	828	1200
Tone	ding	dong	deng	dung	dang	ding

(0 = C# + 47)

Table A1.7. Toth's overview of Balinese intervals (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31)

Tuning of individual instruments:

Both Sorrell and Tenzer have described tuning of individual instruments in great detail, although proposes two completely different approaches. Evident from previous observations related to discussions on tuning, Sorrell uses number sequence for slendro and pelog scales in order to describe the individual tuning of instruments, while Tenzer appears to use tuning propositions made by Andrew Toth as well as describing tuning through measurement of beat frequencies. Both authors have provided the majority of the following information although minor contributions from others occurs.

Thus, on this occasion, a compromise which incorporates the suggestions from Becker, Sorrell and Tenzer have been taken into account in the decision-making process; Becker's staff notation suggests the starting key for pelog to appear somewhat close to E, Tenzer at C#+47 cents, while Sorrell suggests something between approximately C# and D#. As a result, for this music study D-D# is used as the starting pitch for pelog, while slendro tuning - the measurement of tones has been set to accommodate tones slendro5/pelog4 and slendro6/pleog6 accordingly to Becker's intervallic proposition. It is important to address that the intervals/pitches will be given as fixed notes or in-between two notes in order to simplify matters related to actual tones on all gamelan instruments independent on either island and tuning system.

Java

In Java, both slendro (five-tone) and pelog (seven-tone) tuning systems (laras) are actively used and appears to be the most common approaches for measuring pitches on instruments. All authors on Javanese gamelan (with the exception of Becker), only addresses specific tones within unspecified octave (these systems only provide indication of the tones on the instruments and ranges to appear within one or in some cases two octaves) thus do not provide exact intervals/Hz for each intervals/keys/kettles and gongs on Javanese instruments. We only know the order of pitch on an instrument through a single number designation, for instance - tone 3 in the slendro scale, or tone 5 in the pelog scale thus referred to as slendro3 and pelog5, respectively. Sorrell is clear about not providing any fixed intervals and notes in order to propose the relations between various notes for both slendro and pelog; and states that this is because that "…Javanese attach great importance to embat, or intervallic structure" (Sorrell N. , 1990, p. 56). However, he provides a visual impression/measurement to show the variations in tone between the two tuning systems, and insists that this is the most appropriate approach to render tuning relations between the two – to be understandable to the reader. Further, he mentions that slendro5 and pelog4, as well as tones 6 for both tuning systems, are coinciding notes (tumbuk nem gamelan) (Sorrell N. , 1990, p. 57)

slendro										
6.		1	2		3	5		6		i
pelog										
6.	7.	1	2	3		4	5	6	7	

Table A1.8. Sorrell's proposition for tuning relations between slendro and pelog intervals (Sorrell, 1990, p. 57)

Previously, Sorrell has referred to the pitches on slendro to fit roughly with the black keys on a piano, and have suggested approximate pitches to appear around C#-D#-F#-G#-A#-C# in slendro, by taking these pitches into consideration - the following pitches D-E-F-G#-A-A#-C-D should be somewhat in close approximation to those found in pelog.

Authors on Javanese gamelan, do not specify which octaves or Hz values to appear on instruments (nor the inherent playable objects), and only for a limited selection of different instruments we are provided with informed about the octavial relation (i.e. the sarons and slenthem, kethuk and kempyang). As already addressed, the pelog tuning system is operated differently on each island; Java ensembles usually employ all seven tones on instruments in pelog (although compositions may only use five of these), while in Bali only four or five of these tones appears. The slendro is a five-tone tuning system although no tone 4 occurs thus a highest tone to be 6 instead of tone 5.

Author's own tuning of instruments and explanation of compromises made to accommodate Javanese gamelan instruments

The major challenge with Javanese instruments is that no authors on Javanese gamelan has provided a full spectre which shows us the frequency range of each instruments. This has made for a significant challenge when providing calculations of approximate (value of) pitches for both systems, the only author who has proposed any model for calculation of intervallic values for slendro and pelog, appears to be Judith Becker. However, in the discussion of singular instruments we need to rely on Sorrell - as he is the main (and only) author to provides us with specific slendro/pelog numbers for each Javanese gamelan instrument. Taken into account the staff notation proposed by Becker, it appears that the first tone in slendro (slendro1) appears at a lower pitch than pelog (pelog1) - this coincides with Sorrell's proposition as well. Further, Becker also suggests that both slendro 5/pelog4 and slendro6/pelog6 coincides, thus we can be assured that this is an appropriate model to use in order to calculate approximate pitches for Javanese instruments. Becker is suggest that the staff notation for pelog is not entirely precise nor represent the exact pitches in pelog, however based on this we need to take into account that the first note in pelog should appear above D with an intervallic value closer to E (since this is where pelog1 supposedly starts). If we take into account Sorrell's previous assessment regarding the black keys on a piano to express roughly the slendro scale, thus according to his model pelog1 note should appear between slendro1 and slendro2, (C# and D#). Further, we need to be aware of Tenzer's proposition for the first tone (in the Balinese configuration of pelog) to appear at C#+47 cents, as well as the intervallic values proposed by Becker - in order to synchronize intervals so that the coincided notes would correlate. Pelog1 is likely to appear at approximately 260 cents (D-D#) – the following model has been proposed by myself and incorporates/merges information from both Becker and Sorrell, thus the following suggestion for intervallic values for tones in gamelan sekar pethak:

						slendro					
85		305			585	821		1063		1311 ≈ 1285	
≈C#		D#			≈F#	≈G#		A#-B		≈C#	
						pelog					
	260		370	524		821	938	1064	1219		1465 ≈1460
	D-D#		D#-E	≈F		≈G#	A-A#	A#-B	≈C		≈D-D#

Table A1.9. Encapsulated information based on Becker and Sorrell's proposition for slendro and pelog tuning

I will use these numbers as reference when I calculate approximate pitches for the keyboard layouts on the Gamelan VMKLI's, as indicated above a compromise is been made at the next octave. It should be noted that these numbers, should be within close approximation to actual pitches, but likely deviate slightly from actual cents value found on instruments in both gamelan sekar pethak and gamelan gong kebyar. For the sake of simplicity, all tables from now on will show all of the pitches according to their closest Western equivalent notes or "in-between" notes where applicable.

In the rare situations where there has been no mentioning of exact octave in relations to other instruments, I have tried to signify this in the best possible way. Unfortunately, in some cases assumptions of octaves were required due to lack of firm information from any of the authors. The majority of information about pitches on Javanese instruments will be provided by Sorrell, with minor contribution from other authors. In addition, a chart proposed by gamelan.gs (https://gamelan.gs/booklet/a-javanese-gamelan-sound-library/) will be the only other tool to provide us with further insight about the frequency spectrum for all typical Javanese gamelan instruments (the chart suggests a total range for approximately five and a half octaves altogether). All these tools will help us understand the frequency spectrum of each instrument, however, I will use the other authors of Javanese gamelan in order to verify whether some information appears to be valid or not, and the possible deviance in range (if this will occur).

Javanese Instruments

Gong ageng

The gong ageng is the lowest tuned instrument within Javanese gamelan thus it will provide a logical point of reference to initiate the calculation process, however, it is important to address that none of the authors on Javanese gamelan have provided a reference pitch or frequency range for this instrument. The closest is Sorrell who suggests that it is tuned to approximately note 6, and adds that the other instruments are tuned in variance with the gong ageng (Sorrell N. , 1990, p. 35).

Since no authors on Javanese gamelan provide exact reference pitch in terms of Hz or cents, initially we need to take into account the relations between sizes of the same instrument found on both islands – in this case gong ageng appears to be in roughly equal size (at approximately 85 cm) to the Balinese equivalent, stated separately by Sorrell and Tenzer (Sorrell N. , 1990, p. 35) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Based on this information, the difference in pitch should appear approximately within a similar range, thus by taking into account Tenzer's reference pitch for the Balinese large gong – it will enable us to gather possible perspective on the exact octave and approximate tonal range for gong ageng. However, in this occasion we need to be aware of the second gong in Bali, which is tuned approximately 200-300 cents higher than the large gong. This information will be useful when determining the pitch for the Javanese gong ageng.

According to Tenzer the large gong in Bali is tuned to ding (equivalent to pelog 1), and oscillates at about 65 Hz (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 28). Tenzer states that "Balinese prefer slightly smaller (ca. 85 cm) gongs than do the Javanese, because such instruments speak and pulsate more rapidly…" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). By taking into account this statement, in addition to the 65 Hz reference pitch which coincides at C2, tone 6 suggests that gong ageng should be tuned in a lower octave, approximately between 58.270 Hz and 61.735 Hz (A#1/Bb1-B1). This appears to roughly match (approximately at 55.0 Hz) the proposition by gamelan.gs.

Gong suwukan

According to Sorrell, gong suwukan, the second largest gong, is "… tuned to slendro 2, and quite often there will be a second suwukan, tuned to slendro 1, and of a similar size of approximately 63 cm in diameter" (Sorrell N. , 1990, p. 35). Based on this information, it appears obvious that the second gong suwukan will be tuned one tone lower than the first. Since both of them are pitched to the lowest tones within an octave and the gong ageng is tuned to highest tone within a given octave – thus it is logical to assume that the gong suwukan are tuned in the octave above gong ageng. There is no mentioning of any gong suwukan tuned to a pelog note, which may suggest that no such thing exists in gamelan sekar pethak. Because of this we will have to assume that either of the two gong suwukan is used during performances which requires pelog tuning.

Besides the difference in size between the two (85cm versus 63cm), no other information about the difference in pitch between gong ageng and gong suwukan is provided by any of the authors, however Sorrell suggests that a number of gamelan ensembles use gong suwukan as a substitute for gong ageng, which sould be an indication that there is not much difference in pitch between the two. If we make a comparison between the islands, a staff notation provided by Tenzer (which will be further elaborated once we approach Balinese gamelan instruments) suggests that the pitch variance between the large gong and kempur (the Balinese equivalent despite 7 cm larger than gong suwukan) appears to be nearly one and a half octave. However, by listening to sound samples of ageng/suwukan versus gong/kempur – the difference in pitch appears very significant, while the Javanese appears within fairly close approximation, the Balinese equivalents appears much further apart despite the difference in size.

The only other option for reference is the chart provided by gamelan.gs – which suggests a that gong suwukan occupies a tonal spectrum somewhere from 55 Hz to approximately 90 Hz, thus a difference of approximately half an octave between gong ageng and gong suwukan is quite likely. If we take into account this information it appears that first gong suwukan (tuned to slendro2) would oscillate at approximately 77.782 Hz (D#2/Eb2), while the second gong suwukan (slendro1) oscillates at approximately 69.296 (C#2/Db2).

Kempul

The last group of suspended gongs in Java are called kempul, the number of kempuls found in Javanese gamelan is not standardized and may vary quite a bit from one ensemble to another, Sorrell states that the "… typical modern gamelan will have a kempul tuned to the note 6 (serving both pelog and slendro) and others tuned to pelog 5, slendro 5, pelog 1, slendro 1 and pelog 7 (both notes 1, and 7 in pelog lying above the 6 of the kempul tuned to that note)" (Sorrell N. , 1990, p. 35).

As indicated previously, the previous groups of gongs have not been provided with any reference of the exact octave, although the range from the lowest tuned to the highest, should estimate a difference of approximately half an octave (or 600-700 cents), this appears to match a variance in pitch similar to what has been suggested previously between gong ageng and gong suwukan. In addition, this coincides with the information provided by *gamelan.gs* which suggests that the kempuls appears somewhere between approximately 90 Hz and 165 Hz.

If we take into account that the lowest tuned kempul (slendro5) appears within the same octave as the gong suwukan, this suggests approximately half an octave difference between the two, thus the following pitches provided for the kempul instruments; slendro5 = 97.999 Hz (G#2/Ab2), pelog5 = 110.00-116.54 Hz (A2-A#2/Bb2), note 6 = 116.54-123.47 Hz (A#2/Bb2-B2), pelog7 = 130.61 Hz (C3), slendro1 = 138.59 Hz (C#3), pelog1 = 146.83-155.56 Hz (D3-D#3/Eb3. This suggest a ratio of three gongs for slendro tuning, and four for pelog tuning.

The measured range between gong ageng and the highest tuned kempur reveals a range of an octave and a half (1½ octave), if we look at the propositions from gamelan.gs - this information appears to be correct, both in terms of the range as well as the frequency spectrum occupied by these instruments.

Kenong

Sorrell does not provide us with an ascending order of pitches for the kenong instrument, the only information provided is that the lowest tuned gong-chime kettle is tuned to slendro2 while the highest is tuned to pelog1 (Sorrell N. , 1990, p. 36). Sorrell states the following: "Nowadays it is common to find a kenong for each note in pelog and slendro. As with the kempuls, the notes 1 (slendro and pelog) are pitched above the note 6, and slendro 5 may be borrowed to do service as pelog 4 if required. This assumes that the two tuning systems coincide on note 6, which is most of the case (including Gamelan Sekar Pethak)" (Sorrell N. , 1990, p. 36).

In order to understand what Sorrell describes here, it requires that we are already familiar the two cases of coincided pitches, namely slendro5/pelog4 and slendro6/pelog6. Altogether, this suggest a range of one octave for each tuning system, and one gong-chime kettle for each note in pelog and slendro divided onto a total of 10 gong-chime kettles. This requires two kettles to be “borrowed” in order to complement the entire range of consecutive tones in pelog. Unfortunately, we are not provided with any information of frequency spectrum of the kenong, neither is there any equivalent instrument found in Bali to provide additional support, the only indication from Sorrell is that the instrument contains the largest gong-chime kettles in a gamelan ensemble (Sorrell N. , 1990, p. 36).

Thus, only other option to provide us with necessary information of octavial range is provided by gamelan.gs, which suggests that kenong is tuned approximately one octave higher than the smallest kempul, thus the lowest tuned kenong should appear slightly past a 220 Hz reference point – further, gamelan.gs suggests that it also coincides roughly with the kethuk (however this seems unlikely, as we will describe in details very soon!), lowest tuned kettle on bonang barung, and the lowest tuned key on the gender panerus, and saron demung, respectively. Based on the frequency spectrum provided by gamelan.gs thus yields the following pitches:

2	3	5	6 (tumbuk)	i
Hz	**Hz**	**Hz**	**Hz**	**Hz**
311.13	**369.99**	**415.30**	**466.16-493.88**	**554.37**
(D#4/Eb4)	(F#4/Gb4)	(G#4/Ab4)	(A#4/Bb4-B4)	(C#5)

Table A1.10. My proposition for tuning of intervals kenong in slendro

2	3	4 (slendro5)	5	6 (tumbuk)	7	i
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
311.13-329.63	**349.23**	**415.30**	**440.00-493.88**	**466.16-493.88**	**523.25**	**587.33-622.25**
(D#4/Eb4-E4)	(F4)	(G#4/Ab4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(C5)	(D5-D#5)

Table A1.11. My proposition for tuning of intervals kenong in pelog

Kethuk and Kempyang

According to Sorrell the separate kethuk instrument appears like a small kenong but appears larger that the gong-chime kettles found on bonang; it is tuned to note 6 for pelog while tuned to slendro 2 in slendro, if accompanied by a kempyang gong-chime kettle (as part of the kempyang instrument) it will be the lowest tuned of the pair (Sorrell N. , 1990, p. 37). The common difference in pitch between the two is as follows, the kempyang is tuned to pelog 6 (an octave above) and slendro 1 (dot above) approximately a seventh above the kethuk, in slendro (Sorrell N. , 1990, p. 37).

The chart provided by gamelan.gs (https://gamelan.gs/booklet/a-javanese-gamelan-sound-library/) suggests that the pitch on kethuk should appear somewhere past 220 Hz (possibly in a register close to C4), while kempyang should appear past 880 Hz (close to C6). However, one obvious problem emerges; the difference between 220 Hz and 880 Hz comprises two octaves and does not coincide with Sorrell's claims that the difference in pitch between the two should be maximum one octave in pelog (while slightly less in slendro) (Sorrell N. , 1990, p. 37). Further, he points out that the kethuk shares similar traces to the large suspended gongs with its rather flat appearance around the pencum, while the kempyang is shaped similar to a kenong (pencon pangkon) albeit smaller (Sorrell N. , 1990, p. 37). Another problem arises here: how can the kethuk possibly be tuned to a pitch similar to the lowest tuned kettles found on both kenong and bonang? Logically, we need to take into account that the shapes around pencu (protruding boss on instrument) might affect the sound on gong-chime kettles profoundly; it should be noted that despite each kettle on the bonang instrument all appear within the same size, these actually comprises a total range of two octaves. Sorrell states that the lowest tuned kettle on bonang appears to have pencon gandhul shapes and progressively move towards pencon pangkon shapes in compliance with the progression of higher pitches (Sorrell N. , 1990, p. 37).

Further, he suggests that the height of kenongs (more or less) appears to be constant at about 32 cm, while the diameter varies from 37 cm to 34 cm between the lowest to the highest tuned kettle (which all contains pencon pangkon shapes), by comparison the difference in diameter between kethuk and kempyang is 26.5 cm and 24 cm, respectively - further a comparison shows that the smallest gong-chime kettle on bonang panerus is approximately 17.5 cm (we do not receive information about the size of the highest and lowest tuned bonang barung) (Sorrell N. , 1990, pp. 36-37).

Taking into basis what has been discovered so far, the pitch on pencon gandhul shaped instruments appears to be lower in pitch compared to their pencon pangkon shaped counterparts (despite being roughly the same size). Thus, it appears that the kethuk and bonang instruments should be a good indicator/reference regarding correlation between sizes and pitches of gong-chime kettle instruments. The size between the kettles on bonang panerus contains approximately 17.5 cm in diameter, while the kethuk is 26.5 cm – different to these, the kenongs are noticeable larger.

In order to provide intervals for the kethuk, however, a comparison between Java and Bali is necessary, the Balinese equivalent called kempli (26 cm in diameter) contains a similarly flat appearance around pencu and is tuned to approximately 293.66-311.13 (D4-D#4/Eb4). Taking into basis sound samples of both instruments should suggest a pitch within close approximation to each other. When listening to both bonang barung and kenong they all appears to be within a similar frequency range. Thus, by examining all these different facets, the kethuk appears approximately in the same octave as suggested by gamelan.gs. On the other hand, it seems unlikely that kempyang appears around the frequency range proposed by the source. If we take into account that the kethuk appears in the register around C4; tone 6 should appear between 233.08-246.94 Hz (A#3/Bb3-B3), while the kempyang an octave higher in tone 6 at approximately 466.16-493.88 Hz (A#4/Bb4-B4). For slendro tuning kethuk should appear in slendro2 311.13 Hz (D#4/Eb4) while kempyang in slendro1 should appear at 554.37 (C#5/Db5).

Bonang

The typical pelog Bonang (barung and panerus) contains fourteen gongs (two rows of seven) while the slendro pair commonly contains twelve gongs (two rows of six) (Sorrell N. , 1990, p. 37). In both cases the gongs are placed so that the octave lie diagonally around the pivotal octave between the two notes 3, which are directly opposite while the player sits in line with these notes (Sorrell N. , 1990, p. 37).

Bonang barung and bonang panerus both contains gong-chime kettles which are smaller than the kethuk and kempyang – the smallest gong-chime kettle is approximately 17.5 cm in diameter and tuned to slendro$\dot{2}$ (Sorrell N. , 1990, p. 37). Each bonang instrument comprise a range of two octaves both for pelog and slendro, although shares a common octave between the barung and panerus variants (Sorrell

N. , 1990, p. 37). Also, due to the significance of certain pitches used in pelog, the order of 1 and 7 is often exchanged for easier accessibility (Sorrell N. , 1990, p. 38).

Interestingly, the authors on Javanese gamelan do not provide any reference regarding the initial octave of the bonang barung instrument, nor any pitch relation to to other instruments. The only other information in regards to pitch is that it contains the smallest gong-chime kettle found in gamelan – this suggests that the bonang instruments are among the highest pitched instruments found in Javanese gamelan ensembles. If we make comparison to the closest equivalent counterpart in Bali, the reyong – this appears to be valid. Further, the range on both instruments also comprises two octaves (with an additional two tones applied to the reyong), thus it seems apparent that the range appears within a similar figure as to that of the reyong – tuned approximately between C4-C7.

Lastly, the next step is to examine the proposition provided by gamelan.gs (https://gamelan.gs/booklet/a-javanese-gamelan-sound-library/), which also concurs that bonang instruments are among the highest pitched instruments found in Javanese gamelan. However, still it is difficult to figure out exact frequency value for the lowest bonang kettle; according to gamelan.gs the tonal range of the lowest bonang instrument starts slightly past 220 Hz at approximately the same place as both kenong and kethuk. It seems reasonable to believe that the actual tone for the lowest tuned kettle is tuned at approximately 261.63 Hz (C4), while the highest pitched kettle would appear past 1780 Hz – thus gamelan.gs concurs with the assessment about the bonang instruments to appear within a C4-C7 register. Based on this information the following pitches should apply to the slendro tuning - bonang barung:

6 **Hz** **932.33-987.77** / **1864.7-1975.53** (A#5/Bb5-B5 / A#6/Bb6-B6)	5 **Hz** **830.61** / **1661.2** (G#5/Ab5 / G#6/Ab6)	3 **Hz** **739.99** / **1479.98** (F#5/Gb5 / F#6/Gb6)	2 **Hz** **622.25** / **1244.51** (D#5/Eb5 / D#6/Eb6)	$\dot{1}$ **Hz** **1108.73** / **2217.46** (C#6/Db6 / C#7/Db7)	$\dot{2}$ **Hz** **1244.51** / **2489.02** (D#6/Eb6 / D7#/Eb7)
1 **Hz** **554.37** / **1108.73** (C#5/Db5 / C#6/Db6)	$\underset{\cdot}{2}$ **Hz** **311.13** / **587.33** (D#4/Eb4 / D#5/Eb5)	$\underset{\cdot}{3}$ **Hz** **369.99** / **739.99** (F#4/Gb4 / F#5/Gb5)	$\underset{\cdot}{5}$ **Hz** **415.3** / **830.61** (G#4/Ab4 / G#5/Ab5)	$\underset{\cdot}{6}$ **Hz** **466.16-493.88** / **932.33-987.77** (A#4/Bb4-B4 / A#5/Bb5-B5)	$\underset{\cdot}{1}$ **Hz** **277.18** / **554.37** (#C4/Db4 / C#5/Db5)

Table A1.12. My proposition for tuning of intervals bonang barung/panerus in slendro – table showcases actual player's position (superscript dot means higher octave, subscript dot means lower octave)

4 **Hz** **830.61** / **1661.2** (G#5/Ab5 / G#6/Ab6)	6 **Hz** **932.33-987.77** / **1864.7-** **1975.53** (A#5/Bb5-B5 / A#6/Bb6-B6)	5 **Hz** **880.00-932.33** / **1760.00-** **1864.66** (A5-A#5/Bb5 / A6-A#6/Bb6)	3 **Hz** **698.46** / **1396.91** (F5 / F6)	2 **Hz** **622.25-659.25** / **1244.51-1318.51** (D#5/Eb5-E5 / D#6/Eb6-E6)	7 **Hz** **1046.50** / **2093.00** (C6 / C7)	$\underset{\cdot}{1}$ **Hz** **293.66-311.13** / **587.33-622.25** (D4-D#4/Eb4 / D5-D#5/Eb5)
1 **Hz** **587.33-622.25** / **1174.66-** **1244.51** (D5-D#5/Eb5 / D6-D#6/Eb6)	$\underset{\cdot}{7}$ **Hz** **523.25** / **1046.50** (C5 / C6)	$\underset{\cdot}{2}$ **Hz** **311.13-329.63** / **622.25-659.25** (D#4/Eb4-E4 / D#5/Eb5-E5)	$\underset{\cdot}{3}$ **Hz** **349.23** / **698.46** (F4 / F5)	$\underset{\cdot}{5}$ **Hz** **440.00-466.16** / **880.00-932.33** (A4-A#4/Bb4 / A5-A#5/Bb5)	$\underset{\cdot}{6}$ **Hz** **466.16-493.88** / **932.33-987.77** (A#4/Bb4-B4 / A#5/Bb5-B5)	$\underset{\cdot}{4}$ **Hz** **415.3** / **830.61** (G#4/Ab4 / G#5/Ab5)

Table A1.13. My proposition for tuning of intervals bonang barung/panerus in pelog – table showcases actual player's position (superscript dot means higher octave, subscript dot means lower octave)

Saron

So far, we have witnessed a common challenge which occurs to most Javanese instruments, namely lack of information about the frequency spectrum for all instruments, as no authors of Javanese gamelan provides thorough information about this, and unfortunately the saron instruments are no exception.

However, differently, in this context we are provided with reference to at least one other instrument, namely the slenthem. Sorrell suggests a difference in range of four octaves between all saron instruments and the slenthem. The lowest tuned instrument among these is the slenthem which is tuned an octave lower than the saron demung. The saron barung is tuned an octave above demung, and finally the saron panerus (also known as peking) is tuned an octave above the barung, while the gambang cover the entire range of these instruments (four octaves); all of these instruments in addition to the slenthem contains seven keys – the pelog tuning for saron instruments all appears to contains the following sequence 1 2 3 4 5 6 7, while the slendro tuning is: low 6 (dot below), 1, 2, 3, 5, 6, high 1 (dot above) (Sorrell N. , 1990, p. 31).

To further complicate matters, there are no saron instruments commonly found in Bali, in addition the Balinese equivalent counterparts mainly consists of various types of gender instruments (even including the ugal, pemade, and kantilan which are all technically Gender instruments). Besides the shared physical traits found on Javanese gender and slenthem instruments – they contain completely different number of keys, and altogether covers a bigger tonal register than the sarons. Thus, the Balinese instruments may not be a useful resource to figure out the exact octavial range for saron instruments.

Sorrell does not entirely specify whether the slenthem instrument contains the same sequence of tones as the saron instruments, but based on their shared functionality to play the fixed melody within compositions, yet sharing the same amount of keys and range - it likely appears that the same sequence of tones applies to the slenthem instrument as well (Sorrell N. , 1990, p. 33). One source on the internet (http://sumarsam.web.wesleyan.edu/intro_gamelan.html) appears to concurs with this assumption.

$\underset{\cdot}{6}$	1	2	3	5	6	$\dot{1}$
Hz **233.08-246.94** / **466.16-493.88** / **932.33-987.77** (A#3/Bb3-B3 / A#4/Bb4-B4 / A#5/Bb5-B5)	**Hz** **277.18** / **554.37** / **1108.73** (C#4/Db4 / C#5/Db5 / C#6/Db6)	**Hz** **311.13** / **622.25** / **1244.51** (D#4/Eb4 / D#5/Eb5 / D#6/Eb6)	**Hz** **369.99** / **739.99** / **1479.98** (F#4/Gb4 / F#5/Gb5 / F#6/Gb6)	**Hz** **415.3** / **830.61** / **1661.20** (G#4/Ab4 / G#5/Ab5 / G#6/Ab6)	**Hz** **466.16-493.88** / **932.33-987.77** / **1864.70-1975.53** (A#4/Bb4-B4 / A#5/Bb5-B5 / A#6/Bb6-B6)	**Hz** **554.37** / **1108.73** / **2217.46** (C#5/Db5 / C#6/Db6 / C#7/Db6)

Table A1.14. My proposition for tuning of intervals saron demung/slendro/panerus in slendro (superscript dot means higher octave, subscript dot means lower octave)

1 **Hz** **293.66-311.13** / **587.33-622.25** / **1174.66-1244.51** (D4-D#4/Eb4 / D5-D#5/Eb5 / D6-D#6/Eb6)	2 **Hz** **311.13-329.63** / **622.25-659.25** / **1244.51-1318.51** (D#4/Eb4-E4 / D#5/Eb5-E5 / D#6/Eb6-E6)	3 **Hz** **349.23** / **698.46** / **1396.91** (F4 / F5 / F6)	4 **Hz** **415.3** / **830.61** / **1661.20** (G#4/Ab4 / G#5/Ab5 / G#6/Ab6)	5 **Hz** **440.00-466.16** / **880.00-932.33** / **1760.00-1864.66** (A4-A#4/Bb4 / A5-A#5/Bb5 / A6-A#6/Bb6)	6 **Hz** **466.16-493.88** / **932.33-987.77** / **1864.70-1975.53** (A#4/Bb4-B4 / A#5/Bb5-B5 / A#6/Bb6-B6)	7 **Hz** **523.25** / **1046.50** / **2093.00** (C5 / C6 / C7)

Table A1.15. My proposition for tuning of intervals saron demung/slendro/panerus in pelog (superscript dot means higher octave, subscript dot means lower octave)

Slenthem

As stated previously, none of the authors on Javanese gamelan manages to provide us with this information besides saying that it appears an octave below the saron instruments. However, gamelan.gs provides some crucial information about this – although, the slenthem appears to start somewhere between the 110 Hz and the 220 Hz points (although noticeably closer to 110 Hz). This information suggests that the lowest tuned key on slenthem appears at roughly 165 Hz and since we already know that the slenthem and all saron instruments cover a total range of four octaves – the highest tuned saron key should appear beyond 1760 Hz.

6̣	1	2	3	5	6	1̇
Hz **116.54-123.47** (A#2/Bb2-B2)	**Hz** **138.59** (C#3/Db3)	**Hz** **146.83** (D#3/Eb3)	**Hz** **185.00** (F#3/Gb3)	**Hz** **207.65** (G#3/Ab3)	**Hz** **233.08-246.94** (A#3/Bb3-B3)	**Hz** **277.18-293.66** (C#4-Db4)

Table A1.16. My proposition for tuning of intervals slenthem in slendro (dot in front means higher octave, dot behind means lower octave)

1	2	3	4	5	6	7
Hz **146.83-155.56** (D3-D#3/Eb3)	**Hz** **155.56-164.81** (D#3-Eb3-E3)	**Hz** **174.61** (F3)	**Hz** **207.65** (G#3/Ab3)	**Hz** **220.00-233.08** (A3-A#3/Bb3)	**Hz** **233.08-246.94** (A#3/Bb3-B3)	**Hz** **261.63** (C4)

Table A1.17. My proposition for tuning of intervals slenthem in pelog (dot in front means higher octave, dot behind means lower octave)

Gender

Both the gender barung and gender panerus contain 14 keys on each instrument, the tuning of the kettles ranges from low 6 to high 3 for both the slendro and the pelog tuning systems, further, panerus is tuned an octave higher than barung (Sorrell N. , 1990, p. 34). The number of keys on the gender in addition to the order proposed by Sorrell instruments suggests a range of two octaves on each instrument. Unfortunately, besides this information, Sorrell only provides a comparison between the largest key (wilah) found on the slenthem to be 36 cm long and 9.5 cm wide and the smallest key (wilah) on gender panerus to be 15 cm long and 4 cm wide (Sorrell N. , 1990, p. 33). Whether, this would suggest that the gender is tuned higher than the slenthem or in the same range is difficult to obtain based only on this information. Sorrell proposes two different variants of gender in pelog, one with the following order; 7 2 3 5 6 and the other 1 2 3 5 6 (Sorrell N. , 1990, p. 33). He then states that the gender instruments are played in parallel octaves to that of the gambang, which suggests that both instruments appear within the same frequency range (Sorrell N. , 1990, p. 41).

According to the order of gambang keys (from low 6 up to high 3/5), this appears to be correct, further gamelan.gs (https://gamelan.gs/booklet/a-javanese-gamelan-sound-library/) also suggests that both gender and gambang are within the same range and further the lowest pitch on slenthem and gender barung begins at fairly close approximation. Based on this information provided by gamelan.gs and other previous sources, we will get the following range of pitches:

$\underset{\cdot\cdot}{6}$	$\underset{\cdot}{1}$ ($\underset{\cdot\cdot}{7}$)	$\underset{\cdot}{2}$	$\underset{\cdot}{3}$	$\underset{\cdot}{5}$	$\underset{\cdot}{6}$	1 ($\underset{\cdot}{7}$)	2	3	5	6	$\dot{1}$ (7)	$\dot{2}$	$\dot{3}$
Hz **116.54-123.47** / **233.08-246.94** (A#2/Bb2-B2 / A#3/Bb3-B3)	**Hz** **138.59** / **277.18** (C#3/Db3 / C#4/Db4)	**Hz** **155.56** / **311.13** (D#3/Eb3 / D#4/Eb4)	**Hz** **185.00** / **369.99** (F#3/Gb3 / F#4/Gb4)	**Hz** **207.65** / **415.30** (G#3/Ab3 / G#4/Ab4)	**Hz** **233.08-246.94** / **466.16-493.88** (A#3/Bb3-B3 / A#4/Bb4-B4)	**Hz** **277.18** / **554.37** (C#4/Db4 / C#5/Db5	**Hz** **311.13** / **622.25** (D#4/Eb4 / D#5/Eb5)	**Hz** **369.99** / **739.99** (F#4/Gb4 / F#5/Gb5)	**Hz** **415.3** / **830.61** (G#4/Ab4 / G#5/Ab5)	**Hz** **466.16-493.88** / **932.33-987.77** (A#4/Bb4-B4 / A#5/Bb5-B5)	**Hz** **554.37** / **1108.73** (C#5/Db5 / C#6/Db6)	**Hz** **622.25** / **1244.51** (D#5/Eb5 / D#6/Eb6)	**Hz** **739.99** / **1479.98** (F#5/Gb5 / F#6/Gb6)

Table A1.18. My proposition for tuning of intervals gender barung/panerus in slendro (superscript dot means higher octave, subscript dot means lower octave)

6 Hz	1 Hz	2 Hz	3 Hz	5 Hz	6 Hz	1 Hz	2 Hz	3 Hz	5 Hz	6 Hz	1 Hz	2 Hz	3 Hz
116.54-123.47 / 233.08-246.94	146.83-155.56 / 293.66-311.13	155.56-164.81 / 311.13-329.63	174.61 / 349.23	220.00-233.08 / 440.00-466.16	233.08-246.94 / 466.16-493.88	293.66-311.13 / 587.33-622.25	311.13-329.63 / 622.25-659.25	349.23 / 698.46	440.00-466.16 / 880.00-932.33	466.16-493.88 / 932.33-987.77	587.33-622.25 / 1174.66-1244.51	622.25-659.25 / 1244.51-1318.51	698.46 / 1396.91
(A#2/Bb2-B2 / A#3/Bb3-B3)	(D3-D#3/Eb3 / D4-D#4/Eb4)	(D#3/Eb3-E3 / D#4/Eb4-E4)	(F3 / F4)	(A3-A#3/Bb3 / A4-A#4/Bb4)	(A#3/Bb3-B3 / A#4/Bb4-B4)	(D4-D#4/Eb4 / D5-D#5/Eb5)	(D#4/Eb4-E4 / D#5/Eb5-E5)	(F4 / F5)	(A4-A#4/Bb4 / A5-A#5/Bb5)	(A#4/Bb4-B4 / A#5/Bb5-B5)	(D5-D#5/Eb5 / D6-D#6/Eb6)	(D#5/Eb5-E5 / D#6/Eb6-E6)	(F5 / F6)

Table A1.19. My proposition for tuning of intervals gender barung/panerus (1) in pelog – note that this version uses pelog 1 (superscript dot means higher octave, subscript dot means lower octave)

6 Hz	7 Hz	2 Hz	3 Hz	5 Hz	6 Hz	7 Hz	2 Hz	3 Hz	5 Hz	6 Hz	7 Hz	2 Hz	3 Hz
116.54-123.47 / 233.08-246.94	130.81 / 261.63	155.56-164.81 / 311.13-329.63	174.61 / 349.23	220.00-233.08 / 440.00-466.16	233.08-246.94 / 466.16-493.88	261.63 / 523.25	311.13-329.63 / 622.25-659.25	349.23 / 698.46	440.00-466.16 / 880.00-932.33	466.16-493.88 / 932.33-987.77	523.25 / 1046.50	622.25-659.25 / 1244.51-1318.51	698.46 / 1396.91
(A#2/Bb2-B2 / A#3/Bb3-B3)	(C3 / C4)	(D#3/Eb3-E3 / D#4/Eb4-E4)	(F3 / F4)	(A3-A#3/Bb3 / A4-A#4/Bb4)	(A#3/Bb3-B3 / A#4/Bb4-B4)	(C4 / C5)	(D#4/Eb4-E4 / D#5/Eb5-E5)	(F4 / F5)	(A4-A#4/Bb4 / A5-A#5/Bb5)	(A#4/Bb4-B4 / A#5/Bb5-B5)	(C5 / C6)	(D#5/Eb5-E5 / D#6/Eb6-E6)	(F5 / F6)

Table A1.20. My proposition for tuning of intervals gender barung/panerus (2) in pelog – note that this version uses pelog 7 (superscript dot means higher octave, subscript dot means lower octave)

Kendhang

The kendhang instruments are the rhythmic leader of the gamelan ensemble, and usually not tuned to any specific pitches (Sorrell N. , 1990, p. 40). However, the only obvious difference between the two variants is that the ciblong is lower pitched than its smaller male counterpart ketipung, and a variety of sounds/pitches by applying different hand techniques allows the player to compensate for sound/pitches in accordance with the other instruments in the ensemble (Sorrell N. , 1990, p. 40).

Gambang

As previously stated, the gambang instrument covers the same range as both gender instruments (approximately three octaves). The number of keys on gambang instrument varies depending on the tuning system, the one tuned to pelog contains 19 keys (from low 6 to high 3) and either uses note 1 or 7 (we will only display value for the tone 1, not the seventh), while the one tuned to slendro contains 20 keys (from low 6 to high 5) (Sorrell N. , 1990, p. 41). No author mentions any omission of a note 4 to appear in pelog, however, the only way to encapsulate a range (in pelog) onto 19 keys with the starting and ending key intact, is by excluding pelog4. Interestingly enough, the archaic version called gambang gangsa covered the entire range of saron, which may suggest that there could be some correlation between this instrument and the saron instruments; by examining the chart provided by gamelan.gs, the gambang appears to cover the entire register from slenthem and up until about half the range of saron panerus, further gender and gambang also seems to coincide with one another, thus Sorrel's suggestions appears to be valid, the following order of tones on gambang provided as thus:

$\underset{..}{6}$ **Hz** **116.54-** **123.47** (A#2/Bb2- B2)	$\underset{.}{1}$ ($\underset{..}{7}$) **Hz** **146.83-** **155.56** (D3- D#3/Eb3)	$\underset{.}{2}$ **Hz** **155.56-** **164.81** (D#3-Eb3- E3)	$\underset{.}{3}$ **Hz** **174.61** (F3)	$\underset{.}{5}$ **Hz** **220.00-** **233.08** (A3- A#3/Bb3)	$\underset{.}{6}$ **Hz** **233.08-** **246.94** (A#3/Bb3- B3)	1 ($\underset{.}{7}$) **Hz** **293.66-** **311.13** (D4- D#4/Eb4)	2 **Hz** **311.13-** **329.63** (D#4/Eb4- Eb4	3 **Hz** **349.23** (F4)	5 **Hz** **440.00-** **466.16** (A4- A#4/Bb4)
6 **Hz** **466.16-** **493.88** (A#4/Bb4- B4)	$\dot{1}$ (7) **Hz** **587.33-** **622.25** (D5- D#5/Eb5)	$\dot{2}$ **Hz** **622.25-** **659.25** (D#5/Eb5- E5)	$\dot{3}$ **Hz** **698.46** (F5)	$\dot{5}$ **880.00-** **932.33** (A5- A#5/Bb5)	$\dot{6}$ **Hz** **932.33-** **987.77** (A#5/Bb5- B5)	$\ddot{1}$ ($\dot{7}$) **1174.66-** **1244.51** (D6- D#6/Eb6)	$\ddot{2}$ **Hz** **1244.51-** **1318.51** (D#6/Eb6- E6)	$\ddot{3}$ **Hz** **1396.91** (F6)	

Table A1.21. My proposition for tuning of intervals gambang in slendro – note that this table is broken into an upper bottom row to include all intervals on the instrument (superscript dot means higher octave, subscript dot means lower octave)

$\underset{..}{6}$ **Hz** **116.54-** **123.47** (A#2/Bb2- B2)	$\underset{.}{1}$ **Hz** **138.59** (C#3/Db3)	$\underset{.}{2}$ **Hz** **146.83** (D#3/Eb3)	$\underset{.}{3}$ **Hz** **185.00** (F#3/Gb3)	$\underset{.}{5}$ **Hz** **196.0-** **207.65** (G3- G#3/Ab3)	$\underset{.}{6}$ **Hz** **233.08-** **246.94** (A#3/Bb3- B3)	1 **Hz** **277.18-** **293.66** (C#4- Db4)	2 **Hz** **311.13** (D#4/Eb4)	3 **Hz** **369.99** (F#4/Gb4)	5 **Hz** **415.3** (G#4/Ab4)
6 **Hz** **466.16-** **493.88** (A#4/Bb4- B4)	$\dot{1}$ **Hz** **554.37** (C#5/Db5)	$\dot{2}$ **Hz** **622.25** (D#5/Eb5)	$\dot{3}$ **739.99** (F#5/Gb5)	$\dot{5}$ **Hz** **830.61** (G#5/Ab5)	$\dot{6}$ **Hz** **932.33-** **987.77** (A#5/Bb5- B5)	$\ddot{1}$ **Hz** **1108.73** (C#6/Db6)	$\ddot{2}$ **Hz** **1244.51** (D#6/Eb6)	$\ddot{3}$ **Hz** **1479.98** (F#6/Gb6)	$\ddot{5}$ **Hz** **1661.20** (G#6/Ab6)

Table A1.22. My proposition for tuning of intervals gambang in pelog – note that this table is broken into an upper bottom row to include all intervals on the instrument (superscript dot means higher octave, subscript dot means lower octave)

Bali:

Pelog and slendro tuning systems tends to be executed quite differently between the two islands. While Java seems to regard both tuning systems equally or possibly show a slight preference for slendro, Bali practically never performs compositions specific for the slendro tuning system, and instead favours a five-tone pelog scale variant of the seven-tone pelog tuning system. Since the execution is different between the islands - Sorrell has suggested one way to decipher tones accordingly to the Javanese standard which we have discussed before, the tones are divided thus 1 2 3 5 6 (Sorrell N. , 1990, p. 25). This is how we will primarily refer to tones in Bali from now on.

Tenzer suggests that the frequency spectrum of all “key based” instruments range from approximately C3 or C#3 at about 130 Hz, and up to approximately C7 or C#7 2080 Hz. However, the lowest tuned gong to appear at around 65 Hz, approximately one octave lower than the other instruments such as the two jegogans, the two jublags, ugal, the four pemades, the four kantilan, and the reyong/trompong (altogether comprises a range of four octaves) (Tenzer, Balinese Music, 1991, p. 59), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 28).

As previously addressed, the pelog tuning system comprises unequally divided intervals and various Balinese ensembles, despite containing the same types of instruments may demonstrate intervallic deviances of up to a few semitones apart. Thus, as with Javanese gamelan, it would be difficult to estimate precise tones accordingly to exact Western intervallic values. However, in order to allow both Javanese and Balinese gamelan to be operable/playable within a shared keyboard layout, a compromise has been made to incorporate and merge propositions from Becker, Sorrell and Tenzer, despite there will be an option to allow (in most cases) the user to either select Javanese and Balinese instruments.

Concept behind tuning of Balinese gamelan instruments

The tuning of each instrument is mainly provided by Tenzer (unless otherwise noted), and will be described separately. These will be based on figures and staff notations from both books by Tenzer, which demonstrate the range of tones and octaves between all groups of instruments (except the difference between pengumbang/pengisep variants – however these will be discussed shortly) (Tenzer, Balinese Music, 1991, p. 59), (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 44). Tenzer states the following: “…a kebyar gamelan may simply be said to encompass four octaves of five tones each, plus the first note of the fifth octave, but it is also accurately described as a set of forty-two independent pitches, half tuned to pengumbang and half to pengisep" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 33). The phenomenon of pengumbang and pengisep can be easily explained, it is a pairing of same instrument (two or four instruments), divided into a slightly larger female (pengumbang) and slightly smaller (pengisep) variant, with the same amount of keys tuned approximately 100 cents apart (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31). Further, Tenzer describes that the pengumbang and pengisep variants provides a shimmering acoustic beating, or the effect of "unison between two instruments" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31). This specific phenomenon appears to apply to almost all instruments in gamelan gong kebyar, except for gongs.

It should be noted that providing a thorough explanation about the exact difference between pengumbang and pengisep would be too complicated for such a Music Study and would eventually involve a lot of further compromises in terms of precise tuning of instruments. Tenzer does not provide intervallic proposition for both pengumbang and pengisep variants of the respective instruments and largely due to a number of ensembles solely own one single ugal instrument tuned to pengumbang - thus, it has been taken into account that the pitches/intervals (provided by Tenzer) on all Balinese metallophone instruments are referred to by their pengumbang variants.

Large gong

Large gong (approximately 85 cm in diameter) is the lowest tuned gong and the lowest tuned instrument to be found in Balinese ensembles, this is normally tuned to ding (i.e. ≈ pelog1), and should usually oscillate at approximately 65 Hz (C2) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, pp. 28, 47). It should be noted that the tone ding appears at approximately 77.78 Hz (D2-D#2/Eb2) according to the intervallic model proposed specifically for this Music Study. Commonly, two large gongs usually appear in gamelan gong kebyar and is divided into a slightly larger sized female (gong wadon) and a slightly smaller male (gong lanang) variant. The second (and smallest of the two) is tuned to deng (pelog 3) approximately 200 and 300 cents higher than the first (Tenzer, Gamelan Gong

Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 47). Thus, the second gong has been tuned to 87.31 Hz (F2).

Kempur

The kempur (approximately 70 cm in diameter) is tuned to dung (i.e. ≈ pelog5) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). Unfortunately, limited information has been provided about the tuning of the kempur, Tenzer suggests that the lowest tuned large gong (gong wadon) appears to be only three tones apart from the noticeably smaller kempur (approximately 15 cm shorter in diameter) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). Based on the previous findings which suggests that the different types of Javanese gongs are tuned approximately half an octave apart from each other, then we should also take into account that the difference in size between the kempur (approximately 7 cm in diameter) which is slightly larger than its Javanese counterpart should equal less difference in pitch.

Further, McPhee suggests that the kempur is significantly smaller than the large gong, and states that it appears higher in pitch without elaborating the difference in pitch between these instruments (McPhee, 1976, p. 28). In comparison, gamelan.gs suggests that the Javanese counterpart should appear approximately half an octave (600 cents) apart from the gong ageng. However, Tenzer's staff notation suggests that the gong lanang and kempur are tuned one pitch apart from one another, in addition it indicates that the kempur should coincide with the fourth tone of Jegogan (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 44). Thus, kempur should to be tuned to approximately 220.00-233.08 Hz (A3-A#3/Bb3).

Kemong

The kemong (approximately 26 cm in diameter) is usually tuned to dung (pelog5), and is the smallest (separate) gong in the ensemble (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). According to Tenzer's staff notation kemong should coincide with the last tone of tromping (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 44). Thus, it should be tuned to approximately 880.00-932.33 Hz (A5-A#5/Bb5).

The only other reference to gong instruments by Tenzer is the sound characteristics reproduced by each type of gong, which he describes as being “sung” (possibly uttered) in order to simulate the sound that these gongs are supposed to make when stuck. He finishes this assessment by describing the register of each of the three lowest tuned gongs thus; gong (ageng) “Gir (sung on a low pitch …)”, kempur “Pur (sung on a medium pitch …)”, and kemong “Mong (sung on a high pitch …)”, however, no such information of the kempli instrument is provided there (Tenzer, Balinese Music, 1991, p. 43).

Kempli

Tenzer does not provide any information about a specific tone for the kempli, but based on the information which suggests that the kemong is the smallest gong indicates that the kempli is tuned to a lower pitch (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). Based on the staff notation provided by Tenzer, the kempli should coincide with the first tone of calung which is tuned to ding (pelog1) at approximately 293.66-311.13 (D4-D#4/Eb4).

Gender

As addressed above, metallophone instruments in Bali are almost exclusively divided into two variants, tuned to pengumbang (lower) and pengisep (higher). We will propose a set for each pengumbang/pengisep variant of instruments (where applicable), these will take basis on the pengumbang pitches proposed by Tenzer, and provide a pengisep counterpart of the same instrument tuned 100 cents higher.

The lowest pitched Gender metallophone instruments found in Bali both comprises five keys per instrument and is separated by two jegogans and the two jublags. The register of the two jegogans (female/male) consists is one octave starting from ding (pelog1) up to dang (pelog6) and occupies the lowest octave (approximately C3/C#3) of the four octaves which constitutes all metallophone instruments and reyong/trompong (Tenzer, Balinese Music, 1991, p. 59).

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
146.83-155.56	**155.56-164.81**	**174.61**	**220.00-233.08**	**233.08-246.94**
(D3-D#3/Eb3)	(D#3/Eb3-E3)	(F3)	(A3-A#3/Bb3)	(A#3/Bb3-B3)

Table A1.23. My proposition for tuning of intervals jegogan in pengumbang (female)

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
155.56-164.81	**164.81-174.61**	**185.00**	**233.08-246.94**	**246.94-261.63**
(D#3/Eb3-E3)	(E3-F3)	(F#3-Gb3)	(A#3/Bb3-B3)	(B3-C4)

Table A1.24. My proposition for tuning of intervals jegogan in pengisep (male)

The second lowest tuned gender instruments are the two jublags (female/male) which appears one octave higher than the jegogans; they start from ding (pelog1) up to dang (pelog5), further the range of the jublag appears in-between pemade and ugal (Tenzer, Balinese Music, 1991, p. 59).

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
293.66-311.13	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**
(D4-D#4/Eb4)	(D#4/Eb4-E4)	(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)

Table A1.25. My proposition for tuning of intervals jublag/calung in pengumbang (female)

1	2	3	5	6
Hz	**Hz**	**Hz**	**Hz**	**Hz**
311.13-329.63	**329.63-349.23**	**369.99**	**466.16-493.88**	**493.88-523.25**
(D#4/Eb4-E4)	(E4-F4)	(F#4/Gb4)	(A#4/Bb4-B4)	(B4-C5)

Table A1.26. My proposition for tuning of intervals jublag/calung in pengisep (male)

Gangsa

Among the group of ten-keyed Gangsa instruments, ugal is the lowest tuned and comprises a range of two octaves; its lowest tuned pitch starts from dong (pelog2) and up to ding (pelog1) two octaves above; the lower octave of ugal covers almost the same range as the jegogans, although it shares its upper octave with the lower octave of the pemades (Tenzer, Balinese Music, 1991, p. 59). Tenzer suggests that the fifth note on ugal is the same as the first note on jublag/calung (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 45). Often, only one ugal appears in a Balinese gamelan ensemble, however, if two the lowest will tuned to pengumbang (Tenzer, Balinese Music, 1991, p. 45).

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
155.56-164.81	**174.61**	**220.00-233.08**	**233.08-246.94**	**293.66-311.13**	**311.13-329.63**	**349.23**	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**
(D#3/Eb3-E3)	(F3)	(A3-A#3/Bb3)	(A#3/Bb3-B3)	(D4-D#4/Eb4)	(D#4/Eb4-E4)	(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(D5-D#5/Eb5)

Table A1.27. My proposition for tuning of intervals ugal in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
164.81-174.61	**185.00**	**220.00-233.08**	**246.94-261.63**	**311.13-329.63**	**329.63-349.23**	**369.99**	**466.16-493.88**	**493.88-523.25**	**622.25-659.25**
(E3-F3)	(F#3/Gb3)	(A3-A#3/Bb3)	(B3-C4)	(D#4/Eb4-E4)	(E4-F4)	(F#4/Gb4)	(A#4/Bb4-B4)	(B4-C5)	(D#5/Eb5-E5)

Table A1.28. My proposition for tuning of intervals ugal in pengisep (male)

An octave above the ugal/s we encounter the four pemades (two females/males), which similarly comprises two octaves and starts from dong (pelog2) (although an octave higher than ugal) and up to ding (pelog1), two octaves above (Tenzer, Balinese Music, 1991, p. 59). The pemades starts one tone below reyong however covers almost the exact same spectre as the entirety of the reyong (which also covers three tones above pemade), while it shares the lower octave of the upper octave of ugal, and the upper octave of the lower octave of the kantilan (Tenzer, Balinese Music, 1991, p. 59).

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
311.13-329.63	**349.23**	**440.00-466.16**	**466.16-493.88**	**587.33-622.25**	**622.25-659.25**	**698.46**	**880.00-932.33**	**932.33-987.77**	**1174.66-1244-51**
(D#4/Eb4-E4)	(F4)	(A4-A#4/Bb4)	(A#4/Bb4-B4)	(D5-D#5/Eb5)	(D#5/-E5)	(F5)	(A5-A#5/Bb5)	(A#5/Bb5-B5)	(D6-D#6/Eb6)

Table A1.29. My proposition for tuning of intervals pemade in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
329.63-349.23	**369.99**	**466.16-493.88**	**493.88-523.25**	**622.25-659.25**	**659.25-698.46**	**739.99**	**932.33-987.77**	**987.77-1046.50**	**1244-51-1318.51**
(E4-F4)	(F#4/Gb4)	(A#4/Bb4-B4)	(B4-C5)	(D#5/Eb5-E5)	(E5-F5)	(F#5/Gb5)	(A#5/Bb5-B5)	(B5-C6)	(D#6/Eb6-E6)

Table A1.30. My proposition for tuning of intervals pemade in pengisep (male)

Finally, the highest tuned Gangsa instrument are the four kantilan which appear an octave above the pemades and similar to the ugal and the pemades also comprises a range of two octaves. They starts from the tone dong (pelog2) and ends on ding (pelog1) two octaves above, approximately C7 or C#7 which is the highest tone found in Balinese gamelan (Tenzer, Balinese Music, 1991, p. 59). The lower octave of the kantilans shares the same range as the higher octave of the pemades and roughly shares the upper register of the reyong (although surpasses the pitches of the reyong) (Tenzer, Balinese Music, 1991, p. 59).

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
622.25-659.25 (D#5/-E5)	**698.46** (F5)	**880.00-932.33** (A5-A#5/Bb5)	**923.33-987.77** (A#5/Bb5-B5)	**1174.66-1244.51** (D6-D#6/Eb6)	**1244.51-1318.51** (D#6/Eb6-E6)	**1396.91** (F6)	**1760.00-1864.66** (A6-A#6/Bb6)	**1864.66-1975.53** (A#6/Bb6-B6)	**2349.32-2489.02** (D7-D#7/Eb7)

Table A1.31. My proposition for tuning of intervals kantilan in pengumbang (female)

2̣	3̣	5̣	6̣	1	2	3	5	6	1̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
659.25-698.46 (E5-F5)	**739.99** (F#5/Gb5)	**932.33-987.77** (A#5/Bb5-B5)	**987.77-1046.50** (B5-C6)	**1244-51-1318.51** (D#6/Eb6-E6)	**1318.51-1396.91** (E6)	**1479.98** (F#6/Gb5)	**1864.66-1975.53** (A#6/Bb6-B6)	**1975.53-2093.00** (B6-C7)	**2489.02-2637.02** (D#7/Eb7-E7)

Table A1.32. My proposition for tuning of intervals kantilan in pengisep (male)

Reyong

Reyong comprises 12 gong-chime kettles and a range of two octaves with an additional two tones, from deng (pelog3) (coincidentally with the seventh tone of ugal) to dung (pelog5) two octaves above (coincides with the eighth tone of kantilan) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). Tenzer provides a description of the tuning of this instrument thus: "The reyong is conventionally matched with the pengumbang; a similarly constructed instrument, the trompong, is tuned to pengisep" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 31). This gives the following order of pitches for reyong:

3̤	5̣	6̣	1	2	3	5	6	1̇	2̇	3̇	5̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
349.23 (F4)	**440.00-466.16** (A4-A#4/Bb4)	**466.16-493.88** (A#4/Bb4-B4)	**587.33-622.25** (D5-D#5/Eb5)	**622.25-659.25** (D#5/Eb5-E5)	**698.46** (F5)	**880.00-932.33** (A5-A#5/Bb5)	**1174.66-1244-51** (A#5/Bb5-B5)	**1244.51-1318.51** (D6-D#6/Eb6)	**1318.51-1318.51** (D#6/Eb6-E6)	**1396.91** (F6)	**1760.00-1864.66** (A6-A#6/Bb6)

Table A1.33. My proposition for tuning of intervals reyong

Trompong

Trompong is rarely ever used in current Balinese ensembles, it contains 10 gong-chime kettles with a range starting from dang (pelog6) which coincides with the fourth ugal key (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 46). According to what has been stated previously in regards to a pengisep tuning to be applied to this instrument, thus the following order of pitches:

3̣	5̣	6̣	1	2	3	5	6	1̇	2̇	3̇	5̇
Hz	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**	**Hz**
349.23 (F4)	**440.00-466.16** (A4-A#4/Bb4)	**466.16-493.88** (A#4/Bb4-B4)	**587.33-622.25** (D5-D#5/Eb5)	**622.25-659.25** (D#5/Eb5-E5)	**698.46** (F5)	**880.00-932.33** (A5-A#5/Bb5)	**1174.66-1244-51** (A#5/Bb5-B5)	**1244.51-1318.51** (D6-D#6/Eb6)	**1318.51-1318.51** (D#6/Eb6-E6)	**1396.91** (F6)	**1760.00-1864.66** (A6-A#6/Bb6)

Table A1.34. My proposition for tuning of intervals trompong

Kendang

Similar to Java, kendang hand drums are not tuned to any precise pitches and like its Javanese counterpart kendhang, it comprises of one drum which is tuned higher (wadon) than its smaller (lanang) counterpart. However, McPhee, suggests the pitch difference between these two instruments will "…vary from a second to approximate fifth" (McPhee, 1976, p. 33). Tenzer further describes that the instrument is "…made from nangka wood cut in the shape of tapering cylinder about 68 cm long, and with diameters of 30 and 25 cm for the right and left ends respectively. … For the kendang lanang the narrowest part of the hourglass positioned exactly halfway down the drum; this gives it a comparatively higher pitch than the wadon, which is narrower a quarter of the length of the drum from the left hand" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 48). According to Tenzer's staff notation the pitch of wadon should appear to be similar to that of the gong lanang (the higher pitched of the two largest gongs), at approximately, 87.31 (F2), while kendhang lanang should appear similar or coincide with the fourth tone on jegogan, thus 220.00-233.08 (A3-A#3/Bb3) (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-Century Balinese Music, 2000, p. 44).

Cengceng

Tuning of cengceng is not mentioned except for providing "…timbral contrast in the otherwise all-bronze texture" (Tenzer, Gamelan Gong Kebyar, The Art of Twentieth-

Century Balinese Music, 2000, p. 47). Thus, likely not tuned to any specific pitch, although likely the highest pitched instrument found in Balinese gamelan.

Conclusions

Gamelan is perhaps the most complex and challenging music culture in the world. The process acquiring sufficient information in order to establish and cover a fundamental understanding of all aspects of gamelan turned out to be impossible for such a Music Study and in a few cases required assumptions to be made based on the limitations within material revolving tuning of gamelan instruments. The further one gets into different aspects of gamelan music and its tuning systems - the more confounding the process will appear and requires a lot of commitment to the subject and many returned readings of sources before they eventually become clear. Under different circumstances and approaching a completely different musical culture would have taken significantly less time – and probably enabled other important aspects by emphasizing and linking several smaller aspects of the culture in order to provide a more complete and comprehendible Music Study. However, some aspects in gamelan are much more rooted in the respective tuning system than others – aspects that we normally would not expect or be accustomed to within other music cultures.

In this Music Study, several aspects of the music culture had to be omitted and given less priority due to lack of space and time in order to properly elaborate on these facets, thus only the most compulsory aspects regarding tuning of Indonesian gamelan music were explored because of the very complex nature of Indonesian gamelan music. For instance, expectations for aspects of a music culture such as notation and providing an overview on structures of gamelan compositions and what their aspects comprises; such as focus on melodic instruments (non-percussive instruments), explanation and in-depth information about the other tuning systems found in Indonesia, further regional variations of the different tuning systems, explanation of instruments and type of music performed by other types of gamelan ensembles, how musical or rhythmic cycles in gamelan music occurs and arranged, examination of how instruments relate to each other through compositional context, for the most part have been ignored in this Music Study.

Different from the other Music Studies in this Thesis, emphasis on in-depth information regarding fashioning processes of instruments have been provided significantly more space due to the instruments' unusual nature and physical appearances in comparison to other music cultures whose physical traits are similarly rooted in or associated with traditional Western based instruments; such as lute instruments either plucked or bowed, reed instruments, basic percussion instruments etc..

The work undertaken on this Music Study proved to be of an extremely challenging and difficult process. Literature on Indonesian music is difficult to obtain and provide challenges through numerous different "gaps" or "holes" of information in particular this applies to tuning of instruments and various tuning systems. There are very few aspects in gamelan music that are firmly based on standardization and little if nothing appears to be fixed, in general. Tuning and intervals on instruments appear loosely based on approximations rather than being applied to any specific rules, the information sometimes is rendered confusing and it is very hard to obtain anything without investigating various subjects repeatedly before the context eventually appears to be logical. A specific idea that applies to one ensemble rarely appears similar in another. Further, it requires significant time to get acquainted with the instruments because they are based on ideas that appear dissimilar to a Western musician/scholar.

Thus, classifying instruments and understanding the fashioning process of instruments (i.e. understanding how keys and gong-chime kettles are shaped) was necessary and at times required further investigation past scholarly sources. Further, certain instruments were given more attention and required more examination due to inhabiting features not easily detectable without further exploration, namely this applies to instruments with tube resonators; such as the saron instruments, Balinese gender instruments and various gong-chime kettle instruments – these aspects were not entirely covered by any of the scholarly resources.

Since there are no widely accepted classification systems found in Indonesia, it required me to develop my own, thus approximately half of the Music Study was dedicated solely to this development. In particular, Balinese instruments were more difficult to categorise, partly due to fewer written sources available and not covered sufficiently by scholars since these topics have been given less priority than other aspects of Balinese gamelan music. The most apparent challenges with Balinese gamelan ensembles (and instruments) are that they appear to be less exposed worldwide in comparison to Javanese gamelan. Most, if not all gamelan ensembles in the UK (if not worldwide) comprises Javanese instruments thus difficult for a British or UK based researcher to get a first-hand experience and get acquainted with Balinese gamelan instruments.

Similar to Javanese gamelan, Western scholars appears to favour other aspects of Balinese gamelan than individual tuning of instruments and/or in-depth information about their physical shapes; in particular this applies to Balinese metallophone and gong-chime kettle instruments. None of the scholarly sources provided sufficient information about the physical shapes on metallophone keys, or provide much clarity on how these instruments were tuned; most of this type of information was addressed in a rather vague manner.

On the other hand, shapes on Javanese metallophone instruments are described in much more detail, in particular by Sorrell who provides very informative insight about the distinct shapes on metallophone keys as well as easily understandable explanation about the difference between these and how they are classified into distinct subgroups; namely wilah polos and wilah blimbingan.

Unfortunately, in order to establish a sufficient overview of the relation between pitches on Javanese instruments and their octavial ranges both in general and within Javanese gamelan - proved to be the most difficult process for this Music Study. It appears that the main focus for most authors on Javanese gamelan is to prioritise performance and notation thus specified information about tuning of instruments is most commonly assigned to a few pages only. None of the authors proposes any frequency range on any Javanese instruments (besides the saron and slenthem instruments), thus it should be noted that the information about tuning of instruments to some degrees appears insufficient and thus resulted in an extensive comparison of various additional sources in order to provide a sufficient overview on tuning of all instruments found in Gamelan Sekar Pethak.

In this context, some comparison between similar instruments between both two islands (where applicable – to find missing links in relation to pitch relation between equivalent instruments on either island) was completely necessary in order to establish a sufficient overview of the various octaves which applied to each instrument, similarly the chart provided by gamelan.gs, rendered some of the information by Sorrell clearer and helped to put it into context.

It should be noted that Sorrell has been among most crucial resources for Javanese gamelan instruments for this Music Study, in particular his contributions to fashioning and the fashioning process of instruments provided thorough insight into how each single key/gong-chime kettle is tuned according to their slendro/pelog tuning. However, he does not provide much insight into the approximate value in cents or hz for each pitch per octave in pelog and slendro, besides mentioning that slendro is near equally divided and pelog unequally divided. Further, he does not provide sufficient information about the exact octaves which applies to each instrument except the full range of instruments - and the tuning relation between saron, slenthem, gambang and gender instruments (but not the exact initial/final octave for these). Thus, it required me to rely on other sources in order to find answers to these questions (gamelan.gs). Besides, some obvious deviation regarding the pitch/octave of kempyang between Sorrell's suggestion and the chart by gamelan.gs - it appears that everything else should correlate.

Differentlt, Tenzer was an invaluable resource to provide a complete frequency spectrum for all instruments and individual pitches on instruments Balinese gamelan, in addition he provided a good overview on fashioning of Balinese gamelan instruments, both of which were crucial in order to carry out this Music Study. However, due to lack of sufficient information about shapes on Balinese metallophone instrument, much time was spent observing different Balinese metallophone instruments from a wide array of different manufacturers in Bali before concluding that all keys found on Gender instruments share the same physical shapes. Despite slight deviations in terms of flatness, and/or thickness of keys due to being manufactured by different instrument makers, in principal all keys appear in more or less the same type of shape.

Another challenge for this Music Study was that all of the different authors at times provided different, slight deviations and/or sometimes opposing information which required further explorations and eventually lead to delays in order to complete this

Music Study. Further, all authors seem to focus mostly on entirely different aspects of gamelan music by favouring and emphasizing; arrangement on gamelan compositions, methods for playing patterns on instruments and music notation.

Another set of challenges for this Music Study, is that the resources on gamelan music were researched at different periods in time; the oldest source was written by Colin McPhee (among the most widely respected and frequently referenced author on either Javanese or Balinese gamelan music. McPhee did his research in Bali during the 1930s, a period when significant changes occurred in Balinese gamelan music. Some of the information about Balinese instruments, provided by McPhee appears to be somewhat out-dated in current times. Most of the radical changes in instrumentation and compositional structures happened in Bali around the time of his stay, thus a lot of the instruments mentioned no longer applies to current gamelan ensembles. In particular the most obvious of these is the inclusion of several saron instruments, thus some additional sources were necessary in order to establish clarity on the most typical modern Balinese gamelan ensemble. Further, McPhee did not provide much detail about tuning and fashioning of instruments in his book. The other authors made their research in Indonesia between early 1970s and early 1980s and all their account on gamelan instruments should appear much more valid and in accordance with current situation.

Both of the books written by Tenzer were necessary in order to establish clarity on the current instruments used in gamelan ensembles in modern times. In order to get a Western perspective on tuning of Balinese instruments both of his books were useful sources. Interestingly, in the former book (Balinese Music, 1991) Tenzer mentions a gender instrument called Penyacah, at that time it appeared to be rarely ever used (and mostly commonly associated with older compositions), thus it was not included among the core group of gamelan instruments. However, in his latter book he talks more favourably about the instrument (saying that it has started to appear more commonly in Balinese gamelan music since the 1980s), however, due to indecisive position which the instrument has held in the past few decades, it was excluded from the classification system provided earlier in this Music study.

It should be noted that in the end, I managed to provide most of the compulsory aspects on Indonesian gamelan in order to establish clarity on the main tuning systems and relation of tuning between instrument in Indonesia; however, in comparison to the other Music Studies within this Thesis, these aspects can at best be rendered merely sufficient, or possibly adequate. There are still some minor gaps of missing information which appears impossible to cover entirely. Despite that the process working on this Music Study at times was extremely difficult and very hard to process within a short period of time, it is also important to emphasize that learning about Indonesian gamelan has been a generally rewarding experience and the complexity of its inherent music culture has been incredibly fascinating exploration. Gamelan as a general research topic, despite that every single aspect of its culture to be equally weighed and measured would easily cover an entire PhD Thesis by itself, largely due to the fact that gamelan in itself is unbelievable vast.

Obviously, other sources were available (yet fairly limited) and may have provided or explained some of the “gaps” or possibly dealt with aspects that were not covered by the authors applied to this Music Study, however due to severe time constraints and for covering a noticeable if not minor aspect on this PhD Thesis, providing a more comprehensive Music Study would have been completely impossible.

APPENDIX 2

It should be noted that names and pronunciation of prominent musical figures, instruments, places, and musical systems presented in this Music Study might deviate from other sources.

History of India

Indian Music as a whole covers a great variety of many different musical genres, however, due to the limitation of this research we will not discuss any of these with the exception of Indian classical music. According the Wade, the concept of musical arts in India is combined into a threefold model called sangita which derives from Sanskrit and consists of 1) vocal music (gita), 2) instrumental music (vadya), and 3) dance (natya) (Wade, Music in Indian - The Classical Traditions, 2008, p. 15). Traditionally, the most common practice of teaching Indian music has been taught through the ancient practice of Guru/Shishya (master/disciple), where the student (shishya) appoint the master (guru). This practice has experienced a gradual decline for the past 50-60 years due to a more institutionalized Western approaches of teaching music at music schools and music conservatory/Institutions all over India. The remaining part of this Music Study will focus primarily on Indian classical music, thus any other genres or subgenres including vocal music, and dance will not be discussed beyond this point. Further, the significance of notation and improvisation will also be omitted from this research.

Introduction to Indian classical music

"I myself do not pretend to be a scholar; I have received most of my knowledge of the traditions of our music from my guru and other eminent musicians" – Ravi Shankar

According to Shankar the structure and practice of Indian classical music has remained standardized since the musical treatise Rikpratisakhya was written approximately 400 B.C. (Shankar, My Music, My Life, 2007, p. 26). Further, Sorrel & Narayan suggests that Indian Music is based on a five-principle system comprising: 1) sruti, 2) svara, 3) raga, 4) tala, and 5) drone; as such it is not unusual to find the latter three elements present in a composition at the same time (Sorrell & Narayan, 1980, p. 7). It should be noted that the aforementioned principles proposed by Sorrell & Narayan always appears to be interrelated with one another in some state or another. Despite that these principles initially have been presented in a rather plain and vague categorisation; thus, further information needs to be provided in order to provide clarity on what each of these principles involve.

Before we elaborate this topic any further, it is important to make a clear distinction between the musical execution found in Indian classical music and Western music. One elementary aspect in Western music detached from Indian music is the focus on harmony and sets of specific chord progressions which musicians commonly rely on in their music. However, Indian classical music tends to avoid or limit these aspects despite no broad spectre of harmony appears to be found in Indian classical music; neither are pronounced chord progressions, nor stable and fixed temperament which may reflect the somewhat meditative effect that Indian classical music seems to have on certain people. On the other hand, the significance of Indian classical music appears to be rooted in or emphasise other aspects such as pitch variations and maintains constant sound for a certain number of cycles. It should be noted that the conception of precisely calculated (correct) pitch and intonation (commonly associated with Western music) appears differently in Indian music, despite a set of twelve notes may appear in certain Indian scales, however these will not be equidistant (Deva, Indian Music, 1995, p. 29).

Shankar further elaborates that "…Indian music belongs to the system of modal music, it establishes a relationship between the fundamental, unchanging note-the tonic-and successive notes of the scale. This relationship between the tonic and any other scale note determines whether a note is the interval of a second, a third, a fourth, a fifth and so on." (Shankar, My Music, My Life, 2007, p. 26). Although Indian classical music follows certain strict rules of melodic behaviour similarly to Western music, it also includes an additional number of tones/intervals which appear uncommon in Western music. Further, a number of Indian melodic instruments contain features which allows for bending, emphasising, and/or the possibility of embellishing certain notes/pitches - mainly as a result of complex fashioning processes which surpasses regular Western instruments thus enables more flexibility in playing. Deva claims that despite the appearance of regular notes such as those referred to as Ri and Dha, these actually contains at least four varieties (Deva, Indian Music, 1995, p. 29).

Sruti, or srutis (as they are sometimes referred to), in total twenty-two - represents the entire spectre of possible intervals (sometimes referred to as quartertones or microtones) available within the range of an octave. Wade suggests that treatises on early Indian music theory describe two distinct parent scales, called Sa grama and Ma grama – which were "… distinguished from each other by interval sizes measured in srutis" (Wade, Music in Indian - The Classical Traditions, 2008, p. 32). Deva states that sruti means 'to hear' or 'that which is heard' in the Indian language (Deva, Indian Music, 1995, p. 29). However, this is limited to the division of twelve steps in which are named from the word sruti. Within the conception of the common seven notes of Indian scale, Bor addresses that the first and fifth scale degrees appear unalterable, while the five other scale degrees can be altered from their natural position (Bor, 2002, p. vii). The common reference scale in Hindustani music is called raga Bilaval and appears to be almost equivalent to the Western major diatonic scale. This was initially standardized in the 18th century around the time of Mughal aristocrat Nawazish Mohammad Raza (d. 1755) and Deva claims that all notes of this scale were either pure (suddha), high (tivra) and/or flat (komal) (Deva, Indian Music, 1995, p. 27).

All the twenty-two srutis are never used simultaneously in any particular composition and instead only a fraction of these intervals is used, however the numbers tend to vary and appears to be based on the structure of the musical composition in question. Deva describes the phenomenon of srutis as a "… concept of immense practical and theoretical importance, it has generated the greatest discussion-more hot than sound", while he further addresses that it "… has deeply mathematical and occultic implication" and is considered "… a measure as well as an indicative number of intervals-the pitch relation of notes" (Deva, Indian Music, 1995, p. 29).

Despite that the intervals are described as quartertones (in broadly terms), this does not unambiguously suggest that the tones appear to be entirely equally divided; further, no standardization exist in which to determine exact values of each sruti, thus only approximations are provided in Indian music (Sorrell & Narayan, 1980, p. 101). Some scholars have argued that the Indian scale possibly may be divided further into notes/pitches past the regular division of srutis, mainly due to the possibility to further colour and bend notes in the subtlest ways possible. Deva provides an informing insight into the phenomenon of srutis by suggesting that: "… [Sruti] is a measure as well as an indicative number of intervals-the pitch relations of notes" (Deva, Indian Music, 1995, p. 29). This brings us to the next aspect of tuning in Indian classical music, namely the diatonic scale.

Interestingly, despite that the terminology diatonic scale appears to be frequently used in Western music, it is also associated with a number of other musical cultures across the world; among others, the Western diatonic scale works similarly in Indian classical music. The West has long-since established a scale system commonly known as solfège (Do, re, mi etc.), Indians also operates with a similar system called svara which relates to the same notes although with different names and sets of abbreviations: Sa, Re, Ga, Ma, Pa, Dha, Ni, Sa (next octave). Svara appears to be an integral part in order to construct and/or perform Indian classical music. Popley suggests that the concept possibly dates back to ancient times and appears in early Tamil literature such as the Paripadal (A.D. 100-200) and mentioned alongside seven Palai (ancient Dravidian modes); in addition the svara nomenclature can also be found in the ancient Rikpratisakhya, (approximately 400 B.C.) and Mahabharata (500 B.C. – A.D. 200) (Popley, 1921, pp. 9-11).

It should be noted that Indian compositions rarely exceed more than five tones, thus they appear to encompass certain rules which limits a tonal periphery which mainly revolves around a limited number of tones; commonly these appears to consist of a fixed tonic (Sa), and at least the fourth (Ma) or fifth (Pa) as a second tone (Bor, 2002, p. 1). In order to make a comparable distinction between srutis and svara understandable; the aspect of sruti, despite an obvious relation to the intervals - it related even more towards the in-between notes while svara relates to fixed standardized notes. Despite an obvious distinction between the two, a correlation between the two are still apparent and interrelate through their shared aspects in all types of classical compositions. We will further elaborate on the phenomenon of srutis and examine a number of proposed suggestions, later on in this Music Study.

According to Malm, the first mentioning of the word raga appears in Brhaddesi, a treatise written by the musician Matanga (also known as Matanga Muni or Matanga-Bharata) approximately in the 10th century (Malm, 1967, p. 95). Sorrell & Narayan, on the other hand suggests that it was written approximately 9th century (Sorrell & Narayan, 1980, p. 6). It should be noted that other alternate timelines for Matanga has been proposed, some of which suggests that he lived as early as 6th-7th century. Among others, Bor addresses that the majority of ancient Indian musicologists from the 9th century onwards effortlessly classified a significant number of classification systems which also often contradicted each other by grouping the ragas into ancient tone system (gramas) and modes (jatis and grama ragas) – in an attempt for these writers to accommodate ancient theory with the then contemporary theory (Bor, 2002, p. 2). Still, Bor suggests that the origin of these ragas have changed so drastically over the centuries that it is nearly impossible to trace the origin of any raga past the 16th century (Bor, 2002, p. 2). The phenomenon of raga holds a significant place in Indian classical music despite that its melodic aspects have evolved through the centuries; in Indian music raga appears to relate both to melody and mode, although with a slightly stronger emphasis on the former. Neuman states that raga has “no conceptual analogue in Western music”, and further defined by musician and ethnomusicologist Peter Row “as a set of musical materials that together form a unique modal identity that serves as the basis for composition and improvisation” (Neuman, 1990, p. 23).

In ancient times the melodic elements of Indian music were equally weighted with the rhythmic elements however a change occurred in the past few centuries which allowed for greater emphasis on melody. According to Shankar, melody in Indian music still remain focused on limited amounts of modes (contrary to Western music), and despite these limitations the melody appears to dwell on and elaborate to a great extent – in order to produce intense, hypnotic and magical effects (Shankar, My Music, My Life, 2007, p. 26). Hindustani music, while different to Carnatic music appears to have been developing its own specific instrumental structure; whereas Carnatic compositions do not focus specifically on composition for instruments and song, a particular Hindustani composition appears to be formed through its relation and definition based on the raga and tala is used, and generally referred to as gat (Deva, Indian Music, 1995, p. 64).

The phenomenon of raga is governed by a set of rules that relies on specific number of notes/pitches for the musician to work around in each composition, this is not a fixed set of notes and as such they appear different from one composition to another. The notes/pitches in question need to be performed in a particular order and the melodic style requires to be maintained within certain strict confinements – which all comprises certain aspects expected to be mastered by the musician at an early stage during their musical training. The structure of every raga is based firmly on established principles which starts from a lower pitch (tonic), then later ascend (upper tonic) before it is finally descend back to its original pitch; the ascending order is called arohana, while the descending is avarohana (Shankar, My Music, My Life, 2007, p. 32). It should be noted that the severity of these principles initially took place in Indian music within the last few centuries and it appears to be common practice for Indian musicians to understand this information at an early age.

Although a selection of emergent percussive instruments has been introduced to Indian music since the era of the ancient Indus civilisation, the rhythmic aspect (known as tala) probably may be the best-preserved aspect of Indian classical music and simultaneously retain some of its stature since ancient times. The phenomenon of tala relates to rhythm although is it not uniformly inherent in terms of rhythm by itself; each singular beat of tala is called a matra and every complete cycle is called one avritti (Sorrell & Narayan, 1980, p. 116). Deva proposes one description of tala as follows: “Tala is a rhythmic arrangement of beats in a cyclic manner” (Deva, Indian Music, 1995, p. 3). The tala cycles follow patterns based on repetition and divided either into equal or not equal sections – in addition to this the cycles contain time units. The most significant aspect of tala is the cyclic arrangement where its focus on complex rhythm appears to have a bigger impact than commonly accustomed to in Western music.

We have witnessed that there is an apparent interrelation between sruti and svara, however, similarly an interrelation between raga and tala occurs as well. This relates to the structure of the raga although it affects the execution of the tala. In order to become an accomplished tala player, a great deal of time and discipline is required; the musician will undergo a progression initiated by understanding the basic form gradually reach and accomplish the stages in order to become an accomplished tala player. On two specific accounts, tala differs between Hindustani and Carnatic; whereas Hindustani music favours “relative emphasis of the beats of a tala”, the Carnatic music prefer “rhythmic elaborations” in accordance to “internal arrangements of time patterns” within a section (anga) or cycle (avarta) of a composition (Deva, Indian Music, 1995, p. 42). Each raga comprises a set of beats performed in cycles and the most common categorisations of cycles (within a raga)

appears as either 6, 7, 8, 10, 12, 14, 16 cycles of beats –the most common beat is referred to as Tintal (i.e. 16 cycles of beats) (Sorrell & Narayan, 1980, p. 116).
The last principle of Indian music is drone. Drone is easily explained; it is the tonic (i.e. the first tone in a diatonic scale, in this case equivalent to the Sa in Indian tuning) which establishes the foundation in any composition of Indian classical music. The drone is constantly audible throughout any composition and this tone usually remains constant throughout in any composition. Primarily, the tanpura is the preferred instrument for drone although the sitar may also be sufficient for this task (we will further discuss this later on in this Music Study).

The History of Indian classical music

Among the earlier musical influences to be traced in Indian music derives from tribal music of ancient ages and Tamil music which contained its unique blend of melodic styles and made indelible imprints on Indian classical music – at a later point in time these were eventually fused with Indo-Aryan vocal music (Rig Veda and Sam Veda) (Deva, Indian Music, 1995, p. 1). The first known pre-historic musicians known in or around the Indian continent have been described as talented flute players who settled in the Northern regions of the subcontinent; however, their exact ethnic background still appears unknown. The earliest traces of music were uncovered through recent archaeological excavations and dating back approximately 4000 years (in the era of the Indus Valley); apparently archaeologists have discovered that musical performers (possibly Dravidian) were playing flutes, primitive drums, and lute type of instruments similar to modern day veenas (Shankar, My Music, My Life, 2007, p. 27). The history of India is among the most well documented amidst various ancient cultures in the world and can be traced back a number of millenniums. Deva claims the earliest evidence of musical instruments derived from the Indus Valley complex (such as Mehrgarh and Harappa, both part of current-day Pakistan) and dates back to approximately 3000 B.C. – mainly evidenced through depictions on seals and pictographs (Deva, Indian Music, 1995, p. 94). Further, mentioning of veena instruments appears to be found although none of the names coincides with any of the current veena instruments known to exist today, additionally Deva suggests that the ancient version of veena instruments inhabited the shape similar to harps in ancient times (Deva, Indian Music, 1995, p. 94)

According to Wade, the earliest known sources regarding Indian music originally appeared in the liturgical text collectively known as Sanskrit and was written through the first span of writings during the Vedic period or slightly after the Indo-Aryans invasion in the North of India (approximately 1500-500 B.C.) (Wade, Music in Indian - The Classical Traditions, 2008, p. 15). It is important to address that the Sanskrit has been written, re-written, revised and edited throughout the span of many centuries - thus its validation as a reliable source is complex thus its content should be approached with a degree of scepticism due to fear of misconceptions which provides a mixture of actual happenings, factual truths/occurrences associated with legends (Wade, Music in Indian - The Classical Traditions, 2008, p. 15). Thus, any specifically proposed timeline past the last two centuries needs to be approached with a grain of salt.

Rig Veda is the earliest known surviving documentation on musical compositions found in Sanskrit, Deva suggest that Rig veda "…was recited using three tonal regions. Samaveda which is the sung version of Rgveda in its most developed stage was chanted in a descending manner, with seven notes" (Deva, Indian Music, 1995, p. 8). The content of Rig Veda comprises a collection of religious Vedic hymns possibly written approximately 3000 years ago.

The Indo-Aryan occupation introduced vocal music to the Indian subcontinent; originally this occupation was assigned to and performed by Presbyterians (priest's wives) who were chanting for sacrificial ceremonies or reciting religious Vedic texts, although later this task was assigned to male priests (Wade, Music in Indian - The Classical Traditions, 2008, p. 15). This practice appears to have been common until the 9th century, which surprisingly occurred at a time when it appeared to be common practice for women to be students of music in ancient India (Wade, Music in Indian - The Classical Traditions, 2008, p. 15). Later on, the emergence of Hinduism and Buddhism reflected yet another turning point in relation to the execution of religious chant; eventually the chants were performed by ecclesiastical women for the purpose of sacrificial rituals and religious prayers – during a stage when religious chant had become a prominent part of Indian music.

However, another major change occurred in Indian music with the emergence of celestial music (gandharva in Indian) approximately during the 6th century B.C. and in effect possibly coincided with the introduction of the infamous court and temple-patronage system (Shankar, My Music, My Life, 2007, p. 48). Among the earliest known references for musical performances found in Pali Pitaka (i.e. written documentation of Buddha's teaching) appears to date back approximately 300 B.C. and supposedly claims that Gautama Buddha (approximately 480 B.C. and origin of Buddhism) attended a performance of musical significance (Popley, 1921, p. 9).

Shankar addresses that Narada, among the most significant musicians to emerge from ancient India, addresses several types of veena instrument in his treatise called Naradishiksha (approximately 100 A.D.) – although he does not specify or provide details about any features applied to the instrument (Shankar, My Music, My Life, 2007, p. 48). Popley, on the other hand, suggests that the first mentioning of veena instruments appears to be found in the Silappadigaram (A.D. 300), a Buddhist drama which also appears to mention other musicians such as a drummer and a flute player – instruments which all are still commonplace within current Hindustani and Carnatic classical music (Popley, 1921, p. 11).

The Indian theatrologist, musicologist and sage Bharata Muni is often attributed to the writing of the Natya Sastra, an encyclopaedic treatise on performing arts which is included in Sanskrit and appears to be the oldest work in relation to music and possibly written somewhere between the 3rd century B.C. and 5th century A.D. (it should be noted other authors may suggest slight alterations to this timeline) (Sorrell & Narayan, 1980, p. 6). In addition, it appears to be the first reference where any relation between magic power and divinity on music exists (Sorrell & Narayan, 1980, p. 6).

This may be the earliest example to provide resemblance of or display execution either similar or relatable to the current practices of traditional Indian classical music; Sorrell & Narayan suggests that heptatonic modes had been introduced in Indian music at this stage although no mentioning of raga exist until the writing of the aforementioned treatise called Brihaddesi (Sorrell & Narayan, 1980, p. 6). Simultaneously, it appers that South-India experienced a religious awakening in the 7th and 8th century and resulted in great development of musical activity and musical education in this part of the subcontinent (Popley, 1921, p. 13).

Hindustani and Carnatic music, and the split between North and South

Most scholars appear to agree that the pronounced rift between the North and South of India occurred in the 13th century. As a result, Indian classical music was divided between 1) Hindustani (The Northern regions in India), and 2) Carnatic (Southern India, which includes Tamil Nadu, Kerala, Andhra Karnataka, and Sri Lanka). It should be noted that Hindustani and Carnatic classical music have moved in quite different directions throughout history and been affected by various different cultural and historical happenings over the course of many centuries, however the five musical principles discussed previously, appears to be still valid for both. As suggested previously in this chapter, vocal music appears to be the essence of current Indian classical music despite a variety of different languages spoken all over India – yet these all appears to be contributing factors to the shaping on both musical cultures.

An important turning point in Indian musical history appears to have started with the establishment of the sultanate of Delhi in 1206 (Wade, Music in Indian - The Classical Traditions, 2008, p. 17). In the aftermath, Hindustani classical music went through significant changes between the 13th and 16th century largely caused by the emergence of the Islamic Mughal Empire. This period is commonly described as the Indo-Islamic period and appears to be one of the most important in the history of Indian music; among others, this period birthed two of the most prominent and talented composers and performers throughout Indian musical history - namely Amir Khusrau (1253-1325) and Tansen (b. Ramtanu Pandey) (d. 1586).

The approximate timeline of the rift between the North and the South has been dated to the 13th century, however the exact reasons for the rift appears less clear. Neuman largely attributes this to Khusrau’s ambitious musical accomplishments; through his innovation as a composer, in addition to (supposedly) introducing new musical forms and new instruments to Indian classical music (Neuman, 1990, p. 85). Further, Neuman also suggests that this claim is supported by the musician Ramamatya who included this assessment in his musical treatise Svaramelakalanidhi (1550) (Neuman, 1990, p. 6). Although difficult to verify with certainty, it should be noted that Khusrau’s influence on Hindustani classical music is undeniably thus not unlikely a contributing factor to the aforementioned rift; however, without additional support from other scholars, the only obvious assertion to fully credit Khusrau for the rift – is the largely intact ancient music traditions (pre-rift) of the South which lacks a similarly pronounced Arabic or Muslim influence.

It should be noted that opinions on Khusrau's contributions appears divided among scholars, despite that several scholars credit him for introducing instruments to Indian music; however, whether he was the inventor of some or all of them, or brought them into Indian music from other cultures still appears disputed – thus, the majority of scholars seem content that the latter assessment is correct.

Some scholars have argued that the instruments originally attributed to Khusrau most likely were brought to India by Arab and/or Persian musicians who permanently or temporarily settled as performing musicians in royal courts. Considering Khusrau's family background, some apparent clues might support this assumption; Khusrau's parents emigrated from Central Asia, a region significantly influenced by Persian culture, thus it has been suggested that Khusrau introduced Arabic instruments to India and modified/customized them in order to be accommodated with Hindustani classical music (Wade, Music in Indian - The Classical Traditions, 2008, pp. 94-95). This theory is supported by the fact that several of these instruments appears to originate from Arabic music yet maintain similar physical traits and names.

In addition to the arrival of new emerging instruments in the 13th century Northern-India also experienced a radical change in execution of both performance styles and vocal music. Since the era of Indo-Aryans (or possibly earlier) and later through Hinduism and Buddhism influences, vocal music had been a common part of religious practice and rites. With the emergence of Islam, however, all of this changed; vocal music no longer appeared in religious contexts; thus, a new emerging vocal music style called khyal appeared and quickly replaced the former traditional Dhrupad vocal style.

Apparently, largely due to the rift many Northern musicians and scholars were discontent with these changes and moved to the South where they were able to remain in an environment which rendered their musical practice, art and craft acceptable. Further, the old patronage system which had been part of Indian music for centuries up until the 13th century appeared to be more commonly found in the South and governed by Hindu rulers. In the South, musical performances were accessible to every citizen, while performances in the North, were restricted only to wealthy men, kings and members of the courts.

Hindustani music appears to have witnessed major setbacks in the aftermath of Khusrau's death and went into a "Dark Period" which lasted for the consecutive 200 years; thus North-India would be severely subjected to numerous ferocious wars and invasions. Interestingly enough, Hindustani classical music, despite its very brief existence as a separate entity managed to develop a completely new musical direction and adapted many new musical elements, suddenly fell prey to cultural stagnation. However, a re-awakening of the Hindustani music culture occurred in the 15th and 16th century. Among the most prominent changes since the era of Khusrau was the reintroduction of the ancient Hindu singing style Dhrupad, this reintroduction has been mainly attributed to Raja Man Singh Tomar of Gwalior in the 15th century who further developed and modified the style into its current form known today. In current times he is also remembered as the person responsible for assembling and organizing one the first schools of music in India.

Besides Khusrau, the other most significant and respected Hindustani musician of old times, Tansen who was the leading musician at the court of the Mughal Emperor Akbar (1555-1605) (Sorrell & Narayan, 1980, p. 6). Shankar adds that Tansen is said to have "… had complete mastery over sound, especially musical sound" (Shankar, My Music, My Life, 2007, p. 57). According to old sources supposedly he possessed occultist power and performed miracles through the use of music – in effect performing certain ragas in order to produce rain, fire etc. He is known for either creating, or popularizing a number of ragas which still appears to be associated with his name. The Dhrupad style peaked in popularity during this period primarily because of Tansen leading to two lineages of musical tradition (gharanas); Rababiya gharana, and Beenkar gharana, credited to his son and daughter, respectively.

Interestingly, scholars on Indian music have generally put more emphasis on Hindustani music in favour of its Southern counterpart. Although, the continuation of the Hindustani musical tradition has managed to retain its oral (passing of) tradition for the most part, scholars on Carnatic music appears to have moved forward exhibiting much more interest by documenting notation during the past few centuries. The earliest literary collection to properly detail and elaborate the execution of the

Carnatic musical system and raga performances appears to be found in the treatise Svaraniela Kalanidhi (A.D. 1550), written by Rama Amatya (Popley, 1921, p. 18).

Simultaneously, Carnatic music also witnessed an apparent evolution in the 16th century, in addition to a change in general execution of musical performance, form, and instruments, one of the most distinct changes affected the execution of ragas and talas. In current times, Southerners favours shorter musical pieces with less emphasis on improvisation, although more significance on words than its Northern counterpart (Sorrell & Narayan, 1980, p. 4).

Indian theorists (all over India) from the 16th century up until the 20th century have continued to attempt further synthesis and standardizations; despite that ancient terms remains intact, the meanings of the words may have changed, thus in some situations words may still refer to their original ancient meaning while in others they now solely refers to musical practices of the time when the respective works/books were written (Malm, 1967, p. 95).

The next important phase in Indian music occurred between the 18th and 19th century with the emergence and gradual domination of the British East India Company which eventually took political control of India. These periods are often referred to as “the crimson dawn” and “the golden age”, respectively (Wade, Music in Indian - The Classical Traditions, 2008, p. 2). By the turn of the 20th century a new generation of musicians grew increasingly distraught about the roots of Indian classical music and sought a more authentic approach to perform music; at that stage apparently an emphasis of important ancient ideas/principles had been gradually ignored during the previous few centuries. One of the most vital figures responsible for revitalizing classical India music in modern times was musicologist V. N. Bhatkhande Sangeet Vidyapeeth, who wrote the first Hindustani musical treatise to introduce musicology, musical training and employing a system of musical notation to the Indian public; he travelled all over India in order to collect compositions of dhrupad, khyal, and tarana (Shankar, My Music, My Life, 2007, p. 58). This occurred in accordance with the decline in court and temple patronage system, which by then was replaced by concert hall performances and later the significance of radio and gramophone recordings.

Classification of instruments

"The idea of bowing an instrument may well have come from the desire to produce an equivalent of the human voice, and in medieval times it was realised in the Near East and Central Asia that bowed instruments were ideal to produce the sustained sounds as well as the slides, slurs and, importantly, the timbre nearest actual singing" (Sorrell & Narayan, 1980, pp. 59-60).

Natya Sastra

Apparently, India was one of the first cultures to establish a classification system for musical instruments. The aforementioned Natya Sastra (written possibly somewhere between the 3rd century B.C. and 5th century A.D.) describes four possible categorisations of instruments thus; 1) Tata (stringed instruments, including plucked and bowed string instruments), 2) Sushira (wind instruments), 3) Avanaddha (drums), and 4) Ghana (percussion instruments) (Sorrell & Narayan, 1980, p. 6). In order to refer to one particular category of instrument, the word vadya (meaning instrument) is usually applied next to the respective of name of the instrument (e.g. tata vadya).

Among these categories of instruments, the tata vadya group appears to hold the highest status and comprises the most commonly used instruments in classical music (Sorrell & Narayan, 1980, p. 34). Within this group are lute and zither instruments either plucked or bowed. The sushira vadya group consists of reed instruments such as flutes and oboes. In addition to these, both Hindustani and Carnatic music contain one Western instrument each; namely the harmonium (Hindustani) and violin (Carnatic). The avanaddha group solely consists of a barrel drum in Carnatic music, while Hindustani music includes an additional pair of kettle drums called tabla. The final categorisation, ghana vadya comprises percussive instruments, either made of metal, wood or porcelain. Among these a selection of bells and rods can be found; however, despite that these instruments rarely appears in concert music thus omitted from this Music Study (Deva, Indian Music, 1995, p. 3). It should be noted that Wade, Sorrell & Narayan applies the Indian classification system when referring to Indian instruments.

Hornbostel and Sachs

In addition to the indigenous Indian classification system addressed above, Austrian ethnomusicologist and scholar of music Erich von Hornbostel (1877-1935) and German musicologist Curt Sachs (1881-1959) developed their own classification system. Despite that their proposition primarily is based on inherent Western musical principles and perspectives; interestingly, this categorisation system practically coincides with much of the same principles as those found both in Hindustani and Carnatic music, namely basis on acoustical principles which appears to be similarly respected by Indian musicians and scholars. The Hornbostel & Sachs categorisation is grouped as follows: strings, wind, drums and percussion; categorised thus 1) chordophones, 2) aerophones, 3) membranophones, and 4) idiophones (Sorrell & Narayan, 1980, p. 33). Among the most striking indigenous supporters of this categorisation system is the renowned musician and master of music Ravi Shankar, who refers to it when classifying Indian instruments.

For the past few centuries or so, Indian and European music have equally influenced each other. Whereas European instruments made a significant and lasting impact on both Hindustani and Carnatic classical music in the past 300 years, largely due to the contribution of harmonium and violin, respectively. India, on the other hand, introduced sitar and sarod to Western popular music in the 20th century, in large due to Ravi Shankar, who exhaustively toured several European countries in addition to the U.S.A. from the 1950’s onwards,; thus Indian music made a significant imprint on the consciousness of many future popular recording artists in the West.

Instruments of Hindustani and Carnatic music

Ancient Indian instruments have been documented through a variety of stone carvings and paintings, often in contexts where religious figures/Gods are depicted holding musical instruments. Although, to some extent the execution of ancient Indian music and types of musical instruments appears to have been retained and remains intact, still Indian music has gone through a lot of changes in the past 1000 years, or so. For instance, both the Hindustani and Carnatic systems share a number of similar instruments, such as veena (zither instruments, tanpura (plucked string instrument), flute, oboe, and barrel drum instruments; thus it is quite possible that most if not all of these instruments were part of Indian classical music before the split between the North and South.

Although the latter assessment may be interpreted somewhat differently by various musicians and scholars, it is important to include suggestions from renowned scholars who supports and validates this information. Among others, Wade claims that flutes have been depicted in Buddhist art found at the Sanchi Stupa dating back approximately 100 B.C. and further states that "…the playing of the flute is at least as old as the Vedas" (Wade, Music in Indian - The Classical Traditions, 2008, pp. 106, 108). Despite the antiquity of this instrument, flutes have gone through various incarnations and modifications over the course of several centuries. According to Wade, the instrument (at least the variants associated with the Indian subcontinent) appears to originate from the ancient Chinese transverse flute called ch'ih and eventually arrived in India simultaneously with the emergence of Buddhism in China approximately 100 B.C. (Wade, Music in Indian - The Classical Traditions, 2008, p. 106). Interestingly enough, Sorrell & Narayan suggests that the origin of wind instruments can be traced back to the ancient musical history of India, although adds that these instruments have not been part of Indian classical music for a long time (Sorrell & Narayan, 1980, p. 34). In addition, Wade addresses that the double-reed instruments which are found in current-day Indian classical music shows noticeable resemblance to the Western oboe (Wade, Music in Indian - The Classical Traditions, 2008, p. 109).

It should be noted that ancient Indian music is not generally restricted to flutes and wind instruments only; for instance, Popley suggests that the ancient Vedic texts documents several other types of drums and percussion instruments (such as dundubhi, adamhara, bhumi-dundubhi, vanaspati, aghati), different types of flutes, and a number of stringed lute instruments similar to veena (such as kanda veena, karkari, vana), none of which are commonly associated with current-day Indian classical music (Popley, 1921, p. 8). Wade appears to agree that veena instruments and mrdanga drums were mentioned in the Vedic texts, however does not mention any other types of percussion instruments or drums (Wade, Music in Indian - The Classical Traditions, 2008, p. 106).

Deva, on the other hand partially agrees with Wade's assessment, according to him no reference to any drums appears to exist although he concurs that veena instruments belongs to the origin of Indian instruments (Deva, Indian Music, 1995, p. 3). Interestingly enough, the ancient Tamil books Purananuru and Pattiipattu (100-

200 A.D.) claims that the drum was held in a great honourable position in ancient times (Popley, 1921, p. 11).

Despite that some of the aforementioned instruments still appears to be relevant to current-day Indian classical music, it is also important to emphasise that a number of instruments associated with both Hindustani and Carnatic classical music have gone through different phases of popularity throughout their tenure in Indian music history. In order to clarify this assessment, a restricted number of scenarios may appear adequate to suggest; 1) Indian instruments to emerge in ancient times or later which has retained its popularity since the beginning and appears to hold the same stature to this day, 2) instruments from ancient times or later which may have disappeared entirely and never re-emerged, or 3) instruments which emerged in ancient times or later – which gradually acquired popularity either for a shorter or longer period, then became out of fashion and later experienced a renaissance and currently retains its stature to this day – however, it should be noted that instruments which has withstood a significant history within Indian music appears to have been exposed to some type of changes or modifications over the centuries (Shankar, My Music, My Life, 2007, p. 42).

Lastly, one of the most integral and unique flavours of Indian music and remained part of the musical culture since ancient times is the phenomenon of drone. In order to reproduce these sounds, mainly the assistance of stringed long-necked lute instruments has been the preferred choice. Thus, the tanpura (in both Hindustani and Carnatic classical music) is often considered the ideal instrument in order to produce drone sounds; although this instrument is almost always present in Indian classical music it tends to be accompanied by some kind of drum in order to retain the tala cycles of the music (Sorrell & Narayan, 1980, p. 34).

Interestingly, despite inclusion of more or less the same type of instruments in Hindustani and Carnatic music culture, it should be noted that slight deviation in execution appears to be found between the two. In particular, this applies to the veena instruments found in both musical cultures.

In order to provide a sufficiently differentiation between the two, the Hindustani rudra veena can be described as a stick zither, while its Carnatic counterpart - the sarasvati veena appears to be classified as a lute instrument (Sorrell & Narayan, 1980, p. 43). Wade signifies that the presence of the drone in modern Indian classical music appears differently to ancient practice: the phenomenon of drone did not appear to be particularly dominant in its early formation; according to Shankar the position of drone in Indian music appeared to be minor and somewhat neglected until about the 17th century when it eventually became rather prominent in chamber music (Wade, Music in Indian - The Classical Traditions, 2008, p. 49).

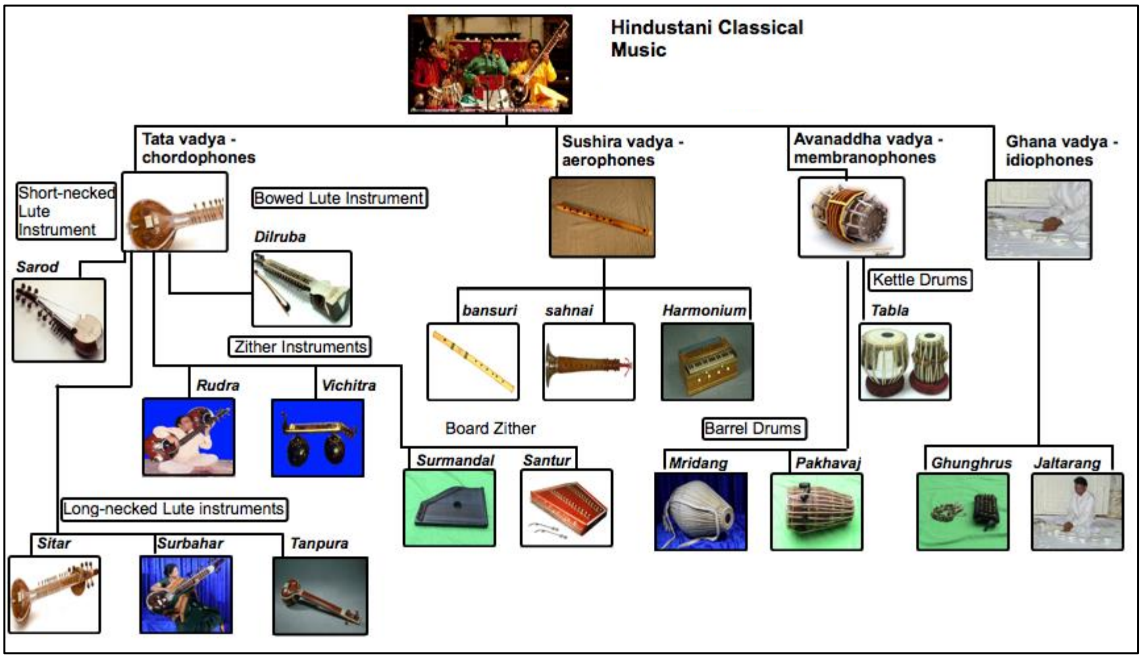

Figure A2.1. Classification system of Hindustani classical music

Hindustani music

The figure proposed above displays a selection of musical instruments which are currently part of Hindustani classical music. It should be mentioned that the instruments included potentially may initiate some debates among different scholars. For instance, it is possible that various Hindustani classical ensembles may contain sets of instruments which are not mentioned in this Music Study while simultaneously ignoring a few of the instruments mentioned here. However, it should be noted that the selection of instruments were mainly based on the following criteria; 1) current popularity (which in some cases involves no historic impact while in others revolves around current popularity in relation to historical stature and significance), and 2) thorough descriptions provided by a number of renowned scholars both Indian and from other parts of the world.

Evidentially, Hindustani classical music has been exposed to changes from foreign musical influences to a larger extent than its Southern counterpart. As a result, this has produced a variety of distinguishable instruments different to those found in Carnatic classical music.

Different to Carnatic classical music, the first category of Hindustani instruments, tata vadya, comprises a large selection of different stringed instruments and is divided into three subcategories; the first comprises a variety of plucked long- and short-necked lute instruments - among the former includes the sitar, surbahar and tanpura; while sarod appears to be the sole short-necked lute instrument. The second subcategory comprises plucked zither type of instruments which includes the rudra veena (also known as bin in India), vichitra veena, and surmandal. Despite, inclusion within the plucked zither subcategory, the santur is played with a set of small hammers. Interestingly, Sorrell & Narayan, suggests that santur and surmandal both can be further categorised as board zithers; alternative names associated with similarly crafted instruments in Western music culture are psaltery (surmandal) and dulcimer (santur) - the latter instrument can also be used to reproduce drones (Sorrell & Narayan, 1980, p. 50). The last subcategory of tata vadya instruments consist solely of one bowed lute instrument called sarangi. The string positions on lute instruments can be characterized as follows: the main strings are usually placed above (when applicable) the bridges, while the sympathetic strings tend to go through holes in the bridges of the instruments.

Sitar:

The sitar appears to be the most immediately recognisable Indian instrument from a Western perspective; similarly, it is the most popular among the plucked lute instruments found in Hindustani music. The origin of the sitar has been the subject of various debates throughout the centuries; medieval texts attributes Amir Khusrau as the inventor of the instrument, although a number of scholars in modern times partially opposes to this assessment and argues that the instrument originated from the medieval three-stringed Persian instrument called sehtar (Wade, Music in Indian - The Classical Traditions, 2008, p. 95). However, quite possibly Khusrau's main contribution was to oversee or somehow influenced and/or modify the initial Indian rendition of the sitar by selecting its current-day placement of the strings by rearranging the order of strings on the veena and then reversing the order (i.e. the main strings attached on the outside of the instrument and the bass strings closest to the performer's body) (Wade, Music in Indian - The Classical Traditions, 2008, p. 95).

In the consecutive centuries, the sitar eventually would be exposed to a number of further modifications, the first to occur in the latter part of the 18th century; according to Wade, Amrit Sen of Jaipur has been credited for adding another three strings to the instrument thus a total number of six strings - apparently the intend for the first four strings was to reproduce the melody while the last two were devoted to drone and rhythm (also known as chikari strings) (Wade, Music in Indian - The Classical Traditions, 2008, p. 95). Deva suggests that frequent appearances of Mughal painting dating between 16th through 18th century depicts instruments which appears to be almost identical to the Persian sehtar (Deva, Indian Music, 1995, p. 95). Later on, an additional string (a third chikari string) was added, thus the instrument comprised seven main strings; four melodic strings and three chikari strings, which is the standardized amount of main strings found on current-day sitars (Deva, Indian Music, 1995, p. 95). The main strings can be located above the frets and either made of copper, brass, bronze or high-carbon steel. In addition, a number of sympathetic strings are located below the frets on the instrument, although no standardized amount of these the sitar usually contains twelve to twenty sympathetic strings.

It is important to address that sitars comes in various sizes and models; thus, each instrument comprise its own tonal range and character – this is partially affected by the amount of resonating strings contained within each instrument and further exert the impact on the fullness of sound. The strings on the sitar runs through the neck and to the bottom of the instrument across the resonating chamber (also known as the belly) which is common made of wood. Further, sitars are commonly found with an additional hollow resonating gourd attached at the end of the neck, however this may not be applicable to every single version/model of the instrument. The purpose of the resonating gourd can be described as serving two equally weighted purposes; it affects the balance of the sound as much as it provides the resonance of the instrument.

One of the most unique features found on the sitar appears to be moveable frets. The frets on the sitar are made of metal, and attached to the instrument by threads which are stretched across the underside of the neck; these threads enables movement of the frets in accordance to particular modes and tuning of ragas; this function can be performed through the assistance of the aforementioned threads which are either made of gut or silk and tied to the respective frets.

Generally, the origin of moveable frets appears to be unknown and has been subjected to disputes among scholars throughout the years. However, two very opposing opinions appears to be interesting; Wade suggest that the invention of moveable frets possibly can be attributed to Khusrau (Wade, Music in Indian - The Classical Traditions, 2008, p. 96). Sorrel & Narayan, on the other hand, hesitate to suggest that moveable frets were part of the instrument until much later, and state the following "…it seems that the frequent and systematic use of the pulling technique has come relatively recently, perhaps only within the last eighty or hundred years" (Sorrell & Narayan, 1980, p. 48).

When the sitar is tuned to a particular raga, the sympathetic strings vibrate in harmony with the main ones in order to reproduce a metallic, lush and shimmering effect (Wade, Music in Indian - The Classical Traditions, 2008, p. 96). In addition to the aforementioned strings, the bridge of the instrument (commonly referred to as a Javari bridge) is another important feature which is largely responsible for the shimmering and buzzing sounds; Sorrel & Narayan suggests that the "… front of the bridge is filed into a smooth curve so that the string leaves it at a fine line angle…" which appears to be the main reason for reproducing these effects (Sorrell & Narayan, 1980, p. 44). Further, they state that "… the flat surface of the bridge and under each string is pulled a short length of thread. When it has been pulled to the correct part of the bridge the sound from the plucked string suddenly increase intensity and duration, and the instrument emit its special buzzing sound" (Sorrell & Narayan, 1980, p. 44).

The sitar is commonly played with a clipped metal plectrum (called mizrab) attached to the right-hand index finger; although it may be obvious to the initiated reader, all of the seven main strings are performed using both upward and downward strokes. Common practice is that the index finger and middle finger are used to stop the (up to) 19 or 20 strings by pressing them against the curved frets (Sorrell & Narayan, 1980, p. 46). Further, in order to reproduce additional pitches or embellishments the strings need to be deflected across the frets. The sitar comes with 16 to 23 strings which can be adjusted to play each particular thats (Wade, Music in Indian - The Classical Traditions, 2008, p. 96).

Sarod:

The origin of the sarod appears to be disputed among a number of scholars; some claim that it is an ancient instrument while others argues that it initially appeared at a later point in time. Among others, Deva suggests that it is a very ancient instrument although the current version may incorporate both local and West Asian features (Deva, Indian Music, 1995, p. 135). Wade states that the instrument has been depicted in old paintings dating back to the earliest part of the Mughal period (1526-1858) while further acknowledge that it was a common instrument in the 16th century largely due to the re-emergence of dhrupad vocal music – and mainly popularised by Tansen (Wade, Music in Indian - The Classical Traditions, 2008, p. 98). Shankar, on the other hand suggests that the instrument is of foreign origin and appears to be a descendant of the Afghan rabab instrument (Shankar, My Music, My Life, 2007, p. 44). Wade states that both sarods and rababs appear to be similarly constructed, and further adds that the sarod has also been found in Bengal and was initially introduced by the musician Khan Saheb Asadullah Khan approximately a century ago (Wade, Music in Indian - The Classical Traditions, 2008, p. 99). Sorrell & Narayan suggests that the sarod originally used to be an accompanying instrument although it has been accepted as a solo instrument in later years (Sorrell & Narayan, 1980, p. 50).

The sarod can be described as a fretless short-necked lute, it contains a circular resonating chamber (body/belly) made of wood and comprises one hollow part which is covered with hide. Despite its round-shaped body, it is pinched just below the point where the neck is attached - the front of the neck contains a polished metal plate and appears thicker at the bottom and gradually narrower at the top where the tuning pegs are placed. Deva addresses that the body is not entirely made of wood, such as that of the sitar (Deva, Indian Music, 1995, p. 135). Similar to the sitar, the sarods may or may not contain a gourd resonator, although the sarod gourd is usually made of metal.

Commonly, the sarod is played with a plectrum made of coconut shell or ivory. According to Sorrell and Narayan, the sarod usually contains eight main steel strings (comprising of four metal strings and four chikari strings) and approximately fifteen sympathetic strings (Sorrell & Narayan, 1980, p. 50). Different to Sorrell & Narayan, Wade addresses the amount of strings on the sarod rather vaguely by providing an approximation of strings; she states that the instrument is commonly found with seven to ten main strings (four or five metal strings and three to five chikari strings), and an additional eleven to sixteen sympathetic strings. The sarod contains four bridges where the main one is placed above the resonating chamber (belly), the next is a Javari bridge positioned at the neck (please read the section about sitar for further information), while the latter two (although they appear smaller in size) are positioned to the pegged side of the instrument.

The sarod contains four or five metal strings. These are tuned to PA (two dots below a) SA (dot below a) PA (dot above a) SA MA and SA (dot below a) PA (dot below a) SA MA, respectively. The lowest string is made of brass while the rest are made of steel. The lowest tuned string is closest to the performer's face (Wade, Music in Indian - The Classical Traditions, 2008, p. 99).

The main bridge on the sarod holds strings at three different levels; on the first and highest level, the playing strings appears and are suspended over the top of the instrument, this includes one jawari string (a drone string tuned to SA) while the other two are drone strings (tuned to SA (dot above a) and SA (dot above a) (Wade, Music in Indian - The Classical Traditions, 2008, p. 100). On the next (middle) level, three sympathetic strings (or jawari strings) go through small holes on the bridge, while the last and lowest level comprises the remaining sympathetic strings, all of which are made of steel and referred to as tarah strings (Wade, Music in Indian - The Classical Traditions, 2008, pp. 100-101)

Surbahar:

The surbahar is a long-necked lute instrument which is often comparable to the sitar mainly due to similarity in construction in addition to sharing many of the same features/traits. The instrument is known for producing deeper tones thus sometimes referred to as a bass sitar.

Surbahar usually comprises seven to eight main strings (four melodic strings and three to four chikari strings), in addition it commonly features approximately eleven sympathetic strings. The instrument contains two Javari bridges and similarly constructed according to the majority of other Hindustani lute instruments which features the following configurations; the main and chikari strings placed over the bridges while the sympathetic strings are placed through the holes on the bridges. The plectrum used for playing the instrument is usually a mizrab plectrum. Surbahar is rarely ever played in Hindustani music and is mainly limited to styles such as the alap, jor and jhala. Shankar believes that surbahar at some point replaced the rudra veena which appears to have been the previously preferred instrument for those styles (Shankar, My Music, My Life, 2007, p. 43). The surbahar is commonly known for containing very thick strings which are usually tuned approximately five tones lower than the average sitar (Shankar, My Music, My Life, 2007, p. 43).

Tanpura:

The tanpura may have been part of Indian classical music since medieval times before the eventual split between the North and the South; it is one of very few Indian instruments which is commonly associated with both cultures - although with a slight variation to the name between the two. Its position and stature in Indian classical music appears to have increased significantly for the past few hundred years and eventually become a more prominent musical element of Indian music in modern times. Interestingly enough, despite being a large-sized instrument, the tanpura may appear to be the least complex lute instrument found in Indian classical music. Unlike its closest tata vadya siblings, no sympathetic strings are found on the instrument. In addition, the tanpura contains no frets mainly because the instrument serves no other purpose than to reproduce the sound of drone (in other words the tonic) which remains constant and unchanged throughout a raga. Commonly, the tanpura player often appears to be a relative, friend or pupil of the main artist.

Usually, the tanpura contains four to six strings and commonly plucked gently by using the fingers. Technically, the instrument requires no great performance skills in order to play the instrument properly – although it is important that the performer is capable to assess the right amount of pressure, at the exact moment and at the correct angle in order pluck the strings properly and with proper precision. The unique sound of the tanpura has been greatly attributed to the design of the bridge which essentially contribute the majority of its unique timbre.

Similar to the sitar, the tanpura also contain a Javari bridge although this is made of bone; in addition a number of cotton threads (usually referred to as jiva) are placed under the strings on this bridge in order to control the position of the node and to provide the characteristic buzzing drone sound to the strings and crucial to the timbre of the instrument.

Surmandal:

The physical appearance of the surmandal is very similar to the Western board zither instrument. The origin of this instrument appears unknown, although it is known to have been part of Hindustani classical music since the latter part of the 19th century. The instrument is entirely made of wood and appears rather small in comparison to the other instruments found in the tata vadya group.

The surmandal is plucked with a plectrum and usually comprises between 21 to 36 strings, all of which can be characterized as main strings. It comes with a resonating sound hole positioned in the middle of the instrument and usually contains two bridges; one which appears at the bottom next to the string-holder while the other is close to the pegs and shaped in accordance to the physical appearance of the instrument itself (i.e. slopes downwards to the right). The strings are all hooked to nails on the bottom of the instrument (and underneath the front) while the pegs are located at the top and can be adjusted for precise tuning. The main purpose of the surmandal is to function as a drone instrument (while the open strings tuned to the notes of the raga) in order to accompany vocal music and is quite often played by the vocalist (Sorrell & Narayan, 1980, p. 50).

Santur:

The santur appears to be a variation of the ancient Persian santoor instrument. At first, an apparent similarity between the design and construction of santur and surmandal may seem apparent; however, despite this interesting juxtaposition both instruments appear to have emerged more or less at the same time in Hindustani classical music. The santur is commonly performed while seated or standing, although in the latter case a strap is attached to the instrument.

Different to the surmandal, the santur is known for containing a significantly larger amount of strings; as such, certain models may carry up to 100 strings, although this amount varies. The strings are usually grouped into sections of four strings which are assigned to one bridge each, at the most up to 25 bridges can be found on the instrument.

Similar to the surmandal, the santur is not a commonly used instrument in Hindustani classical music, however, it appears to be more favourably accepted in Indian folk music. Different to other Indian stringed instruments, the santur is usually played using a set of hammers and is not regarded as a versatile instrument thus not ideal for recreating ornamentation (Sorrell & Narayan, 1980, p. 50).

Veena instruments:

In general, veena instruments (independent of their respective Northern or Southern music culture) appears to be the oldest type of stringed instrument mentioned in Vedic literature (1500-500 B.C.) (Wade, Music in Indian - The Classical Traditions, 2008, p. 89). Similar to the majority of stringed instruments found in Hindustani classical music, the history of veena instruments also appears to have been subjected to various discussions over the years; for instance Wade claims that the lute category of veenas (i.e. the Carnatic type of veena instruments) can be dated back to at least 100-200 A.D. (Wade, Music in Indian - The Classical Traditions, 2008, p. 89).

Interestingly, although the name veena could easily suggest similar or possibly identically counterparts between the North and South, some noticeable deviation between the two cultures occur. For instance, the Hindustani veena instruments (such as rudra veena and vichitra veena) can be described as stick zithers with two resonating gourds at either end and appears to have emerged slightly later in comparison to their southern veena counterparts. According to Wade, the first documented example of Hindustani veenas are depicted in Mahabalipuram reliefs dating back to 800-1100 A.D. (Wade, Music in Indian - The Classical Traditions, 2008, p. 89). Despite, that the veena instruments may share some resemblance to the sitar, they are generally regarded as much more difficult instruments to master. The veena instruments contains frets that are tuned to every semitone in the theory system and fixes them in resin (Wade, Music in Indian - The Classical Traditions, 2008, p. 96).

Rudra veena:

The rudra veena is shaped like a fretted bamboo stick (about four to five feet) with two large gourd resonators attached at either end of the instrument. It usually contains four main strings and three additional chikari strings with a total of twenty-four frets (although the chikari strings are not extended over the frets) across a tonal range of 2½ octaves. The rudra veena may be played using plectrum or by fingers since no apparent standardization is associated with this instrument. It is known for producing deep but sweet tones and regarded as suitable particularly for dhrupad vocal music – it is commonly used as a solo instrument and occasionally appear with pakhavaj accompaniment (Sorrell & Narayan, 1980, p. 48). It appears to be the lowest pitched stringed instrument found in Hindustani music.

The rudra veena appeared to be the primary stringed instrument found in Hindustani classical music up until the 18th century, however it was replaced by the sitar largely due to the re-emergence of the khyal style (Wade, Music in Indian - The Classical Traditions, 2008, p. 92) (Shankar, My Music, My Life, 2007, p. 43). Thus, it is rarely ever used in current Hindustani music.

Vichitra veena:

Despite that vichitra veena and rudra veena both can be described as stick zither instruments with gourd resonators attached at either end, the similarities between the two ends there. Wade suggests that the vichitra veena possibly is the oldest among the two, mainly since no association with frets has been known to occur on veena instruments until approximately 1000-1100 A.D. (Wade, Music in Indian - The Classical Traditions, 2008, p. 90).The vichitra veena contains no frets and commonly appears with a total of nine strings (although five are chikari strings) in addition to thirteen sympathetic strings positioned underneath the main strings.

The instrument is played using plectrums attached to the index and middle finger on the right hand while a round piece of glass is held in the left hand. Sorrell & Narayan implies that this allows for slides and ornaments of the utmost delicacy and smoothness, thus it is plausible to presume that the intention of the instrument was to achieve a closer approximation of the human voice (Sorrell & Narayan, 1980, p. 48).

Sarangi:

Similar to the sitar and the sarod, the origin of the sarangi appears to be disputed among scholars. For instance, Sorrell and Narayan believes that the instrument possibly derived from an ancient folk spike fiddle called ravanhattha, or from the rabab; however, the instrument currently known as sarangi appears to have emerged in Hindustani music approximately 16th century, Neuman concurs with this assessment (Sorrell & Narayan, 1980, p. 64) (Neuman, 1990, p. 8). Similar to its suggested predecessor, it was initially regarded as a folk instrument although later became a court instrument (Sorrell & Narayan, 1980, p. 64). On the other hand, Wade believes that the instrument may originate from Persia and introduced by the Mahomedans (Muslim followers of the prophet Muhammad) at some point during medieval times (Wade, Music in Indian - The Classical Traditions, 2008, p. 104).

According to Sorrell & Narayan, the stature of the sarangi has gradually declined in the past 200 years and rarely performed in current Hindustani classical music, supposedly it is held in less esteem than the harmonium (Sorrell & Narayan, 1980, p. 65). On the other hand, Shankar claims that the sarangi is the most popular among the bowed lute instruments found in Hindustani classical music and appears to be regarded equally to that of the violin in the South (Shankar, My Music, My Life, 2007, p. 44).

The sarangi usually contains three and sometimes four main strings, in the former case these are all made of gut (although if the instrument is used in order to play higher pitches all of the strings are made of metal), while in the lattercase it contains an additional chikari string made of brass. In addition, the instrument usually contains up to 35-40 sympathetic strings made of steel or brass which vibrates under the main strings and are tuned chromatically and attached to pegs alongside the fingerboard (Sorrell & Narayan, 1980, p. 58). The purpose of the sympathetic strings appears to assists intonation and may be described by some as "…the soul of the sarangi", or the instrument with the closest association of the human voice (Sorrell & Narayan, 1980, p. 58).

Sorrell & Narayan proposes a model in which defines the construction of the sarangi through a three-fold model as thus: 1) the body, 2) neck, and 3) peg-box (Sorrell & Narayan, 1980, p. 55). The sarangi appears to be the least standardized among the tata vadya instruments and emphasized through the shape of a thick-waisted body with a broad neck and no frets. Sorrell & Narayan further elaborates that the instrument comprises one piece of hollowed out tun wood and its body being covered with goat skin glued onto it; sometimes it also contains three holes which are cut or burnt into it in order to both make the instrument airtight as well as affecting the overall sound of the instrument (Sorrell & Narayan, 1980, p. 55).

The body of the instrument is pinched with a square bottom in order to allow for feasible bowing options. Further, a string-holder made of wood is attached to the bottom of the instrument with additional sets of bone rings attached around each string hole to protect the wood from wear caused by tension of the strings. For further protection, commonly a metal plate is either screwed or nailed onto the bottom of the body. The peg-box contains two separate sections, both of which are hollow; the upper section houses approximately eleven small pegs in addition to the sympathetic strings. The lower section contains four large pegs, in which three of them are main strings made of gut while a fourth is one sole sympathetic metal string.

Altogether the sarangi usually contains four bridges, although only two of them appears to be essential to the timbre of the instrument, these are made either of camel bone or plastic. Among these, the main bridge rests on the skin which surrounds the body of the instrument and appears to be the only bridge where all strings pass through. Thus, the three main strings are placed on the top, above the sympathetic strings which are passed through additional holes which are drilled into the bridge.

Further, a leather strap is glued to the sides of the body (on top of the goat skin) to in order to support the two feet of the bridge and to prevent the instrument from breaking due to its overall heavy weight. The other essential bridge is placed on top of the neck and only carries the main three gut strings (Sorrell & Narayan, 1980, p. 56). The last two bridges appear to be reserved solely for the sympathetic strings, whereas one is a Javari bridge and may sometimes come with threads in order to reproduce a similar tone associated with sitars and tanpuras.

In order to master the instrument properly, it demands for very complex fingering and bowing techniques although no proper fingering technique is standardized and may vary from one performer to another (Sorrell & Narayan, 1980, p. 61) This appears to be the main reason for the lack of popularity in current times. When played, the instrument is held vertically while the bow is commonly placed in the right hand and the strings are stopped with left hand. The bow is a convex shaped stick made of hard solid wood and commonly contains 22 inches long hairs made of horse's tail attached to it.

The ornamentation appears to be lesser than that found on the other plucked stringed instruments mainly due to the complicated physical appearance of the sarangi. Sorrell & Narayan states the following about the instrument: "…it can produce all notes and microtones and imitate other instruments, as well as the human voice" (Sorrell & Narayan, 1980, p. 64).The main task of the sarangi is to accompany the tala, and rarely ever used as a solo instrument.

The second instrument group; sushira vadya is a rather small group which consists of few instruments. Common for both Hindustani and Carnatic classical music is the flute and oboe - the Hindustani names for these are: bansuri and sahnai, respectively. However, harmonium is usually restricted to Hindustani music only.

Bansuri:

Bansuri appears to be an ancient instrument. Among others, Shankar claims that depiction in ancient art shows Lord Krishna playing a bansuri flute, (Shankar, My Music, My Life, 2007, p. 44). Further, Sorrell & Narayan suggests that the bansuri flute is commonly made of bamboo and usually appears to be larger in size than its Southern counterpart (although no specific size appears to be standardized) and consequently inherent a lower pitch and a mellower tone (Sorrell & Narayan, 1980, p. 34). The size of the Hindustani bansuri flute usually appears from one foot to 2½ feet in length.

The majority of current bansuri flutes includes seven holes (across a range of 2½ octaves) in order to reproduce tones in which to coincide with the writings of svara. However, it is not uncommon to find the instrument with six to eight holes (in the latter case, the range covers three octaves) in addition to the mouth hole. The seven pitches are played in ascending order; by putting the finger in front of the holes while closing and open them in succession from right to left toward the mouth hole.

At a later stage, an increasing demand for more flexibility in terms of execution became necessary in Hindustani music and in particular the ability to handle each scale on one instrument; thus, a new proposition which suggested partially closing and opening the finger holes on the flute in order to produce semitones. Thus, this solution made it possible to play any scale on one singular instrument. Sorrell & Narayan claims that the music is closely related to vocal music and the instrument is capable of capturing the sustained legato of the human voice (Sorrell & Narayan, 1980, p. 34). The Bansuri flute is known for creating a beautiful mellow and subdued tone.

Sahnai:

Sorrell & Narayan and Wade believes that the sahnai was introduced to Indian music by Mahomedans approximately 400 years ago (Sorrell & Narayan, 1980, p. 35) (Wade, Music in Indian - The Classical Traditions, 2008, p. 111). Previously, the sahnai used to be a folk instrument, although it has gained popularity within the Hindustani classical music for the past century and appears to be found as a solo instrument accompanied by an ensemble which commonly consists of drones and a drum (Shankar, My Music, My Life, 2007, p. 45). Further, it is commonly used in procession and weddings.

The size of the sahnai appears to be slightly longer than the bansuri and slightly smaller than its southern counterpart the nagasvaram, however slight disagreements about size and additions occurs between authors. According to Sorrell & Narayan, the sahnai is 1½ to 2 feet long and contains a metal bell attached at the lower end of the instrument (Sorrell & Narayan, 1980, p. 35). Wade partially disagrees about the size of the instrument and implies that the instrument should appear at 1 to 1½ feet and further adds that the double-reed is attached to a narrow stem which rises out of the top of the instrument (Wade, Music in Indian - The Classical Traditions, 2008, p. 110).

The sahnai commonly comprises seven holes which are conical bores and double reeds although sometimes with one or two additional holes which are (not covered while playing and) stopped by wax or left open as is, which influence or possibly make adjustments to the pitch of the instrument (Sorrell & Narayan, 1980, p. 35). Regrettably, the instrument does not appear to have experienced an easily adoption into Hindustani music mainly due to lack of advanced and flexible blowing and fingering technique. The tone of the instrument is known for being loud and raucous.

Harmonium:

The Indian harmonium originates from Britain and eventually emerged during the early period of the British colonisation of India, it is generally regarded as a wind instrument which contains free reeds made of metal. Sorrell & Narayan claim that "…the harmonium … was brought to India by nineteenth-century European missionaries" (Sorrell & Narayan, 1980, p. 35).

Essentially, the execution of Indian harmonium appears to be slightly different than the Western approach. Whereas the Westerners generally tends to use one hand in order to play chords while dispositioning the other hand for bass accompaniment; differently Indian musicians usually use the same hand in order to play chords while controlling or moving the bellows on the instrument by using the other hand. In addition, the Indian version of the harmonium commonly appears smaller than the standardized British version; thus fitted through the shape of a portable box comprising the size of two feet by one foot by nine inches (high) while the rear contains the bellows of the instrument (Sorrell & Narayan, 1980, p. 37).

Interestingly, despite being adopted into a new musical culture, the Indian version of the harmonium appears to be based on Western principles which pertains the chromatic scales of 12 semitones. The problem with the harmonium is that it cannot be easily adjusted to Indian music, due to the combination of the keyboard and reeds which are pre-tuned to a Western standard. According to Sorrell & Narayan the harmonium is restricted to the notes reserved for a typical Western keyboard and does not offer variation outside its restricted palette, which prevents a variety of options for portamento (Sorrell & Narayan, 1980, p. 37).Due to its inadequate temperament (through an Indian musical perspective) it was not fully accepted into Hindustani classical music until the 20th century; while the renowned All India Radio did not fully accept its inclusion until the latter half of the 20th century. The main contribution of the harmonium appears to provide convenient background sounds which compliment singers and the instrument is capable of reproducing a steady tone which resembles that of the sarangi (which previously retained a similar popular stature of which the harmonium holds today).

The harmonium has retained a strange position in Indian classical music. It commonly comprises a range of three octaves of inflexible pitches (Wade, Music in Indian - The Classical Traditions, 2008, p. 112). It is generally favoured in the South and holds a similar significance to that of the sarangi in the North.

The third instrument group; avanaddha vadya consists of two different categories comprising kettle drums and barrel drums. Essentially, the pair of kettle drums is referred to as tabla; a name which can be applied to both the instrument as well as one of the drums. The other category consists of two different barrel drums, called mridang and pakhavaj respectively; despite different names the shape of these instruments appears almost identical, although the pakhavaj is the most commonly used among them.

Tabla:

Wade claims that the earliest depiction of Indian tabla instrument appears in India as late as 1808, this is quite an interesting assessment considering that the tabla is held in great esteem in Hindustani classical music and may possibly be the second most recognisable Indian instrument to any Westerner (Wade, Music in Indian - The Classical Traditions, 2008, p. 136). Wade exhibit two theories which might shed some light to the origin of the instrument in India; one theory elaborates on a “fairy tale” by Chaitanya Deva which suggests it might have emerged during Emperor Akbar’s time (1556-1605), while the other suggests it was introduced by Amir Khusrau in the 13th century (Wade, Music in Indian - The Classical Traditions, 2008, p. 135). The name appears to derive from the Arabic word “tabl”, which means drum in its native Arab language or it may possibly derive from the Akkadian word “tabalu” (a language which was already extinct more than a millennium ago) (Wade, Music in Indian - The Classical Traditions, 2008, p. 136).

The tabla appears to be the most important pair of drums found in Hindustani classical music. The appearance of the instrument is literally found in all styles of Hindustani classical music and commonly used as an accompanying instrument which complements the sitar, sarod, and sarangi. In some contexts, it may appear as a solo instrument although this does not occur often (Sorrell & Narayan, 1980, p. 40). Despite that the instrument comprises a set of two drums, Wade suggests that tabla is considered as one drum although played by two hands (Wade, Music in Indian - The Classical Traditions, 2008, p. 135). Still, each drum is commonly referred to by separate names; the right drum is most commonly called daya or tabla (although sometimes referred to as dahina) and made of hollowed out wood (either by oak or rosewood), while the slightly bigger left drum is called baya and made of metal.

Daya is the highest pitched of the pair and also the most accurately pitched; the shape of the drum is slightly wider at the bottom and slightly narrower on top with its widest point at approximately five to six and a half centimetres above the base. Its appearance has been compared to a pot on a potter’s wheel. In addition, it is generally held in higher esteem which may be the reason why this is sometimes referred to as table, further the right (playing) hand is considered to be the dominant hand. The left drum is called baya (sometimes also referred to as the bass) and commonly tuned an octave lower than the daya. Generally, the baya appears to be noticeably wider than the daya; despite narrower at the bottom than the top, its widest section appears midway up.

Each tabla drum comes with a number of leather straps attached vertically across the instrument in order to affect the tuning and can be achieved by slackening or tightening the straps. Interestingly, only the daya commonly contains tuning blocks affixed to it (similar to the appearance of wine corks). Further, the skin on each drum contains a double layer of goatskin where the main layer is affixed to the second by the appearance of smaller circular ring comprising a width of approximately one inch and running around the circumference (Sorrell & Narayan, 1980, p. 40). In addition, a narrower circular area of paste appears at the centre on each of the drums and is commonly referred to as syahi. The syahi on the right-hand skin appears as a permanent black spot which comprises a mixture of boiled rice, manganese dust, iron filings and water (Sorrell & Narayan, 1980, p. 40). This mixture of biological material provides a hardening/stiffening effect on the drum skins; however, it needs to be replaced occasionally due to tendencies of cracking over time.

The baya drum also contains a similar mixture pasted onto it, despite it may appear white in colour it comprises a mixture of either boiled rice, wheat or flour mixed with water. Different to the daya, this mixture of paste is added and removed at the beginning and end of each performance, respectively. Lastly, two round-shaped cushions are placed underneath each tabla drum.

Despite that tabla may seem as an easy instrument to play, the ability to accurately execute strokes precisely to the degree of absolute perfection is a difficult process and commonly takes a number of years to master. The main sounds reproduced on the daya and baya are either open or closed (i.e., damped or undamped) (Wade, Music in Indian - The Classical Traditions, 2008, p. 139). According to B. S. Ramakrishna (1970) tabla has harmonic overtones, a feature which is enabled through the appearance of the black spot found in the middle of the on both drums (Sorrell & Narayan, 1980, p. 40). The number of basic sounds (known as bols in India) reproduced on tabla has been debated. Some sources has insisted that there might be up to 13 basic sounds on the tabla; however it contains at least seven basic sounds which are divided between both drums, two appears on the baya (left drum) while five (or the rest) on the daya (right drum) (Sorrell & Narayan, 1980, p. 41) Still different pressures produced in effect by the heel of the hand can affect the pitch while sliding across the skin can also create a glissando (Sorrell & Narayan, 1980, p. 42).

The two basic strokes on the baya are called ghe and kat; the ghe is performed by using the heel of the hand pressed against the head of the skin and make a bounced stroke with one or two fingers between the aforementioned syahi and the layered skin around the perimeter of the drum (kinar) in order to produce a resonant sound (Sorrell & Narayan, 1980, p. 42). The kat is performed by slapping the surface of the drum with a flat hand thus reproducing a closed sound (Sorrell & Narayan, 1980, p. 42).

Interestingly enough, the rigidness of the daya instrument allows for a number of additional sounds although these will be discussed towards the end of this Music Study. The daya is tuned to the SA of the raga in accordance with the mridangam and pakhavaj. In order to achieve this, a set of blocks (similar in shape to the resembling wine corks) are hammered thus providing tension from the leather straps in order to stretch the skin, while fine tuning can be achieved by further hammering gently the hoop that holds the skin. This practice appears to be assigned to the left drum (baya), although the main purpose is not so much about achieving completely accurate pitch, but rather achieve the right sonority.

The most important bols found on the daya drum is as follows: 1) ta or na (by striking the kinar with first finger while the third rests lightly on the skin between the kinar and the syahi), the dampening technique is essential in order to create a clear sound of SA (and eliminate a possible note about a minor seventh below the SA), 2) tin, (similar stroke, but the first finger strikes between the kinar and syahi instead of on the kinar), 3) tu (produced by a glancing, bounced stroke of the first finger on the syahi and recreates a clear sound of just the tone, which is supposed to be about a minor seventh below the note in which the daya is tuned), 4) dha (the ta is combined with ghe (baya), please read section about ta for reference), 5) dhin (tin is combined with ghe, please read section about tin for reference) (Sorrell & Narayan, 1980, pp. 42-43). The bols have distinctive qualities about them; and a clear difference between ta and tin compared to dha and dhin. In order to reproduce the latter two, a resonant sound from the baya is necessary. The former two are crucial to the structure and articulation of tala (Sorrell & Narayan, 1980, p. 43).

Mridang:

According to Sorrell & Narayan, the origin of the mridang appears to be of great antiquity and its name traced back to the ancient musical treatise called Natyasastra (Sorrell & Narayan, 1980, p. 38). Interestingly, the name suggest that the instrument originally was made of clay and shaped as a pottery drum, although no proper evidence of this appears to be documented. The current-day mridang is made of jackfruit wood and has remained as such for a number of centuries, the appearance on the outside maintains the shape of a barrel drum, while on "… the inside, the bore toward the two ends is slightly conical" (Wade, Music in Indian - The Classical Traditions, 2008, p. 129).

The size of the mridang is approximately two feet and contains drum skins attached at either side which comprises two layers of goatskin and syahi (similar to table). In addition to these, a number of leather straps are affixed to the instrument which can be slacked or tightened to affect tuning. The instrument is commonly played while seated where the widest skin is facing towards the players left side and the smaller to the player's right. The mridang is not commonly used in current Hindustani classical music, and has been surpassed by its almost identical yet slightly larger “cousin” called pakhavaj in later years. The mridangam comes in two different sizes; the largest is tuned within the approximate pitch area between SA to RE (in Western terminology, C to D below middle C), while the other is tuned within the approximate area between MA to PA (F to G below middle C) (Wade, Music in Indian - The Classical Traditions, 2008, p. 129).

Pakhavaj:
In principle the pakhavaj practically shares all of the same characteristic as those found the same instrument as the mridang although with slight modifications applied to it (please read the section about mridang for further details). Different to the mridangam (equivalent to Hindustani mridang/Southern counterpart), the outer layer of the skin is commonly cut away more on the pakhavaj while the surface of the second layer appears more exposed; thus the instrument contains a wider playing area which affects the dampening of higher partials and less accurately pitched than the mridangam (Wade, Music in Indian - The Classical Traditions, 2008, p. 132).

The size on the pakhavaj may vary to an extent although commonly found with a height from 66 to 76 cm and a diameter from 20 to 30 cm at its greatest girth (Wade, Music in Indian - The Classical Traditions, 2008, p. 131). Commonly, the right skin on the drum appears from 16½ to 19 centimetres in diameter while the left head appears from 25½ to 28 centimetres. A wheat flour paste is attached to the centre of the left skin prior to every performance. The pakhavaj contains visible tuning blocks placed underneath the leather straps and against the barrel near the left-hand end (Sorrell & Narayan, 1980, p. 40).

Lastly, the fourth group of instruments; the ghana vadya group appears to be very different between Hindustani and Carnatic music, in particular the Hindustanis favours bells (ghunghrus) and porcelain bowls (jaltarang) over pot drum (will be discussed shortly).

Ghunghrus:
Ghunghrus comprises a set of small bells affixed to an object worn around the dancer’s ankles and the execution of this instrument appears to be rather uncomplicated. The ringing of the bells (or reproduction of sounds) literally responds

in accordance to the movement of the dancer. Despite that Ghungrus is considered as an ancient instrument (although the origin is unknown), it is mainly reserved for dances and rarely ever found in other styles of Hindustani classical music.

Jaltarang:

Jaltarang comprises an unspecified number of separate porcelain bowls which appears in different sizes and each with fluctuating amount of water highly dependent on the sound considered desirable by the performer (since adding or removing water adjusts the tuning on each bowl). As indicated above, no standardized amount of bowls appears in Hindustani classical music although most commonly it appears to be fourteen to twenty bowls. The jaltarang is commonly performed while seated and arranged in a semi-circle in front of the performer who strikes the outer rim of the bowls with a pair of bamboo sticks; the smallest bowl appears on the right side of the player while the sizes gradually progresses to the largest bowl located on the opposite (left) side.

Jaltarang is not commonly found in current Hindustani classical music and this may largely be attributed to its inability to reproduce sliding and ornamentations. In addition, it is not a well-respected instrument and appears to receive similar criticism to that of the harmonium (Sorrell & Narayan, 1980, p. 38).

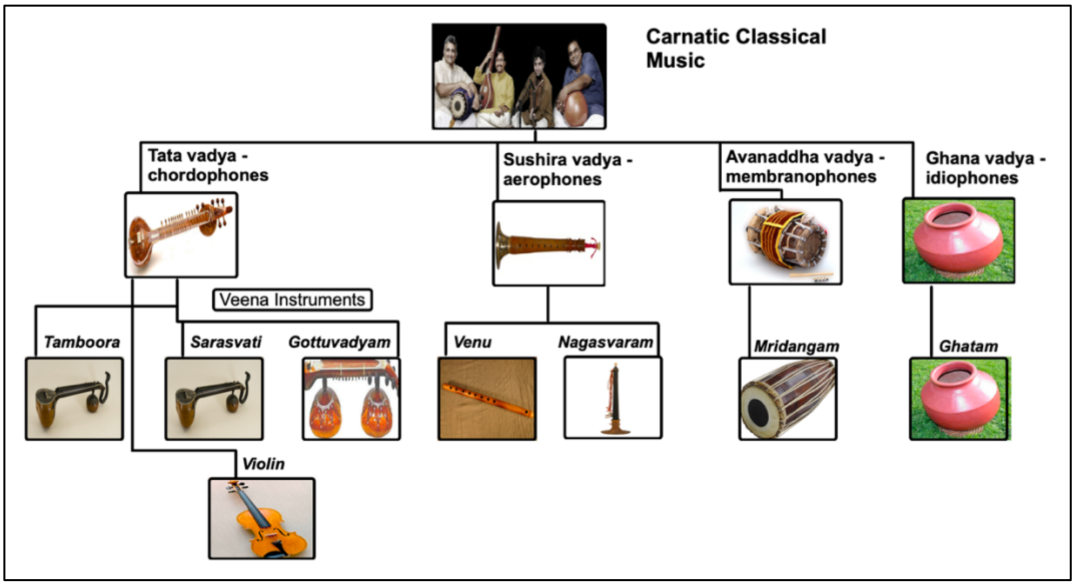

Figure A2.2. Classification system of Carnatic classical music

Carnatic music

Despite the many obvious similarities between instrumentations found in Hindustani and Carnatic music (i.e. lute instruments, veena instruments, flute, oboe, and barrel drums etc.); Carnatic classical music is different and in particularly reflected by a significantly smaller selection of lute instruments.

The first group of Carnatic instruments; tata vadya, comprises a small selection of plucked long-necked lutes which includes the tamboora, sarasvati veena, and gottuvadyam veena. The only other instrument within the tata vadya categorization is the violin.

Tamboora:

The Carnatic tamboora appears exactly like its Northern equivalent, for further description of the instrument please read the section about the tanpura. Similar to Hindustani classical music, its primary purpose is to provide drone. As implied, the tanboora contains all the same features as that of the Hindustani tanpura; it is fretless and contains four to six strings which are plucked by fingers.

Veena instruments:

The Carnatic veena instruments differ from their Hindustani counterparts; whereas the Hindustani veena instruments are categorized as stick zithers, the Carnatic veena instruments are categorized as long-necked lute instruments mainly due to the additional belly at the bottom of instrument. As previously addressed, the Carnatic versions of veena instruments are considered the most ancient among the two. Wade states that the earliest documentations of veena instruments (although with minor variations) are found in temple sculptures at Sanchi, Bhaja and Bharat dating back to 200-100 B.C. (Wade, Music in Indian - The Classical Traditions, 2008, p. 89).

Sarasvati veena:
The sarasvati veena appears to be the Southern counterpart to the rudra veena; the main difference between the two is the addition of a belly and one sole gourd resonator on the former instrument. Despite, the obvious difference between the physical appearances, the sarasvati veena and the rudra veena also share a number of similar sound characteristics in addition, the sarasvati veena also commonly contains seven strings (where three are chikari strings) and twenty-four fixed frets across a range of 2½ octaves.

Gottuvadyam veena:
Similar to sarasvati veena, the gottuvadyam veena contains a belly at the bottom with a corresponding gourd resonator at the top. The gottuvadyam veena commonly contains four main strings (although some models may contain more) and an additional eleven to thirteen sympathetic strings. The instrument is considered as the Southern counterpart to the Hindustani vichitra veena and appears to be played frequently in Carnatic classical music.

Violin:
According to Shankar, the violin is the most popular bowed stringed instrument found in the south (Shankar, My Music, My Life, 2007, p. 54). Most likely it was introduced to Carnatic classical music by the end of the 18^{th} century, although its emergence in Indian music has been subjected to debates which somehow appears contradict one another. Wade suggests that one particular story claims that violin was first introduced by a Tanjore court minister who brought it back from a business trip in Madras. On the other hand, Neuman claims “The violin… …has been part of the tradition since 1784” (Neuman, 1990, p. 114). Lastly, the most widely accepted story attributes the Carnatic musician Balaswami Dikshitar (1786-1858) as the first musician to adapt the violin to Carnatic music (Wade, Music in Indian - The Classical

Traditions, 2008, p. 101). It is frequently played as a solo instrument although often appears as an accompanying instrument.

Indian musicians commonly sit cross-legged when playing and the instrument is placed in a vertical position and balanced between the chest and the right foot while the left hand execute movements up and down on the fretboard. Despite that the Indian violin commonly contains four strings similar to the European violin, it may also appear with a total of seven strings. According to Neuman, the reason why the violin is not commonly found in Hindustani can be attributed to the presence of the sarangi whose stature in Hindustani music appears to hold an equivalent significance to that of the violin in the south (Neuman, 1990, p. 114). The amount of strings on violins is not always standardized because some violins comes with seven strings and are pitched an octave higher than the accompanying voice (Wade, Music in Indian - The Classical Traditions, 2008, p. 101).

The second group of Carnatic instruments - sushira vadya, solely comprises of two instruments, which is the flute (venu) and the oboe (nagasvaram).

Venu:

The venu (flute) appears to be one of the most ancient instruments found in India, largely due to its mentioning in Vedic texts (Deva, Indian Music, 1995, p. 3). The venu is a bamboo flute which comprises a similar appearance as that of its Northern flute counterpart although the Carnatic variant is commonly slightly smaller in size and higher pitched. All Carnatic flutes contains eight holes in addition to the blowing hole (Wade, Music in Indian - The Classical Traditions, 2008, p. 108).

Nagasvaram:

Some scholars claim that the emergence of the sahnai (the northern counterpart) appeared to be evident in Hindustani classical music approximately 400 years ago and introduced by Mahomedans (Sorrell & Narayan, 1980, p. 35). On the other hand, the history of the nagasvaram (Carnatic oboe) seems to stem from an entirely different situation; it may possibly be among the older instruments found in Carnatic instrument (or possibly in Indian music) although its origin appears to be unknown. Surprisingly, the oldest reference to nagasvaram does not appear to be of an indigenous Indian origin, but referenced in ancient Tamil texts of unknown age.

The nagasvaram commonly used to be performed in Hindu temples and weddings, although in recent years its appearance in concert performances has witnessed an apparent increase in numbers. Different to its Northern counterpart, the nagasvaram is slightly larger and comprises a size of 2 to 2½ feet long and commonly made of wood with a conical bore towards the lower end in addition to a detachable bell (Wade, Music in Indian - The Classical Traditions, 2008, p. 109). Commonly, nagasvaram contains twelve holes; eight in front while two on each side of the instrument (Wade, Music in Indian - The Classical Traditions, 2008, p. 109). It should be noted that only the upper seven holes are used for playing while the other holes are usually filled entirely or partially with wax and adjusted accordingly for reproduction of desirable pitches. The double reed on the instrument is affixed to a metal staple at the top and as such does not extend down into the instrument. Further, additional spare reeds and an ivory needle are included for cleaning and adjusting. In order to play the nagasvaram at its utmost potential, it requires a specific approach which allows for the holes to be partially closed and employed using varying lip and tongue techniques when in contact with the reed (Wade, Music in Indian - The Classical Traditions, 2008, p. 109). The instrument is commonly played by two performers.

The third Carnatic instrument group - avanaddha vadya comprises only one sole barrel drum (mridangam) which also appears to be the main drum used in Carnatic classical music.

Mridangam:

Although addressed previously in this Music Study, the Hindustani mridang drum and the Carnatic mridangam both appears to be of great antiquity. Among others, Sorrell & Narayan claims that the mridangam is included in the music treatise called Natyasastra (Sorrell & Narayan, 1980, p. 38). The only difference between the northern and southern version of the instrument is a slight variation on the name of the instrument, thus the mridangam’s physical shape, size and general appearance is identical to that of the mridang. Despite these similarities, one obvious difference between the two needs to be addressed; whereas the mridang is commonly known to exhibit one specific size, the mridangam appears in two main sizes where the tallest is approximately twenty-five inches long and comprises the tonal spectre of Sa to Re

(C to D below middle C), while the smaller is approximately twenty-three inches long comprising the tonal spectre of Ma to Pa (F to G below Middle C) (Wade, Music in Indian - The Classical Traditions, 2008, p. 129). The general intension for this division is rather obvious and solely relates to the register of human voices, thus the largest version is assigned to accompany male voices while the smallest is meant to accompany female voices. Other common instruments used for accompanying the mridangam is the venu flute and sarasvati veena.

The current version of the mridangam is made of jackfruit log with a barrel shaped appearance on the outside while the bore toward the two ends appears fractionally conical on the inside of the instrument. The mridangam is known for producing a variety of different sounds, thus the complexity of South Indian rhythm possibly enables it to be among the most sophisticated drums in the world (Sorrell & Narayan, 1980, p. 40). The instrument is commonly slightly smaller than the Hindustani pakhavaj (the most common barrel-shaped drum in the North).

Each side of the mridangam drum is made of several layers of drum skins which comprises cowhide and goatskin and further signified by additional features which attributes to very complex designs of the skins; thus, a rim of buffalo thong is braided around the edge of each drum skin in order to "… provide maximum clarity, variety, controllability of tone" (Wade, Music in Indian - The Classical Traditions, 2008, p. 130). Wade claims that this rim is responsible for providing the instrument with significance resistance in which to maintain extremely high tension while "… buffalo hide lacing is pulled through it at sixteen points and stretched in a V pattern over the body from head to head" (Wade, Music in Indian - The Classical Traditions, 2008, p. 130).

It needs to be addressed that this task demands the craftmanship of the utmost professional and skilled craftsman in order to properly fashioning it successfully. Prior to every performance, an amount of wheat flour paste is attached at either end of the drum skin for the purpose of accurate tuning; although this particularly applies to the left skin, the paste on the right skin may last for a somewhat longer time before it cracks (however, the paste needs to be completely removed before any new is added) (Wade, Music in Indian - The Classical Traditions, 2008, p. 130).

Different from the left drum skin, right drum skin contains some thin pieces of straw which are inserted between the first and second layer, and these are broken off to prevent them from reaching into the playing area. Thus, the two vibrating (layers of) skins are kept from ever physically touching one another and this arrangement affect the overall tone in a positive way.

Lastly, the fourth group of Carnatic instruments isghana vadya which comprises one sole earthenware pot drum.

Ghatam:

Ghatam is a nearly round shaped earthenware pot instrument commonly made of clay and holds a secondary position to that of the mridangam drum in Carnatic music. The origin of the instrument appears to date back to ancient times although its emergence in Carnatic classical music is unknown. Ghatam is generally performed by hands while seated and held in an upright position; the instrument is known for its supplementing ability to reproduce a variety of sounds and rhythms (Sorrell & Narayan, 1980, p. 38). It can be found performed alongside an additional group of several ghatam pot drums or as the sole pot drum instrument.

Indian Tuning

The music of India is possibly among the oldest in the world. Historically, firm evidence of physical documentation mainly provided through ancient scribed palm leaves and stone carvings depict ancient musical instruments and activities to verify musical activities in ancient Indian Vedic times. The Sanskrit Mandala is considered the first source which documents any mentioning of a tuning system in India and appears to date back to the second millennium BC (Sorrell & Narayan, 1980, p. 94).

Despite that the Sanskrit Mandala is regarded as the earliest known source for ancient Indian music, the earliest documentation which refers to music theory is found in a musical treatise called Rikpratisakhya (approximately 400 B.C.) – this source suggests that the earliest execution of Indian music comprised a register of three voices and seven notes of the gamut (Popley, 1921, p. 9). Although no exact time period for this has been properly accounted for, Wade believes that the Rikpratisakhya was written approximately 600 B.C., when a transitional phase occurred which has been evident in replacement of old idiom in reference to pitches in favour of new ones, some of which are still applied to in current Indian music (Wade, Music in Indian - The Classical Traditions, 2008, p. 37).

Although the significance of Sanskrit in Indian music cannot be understated, it is still important to address that the inherent ancient writings contains other various aspects of ancient Indian history and culture, thus not a resource exclusively reserved for music. In addition, Sanskrit is also recognized as an ancient Indian language which appears to have existed between Vedic times up until approximately the 13th century, and eventually extinct as a result of the Islam invasion followed closely by the emergence of the Mughal Empire. Similar to other known extant ancient writings/literature found in a variety of other cultures which originated from a similar time period (in and around the time of Sanskrit) appears to have been exposed to a number of re-writings and editing across a span lasting within the first few centuries of existence. Thus, any exact time periods or year/s applied to the emergence of specific information should be approached with caution due to the potential of minor or major inaccuracies/deviances.

In addition, India has been affected by outside influences derived from nearby surrounding cultures of the Indian subcontinent in addition to territories connected to other continents (such as the Arab World) for the past 4000 years. Thus, a melting pot of different ethnicities has made a major impact on the development of Indian music throughout the ages which have affected the evolution into the current Indian musical identity of today.

Historically, in ancient times contributions from numerous local tribes ushered their own musical identities by bringing their own indigenous instruments (although new to Indian music at the time) and is evident in these emerging ideas/concepts to affect Indian music. However, the majority of these influences and contributions does not seem to have surfaced distinctly in Indian classical music, except for significant impact on the execution of current Indian classical music. Sorrell & Narayan claims that the first concepts of sounds and tuning in Indian music was achieved through recitation comprising three tones, however it appears that this was extended over a certain period of time and eventually evolved into a seven-toned chant (Sorrell & Narayan, 1980, p. 2). Manifestation of intervals between successive pitches was supposedly held in much higher esteem in ancient times compared to current Indian music. Among others, Shankar states that the first pitch, SA, became the point of reference for the tonic at some point and the main importance in music eventually became centred on the relationship between SA and the other pitches (Shankar, My Music, My Life, 2007, p. 49).

Despite that some form of comparison between the Indian Sa and the Western Do (re mi) has been addressed previously in this Music Study; it should be noted that the SA (of Indian tuning) does not correspond to an accurate fixed pitch, thus appears to be different from the Western conception which is firmly tuned to the middle C. However, broadly speaking the SA should correspond to a 'movable' DO, which is a terminology commonly found in the Western solfeggio system.

In order to make the following assessment understandable to an uninitiated reader; Shankar suggests that a Westerner always refer to the common DO RE MI etc. by singing solfeggio syllables for a scale in any key such as C major, E-flat, G, A minor, similarly this relates to the Indians SA RI GA MA PA DHA NI SA system in the same manner (Shankar, My Music, My Life, 2007, p. 55).

The seven notes within the octave are called the saptaka, which means 'cluster of seven' in India; interestingly these seven notes are also referred to as the seven svaras. Despite that the saptaka intervals may be considered as an Indian indigenous phenomenon by some individuals, the first description of these intervals (saptaka) appears in a Tamil work called Tivakaram (A.D. 200-300) (Popley, 1921, p. 31). Further, the scale was divided into twenty-two matras (equivalent to the North Indian division of srutis) and referred to as alaku in Tamil books (Popley, 1921, p. 31). These works suggest the following distribution for the twenty-two srutis:

Sa	Ri	Ga	Ma	Pa	Dha	Ni	
4	4	3	2	4	3	2	= 22

Table A2.1. The 22 Srutis as explained by Popley (Popley, 1921, p. 32)

The concept of tuning in Indian music is based on the average human vocal range, thus the majority of Indian instruments commonly comprises a tonal range of 2½ octaves, however in some cases up to 3 octaves. It is important to address that the Indian conceptions of scales is similar (although not entirely equivalent) to the Western conception of scales and addressed differently between Hindustani and Carnatic music, namely as thats and mela (or melakarta) respectively. According to Deva, this conception appears to have replaced a former yet similar function called moorcchana approximately in the 14th century (Deva, Indian Music, 1995, p. 30). Mela and thats are based on the same principle of seven notes (1 2 3 4 5 6 7) including the upper 1 (Shankar, My Music, My Life, 2007, p. 32). Despite this, certain ragas also appear with more or less notes although this subject will not be further explored in this Music Study.

The execution of North Indian classical music relies on the principle of thats (heptatonic scales) which are equivalent to Western principles of modes. Sorrell & Narayan suggests that the following six (out of a total of ten) thats are similar to Western modes; Kalyan (F-mode – Lydian), Bilaval (C-mode – Ionian, also C major scale), Khamaj (G-mode – Mixolydian), Kafi (D-mode – Dorian), Asavri (A-mode – Aeolian), and Bhairvi (E-mode – Phrygian) (Sorrell & Narayan, 1980, pp. 95-96). An additional four modes exist in Hindustani classic music, namely Bhairav, Purvi, Marva, and Tori; although these cannot be properly rendered nor translatable to Western scales and showcase characteristics which are comparable to oriental music found in central and East-Asia.

Despite that the latter four thats are widely accepted in India, Sorrell & Narayan states that "… it does pose problems, such as how to classify rags with a heptatonic scale slightly different from any of the ten that's (maybe by just one note) or with fewer or more notes than seven. In practice this means between five, the minimum number of notes a rag may have, and twelve, the maximum number used in present-day nomenclature." (Sorrell & Narayan, 1980, p. 94).

In addition to the distinct separation between Hindustani and Carnatic classical music, Indian music witnessed further influences through a number of significant changes through the years. Popley claims that the Svaraniela Kalanidhi written around 1550 by the Carnatic musician Rama Amatya appears to be the first exposition of southern music and eventually led to execution of ragas from a common tonic, shadja (also referred to as SA) which is equivalent to C in Western tuning (Popley, 1921, p. 18).

Despite that certain modes are executed accordingly in a raga (which is highly important in Indian music); however, since most ragas would allow performers to express themselves freely (at least to some extent) the performer's ability to reproduce ascent and descent notes to exact specifications (within a particular mode/that) is not necessarily the most essential element in a singular performance. If the raga basically is heptatonic, then most likely it will include all the notes in descent (avroh in Indian) (since all are included in heptatonic scales). On the other hand, this will lead to a problem when the notes appear in ascent (aroh) since one or two notes are omitted in heptatonic scales (Sorrell & Narayan, 1980, p. 96). Thus, this can be solved by a pentatonic ascent and heptatonic descent (for instance, this occurs in raga Bhimplasi) (Sorrell & Narayan, 1980, p. 96). However, the situation is less complicated for pentatonic ragas; Sorrell & Narayan states that "…the typical aroh-avroh is straight up and down using all notes, since an ascending or descending line, like the rag itself, requires a minimum of five notes" (Sorrell & Narayan, 1980, p. 96).

Indian compositions (in particularly those performed in concerts) mainly rely on a register of three octaves and appear in the following order; mandra (lowest octave), madhya (middle octave), and tar (highest octave) (Bor, 2002, p. vii). Further, the notes are commonly incorporated and assigned to specific groups of notes. From a theoretical perspective, Shankar points out that each octave in Indian scales can be divided into two groups of tetrachords, a first and a higher limb (which in Western terminology can be described as upper and lower tetrachords) of which each comprises four notes; the lower group is called purvanga (first limb) and comprises the following notes: SA RI GA MA, while the upper is called uttaranga (higher limb) and comprises the notes: PA DHA NI SA (Shankar, My Music, My Life, 2007, p. 32). Bor also suggests a secondary consecution of notes for both purvanga and uttaranga thus; Sa to Pa and Ma to Sa, respectively (Bor, 2002, p. vii).

Shankar further adds: "This is in no way merely an arbitrary division, for the notes of the two tetrachords usually correspond closely with each other. A raga generally dwells predominantly in one or the other tetrachord, and this determines in part its expression or mood. Every raga has a distinct ascending and descending structure, just as a Western scale is played from the lower tonic through the octave to the upper tonic and back down again" (Shankar, My Music, My Life, 2007, p. 32). Bor, on the other hand, suggests that each octave can be divided into a lower tetrachord or pentachord (from SA to MA or SA to PA), and higher tetrachord or pentachord (from Pa to Sa or Ma to Sa) - and refers to these as two processes called purvang and uttarang, respectively (Bor, 2002, p. vii).

With the exception of SA (or the tonic, which serves as the “home base” in a raga), every raga comprises a predominant note called vadi (the sonant and also known as the “King of Notes” in India) which is the most commonly used and emphasized note whose main purpose is to set the mood of the raga (Shankar, My Music, My Life, 2007, p. 32). Similar to the two tetrachords (purvanga/uttaranga) which comprises the scale, vadi also has a corresponding note to it called samvadi and is considered to be the second most important note found in ragas (Shankar, My Music, My Life, 2007, p. 32). Further, the intervallic distance between samvadi and vadi always appears to be a fourth or a fifth apart - the main purpose of samvadi is to strengthen the sonant (Shankar, My Music, My Life, 2007, p. 32).

Besides vadi and samvadi, another two categorizations of notes appears to be collectively referred as 1) anuvadi, (or assonants); while all other notes outside of a scale are referred to as 2) vivadi (dissonant notes, or “enemy notes”) - the latter group of notes are rarely ever used in ragas and singularly for special timbre or effect of dissonance (Shankar, My Music, My Life, 2007, p. 32). In Indian notation, the division of flat notes are shown as R, G, D and N, and sharp M (line above M); further, high notes have a dot above the letter; low octave has a dot beneath (Bor, 2002, p. vii).

Despite that the Indian tuning system allows for a wider palette of intervals compared to Western musicians, no standardisation of fixed pitches appears to found. According to Bor, the exact position of semitones generally may be interpreted slightly different dependent on the musician in question, however this does not commonly apply to the natural fourth, natural fifth and octave (Bor, 2002, p. vii). Bor further adds that flat notes can be lowered by approximately 20 cents to make them appear flatter in tone and as such the notes will change and then become komal (flat), or ati komal (very flat), while augmented fourths may be sharpened (by approximately 20 cents) and then appear as tivrar (sharp); such microtonal variations are commonly referred to as srutis (Bor, 2002, p. vii).

Although the phenomenon of drone is also found in Western music and mostly associated with bagpipe music, the Indian drone exhibit an entirely different texture/timbre (or sound characteristic). For instance, Farrell suggests that the tonic note (Indian drone) can be heard throughout a performance while the tanpura also recreates some type of ostinato to emphasize certain notes, which most commonly applies to the fifths (Farrell, 1997, p. 38). However, he further states that "…this spread of notes is not linked rhythmically to the melody of the composition, but rather provides a background wash of sound, rich in harmonics, due to the manner in which the strings vibrate on the bridge of the tanpura (Farrell, 1997, p. 38). The keys D, A, and F on the tanpura appears to be particularly predominant although it provides little information in regards to actual pitch of the original tonic; the tonic note SA, is flexible and commonly varies from one singer to another, while additional instruments appears to be adjusted accordingly to accommodate the singer's voice (Farrell, 1997, p. 39). In practice, this means that A4 (a common reference pitch in Western terminology) would have to be adjusted either flatter or sharper to accommodate the singer's voice and additionally affect the other keys in the spectrum of the octave; for instance if the tuning of A4 decreases to 415Hz rather than stay at 440Hz, a D would then appear C# which is a common tonic found in Indian music, while the opposite approach would turn flatter keys such as F# to become natural F (Farrell, p. 39).

According to Shankar, the primary ingredient in order to breathe life into a raga and make the tones come alive and provide the musical textures of a raga can be achieved through the system of ornamentation and embellishment. Often, these notes are described as grace notes (or gamakas, in Indian); Shankar describes these as "… subtle shadings of a tone, delicate nuances and inflictions around a none…" that please and inspire the listener" (Shankar, My Music, My Life, 2007, p. 33). The change from one note to another in Indian music is executed differently than the firm direct and clear transition between notes associated with Western music; on the other hand, Indian transitions are smooth and soft, like a glide, or ornament (Shankar, My Music, My Life, 2007, p. 33). Further, Indian classical music also contains andola (or andolita) - sometimes referred to as a "swing" effect which in essence appears as a delicate rocking between microtones; and lastly another categorization of gamaka exists which consists of ascending succession of tones that may be perceived as the sound of laughter (Shankar, My Music, My Life, 2007, p. 33).

Sorrell & Narayan suggests that instruments can accompany the voice in four possible ways, 1) through the idea that the instrument plays consistently in unison with the voice, 2) the instrument provides harmony or a counter melody, 3) the instrument alternates with the voice by providing interludes, and 4) the instrument ‘shadows’ the voice by imitating what has been previously sung, occasionally anticipating the voice and playing in unison along with it. However, it is not common for the instruments to provide harmony, or counter melody in Hindustani classical music (Sorrell & Narayan, 1980, p. 60).

The phenomenon of srutis

Despite that the phenomenon of srutis has been addressed previously as literally uncalculatable in Indian music, a number of Indian scholars have made attempts to come up with suggestions in which to offer approximate calculations of each sruti. Despite the slightly fluctuating divisions of srutis it may often be executed with minor differences from one musician to another; thus, this Music Study will focus on calculated propositions of srutis provided by a limited number of different scholars on Indian music.

Popley proposes a table which addresses each of the twenty-two srutis by name while also referring each sruti accordingly to its closest equivalent found in the Western tone system:

TABLE OF SRUTIS			
Sruti Name	Western Note	Sign	Carnatic Name
22. SHADJA TARA ...	C	S	Shadja Tara
21. Tivra ...	B	N+	
20. SUDDHA NI ...	B	N	Kakali Ni
19. Komal Ni ...	Bb	n	Kaisiki Ni
			Shatsruti Dha
18. Atikomal Ni ...	Bb	n-	
17. SUDDHA DHA ...	A	D	Chatuhsruti Dha
			Suddha Ni
16. Trisruti Dha ...	A	D-	
15. Komal Dha ...	Ab	d	Suddha Dha
14. Atikomal Dha ...	Ab	d	
13. PANCHAMA ...	G	p	Pa
12. Tivratara Ma ...	F#	m+	
11. Tivra Ma ...	F#	m	Prata Ma
10. Ekasruti Ma ...	F	M+	
9. SUDDHA MA ...	F	M	Suddha Ma
8. Tivra Ga ...	E	G+	
7. SUDDHA GA ...	E	G	Antara Ga
6. Komal Ga ...	Eb	g	Sadharana Ga
			Shatsruti Ri
5. Atikomal Ga ...	Eb	g-	
4. SUDDHA RI ...	D	R	Chatsruti Ri
			Suddha Ri
3. Madhya Ri ...	Db	R-	
2. Komal Ri ...	Db	r	Suddha Ri
1. Atikomal Ri ...	Db	r-	
0. SHADJA ...	C	S	Shadja madhya

Table A2.2. Displays the 22 srutis from Popley (Popley, 1921, p. 5)

Deva proposes a table which lists the twelve notes commonly used in Hindustani classical music while simultaneously mentioning that Carnatic music contains an additional four notes which yields the total of sixteen notes (Wade, Music in Indian - The Classical Traditions, 2008, p. 38). However it is important to address that four of these only appears as an accompanying note to its closest equivalent and should not really possess any noticeable difference in tone besides the name, thus: sruti 4. SUDDHA RI = Chatsruti Ri/Suddha Ri, sruti 6. Komal Ga = Sadharana Ga/Shatsruti Ri, sruti 17. Sruti 19. SUDDHA DHA = Chatsruti Dha/Suddha Ni, and Komal Ni = Kaisiki Ni/Shatsruti Dha (Deva, Indian Music, 1995, p. 27). Wade also concurs with this assessment (Wade, Music in Indian - The Classical Traditions, 2008, p. 38).

Deva proposes a table which displays the approximate position of intervals found in

Sa grama and Ma grama - which is the modern octave found in Hindustani music and the Western natural diatonic scale in relations to each of the twenty-two srutis (Deva, Indian Music, 1995, p. 29). The table is thus:

Sruti	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Sa-grama	ni				sa			Ri		ga				Ma				Pa			Dha		ni
Ma-grama	ni				sa			Ri		ga				Ma			Pa				Dha		ni
Modern																							
octave																							
(Hindustani)	Sa				Ri			Ga		Ma				Pa				Dha			Ni		Sa
Western																							
natural																							
diatonic	C				D			E		F				G				A			B		C

Table A2.3. Deva's approximate proposition of intervals between the 22 srutis (Deva, Indian Music, 1995, p. 29)

Popley further proposes another table which includes all of the basic seven notes found in Indian music, including specific sruti names in addition to their approximate cents value; however, he clearly states that the sruti numbers are "…really only approximations but the cents are course accurate", thus these appears as follows:

Octave	…	22	srutis	i.e.	1200 cents
Fifth	…	13	"	"	700 "
Fourth	…	9	"	"	498 "
Tone	…	4	"	"	204 "
Minor-Tone	…	3	"	"	182 "
Semi-Tone	…	2	"	"	112 "

Table A2.4. Displays all the basic seven notes found in Indian music and the approximate cents value of srutis (Popley, 1921, p. 31)

In addition to the information provided by these tables, a few more authors on Indian music have provided significant contributions in order to establish some understanding of the approximate division between each sruti. Doctor Vivek Bansod and Professor Mohit Sharma both contributes approximate frequency values in Hertz for each sruti, while Professor Dinesh Thakur proposes cents values and ratios for each sruti (Bansod & Sharma, 2019, pp. 249-250) (Thakur, 2015, pp. 519, 523). Despite that Popley only mentions the basic seven notes in the Indian scale, however all of these completely coincides with the exact same values as proposed by Professor Thakur. When combining all of these elements in addition to the information already provided by Popley, Wade and Deva, the following table should offer a somewhat thorough overview of all twenty-two srutis:

TABLE OF SRUTIS

Sruti Hindustani Name	Cents	Ratios	Frequencies	Western Note	Sign	Carnatic Name
22. SHADJA TARA …	1200	2:1	200 Hz	C	S	Shadja Tara
21. Tivra …	1110	243:128	189.84375 Hz	B	N+	
20. SUDDHA NI …	1088	15:8	187.5 Hz	B	N	Kakali Ni
19. Komal Ni …	1018	9:5	180 Hz	Bb	n	Kaisiki N
						Shatsruti Dha
18. Atikomal Ni …	996	16:9	177.777777 Hz	Bb	n-	
17. SUDDHA DHA …	906	27:16	168.75 Hz	A	D	Chatuhsruti Dha
						Suddha Ni
16. Trisruti Dha …	884	5:3	166.666666 Hz	A	D-	
15. Komal Dha …	814	8:5	160 Hz	Ab	d	Suddha Dha
14. Atikomal Dha …	792	128:81	158.0246913 Hz	Ab	d	
13. PANCHAMA …	702	3:2	150 Hz	G	p	Pa
12. Tivratara Ma …	612	729:512	142.3828125 Hz	F#	m+	
11. Tivra Ma …	590	45:32	140.625 Hz	F#	m	Prati Ma
10. Ekasruti Ma …	520	27:20	135 Hz	F	M+	
9. SUDDHA MA …	498	4:3	133.33333 Hz	F	M	Suddha Ma
8. Tivra Ga …	408	81:64	126.5625 Hz	E	G+	
7. SUDDHA GA …	386	5:4	125 Hz	E	G	Antara Ga
6. Komal Ga …	316	6:5	120 Hz	Eb	g	Sadharana Ga
						Shatsruti Ri
5. Atikomal Ga …	294	32:27	118.51851 Hz	Eb	g-	
4. SUDDHA RI …	204	9:8	112.5 Hz	D	R	Chatsruti Ri
						Suddha Ri
3. Madhya Ri …	182	10:9	111.111111 Hz	Db	R-	
2. Komal Ri …	112	16:15	106.666666 Hz	Db	r	Suddha Ri
1. Atikomal Ri …	90	256:243	105.3497942 Hz	Db	r-	
0. SHADJA …	0	1:1	100 Hz	C	S	Shadja madhya

Table A2.5. A complete overview of the 22 srutis containing Hindustani and Carnatic note names, ratios, frequencies and Western notes proposition – contributers of information: Popley, Wade, Deva, Doctor Vivek Bansod and Professor Mohit Sharma

Conclusion

In general, Indian Music appears to be a particularly broad topic which comprises many different genres and with great variety of various musical instruments - some of the instrument mentioned in this Music Study appears to be found in more than one genre while some might appear more commonly in completely other genres than

Indian classical music. Further, it should be noted that some historical aspects of Indian classical instruments appear to be logical, in particular this applies to the majority of ancient instruments commonly found in and associated with both the Hindustani and Carnatic music cultures. However, debates arise in regards to the origin on some Indian instruments which may not yield the most obvious answers, in particular this applies to the origin of the sahnai and nagasvaram which does not provide any clear factual information regarding their initial appearances in Indian music.

In addition to this, scholars appear to disagree about the time periods attributed to a large number of short-necked and long-necked lute instruments found in Hindustani music. These debates mainly concern the actual timeframes for their initial emergence, actual origin, or whether they were invented or already extant instruments which were exposed to modification by Amir Khusrau. Despite that scholars seems to disagree about the exact extent of Khusrau's influence and achievements, still the majory have concluded that Khusrau's involvement mainly concerns modification of noted instruments. It is interesting to witness the appearance of a large selection of lute instruments in Hindustani classical music while such a phenomenon is barely apparent at all in Carnatic classical music - however whether this difference can be specifically attributed to Khusrau or not, is difficult to answer.

Generally, the ability to establish a clear idea of what constitute an actual core group of Indian instruments to be commonly found in classical ensembles has been a rather difficult process - in particular this applies to Hindustani classical music. Current popularity among Hindustani instruments appears to somewhat reflect the complexity in relation to mastering and/or playing particular instruments (and obvious to a number of Hindustani lute instruments addressed in this Music Study); for example, the rudra veena used to hold the highest position among Hindustani instruments until it was surpassed by the sitar which is now considered to be a noticeable easier instrument to master. Another possible reason that may affect the popularity among Hindustani instruments may be attributed to the fact that some of the lute instruments are specifically used only for certain subgenres within classical music (which are previously described in the instrument section of this Music Study).

Further, it is not always easy to pinpoint the exact extent of popularity in regards to certain Hindustani instruments in performance. The best example of such an instrument is the sarangi, which is given a thoroughly detailed description by Sorrell & Narayan, but only receives occasional mentioning by Wade and Shankar, thus confusing as to why this instrument receives more attention than certain other instruments which appears to be considered more favourable in Hindustani classical music - such as surmandal, santur, surbahar, and both veena instruments.

One of the great advantages by exploring Indian classical music is that there is much literature easily accessible and which encompasses the majority of all integral musical aspects of India. Several scholars have written about Indian music and provides a diverse selection of authors who each specialising in different aspects on Indian classical music; this has provided a wide and thorough selection of information and resources for this Music Study. However, it needs to be addressed that in order to create a complete overview of Indian classical music, some minor yet important aspects in regards to Indian music were still lacking and managed to make this process somewhat challengeable.

For instance, a lot of attention has been given to the history, tradition, and performances on instruments in Indian music, although sufficient information past basic tuning has proven difficult to obtain. The information about the fundamental Indian scale (SA RE MA etc.) has been covered sufficiently thus enabled us to establish how this system works in practice. However, very little in-depth information appears about the exact calculation of the twenty-two sruti intervals and as such only very recent sources appears to provide some approximations of these. A possible reason for this may be reflected in the old oral Indian tradition while possibly some of the fundamental ideas about this may have been lost at some point during the course of its history.

Further, thorough description on tuning of lute instruments for the most part appears to be neglected, although such instruments as sarod and tabla has been described sufficiently. A possible reason for this may be attributed to the fact that many of the lute instruments already does not appear to be subjected to any standardized amount of strings.

Lastly, the final challenge in this Music Study has been to find sufficient information about Carnatic music, which seems to be somewhat neglected in favour of the more popular Hindustani classical music. From a Western perspective and the average knowledge possessed by Westerners regarding Indian music; Hindustani instruments are the most widely recognizable in the Western world. This may be largely due to the fact that the Hindustani musician Ravi Shankar (one of the most famous Indian musicians of all times) managed to bring the awareness of Hindustani classical music – through extensive touring all over the world for several decades and through his Western musical acquaintances influenced and affected several Western musical genres within pop/rock, experimental and contemporary music, mainly through musical acts such as the Beatles, the Rolling Stones, the Byrds, LaMonte Young etc. Shankar thus may probably be the most significant Indian musician ever responsible for exposing Indian music to the Western world (or the rest of the world).

APPENDIX 3

Arabic maqam

"The history of research in Arabian music is as old as Arabian cultural history. Already in the eighth century, Arabs wrote treatises on Arabian music" – Habib Hassan Touma

Figure A3.1. An overview of all the 22 Arab nations in yellow

Identification of the Arab World

Determining what is generally considered the Arab World today is not the easiest task approachable. The current Arab World comprises a large number of people from different ethnicities which originates from a variety of different areas such as North Africa (mainly Arab-Berbers), most of the Arabic Peninsula (Hebrews, Assyrians) including Middle-East (with the possible exception of Israel), certain nations in the East-African coast (Somalis, Sudan, and certain local East-African tribes), and Iraq (Kurds, Chaldeans, Turkmen etc.) with its Eurasian connection bordering Pakistan and Afghanistan closely associated with the Indian subcontinent. In essence, it may be justifiable to suggest that the people of the Arab World consist of a melting pot of various peoples who all claim to be part of or belong to one group of people shared by a common cultural heritage. The unifying factor for this diverse collection of territories and peoples is the Arabic language which engenders a sense of cultural unity to an extent, and or at least various cultural artefacts that can be said to hold an Arab identity; amongst these artefacts is Arabic Music.

History of the Arab World

The Arab World currently consists of 22 states – some of which have been part of the Arab World for at least a millennium while others were granted membership within the past few centuries. The most common language found in the Arab World is self-evidently; Arabic, although a wide selection of second languages being spoken are also found in the Arab culture, among others; French (commonly found in Morocco, Algeria, and Tunisia), Berber (commonly found in Morocco, Algeria, Mauritania, Libya, and Tunisia), Assyrian language (mainly in Syria, although only a fraction of the population speaks this language), and Kurdish languages (among others found in Iraq and Syria, although only a minority of the population speaks this language).

The History of ancient Arabic Music

It is important to address that spellings of people's name, general musical terms and instruments found in this Music Study might derive slightly from other sources!

The reputation of Arabic music has gone through a number of different phases which has affected the popularity and general acceptance among its habitants through a number of significant yet tumultuous challenges throughout history. Especially, the most significant change occurred with the emergence of Islam and for more than a millennium it appears to have been the main signifier to split and divide the opinions about Arabic music and consequently its stature among the Arab population and many a ruler. The reasons for such contradicting views derive from the religious writings documented in the Qu'ran which states that the expression of music is neither accepted nor dismissed; thus, certain epochs have been affected by differing acceptance of music among Arabic rulers and theorists, while in others it has been considered forbidden and proclaimed as denounced or frivolous and mainly associated with or performed by criminals or bums (Touma, 1996, 2003, pp. xix, 4). The general consensus about Arabic music appears to have retained its popularity for the first few centuries after the emergence of Islam, however, between medieval times (approximately 13th century) and up until the early part of the Modern-period (from 1799 onwards) the popularity of Arabic music gradually experienced a decline and eventually reached its nadir. Marcus suggests that the renewed interest in Arabic music possibly was initiated by 19th century Turkish music (Marcus, Arab Music Theory in the modern period, 1989, p. 25). The current music in the Arabic Arab, however, is still closely related to Persian and Turkish influences (Touma, 1996, 2003, p. 15).

Maqam

One of the most important aspects of Arabic music is *maqam* (in essence equivalent to a system of scales) and has been considered an integral part of Arabic music for the past 400 years; however, its initial emergence in Arabic music (upon which its primary purpose to describe the melodic aspect of Arabic traditional music) still appears unknown.

Various tone systems in Arabic music tradition has been pulled in different directions throughout its history. It should be noted that the acceptance of the current concept of tuning in Arabic music has been widely debated among a number of renowned Arab scholars both past and present; even today musicians and scholars approach the Arabic tuning system with contradicting views. Although, some aspects of the Arabic music and traditions have remained intact for centuries and possibly remained as such since the early ages (i.e. styles of music with connotations related to) such as important social events (i.e. funerals, festive celebrations, weddings etc.), religious rituals (prayers, chants) and secular music. Arabic music constitutes a variety of different styles, such as diverse local traditions, folk, pop, classical, and religious genres (Farraj & Shumays, 2019, p. 1).

Arabic music is strongly associated with vocal music (whereas the singer is known for producing the most powerful and versatile ornamentations (zakhrafa in Arabic) and embellishment) which still remains a compulsory yet significant part of Arabic music and performances, although accompaniment of musical instruments is commonly present in the majority of Arab compositions. Among common instruments found in both European and Arabic cultures, Farraj & Shumays mentions the ancient rababa (European: rebec), which he claims was brought to Europe (Spain, Italy and southern France) during the medieval period, and eventually evolved into the European violin (Farraj & Shumays, 2019, p. 26). Landis claims that the wooden body on a number of ancient Greek aulos were made of nettle-tree wood (*celtis australis*) called lotos (also referred to as 'Libyan' because the wood originated from the North-African continent) which can possibly bridge and support the notion of Western/European awareness of and/or understanding of Arabic instrument-making craft as early as the 7th century A.D., thus it suggests contact between Arabs and Europeans in ancient times (Landis, 1999/2001, pp. 26, 33).

Regional variances of Arab music

Farraj & Shumays specifically proposes three regional variances within Arab music; al-khalij (which belongs to Iraqian and Iran tradition (although the latter is no longer considered part of the Arab world)), al-sharq (Egyptian, Palestinian, Jordan, Lebanese, and Syrian tradition), and al-maghrib (Libyan, Tunisian, Algerian, and Moroccan tradition), however we will not further elaborate any of these besides just mentioning them.

Earliest traces of musical activities in the Arab World

According to Touma, the first known musicians from the pre-Islamic period of al-Jahiliyyah were grouped into either of two different categories; 1) Bedouin nomad singers, and 2) preposterous female singers and performers called qaynah (pl. qiyan) (Touma, 1996, 2003, p. 2). Burkholder et al. suggests that the earliest evidence of musical activities in the Arab World occurred in Mesopotamia (current day parts of Iraq and Syria) at some point between 6000-4000 years ago (Burkholder, Grout, & Palisca, 2010, p. 6).

The earliest known musical instruments associable with Arabic music were discovered through archaeological excavational in the royal tombs at Ur (a Sumerian city on the Euphrates) which comprised several [bull] lyres and harps, two types of plucked string instruments, a selection of clay tablets containing scribed depictions which displayed execution of these instruments, which all supposedly dates back approximately 2500 B.C. Burkholder et al., suggests that these ancient writings provide instructions on tuning of ancient stringed instruments and possibly offer indications that Babylonian musicians were capable of embracing a seven-tone diatonic scale during or possibly before ancient Greece (Burkholder, Grout, & Palisca, 2010, p. 8). Further, Burkholder et al., claims that the Babylonians were early adopters of written/scribed music as early as approximately 1800 B.C., while further states that the "… Babylonians used their names for intervals in order to create the earliest known musical notation"; however, the only apparent proof of this is a nearly intact document of a musical composition discovered on the Syrian coast by an unknown composer written between 1400-1250 BC, although due to its antiquity and primitive notation style no modern scholar has yet managed to fully apprehended its exact meaning with confidence (Burkholder, Grout, & Palisca, 2010, pp. 8-9). In addition, documentations suggests the name Enheduanna to have been the first Arabic composer known by name (fl. approximately 2300 B.C.) and composer of hymns specifically addressed to then-contemporary Gods, although no music by her survive, texts on clay tablets still exists (Burkholder, Grout, & Palisca, 2010, pp. 6-7).

In accordance with Burkholder et al., Farmer states that there was a seven mode system in existence already prior to the emergence of Islam and documented in the Ramayana which was a selection of Indian Sanskrit epics about ancient-Indian culture and written somewhere between 400 B.C. and 200 A.D.; despite no singular author credited, a twelve mode system supposedly occurred in the time of Khusrau Parwiz (590-628 A.D.) (Farmer, 1930/2015, p. 60). Maalouf claims that no music literature from the al-Jahiliyyat (pre-Islamic) period have survived in modern age and therefore little knowledge about pre-Islamic Arabic music is currently known (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, pp. 15-16).

So far we have witnessed a number of authors which concurs with the assessment of a seven-tone fundamental scale system to be part of ancient Arabic music; however besides Burkholder et al., no other author provide specific information about musical instruments nor any written documentation of music extant prior to the 5th and 6th century A.D., although Touma suggests that the earliest writings from approximately the 6th century supposedly covered at least a millennium of Arabic musical history up until that point in time (Touma, 1996, 2003, p. 1). Unfortunately, none of these documents appears to exist anymore.

Simultaneously, an increased awareness and influence from the West began to signal a shift in Arabic music and manifest the beginning of an emergent yet significant epoch in which the identity of Arabic consciousness and music gradually merged with Western ideals from ancient Greece. Farmer suggests that the introduction of Byzantine and Persian theories in Arabic music are likely to be credited to the Saudi-Arabian composer and music theorist Ibn Misjah (d. approximately 705-714 A.D.) who translated songs from Byzantine and Persian regions into Arabic language (Farmer, 1930/2015, pp. 236-237). Byzantine, formerly a Greek colony which pertained music and theory based on the Pythagorean tone system (of Greek origin) where fundamental principles of a tone system was most likely proposed by Ibn Misjah; although in order to distinguish it from a previous pre-Islamic system, it later became known as the "Old Arabian System" during the era of Persian musician Ishaq al-Mawsili (d. 850 A.D.), (Farmer, 1930/2015, pp. 236-237). Unfortunately, even in modern times, still no-one appears to know the conceptualization of Ibn Misjah's tone system nor how the intervals were divided.

Further, Arabic influence swept across the Iberian Peninsula (the majority of current day Spain and Portugal) with the arrival of the Moors in the 8th century. According to musicologist Carl Engel (1818-1882), at this stage the Arabic World appeared to be more cultivated advanced than its Western Europe counterpart; Farmer states that the Arabs even brought diverse musical instruments to the Western culture and were the first to give scientific description of musical instruments "…and the only didactic instrumental methods that we possess in the Middle Ages come from Arabic" (Farmer, 1930/2015, pp. 61-62).

It appears that some of the contemporary scholars of Arabic music from this period were highly influenced by ideals of the ancient Greeks. Among others, Touma states that two individuals; philosopher, mathematician and musician Ya'qub Ibn Ishaq al-Kindi (d. 870) and philosopher, scientist and music scholar Abu Nasr al-Farabi (d. 950 A.D.) both were early champions of the ancient Greeks ideals and practices of Greek music, although the latter did attribute a lot of the basis to himself in his musical treatise *"Kitab al-Musiqi al-Kabir",* (The Great Book on Music) (Touma, 1996, 2003, p. 46). Although a champion of ancient Greek theory at first, al-Farabi later came to the conclusion that musical treatises written by scholars of the ancient Greek appeared to be incomplete (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 18).

The significance of intonation has been one of the most important aspects of Arabic music since ancient times; Marcus claims that a number of treatises written between the 8th and 13th century revolved around this particular subject, although he attributes the position as “the chief model for subsequent generations” specifically to Persian musician and theorist Safi al-Din al-Urmawi (also commonly referred to as simply al-Din) (c.1216 - d. 1294) (Marcus, Arab Music Theory in the modern period, 1989, p. 161). As an apparent advocate of the Pythagorean school of ancient Greek music theory, al-Din’s proposition was strongly influenced by the Pythagorean theorem although his ideas led to an entirely new innovation resulting in a fully categorized tuning system which contained seventeen tones per octave (Marcus, Arab Music Theory in the modern period, 1989, p. 161). The intervals in al-Din’s tuning system were divided unequally and comprising mainly of limmas (90.2 cents) and commas (23.5 cents) while renowned measurements derived from concepts used in ancient Greek music theory (we will provide extensive details on al-Din’s scalar theories later on in this Music Study) (Marcus, Arab Music Theory in the modern period, 1989, p. 161).

Safi al-Din wrote the book *”Kitab al-adwar”* (translated to Book of Modes) published in the 13th century; this treatise appears to be among the more substantial and comprehensible pieces of work of its time and covers a variety of musical aspects such as tone, composition, mode, rhythms of Arabic music etc. (Touma, 1996, 2003, p. 10). Besides al-Din’s scalar theories, only scant documentation by theorists and scholars appears to exist between the 14th and 18th century; however, we know that a transition from al-Din’s seventeen-tone scale to a twenty-four-tone scale would occur at some point during this period.

Despite some obvious and significant differences from the current Arabic tuning system, the current fundamental scale of Arabic music still retains some of the individual note names associated with 13th century Arab theory (Marcus, Arab Music Theory in the modern period, 1989, p. 84). The concept of a seven-tone fundamental scale existed in Arabic music as far back as the ancient times, although Marcus informs that a reconceptualization of the quarter steps (later to be known as rub’, pl. arba’) occurred at some point during the 1700s (Marcus, Arab Music Theory in the modern period, 1989, p. 74).

It should be noted that Safi al-Din’s tuning proposition was received generally favourable in the first few centuries during its existence however experienced a gradual decline during the consecutive centuries and by the second half of the 18th century the stature of Arabic music eventually reached its nadir to a point when Arabs generally had become dismissive of it. Unfortunately, the Arab's attitude towards their own music had by then been surpassed by European music and an adoption of contemporary Western ideals and concepts on theory within Arabic music had by then become apparent and would seemingly last until the 20th century. Although Arabic music would absorb strong influences from the Turks and Persians, Marcus states that the music tradition gradually developed its own identity over time since the established musical theorem of al-Din back in the 13th century; however, the French music composer and theorist Jean-Benjamin de Laborde (1734-1794) is credited for being the first to propose a twenty-four quarter-tone system in Arabic music (Marcus, Arab Music Theory in the modern period, 1989, p. 13).

The development of an Arabic twenty-four tone system have gone through significant changes since the 1780s, a period which is mainly distinguished into three significant periods of which Marcus refers to as 1) Early-Period School, 2) Middle-Period School, and 3) Present-day-Period School (Marcus, Arab Music Theory in the modern period, 1989, p. 60).

Early-Period School

The Early-Period School, estimated to have lasted between 1780s to late-1800s and/or early-1900s; appears to be dominated primarily by the written works of four eminent authors/scholars: namely, Laborde, Villoteau, Mashaqah and Shihab al-Din (Marcus, Arab Music Theory in the modern period, 1989, p. 60). The main concerns about Arabic music revolved around advocating the twenty-four-tone tuning system in addition to reconceptualizing tones associated with the fundamental scale of ancient Arabic music in order to customize with the then current 24-tone tuning system. This appears to be the first time that scholars mention the word rub` (pl. arba`) "quarter" tones in Arabic music, however, at this stage the associations of modes did not appear to be specifically connected to a scale nor any principles of tetrachords, however instead each mode appears to be addressed through a unique melodic phrase (Marcus, Arab Music Theory in the modern period, 1989, p. 60).

It should be noted that the intervening period between the latter part of the Early-Period-School and the beginning of the Middle-Period-School (lasting approximately 60 years) showed little if any traces of transitional overlapping in-between; however, when we enter the Middle-Period School, a significant change in direction would occur and showcase a stronger emphasis on tetrachordal practices in Arabic music.

Middle-Period School

Different to Early-Period-School, a renewed interest in traditional Arabic music became apparent among contemporary scholars, the most significant ones to mention here are: Dhakir Bey (1903), al-Khula'i (1904), Salfun's Rawdat al-Balabil (The Garden of Nightingales) (1920), D'Erlanger (Instr. of Oriental Music) (1933), al-Hifni (1938), al-Shawwa (1946), Salah al-Din (1946), al-Sabbagh (1950). This period was marked by definitions of modes across scales covering a two octave range (where a large number does not duplicate at the octave) and complex tetrachordal analyses; however another important aspect from this period deals with significant focus on the melodic movement for each mode, of which Marcus suggests was indicated by "… a starting note and the order in which a mode's constituent tetrachords should be performed" (Marcus, Arab Music Theory in the modern period, 1989, pp. 60-61).

Present-day-Period School

The very last period which is termed Present-day-Period School also saw the arrival of new emergent authors born in and around the infamous Cairo Congress; Mahfuz (1963), al-Halqah (1964), Ibn Dhurayl's al-Musiqa fi Suriyyah (Music in Syria) (1979), Muhammad (1984), Surur (1986) etc., but also marked by contributions from then veteran authors such as Dhakir Bey and Khula'i, and al-Hilu (1961). The exact time period when this period was initiated has been estimated to appear between 1930s-60s although with a slight edge towards the latter half. While the focus on how modes were performed in practice remained intact, this period witnessed a change which steered away from two-octave scale practices in favour of one-octave scales, thus limiting the number of tetrachords to only two per mode which was different compared to previous periods, it appears that melodic movement of modes (lack of any mentioning of starting note) was to be neglected in Present-day-Period School (Marcus, Arab Music Theory in the modern period, 1989, p. 61). Despite that a rather brief overview of the three schools of Arabic music is presented above, it is necessary to examine the works of the aforementioned authors in order to sufficiently understand the significance of their contribution to Arabic music.

Besides Laborde, Farmer claims that one of the first advocates of Arabian influence on theory of music was the French musicologist Guillaume André Villoteau (1759-1839), who found it reasonable to believe that Arabic music had been influenced and adapted into the music theory of ancient writings from approximately the first millennium of modern era by the Italian music theorist Guido of Arezzo (d. approximately 1050 A.D.), thus suggests that it arose out of the Greek system (Farmer, 1930/2015, p. 267).

The principle of a two-octave range appears to have been adopted by Arab theorists at some point during medieval times and is still accepted in (some parts of) modern Arab theory. The idea derives from the belief that it constitutes the natural range of human voices as well as the optimum range on a number of traditional Arabic instruments (such as the ‘ud and the nay) - the two-octave practice is considered as a continuation of ancient Greek music theory; (Marcus, Arab Music Theory in the modern period, 1989, pp. 106-107).

In 1780, Laborde wrote his musical treatise called *“Essai sur la Musique ancienne et modern”*. He subdivided the fundamental note names by applying nim (pl. nimat) and tik (pl. tikat) designations in front of note names in order to signify lower and higher pitched notes (across one octave), respectively (Marcus, Arab Music Theory in the modern period, 1989, p. 68). Marcus, describes that the nimat and tikat is part of a third category of notes (in addition to; 1) fundamental notes, and 2) “half” notes (s. `ansaf, pl. `arabat)), altogether ten in numbers (across one octave) and their purpose is to “… divide the remaining undivided half-step intervals in the octave scale” (Marcus, Arab Music Theory in the modern period, 1989, pp. 88, 97). In addition to divide twenty-four tones across the range of one octave, he further identifies seven fundamental notes (and an eight note at the first octave); this tone system first appeared in Syria and later in Egypt, although principles on modern tetrachordal theory was still neglected for approximately 100 years after Laborde’s treatise (Marcus, Arab Music Theory in the modern period, 1989, pp. 13-14).

Before we go any further, it should be noted that the originator behind the definition of twenty-four equally tempered intervals appears to be a disputed case. According to Marcus this idea first emerged in a report written by French military officer Francois Baron de Tott (1733-1793) and who stated that Laborde was the first known person to present a twenty-four tone system for Arabic music, although this concept appeared to be clearly inspired by the European twelve-tone equal-tempered scale (with a twenty-fifth interval at the octave) (Marcus, Arab Music Theory in the modern period, 1989, p. 162). He determined all intervals to be equally divided with a starting point from C to c (where the 25th tone appeared at the octave) (Marcus, Arab Music Theory in the modern period, 1989, p. 162).

However, this is where the disputed case appears, was this idea actually conceived by Laborde or did it originally derive from de Tott himself? It should be noted that Laborde does not specify any exact values on the intervals in his own writing although he states the following: "By comparing [the rab method of dividing the scale] with the division by equal semi-tones, we find there is a clear correspondence. One sees that they divide in quarter that which the Europeans divide in two …" (Marcus, Arab Music Theory in the modern period, 1989, pp. 162-163). Thus, we are not entirely sure whom to attribute the idea of an equally tempered Arabic scale, (de Tott never heard any Arabic music prior to writing the report), although we know for certain that the idea originated back to at least the end of the 18th century since de Tott died in 1793.

Although, Laborde is credited for introducing the twenty-four-tone system to Arabic music; the Syrian based musician shaykh Muhammad al-`Attar's (1764-1828) manuscript, *Rannat al-Awtar fi Jadawil al-Afkar fi Fann al-Musiqar (The Sound of Strings [arranged] in Rubrics to Bring to Mind What Concerns the Musician's Art (c.1820))* appears to be the first Arabic scholar to write a treatise about this subject (Marcus, Arab Music Theory in the modern period, 1989, p. 163). In conjunction with Laborde, al-`Attar presented the Arabic/Persian note names over two octaves in the aforementioned treatise (Marcus, Arab Music Theory in the modern period, 1989, p. 68). Interestingly enough, some differences between then current contemporary European and Arabic scholars seems obvious; whereas an infatuation with the European equal-tempered scale appears to be significantly regarded among many European scholars, the opinions from Arab scholars, on the other hand, seems divided.

Unfortunately, no complete specimen of al-`Attar's original manuscript appears to exist; thus, we can only rely on the work provided by his student Lebanese historian and Doctorate in Music Mikhail Mashaqah (1800-1888) in order to establish some understanding of the attitude among Arab scholars by the turn of the 18th and 19th century. It should be pointed out that Mashaqah's treatise *al-Risalah al-Shihabiyyah fi al-Sina`ah al-Musiqiyyah (The Shihabi Treatise on the Musical Art),* appears to be the first indigenous description of a twenty-four-tone scale and referred to "… as a "quarter tone scale"" extant today; despite no firm date or year of published work, it is believed to have been written between 1829 and 1840, (Marcus, Arab Music Theory in the modern period, 1989, pp. 164, 44-45). Thus, Mashaqah might be the first among Arabic writers to discussed the scale by referring to tones as rub`(pl. arba`), which literally means "quarter" in the Arabic language (Marcus, Arab Music Theory in the modern period, 1989, p. 70). Later on, it appears that Mashaqah rendered al-`Attar's original demonstration of exact placement of twenty-four pitches to be faulty, and stated that "… al-`Attar's scale was, by intention, a quarter tone scale in which the quarter tones were all of equal size, i.e., an equal tempered quarter-tone scale" (Marcus, Arab Music Theory in the modern period, 1989, pp. 163-164, 166).

As a result Mashaqah determined that the octave contained twenty-four arba` (quarter tones) and concluded that the fundamental scale contained three large intervals of four arba` and four small intervals of three arba` (although no mathematical theorem provided to explain the exact placement of the intervals in the scale); Mashaqah stated the following "… the [distance between the frets of] the quarter tones diminishes according to a geometric progression and not as the shaykh has indicated…" (Marcus, Arab Music Theory in the modern period, 1989, pp. 164-166). After addressing this issue, Mashaqah proposed yet another three methods, showcasing both geometric and arithmetic demonstration "… for arriving at the correct fret placements" (Marcus, Arab Music Theory in the modern period, 1989, p. 166). This appears to be the first example of a scholar who challenged the already established idea of a twenty-four-tone equally tempered scale in Arabic music; however, in the consecutive centuries a number of scholars whose scepticism towards an equally tempered scale would become more obvious, in particular when approach more recent history.

Among the most important and renowned scholars within the past 100 years or so is French painter and musicologist Baron Rodolphe d'Erlanger (1872-1932); an early champion of Mashaqah's ideas and also an opponent to the concept of an equally tempered scale in Arabic music. In accordance with Mashaqah his studies were also significantly based on the emphasis of measuring string lengths and tuning of the tanbur (we will address this thoroughly later on in this Music Study) (Marcus, Arab Music Theory in the modern period, 1989, p. 166).

D’Erlanger adds that common ensemble practices originally comprised of three to five native instruments by the 1920s and 1930s and were later replaced by large orchestral ensembles which featured violin sections, a few cellos, contrabass, and later guitar, accordion, bongos and electric organ (Marcus, Arab Music Theory in the Modern Period, 1989, p. 32). Eventually this Westernization of Arab music had become so apparent within practices that by 1932 a survey revealed that there were far more students and teachers of Western music in Egypt than that of their own music; the Western solfeggio syllables and Western notation had by then established a profound effect on the authenticity and identity of traditional Arabic music (Marcus, Arab Music Theory in the Modern Period, 1989, pp. 30, 156).

A significant turning point in Arabic music occurred when a global meeting which comprised renowned scholars representing both native and international territories and who were appointed to partake in a comprehensive yet definite concluding regarding the consensus of Arabic music and the constitution of a widely accepted authentic Arabic tuning system. This meeting is commonly known as the Cairo Congress of 1932, and despite it did not result in a widely accepted conclusion regarding execution of Arabic music among Arab musicians and scholars (with the sole exception that equally-tempered tuning system would be rejected); however, the aftermath of this meeting still inspired a number of scholars to continue theorizing and further develop/exploring aspects of Arabic music in the hope of bridging the gap and to provide an “answer” to the aspects which eventually could lead to or constitute an authentic and widely accepted Arab tuning system.

Marcus suggests that the original ideas suggested by Mashaqah still appears to be relevant among contemporary scholars today. Mashaqah suggested that the seven fundamental notes constituted "a ladder” [sullam] with each step to appear above the other; despite the intervals not to be equally spaced but rather instead grouped into two different categories; namely larger and smaller intervals where the “… larger is that in which the interval between two adjacent fundamental notes is four arba` [quarter steps]. The smaller is that in which the interval is three quarters. [1840] 1899:220)" (Marcus, Arab Music Theory in the modern period, 1989, p. 84). This view is shared among a number of renowned authors/scholars in the twentieth century, such as al-Shawwa (1948), al-Hilu (1946), Fahmi (1965), and Farah (1974) (Marcus, Arab Music Theory in the modern period, 1989, pp. 85-86).

Arabic Maqam

The traditional Arabic music can be described as predominantly focused on melody rather than harmony, while music performances often deal with a greater variety of octaves than we are accustomed to in Western music (which is also similar to Indian music). Both Arabic and Indian musics also describe their tuning systems as modal and mainly operates with a seven-note fundamental scale although in rare cases Arabic music can be found with eight notes depending on the particular maqam family (scale) from which it derives. Farraj & Shumays suggests that Maqam can cover both composed and improvised music, in addition to vocal or instrumental music (Farraj & Shumays, 2019, p. 4).

Maqam (pl. maqamat) can be described as a system, or taxonomy (collection) of scales. However, Farraj & Shumays states that maqam contains a few more elements to it such as "… habitual melodic phrases, modulation possibilities (e.g., the process of moving from one place to another in music), ornamentation norms, and aesthetic conventions that together form a very rich artistic tradition" (Farraj & Shumays, 2019, p. 4). It should be addressed that some scholars appears to describe maqam only as a collection of "melodic modes", although Farraj & Shumays consider such a term to be insufficient and only cover the phenomenon of maqam to some extent; according to them a mode is only "… a scale or a set of tonal intervals", and further suggests that Western terminology will not cover all aspects of the original Arabic meaning (Farraj & Shumays, 2019, p. 4).

A cultural commonality to all Maqam regardless of the constituent tones is a unique type of improvisation associated with both secular and religious Arabic art music. Maqam is the foundation of traditional Arabic music, and (as previously mentioned) can be traced back at least 400 years, Touma claims that the singer Mulla Hasan Babujidji (c. 1760-1840) is the first person referred to as a maqam singer by name (Touma, 1996, 2003, p. 55).

Jins

Traditionally maqam has been classified into families based on their lower jins (pl. ajnas), however Farraj & Shumays use the English translation “genus” (meaning a type, a kind, or a group marked by common characteristics) in order to describe jins, and continues by stating that they are “… the basic melodic unit of Arabic music” (Farraj & Shumays, 2019, p. 192). Jins are small melodic fragments comprising a few notes (between three and five notes) which each conveys a certain “mood” or “character” when they are put together in a row with three to five other jins (each “jin” shares a tonic note/end note whichh fits together with one another) it enables construction of longer melodies (in some cases it can construct something called maqam families which we will discuss shortly) (Farraj & Shumays, 2019, p. 193).

A jin is roughly described as a tetrachord in contemporary Arabic music theory, though less frequently it may also refer to a trichord or even a pentachord. In essence, these terms refer to collections of 3, 4, and 5 notes (i.e. trichord, tetrachord, pentachord) without noticeable large intervallic gaps between the notes (Farraj & Shumays, 2019, p. 7). Thus, tetrachord appears to be a sufficient term in order encompass the majority of aspects which comprises the qualities of a jins. However, Farraj & Shumays clearly suggests that this term appear somewhat deficient, in particular this applies to the lack of a couple aspects related to “melodic behaviour”, by which the inherent meaning of a jins comprises “… habitual phrases and customary modulations” (Farraj & Shumays, 2019, p. 201). The governing interval (space between lowest and highest tones) can vary microtonally – thus a tetrachord is not always within the space of a perfect fourth. According to the scholar al-Hifni, the phenomenon of *ajnas* (pl. form for jins) are considered the fundamental building blocks which creates every maqam and the origin of this idea appears to have been established by scholars prior to the modern era (i.e. pre-1798) (Marcus, Arab Music Theory in the modern period, 1989, p. 271).

Marcus states that the most common approach for classifying maqamat has been by categorising their tonic pitch in ascending order and has been the common practice for the past 200 years; Marcus further claims that scholars altogether have recognized at least fifteen notes which are considered to be appropriate tonic pitches for maqam of which the eight most common are: GG, AA, BBb, BB-b-, C, D, E-b- and F, with modes based on these (Marcus, Arab Music Theory in the modern period, 1989, p. 368). As previously addressed in this Music Study, a focus on (or yet the debatable revival of) tetrachordal concepts in the 20th century appeared to be essential to scholars who by then developed a new system for classifying the maqamat. Marcus believes the idea is based on the mode's lower tetrachord upon which scholars recognized nine or eleven of such groups, although the introduction of the Western notation in Arabic music eventually changed the execution of a particular traditional model and directed yet another system of classification where key signatures were necessary for further transcription (Marcus, Arab Music Theory in the modern period, 1989, pp. 368-369).

Variations in tuning and ornamental inflections appears to be inherent in songs contained within individual maqam families, these often appears to be based on regional traditions found all over the Arab World; the main regions being North Africa (Morocco, Algeria, and Tunisia), Central Arab world (Egypt to Syria), and the East (Iran and Iraq). A vast amount of modes exists which are both dependent and independently of regional variations, however due to lack of documentation throughout history it is almost impossible to precisely date when most of these emerged in Arabic music thus classification of entire sets of Arabic modes does not exist.

This may further suggest that the cultural approach to improvisation (for instance the melodic exploration) of a maqam appears to be the stronger part of the tradition and enables the performer to incorporate tonality from a range of diverse indigenous influences. However, Farraj & Shumays points out that ornamentation in Arabic music does not necessarily mean that the musician is required to render compositions faithfully note by note, however it allows for a certain space for the musician to express their individuality as a performer mainly since the technique is taught orally and no accessibility of a functional notational system enables ornamentations to be written down (Farraj & Shumays, 2019, p. 8). A selection of the most common jins are displayed below:

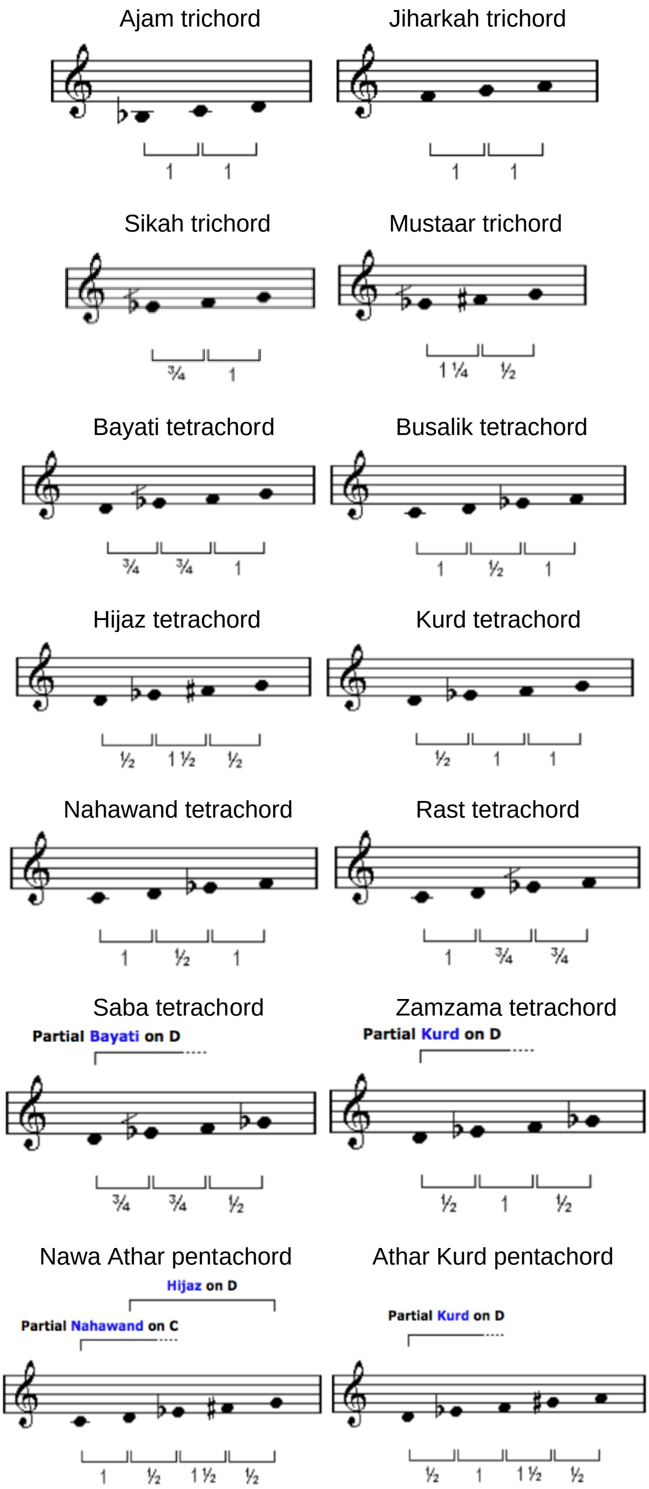

Figure A3.2. The most common jins (trichords, tetrachords and pentachords) (Farraj & Shumays, 2019, p. 8)

The examples of jins displayed above shows different variants of trichords, tetrachords, and pentachords found in Arabic music, although only a few appears entirely in accordance with the ancient Greek system (such as ajam and jiharkah). As we addressed previously, most jins do not entirely fit with the ancient Greek terms; for instance, gaps of approximately ¼ of a tone (sikah and mustaar), and approximately ¾ of a tone (saba and zamzama) are commonly found despite that each appear within close approximation in order to render them classified under their respectful Greek term.

Maqam family

Farraj & Shumays describes the maqam family as a phenomenon which contains two (or sometimes three) ajnas (plural form for jins) where the first jin always starts with its tonic, while the second jin starts at the ghammaz (modulation point) of the first jin and is most commonly the upper note of the second jin (in case a third jins is used, its tonic will coincide with the ghammaz of the second jins) (Farraj & Shumays, 2019, p. 288). The basic maqam families which relies on seven-note scales are as follows; 1) maqam ‘ajam, 2) maqam bayati, 3) maqam hijaz, 4) maqam kurd, 5) maqam nahawand, 6) maqam nikriz, 7) maqam rast, 8) maqam sikah. The exceptions are maqams based on eight-note scales which contains more unusual notes not commonly associated with Western music (we will discuss this further towards the end of this chapter). Most of the seven-note maqams repeats at the octave (on the eighth note), although some do not.

Marcus explains that the inherent meaning of the word maqam is not easily definable on its own and can be used in different contexts. For instance, alongside words such as naghamah, and lahn, and maqam all of which can be used in order to describe mode; although, naghamah and sometimes maqam can also be referred to as notes, while the words naghamah and lahn are used in contexts to mean melody (Marcus, Arab Music Theory in the Modern Period, 1989, p. 9). Touma claims that maqam is the root to all genres of improvised Arabic music which encompasses vocal and instrumental music; in addition its improvisational technique can also be found in both secular and sacred music (Touma, 1996, 2003, p. 38).

Qualities of Arabic music

Arabic music is generally recognized for being melodic, however, the same cannot be said of its harmonic qualities since the focus and usage of harmonic notes are far less crucial to the music than we are accustomed to in Western music. Further, heterophony (a non-harmonic musical texture which can be described as a variation of a single melodic line) is also found in Arabic music and appears to be a compulsory ingredient to rhythmic elements of Arabic music, while it also occurs in the melodic aspects to certain extent; Farraj & Shumays describes it as "…the sound that results from multiple instruments playing essentially the same music without playing in unison" (Farraj & Shumays, 2019, p. 99).

Different to melodic instruments, the Arabs generally show less concern when tuning rhythmic instruments, thus the attention to precisely tuned skins (tuned to a precise pitch which is a common Western musical practice) is not given much attention since the main focal point revolves around skins which are sufficiently tight and comfortable (i.e. by using less energy or force) for the musician to play; thus Arabic percussion instrument are not tuned in accordance with each other nor with any melodic instruments and might provide explanation to why rhythms always contains heterophony (Farraj & Shumays, 2019, pp. 47-48).

Further, maqam does not rely on any firm idea of fixed meter which may render the overall impression and listening experience for non-Arab listeners with a general idea that Arabic music generally appear shapeless and lacking in terms of themes and elaborations while the compositions may seem to lack a firm sense of a beginning and end. However, Tourna argues that Arabic music does contain all these elements although the approach towards form, structural elements, melodic passages, phrasing, tone levels, and emotional content (although performance styles does not reflect the style of a particular maqam) is unusual and can be perceived differently to the Western ear and seems to apply to both vocal and instrumental forms (Touma, 1996, 2003, p. 39). It should be noted that every musical structure can be specified by two major factors which oppose one another; 1) space in relation to tonal factors, which is essential to the factor of fixed and binding organization of the maqam, while 2) the time (or tempo) related to rhythm, allows for a more freely execution (Touma, 1996, 2003, p. 38).

Touma states that the performance of a single-voiced melody line embedded in a particular maqam relies largely on the modal structure of a given compositional piece (within its maqam family) upon which it is conceptualized; in addition, a number of different elements are important such as the tone row, predominance of vocal music, vocal technique, song style, texts; which are followed by the cobbling together of musical form elements, arrangements of small melodic elements, repetition, combination and permutation within the framework of a tonal-spatial model, absence of polyphony, polyrhythm and motivic development and finally alternated between a free rhythmic-temporal and fixed tonal-spatial organization in one situation and fixed rhythmic-temporal and free tonal-spatial structure in the other (Touma, 1996, 2003, p. xx). Another important aspect is modulation which is one of the most important elements found in Arab modal music; this allows musical execution to move from one maqam to another within a given performed piece of music (Marcus, Arab Music Theory in the modern period, 1989, p. 754).

Maqam row

The last aspect of maqam (dealt with in this Music Study) is the maqam row. Maqam row is yet another essential aspect of Arabic music and comprises a small selection of available tones which are made up of a combination of minor, medium, major, and augmented seconds; sometimes one maqam row can be constructed entirely based on medium and major seconds, while another maqam row can be based solely on minor and major seconds (Touma, 1996, 2003, p. 28). Further, the Arabic tone system contains all tones found in more than seventy modes, or maqam rows based on heptatonic scales that can be constructed "…from augmented, major, medium, and minor second intervals" (Touma, 1996, 2003, p. 18).

Tarab

Another important aspect of Arabic music which has not been sufficiently discussed thus far is the phenomenon called *tarab* and relates to the mental state that a listener and/or performer can achieve while listening to and/or performing music; this relates to their ability to reach a state of trance or ecstasy (mentally/physically) through interaction with music. Racy adds that an essential part of maqam is the ability to establish a strong sense of ecstasy, which in equal measure is necessary in order to create a strong modal presence. This is done by emphasizing the tonic and going back to it frequently during a particular piece and sometimes let it act as a drone to affect and engage the listener; the significance of modal presence means that the intervals of the mode are steadily presented and reproduced with absolute accuracy (Racy, Making Music in the Arab World, 2003, p. 100).

Racy presents a reasonable explanation on how tarab can be interpreted; it is an essential element to music listening which is related to the emotional transformation connected through listening (and performing) music, although the word cannot entirely translatable into the English idiom, however the meaning resembles and evokes such connotations as ‘state of ecstasy’ or ‘trance’ (Racy, Making Music in the Arab World, 2003, pp. 5-6). Touma adds that current Arab music mainly focuses on the combination of two aspects; the song (ghina) and tarab (Touma, 1996, 2003, p. 13). The tarab ecstasy is usually associated with physical and emotional musical experiences which occurs in social yet discreet contexts, since the ecstatic behaviour have a bad connotation if encountered in public appearances and might result in condescending social ridicule, or moral and religious criticism (Racy, Making Music in the Arab World, 2003, p. 8).

Current Arabic music is divided into five important musical aspects such as; 1) a tone system with specific intervallic structure, 2) rhythmic-temporal structures to accompany and shape vocal and instrumental music, 3) the musical instruments associated with the tuning system and their construction and design, 4) social contexts for construction and execution on styles of music which are divided into urban, rural, or Bedouin, and 5) a musical mentality (Touma, 1996, 2003, p. xix). Arabic music can be found accompanied by rhythmic patterns, although this is not always the case since certain music genres do not contain a rhythmic accompaniment (Touma, 1996, 2003, p. 47).

Similar to Indian music, accompanying musicians are an important part of Arabic music culture and their task is to be effective and to complement/fill the musical space with sparse ornamental ideas, basic rhythmic or melodic backdrop while not taking up too much space which may overpower or detract from the performance by the main performer (Racy, Making Music in the Arab World, 2003, pp. 83, 86). In order to recreate ecstatic performances (tarab) successfully, it is essential that singers are capable of reciting songs by mastering accurate pitch and often present melodic intervals predominantly in the shape of microtonality; Racy states that tarab in practice “… exhibits an intricate and a highly patterned system of intonation…”, with “…Western inspired theoretical system of equal-tempered half-steps, three-quarter steps, whole steps, augmented seconds, and so on, intervals derived from a theoretical scale of 24 equal quarter-tones per octave” (Racy, Making Music in the Arab World, 2003, p. 106).

Evidentially, the phenomenon of maqam is highly complex and not easily definable; numerous scholars appear to struggle somewhat when they approach and present an adequate and complete definition in order to cover all aspects of its native meaning. Despite being an integral part of the Arabic music tradition for centuries, no scholar appears to know with certainty when the phenomenon of maqam eventually became established in Arabic music. Most likely the concept appeared sometime in medieval times during a time when Arabic music was strongly influenced by Greek ideals in general. Interestingly enough, jins (or ajnas) which roughly estimates the tetrachordal principles of ancient Greek music, does not appear to have been properly established in Arabic music until after the dawn of the modern era (from approximately 1798 onwards).

Classification of instruments

Before we go any further, it is important to address that a small selection of the instruments presented in this Music Study may be restricted to or more commonly found in specific regions of the Arab World (i.e. Egypt, Persia etc.). Providing a full list of all current Arabic instruments found independently and based on regional traditions would be incomprehensible for this type of Music Study, thus a vast number of instruments have been omitted.

A variety of Western instruments can be found in Arabic music today such as accordion, electric guitar, electric organ, oriental keyboard, piano, saxophone, trumpet, and European violin. However, since these cannot be entirely characterised as traditional Arabic instruments, thus omitted from this Music Study. However, the violin has been exempted since it is the only bowed stringed instrument commonly found all over the Arabic World (with the sole exception of the kamanjah (an elder "Arabic" equivalent to violin and found primarily in specific regions such as Egypt) which has been omitted from this Music Study due to insufficient information from any scholar), in addition to being customized for Arabic tuning and its relation to the ancient rabab instrument has validated its inclusion in this Music Study.

Typical Western instruments such as electric guitar, electric organ (org), oriental keyboard have also been customized for Arabic tuning, however, their emergence in Arabic music has occurred within the past 100 years thus found inadequate to include these; neither are accordion and piano and in accordance with other scholars

– thus these instruments appears to be somewhat insignificant to the overall history of traditional Arabic music. Interestingly, Arabic instruments also appears to have influenced Western music; the origin of words such as lute, rebec, guitar and naker derives from Arabic instruments such as al-‘ud, rabab, qitara and naqqara (Farmer, 1930/2015, p. 137).

Instruments represented in this research and reasoning for inclusion

The instruments provided in this Music Study appears to be represented in the majority of, if not all regional traditions in the Arab World. The reason for their inclusion is largely due to thorough and significant in-depth information from a number of scholars, although a small selection of instruments strongly associated with Arabic music may appear to be missing – these were omitted either due to insufficient information (by any scholars), modernization of previous instruments, or simply replaced by other instruments currently considered more significant and which possesses a higher stature across a wider areal within the Arab world.

In order to provide a comprehensive list which covers the most fundamental yet important set of instruments associated with the tradition and considered inherently Arabic, a few obvious criteria have been taken into account; emphasis on instruments 1) with strong ties and importance to current Arabic music, 2) those whose substantial amount of literature has been provided by renown and respected scholars, and lastly 3) historic significance in comparison to current stature. It is also important to address that the importance on every instrument is not shared equally among numerous scholars. Largely due to different preferences, or the scope (or focus) is limited to a few or one sole region of the Arab World rather than all. Thus, compiling a selection of Arabic instruments for this Music Study has been quite a challenging process. It is fully understandable if any Arab musician would be confounded by the overall selection since its inclusion might favour instruments considered less common or uncommon in their region, while ignoring aspects of others.

Indigenous classification systems proposed in the 10th century

Touma addresses that Arabic music introduced a classification system for music instrument as early as the 10th century. Arabian scholars such as Ibn Zaylah, Ikhwan as-Safa, and Ibn Sina apparently came up with a system that divided percussion, plucked, bowed, and wind instrument into separate categories; this categorization separated instruments into different groups depending on their ability to produce tones which were rendered either short, long, or lasting, in addition to different categories of stringed instruments which contained frets or not (Touma, 1996, 2003, p. 109). However, Farraj & Shumays distinguishes between melodic and percussion classification of instruments. They have divided Arabic melodic instruments into two groups; 1) “sahb” (pulling), a category of sustaining instruments comprising wind and bowed instruments, 2) “naqr” (tapping), a category for “percussive” melodic instruments such as ‘ud, qanun, santur, buzuq, while compiling percussion instruments into another separate group (Farraj & Shumays, 2019, pp. 14, 47). It should be noted that ror this Music Study, Farraj & Shumays classification system has been selected.

The history of Arabic musical instruments has been affected by a number of radical changes during a number of transitional epochs, such as; 1) the emergence of Islam which affected the music tradition of the Jahilliyyah period, 2) the beginning of the Abbasid Caliph when the capital of the Arabic cultural centre was moved from Damascus to Baghdad and eventually brought Persian influences to Arabic music, 3) the Ottoman rule which imposed Turkish influence on Arabic music, and lastly 4) the acceptance of Western concepts and theories. All of these four influences brought new musical ideas and instruments to Arabic music; thus, a number of different instruments have been part of the tradition for a certain period of time (among others the aforementioned examples rabab, qitara and naqqara), then later to be replaced or vanished from the tradition.

The next section will look at some disputed examples of instruments as well as instruments no longer associated with tradition Arabic music.

According to Farmer, the first mentioning of an instrument still currently used in Arabic music is the ‘ud which he claims emerged at the turn of the 6th century after replacing (among others) a similar instrument called mizhar (Farmer, 1930/2015, p. 52). Interestingly enough, no source appears to mention any types of Arabic instruments prior to this, thus we do not know for certain what types of musical instruments to have been part of Arabic music prior to the 6th century.

Touma explains that by the 7th century, ensembles commonly comprised various musical instruments performed by qiyan singers and among these instruments a short-necked stringed instrument similar to modern day ‘ud, flute, oboe or clarinet, and hand drum; according to Touma very little outside influence appears to have affected Arabic music at that point (Touma, 1996, 2003, p. 3). This period lasted until the beginning of the Abbasid Caliph with the emergence of mukhannathun musicians, during a stage when ensembles increased in size and affected by a significant change in instrumentations which then would comprise of lute, zither (mi’zafah), the flute (qassabah), the clarinet (mizmar), and a square hand drum (duff) which was most commonly assigned to female musicians (Touma, 1996, 2003, p. 7).

Further, Farmer states that there is evidence of musicians playing ‘ud, pandore (tanpur), lyre (mi’zaf) and clarinet in Byzantine and Persia as far back as the 7th and 8th century and further adds that ancient theorists claimed that these instruments were of Arabic origin; vice versa Persian and Byzantine musicians supposedly led the Arabs to adapt melody from their cultures and added it to their distinctive Arab poetry (Farmer, 1930/2015, pp. 53-54).

Among the instruments various emphasised in this Music Study, it seems apparent that some type of short-necked lute (whether this was an actual ‘ud is disputable), qanun, and duff most likely were part of the original core group of ancient instruments found in or around the area currently comprising the Arab World; however, Touma clearly points out that qanun is not referred to as such until the 10th century by al-Farabi (Touma, 1996, 2003, p. 123).

It is interesting to observe that Touma claims that the appearance of short-necked lute instruments found in Arabic music around the 7th century was slightly different (although similar) to that of the current-day ‘ud, despite that Farmer claims its existence to be apparent approximately a century before. However, it is difficult to verify which of these statements to be correct; Farmer’s book was originally published approximately 90 years ago, while Touma’s book was first published in the latter half of last century. Without any further information nor documentation provided in order to support more recent discoveries, we can only conclude that the ‘ud (or a similar variant of the instrument), likely appeared no later than the time period suggested by Touma.

Between the 8th century and the modern era (from 1798 onwards) it appears difficult to decipher which types of instruments to constitute Arabic music; Farmer mentions that the naqqarat (i.e. formerly timbale) became known under its current name in the 16th century, although its history appears to date further back in time; in addition, Farmer suggests that a selection of percussion instruments named adufe (square-shaped tambourine), pandarete (round-shaped tambourine), tar (round-shaped tambourine) tanbur (drum) were part of Arabic music at some point (Farmer, 1930/2015, pp. 138-139). However, since Farmer does not mention nor give any indication as to whether these instruments were already obsolete or part of contemporary Arabic music by the time his book was published, these instruments were omitted from this Music Study.

Interestingly, among various modern instruments, an obvious disagreement between scholars seems apparent. Touma present a selection of Arabic instruments supposedly present in current maqam, such as bendir (frame drum), sunuj (cymbals), and a selection of less known wind instruments called shabbabah, sunray, mijwiz, argul, and qirbah (all flute or reed instruments); however, none of these are mentioned by name by other scholars approached for this Music Study. In addition, Farraj & Shumays mentions buzuq (fretless stringed lute instrument), katim (frame drum), and tabl baladi (double skin goblet drum) as instruments currently found in maqam; neither of these appears to be mentioned by any other scholar. Besides the buzuq, (mainly due to significant information provided) none of the instruments mentioned by Farraj & Shumays will be taken into account in this Music Study.

Further, a number of instruments such as bendir (frame drum), naqqarat (kettle drums), sajat (copper cymbals/castanets), are mentioned as current instruments in Arabic music but these appears to be solely related to religious rituals, dances (Sharqi Raks) and processions; since they are only mentioned sporadically by scholars, thus omitted from this Music Study.

As evident in the last few paragraphs, a vast number of different instruments have been part of Arabic music at some point or another, thus too many to be described and examined thoroughly in this section of the Music Study. Based on what we have gathered so far, among the old instruments such as ‘ud, qanun, and duff are still currently present and might have been part of the tradition since the Jahilliyyah era (the earliest known period of Arabic music). These instruments appear to be the most popular among Arab instruments whereas the ‘ud particulary holds a significant position and considered by some to be the “heart and soul” of Arabic music.

The next group of instruments considered part of current Arabic music (maqam) is the mazhar (Egyptian mazhar), nay, riqq, santur, and darabukkah (also known as tabla or tabl); among these only the santur and darabukkah contains a somewhat sufficiently documented history. Touma claims that the name tabl can be traced back to Medieval times and possibly from the Persian word tabir which first appeared around the era of the Crusaders (ca. 11th century) (Farmer, 1930/2015, p. 139). He also suggests that the name Santur originates from Persia, Turkey and Iraq, although the name of the instrument appears from the Greek word psalterion, unfortunately no specific time period for the emergence of this instrument has been provided (Touma, 1996, 2003, p. 125).

All of the instruments discussed in the next section of the Music Study have been exposed to some customization and modification in order to be compounded with then current concepts of tuning systems during their epoch of existence. A vast selection of percussion instruments still appears to be found in Arabic music, although less amounts of plucked string instruments while bowed instruments and wind instruments are commonly assigned to one instrument each, the arrangement of categories is provided as follows:

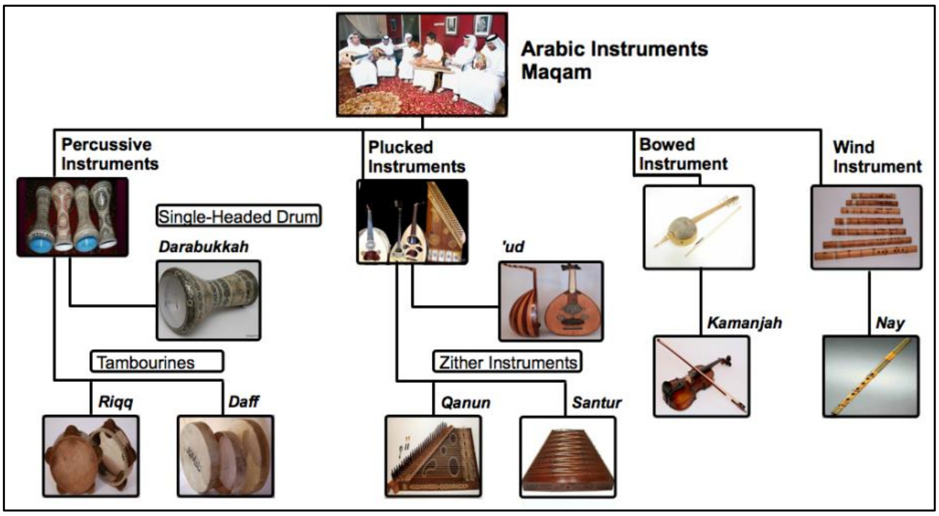

Figure A3.3. Classification system of Arabic Maqam

Percussion instruments:

Riqq:

The riqq is a heavy tambourine commonly found with brass cymbals affixed to the side of the instrument and with a head usually made of thin and stretched fish skin (or sometimes goat skin) glued to the frame; Racy states that the instrument is known for producing a variety of timbral effects in order to establish metric modes or beat patterns (Racy, Making Music in the Arab World, 2003, p. 78). The diameter of the riqq is usually 20 cm and contains a wooden frame which is about 6 cm deep (Farraj & Shumays, 2019, p. 51). The side of the instrument contains five sets of small paired cymbals (about 5 cm in diameter) made of brass – each set affixed inside separate little square spaces (i.e. cymbal windows) cut out at five different sections on the frame (Farraj & Shumays, 2019, p. 52).

The riqq is held in the left hand with a firm grip by placing the thumb on the inside of the frame and allowing the remaining fingers to gently strike the rim of the frame, while the right hand is used to hit the tambourine at the centre or at the edge, either lightly or heavy (Touma, 1996, 2003, p. 132). The strokes appear as taps and known for producing complex acoustical effects in line with the membraphonic skin and the idiophonic vibrations of the small cymbals – the riqq is commonly associated with art music (tarab) and often found with darabukkah accompaniment (Racy, Making Music in the Arab World, 2003, p. 78). The exact origin and emergence in Arabic music appears unknown.

Daff:

The daff appears to be of very ancient origin and quite possibly the oldest instrument found in the Arab world; Farraj & Shumays states that ancient Egyptian paintings of unknown age have depicted musicians playing frame drums (Farraj & Shumays, 2019, p. 49). The lack of documented history makes it difficult to date the first appearance of this instrument accurately. However, quite likely some type of frame drums have been used as far back as in the jahiliyyah era and possibly emerged around the advent of Islam. According to Touma the instrument was originally reserved for women only, although later was commonly played by mukhannathun musicians (effeminate men) (Touma, 1996, 2003, p. 135).

The daff is a frame drum which usually comes with a dozen small circular strings attached to the inside of the frame with approximation to the skin. It is usually found with a diameter of 30 cm (the size might derive somewhat); thus, significantly larger, with a narrower yet deeper frame (7½ to 12½ cm) than that of the riqq. Most commonly, the skin on the daff is made of goat, calf, deer, or synthetic skin and usually comes with a round hole in the middle of the frame's width (Farraj & Shumays, 2019, p. 50). It is common to shake the instrument in order to produce buzzing, tremolo types of effects which are mainly affected by the vibrations produced by the resonating strings attached to it; sometimes musicians strike the raff against their body (Touma, 1996, 2003, p. 135).

The daff may come with cymbals paired in five affixed places on the frame similar to that of the riqq; however, in that particular case the instrument is more commonly known as (Egyptian) Mazhar while played similarly to the riqq (Farraj & Shumays, 2019, p. 51). Possible tuning possibilities or techniques for riqq and daff mainly depends on the age/vintage of the drum; elder drums would require heating possibilities when tuning the skin, although newer drums (with synthetic skins) tends to come with tuning screws which enables easy adjustment by using a tuning key.

Darabukkah:
As previously addressed, Farmer suggests that darabukkah appears to have emerged in the era of the Crusaders (approximately 11th century); however, lack of information makes it difficult to decipher whether the instrument was already an established part of traditional Arabic music, either before or brought to the music culture by Persians. The name darabukkah (or tabla) is also known under various other names or through slight spelling variations largely dependent on the region in question; it is either known as tabla (tablah or tableh) or slight variations on the pronunciation of the word darabukkah (i.e. darbuka, tarabuka, doumbec, dumbelec etc.). Darabukkah is a single-headed drum in the shape of a goblet or chalice (with the skin covering the top part). Touma explains that the body used to be made of clay long ago although more recently it is made of brass or metal. The instrument comes with tension rings found on the top of the drum and on the edges (where the skin is attached on the drum), these works as tightening devices that allows the musician to regulate and fix the tension of the membrane; the instrument is either played while standing or seated - in the former case, it is held under the musician's arm, while in

the latter case the drum is resting in the performers thigh (Touma, 1996, 2003, p. 136).

The membrane is struck with both hands while striking the instrument near the rim where it mainly produces the drumbeats. The head is usually made of sheep or goat skin (might also come with fish skin although this is usually assigned for professional musicians only); the instrument is commonly found in art music and folk music (Touma, 1996, 2003, p. 136). The instrument is known for producing loud and high-strung sounds although Racy does not specify whether this feature is attributed to an instrument known as tabl baladi, the tabla (durabukkah) or both; however, since both comprises a small surface of high-pitched skin it can be assumed that his argument applies to both instruments (Racy, Making Music in the Arab World, 2003, p. 78). The darabukkah is usually played while standing, either squeezed under the armpit or by a belt which is attached to the instrument and wrapped around the player's neck (Farraj & Shumays, 2019, p. 55).

Plucked instruments:

'ud:

Probably the most characteristic and most important instrument (often referred to as the "Sultan of Musical Instruments") of Arab music. As previously mentioned, Farmer claims that the instrument possibly dates back to the Jahilliyyah era, and has been in existence since the turn of the 6th century (Farmer, 1930/2015, p. 52). Further, he addresses that the musician al-Hijaz claims that the instrument is either of Iraqi or Persian origin (Farmer, 1930/2015, p. 236). The instrument is commonly found in Turkey, Greece, and Iran – although these nations possesses their own blend of technical specialities, different ornamentation techniques, and variations of 'ud which reproduces specific timbre unique to each of these regions (Farraj & Shumays, 2019, p. 16). Further, the 'ud has managed to retain its popularity since the early beginnings of Arabic music.

'ud is a fretless plucked short-necked lute instrument with a pear-shaped body, the instrument is recognized for producing a sweet and tender sound which by some individuals has been comparable to the sound of a nightingale (Touma, 1996, 2003, pp. 109-110). Farraj & Shumays describes the sound of the 'ud to represent a mellow and warm timbre due to the lack of frets on the instrument (Farraj & Shumays, 2019,

p. 17). Racy also adds that the ‘ud is praised for its affective sound qualities which occupies a relatively low register, thus the sonic characteristics revolves around a sonic definition rather than as a function of harmonic specialization (Racy, Making Music in the Arab World, 2003, p. 77).

Throughout the course of history, from its initial emergence in Arabic music up until modern times, the ‘ud has gone through a number of different changes before finally attaining its current shape and features. Although, Farmer does not refer to the instrument as ‘ud in ancient times, he addresses that a stringed short-necked lute instrument (comprising a bamm and asir string) existed at the time of the Arab conquest in Iran (approximately mid 7th century); however, by the time of Barbad (of Persian origin, d. approximately 718 A.D.) the same instrument apparently came with four strings - bamm and sir (the highest and lowest tuned strings), mathlath and mathna (second and third strings) (Farmer, 1930/2015, pp. 240-241). It is worth mentioning that Farmer does not use the word ‘ud, although the amount of strings and the string names appears to be strongly associated with ‘ud, thus it is very likely that he is discussing this particular instrument.

Farmer states that an accordatura for a four stringed lute instrument designed to reach the octave existed in the 8th century, which proposed a tuning for the instrument thus C-D-G-a (Farmer, 1930/2015, p. 241). However, according to Farmer, a new accordatura of fourths was presented shortly after and supposedly lasting for approximately 700 years (between the era of Ishaq al-Mawsili (d. 850 A.D.) and Ibn Ghaibi (d. 1435)), providing a A-D-G-c tuning of the instrument – as a result the instrument was changed and modified to provide a double octave mainly by adding a fifth string (hadd) in the 9th century, although the tuning of “fourths” remained intact (Farmer, 1930/2015, p. 241).

Touma suggests that there were two types of ‘ud commonly found up until the 15th century; namely 1) ‘ud qadim, comprising four strings tuned to fourths (by Touma referred to as old category) and identified with four body humors and four temperaments, and 2) ‘ud kamil with five strings (also known as the complete ‘ud) (Touma, 1996, 2003, p. 111). A student of al-Mawsili, the Arabic composer, singer, ‘ud player and teacher Abu l-Hasan ‘Ali Ibn Nafi’ (ca. 789- ca. 857) (also known as Ziryab) separated the strings by colouring them thus: highest string yellow (bile), second highest red (blood), the third white (phlegm), and the lowest black (black bile), he described the last string (placed between mathna and mathlath) to symbolize the soul (Ziryab is also credited for introducing a soft featherlike type plectrum commonly used today despite most modern day plectrum are made of plastic); ‘ud would reach its zenith as an instrument as late as the 16th century (Touma, 1996, 2003, p. 111). The range of the five stringed ‘ud comprises two octaves and Maalouf credits this invention to al-Din (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 205).

Touma’s statement about the existence of two types of ‘ud appears to be in accordance with Farmer, however the proposed timeline appears somewhat less clear between the two. Both authors accept that these variants were part of Arabic music by the 15th century, although none of them provide clear information about the emergence of either variant in Arabic music. If we take into account Maalouf’s suggestion, the five-stringed version of the ‘ud quite probably emerged sometime in the 13th century, while the four-stringed version likely appeared somewhere between the 7th and the 15th century.

The standardized ‘ud of today contains five strings, the three highest are made of gut or nylon, while the lowest are made of silk wound with copper wire and comprises the following tonal range: G, A, d, g, c’; the ‘ud can also be found with six strings although this variant is not particularly common (Touma, 1996, 2003, pp. 111-112). Farraj & Shumays suggests that the six stringed ‘ud became known during the 20th century and tuned as follows: C2, F2, A2, D3, G3, and C4 (despite that the following tuning is popular in Egypt; F2, A2, D3, G3, F4). In addition, a seven stringed ‘ud also exist, this variant was first mentioned by Mikha’il Mishaqa in the 19th century, according to Maalouf it covers a range of two octaves and tuned thus; “… [the] first pair of strings is tuned to Qarar al-Jaharkah (f) or to Yakah (g), the second pair to Rast (c^1), the third one to awa (g^1), the fourth one to Dukah (d^1), the fifth one to ‘Ushayran (a), the sixth one to Busalik (e^1), and the seventh one to Nahaft (b^1)” (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 204).

It should be noted that ‘ud definitely is the most widespread Arabic instrument found in Western music culture; Touma claims that it first arrived in Europe (in particular the Iberian peninsula) and Byzantine (in the East) during the Middle Ages (Touma, 1996, 2003, p. 111).

Qanun:

The origin of qanun is difficult to trace and in accordance with other scholars, Touma suggests that it is of ancient origin and possibly was a part of Arabic music as far back as the 10^{th} century (Touma, 1996, 2003, p. 123). It is a left side trapezoid shaped plucked zither known for producing distinctive timbres which are mainly generated by the bridge which rest on five thin rectangular pieces of stretched fish skin; further, the hand orientation plays a significant part on sound reproduction, the right hand usually cover the treble register of the instrument while the left hand echoes the melody on the bass register an octave lower (Racy, Making Music in the Arab World, 2003, p. 77). The trapezoidal box in which the qanun is embedded has a wooden surface that almost covers the body of the instrument in its entirety. (Touma, 1996, 2003, p. 121).

The amount of strings on qanun usually varies between sixty-three and eighty-four strings which are all diatonically tuned. Touma claims that the instrument contained forty-five strings back in ancient times, although he does not propose any specific timeline for this alleged occurrence (Touma, 1996, 2003, p. 123). Different to Touma, Farraj & Shumays suggests that the qanun contained more strings in ancient times in comparison to the current-day situation, with a selection of approximately 78 to 81 strings (Farraj & Shumays, 2019, p. 19.). In modern times the instrument is most commonly found with seventy-two strings made of either gut or nylon which are stretched across the top of the instrument and grouped together, while each set of three strings tuned to the same pitch; thus a sound reproduction of twenty-four different tones appears and usually in the range from F1-c” (Touma, 1996, 2003, p. 121). The instrument is placed horizontally in the performers lap with the oblique side to his/her left (Touma, 1996, 2003, p. 122). The strings on the qanun are plucked using two horn plectrums, one held against the index finger on each hand through resistance from a metal ring (Racy, Making Music in the Arab World, 2003, p. 77).

An additional variant of the qanun can be found in Egypt which comprises seventy-eight strings with the capability to reproduce twenty-six different tones (Touma, 1996, 2003, p. 121). The tuning pegs on the instruments are located on the oblique side and arranged in groups of three; close to these pegs we find 156 attachable and detachable metal bridges which can be placed below the strings to alter their length and eventually affect the tuning (six metal bridges available for each set of twenty-six sets of strings), which Touma describes as "… a syncopated, heterophonic two-voice composition in parallel octaves" (Touma, 1996, 2003, pp. 121-122). Like the ‘ud, the qanun mainly manifests itself as a solo instrument commonly used in taqsim pieces and accompany layali singing (Touma, 1996, 2003, p. 123). Racy adds that the instrument is regarded as ideal for tarab vocal music and is the preferred instrument for accompanying singers while improvising their parts (Racy, Making Music in the Arab World, 2003, p. 77).

Santur:

Santur appears to be an old instrument which Touma believes can be traced back to Persian, Turkey and Iraqi origins, although the name derives from the ancient Greek psalterion instrument (Touma, 1996, 2003, p. 125). Whether the santur is a modification of a mi’zafah (the first documentation of a zither instrument found in Arabic ensembles and dates back to the early Abbasid period), or a completely different instrument emerging centuries later, can only be left for speculation.

There are a variety of regional variations of the santur to be found all over the Arab world, however, two versions of the santur are particularly common: 1) the Persian santur, and the 2) Iraqi santur. In principle their apparent physical appearances are obvious on this occasion and evident through the trapezoidal shaped box zithers where both left and right side are contained within a walnut body, although this is as far as any similarities go between the instruments for the most part (Touma, 1996, 2003, p. 125).

The Persian version comprises seventy-two strings with groups of four strings tuned to the same pitch, thus reproducing a total of eighteen different tones despite that the instrument contains an additional two rows of bridges (Touma, 1996, 2003, p. 125). Different to the Persian variant, the Iraqi version is struck with two wooden mallets and contains a total of ninety-two metal strings grouped separated into a group of four (which are tuned to the same pitch) (Touma, 1996, 2003, p. 125). The tuning covers the range from low G (Arabic name: yakah) up to a" (jawab jawab husayni), where sound reproduction comprises twenty-three different tones and comes with three rows of bridges parallel to the oblique side of the instrument and twelve bridges which are meant to "…divide alternate sets of strings so that exactly one-third of their vibrating length is to the left of the player, and two-thirds is to the right" (Touma, 1996, 2003, p. 125).

The santur features a playing side divided between left and right which provides a parallel octave function similar to that of the qanun; thus both playing sides are played frequently, with the right side (of the bridge) playing an octave lower than the left (oscillation ratio 2:1) (Touma, 1996, 2003, p. 125). Further, close to the right side of the instrument eleven to fourteen bridges are arranged in groups of seven, eight, nine, or ten, and four – these bridges are located beneath the remaining sets of strings (Touma, 1996, 2003, p. 125). Touma explains that the "…four remaining bridges partition off the distance between the right edge of the instrument and the row of twelve bridges"; yet, one-third of this distance is to the right of the bridge and two-thirds to the left, and yet again, the strings may only be struck to the left of the bridge" (Touma, 1996, 2003, pp. 125-126).

All of the metal strings on the santur retains the same measurement thus the pitch entirely depends on the tension of each string - the bridges looks like pawns and the strings do not rest straight onto the bridges but rather on a nail placed across the upper part of the bridge which aids in the reproduction of a clean metallic sound of the instrument; according to Touma, taqasim and maqam al-'iraqi are the most common repertoire for this instrument (Touma, 1996, 2003, p. 127). Apparently, in this Music Study, Touma appears to be the sole scholar who claims that this instrument holds any significant importance within Arabic music by providing sufficient information for both the Iraqi and Persian santur; despite that none of these appear to be favoured within this Music Study, thus both are equally weighted.

Bowed instruments:

European Violin:

European violin (despite wrongfully known as kamanjah within certain parts of the Arab World): The most common bowed string instrument found in Arabic music today is an adoption of current-day European violin which has been customized for the Arabic tuning system. Prior to its adaption into Arabic music in the 19th century, the name for a similar inherent Arabic instrument called kamanjah (possibly dating back to 17th century) has been erroneously applied to this European adaption of the violin. Interestingly, some scholars attribute the proper precursor of the violin to the ancient rabab, which appears to have reproduced similar tones by using similar playing/bowing techniques (Touma, 1996, 2003, p. 117).

Racy suggests that violin holds a significant stature in Arabic music due to its ability to express emotions similarly to the human voice - the bowing enables reproduction of long notes and largely due to the fretless neck has made it easily adaptable to produce tonal nuances with great agility (Racy, Making Music in the Arab World, 2003, p. 77). The playing technique is quite similar to that of the Western approach, although its approaches towards bowing and ornamentation have been developed in order to accommodate Arabic music and tuning (Farraj & Shumays, 2019, p. 26).

However, the Arabic violin does not apply European tuning; Touma claims that the strings relates to an Arabic concept based on the tones yakah (G3), dukah (D4), nawa (G4), and kurdan (C5) (Touma, 1996, 2003, p. 116). Farraj & Shumays, on the other hand, proposes the following tuning: G3, D4, G4, D5, and based on alternating fifths with a fourth (Farraj & Shumays, 2019, p. 26). Touma explains that the appearance of the body of the Arabic violin is also different to that of the European version and comprises "…half a coconut shell covered with the skin of a sheep or a fish" (Touma, 1996, 2003, p. 117). It should be noted that both Touma and Farraj & Shumays appears to propose very similar tuning for the violin, in essence the tones seem to correspond particularly well until the highest string which showcase a deviation of roughly 100 semitones occurs.

Wind instruments:

Nay:

The exact origin and history of nay in Arabic music appears to be unknown although Farraj & Shumays suggests that it derives from the Persian reed instrument called ney and possibly existed in or around the Middle-East area for the past 1000 years or so (Farraj & Shumays, 2019, p. 22). It should be noted that the earliest sources proposes completely different names for the flute; thus, we cannot conclude with any exact time period for the emergence and when the nay eventually became part of traditional Arabic music (Farraj & Shumays, 2019, p. 22). Similar variants of this flute can also be found with slightly different spellings in nearby cultures of the Arabic peninsula, such as Romania (nai), and Turkey (ney).

The nay is an open-ended reed flute, usually made either of bamboo, cane (elder nays are regularly oiled to prevent cracking) or plastic (modern versions); commonly it contains one hole beneath the underside of the performer and another six on the frontside (Touma, 1996, 2003, p. 129). The instrument allows for an overall range of three octaves which can be renderer comprehendible only to the most experienced and technically skilled nay players (Touma, 1996, 2003, p. 129). Performers commonly tends to use both large and small nays during a concert performance while holding the flute in an oblique position and blows against the edge of the pipe-opening (Touma, 1996, 2003, pp. 128-129).

The fundamental tones of the nay are affected by the length of the pipe. On this occasion, the longest nays are capable of reproducing all necessary tones of a maqam row on one sole instrument. However, as indicated above, it requires extensive hours of practice and finesse in order to master the instrument to its full extent and this particularly applies to rendering the precise lip and head positions essential to achieve ideal blowing technique in order to reproduce the tones accurately. In addition, finger techniques also plays a major part and achieved either by entirely closing the playing holes, or through half-holing (a term used by Farraj & Shumays) which indicates that the playing holes are partially closed when played (Farraj & Shumays, 2019, p. 23). The instrument has nine joints and a blowing technique which requires both lips to be in physical contact with and partially closes the end of the bevelled tube opening (Farraj & Shumays, 2019, p. 23). The nay is most commonly associated with intense tarab settings (or situations) and a highly regarded instrument in spiritual contexts such as Sufi rituals.

The nay appears in a variety of sizes, although the most common types are 1) large nay (dukah nay – also known as a D4 nay) with d as the second lowest tone, and 2) small nay (nawa nay – also known as G4 nay) with g as the second lowest tone (Racy, Making Music in the Arab World, 2003, p. 77). Sometimes, as many as seven nays (in a different lengths and pitches) may be required for certain performances by the same performer and played in accordance to the pitch of the respective composition performed. Further, nay is characterized for its breathy or reedy timbre, qualities which are ideal for recreating thrilling and ornamenting styles; Racy describes that its register for the most part is "…an octave above the treble register" (Racy, Making Music in the Arab World, 2003, p. 77).

Tuning

"Actual pitches can deviate from notated pitches by as much as a fourth in either direction. The extent of this deviation depends upon the vocal range of the singer, to which the instrument is also tuned … the interval sizes within the Arabian scale have not yet been comprehensively investigated by means of electronic measuring instruments" – Habib Hassan Touma

In order to establish a comprehensive overview which encompasses several aspects in relation to how past and current Arabic tuning systems have been operated through history, the necessity of thorough exploration/examination of various propositions of Arabic tuning has been required. In order to verify the significance of this information, thorough exploration of the most significant extant documentation of ancient musical history was necessary during this process and enabled a significant comparison to findings of more recent and/if not popular conception expected of what can be constituted as an authentic Arabic tuning system.

Apparent through examining past history in the Arab World, some of the most essential and important inventions in terms of human evolution in general; documentation on music and its eventual progression through its earliest incarnations of pre-Islamic times and up until medieval times appears rather scant based on information presented by several scholars. However, the most recurring problem is that longer periods of times (i.e. duration of 200-300 years or more) without the addition of any new written information apparent, thus the introduction of new propositions of tuning systems which has been completely removed from previous conceptions.

Farmer claims that the earliest mentioning of conceptual ideas in regards to tuning or scale in Arabic music appears to be found in Ramayana, which comprises a collection of Sanskrit epics from ancient-India and dating approximately 400 B.C. –

200 A.D. during a stage in history when Persia seemingly had established a seven mode system (Farmer, 1930/2015, p. 60). Farmer suggests that the establishment of a fundamental seven-tone system originated from the Sanskrit (i.e. ancient Indian writings) and ancient Greek, while the order of notes was borrowed from Indian music and has been part of Arabic music since pre-Christian times (Farmer, 1930/2015, p. 75).

Other sources on Arab music agrees that the seven-tone fundamental scale was part of ancient Arabic music, although Touma suggests that the earliest writings dated approximately 6th century supposedly comprised at least one millennium of Arab musical history, despite this, scant information about musical instruments and music appears to have existed prior to the sixth century A.D. (Touma, 1996, 2003, p. 1).

According to Farmer, by the 6th and 7th century (in the period of Khusrau Parwiz (590-628 A.D.) the seven mode system had evolved into a twelve mode system, although this applied to Persia at first; Syrian philosopher, historian and theologian Bar Hebraeus (1226-1286) suggested that the Arabs used their own national modes before adopting the Persian modes at a later yet unspecified time period (Farmer, 1930/2015, p. 60). Farmer continues by stating that outside musical influences would leave a large imprint on Arabic music during the era of the Rashidun Caliphate (632-661), in addition to strong influences from Byzantine and Sasanid (early Neo-Persian Empire) which swept over the Arabic World at the dawn of the Islamic establishment during a time when the Persian system supposedly had reached a far more advanced level than that of the Arabic (Farmer, 1930/2015, pp. 19, 54). As pointed out previously in this Music Study, written treatises about Arabic music up until and including the 8th century no longer exist, thus we need to rely on information from newer sources in order to establish some kind of perspective on how musical theory and practices were executed in ancient Arabic music.

Al-Farabi's 25-tone tuning system from 10th century

Touma concurs with Farmer's assessment regarding Byzantine and Persian influences in Arabic music, however, he specifically emphasise the epoch between the 9th to 13th century as more significant by which these influences became a major part of Arabic music; this period witnessed a new set of challenges which questioned the identity of old Arabic music and appeared to be the first phase of opposing ideas since the emergence of Islam (Touma, 1996, 2003, p. 17). Among the most apparent changes on this occasion dealt with compositional structure, such as approaches to define beginnings of, and the settlement of second or third tones for compositions. Besides the fundamental scales described above, no fully conceptualized tuning system appears to be known prior to the twenty-five-tone tuning system proposed by philosopher, mathematician and musician Abu Nasr al-Farabi (ca. 872-950/951).

Al-Farabi's proposition

Touma states the following about al-Farabi's proposition: "… the octave, which comprises two tetrachords and a whole tone, contained twenty-five different tones, from which al-Fârâbî extracted the following intervals: octave, fifth, fourth, seventh, whole-tone, half-tone, and quarter-tone" (Touma, 1996, 2003, p. 19). The following table display ten possible intervals extracted from the division of the tetrachord:

Fraction	1/1	256/243	18/17	162/149	54/49	9/8	32/27	81/68	27/22	81/64	4/3
	c					d				e	f
Cents	0	90	98	145	168	204	294	303	355	408	498

Table A3.1. Displays the first tetrachord of al-Farabi's 25-tone tuning system – tetrachord + tetrachord + whole tone = 1200 cents (Touma, 1996, 2003, p. 19)

For melodic structure, al-Farabi only used a combination of seven tones which Touma describes as a heptatonic scale and the first tetrachord also appears identical to the modern rast row (Touma, 1996, 2003, p. 21). The following table displays this seven-tone heptatonic scale:

Tone	oscillation ratio	relative cents	cumulative cents
c	1/1	0	0
d	9/8	204	204
e	27/22	151	355
f	4/3	143	498
g	3/2	204	702
a	18/11	151	853
b	19/9	143	996
c	2/1	204	1200

Table A3.2. Arabic seven-tone heptatonic scale (Touma, 1996, 2003, p. 21)

Although, the current-day 'ud is known as a fretless instrument, Touma claims that it contained frets in the 10th century and on this occasion al-Farabi identified pitches accordingly by naming the finger used to stop a particular tone on the neck of the lute, thus; "index finger fret" to stop the first tone, the "middle finger fret", or "Zalzalian middle finger fret" for the next, each of these moves would suggest either a half- or a whole-tone step (Touma, 1996, 2003, pp. 8, 10). It should be noted that no specific period has been provided in regards to signify the disbandment of the fret system of the instrument nor its eventual reintroduction, despite that the instrument has not been commonly found with frets for the past 200 years.

Further, by taking into consideration al-Farabi's appreciation (or acceptance of) and approval of the ancient Greek tuning system, it appears to be justifiable to suggest that the fret system was adapted accordingly to fit with Pythagorean tuning principles/ideals. It is important to address that the acceptance and appreciation of Greek ideals in medieval times have been supported by other scholars as well.

The abandonment of the fret system (on the 'ud) may have been introduced at a later point in history and emerged as a consequence of and necessity of physical adjustments in order to make the instrument accustomed to an entirely different conception of tuning in Arabic music. Thus not unlikely that this was initiated by either Safi al-Din's (d. 1294) through his proposition of a 17 tones per octave system in the 13th century, or even later when the 24 tone tuning system (a compromise to fit with then current Western ideologies and notations in order to influence a modern Arabic tuning system) supposedly emerged at the beginning of the modern era (1798), although this assessment can only be left for speculation.

Interestingly, al-Farabi's proposition of a tuning system contains only one more tone within the octave in comparison to the 24 tone system of today despite that this phenomenon emerged approximately 800 years later, yet a fretless variant of the 'ud is known to be the standardized version found in current Arabic music. Marcus also agrees that the pre-modern era is a very significant period upon which important fundamental ideas were establishing in Arabic tuning system, however, his estimated timeline is slightly different than Touma's, namely dating from the 8th to 13th century rather than from the 7th to 13th century.

Apparently, a number of aspects related to music theory were established in Arabic music during medieval times which includes accompanying rhythmic patterns, texts, metric feet, and contemporary composers were rightfully credited for their work; although sufficient information concerning melodic approaches, tones and measurement of pitches was still thoroughly neglected (Touma, 1996, 2003, pp. 8-9). According to Farmer, the 10th century Arabic music comprised eight modes each named after fingers and were mentioned in *"Kitab al-Aghani"*, a musical treatise written by Persian historian Abu al-Faraj al-Isfahani (Farmer, 1930/2015, p. 60). It should be noted that little appears to be known about al-Farabi's tuning system today. Among others, Touma does not agree that Arabic music had developed a fully categorized tuning system at this point, besides Marcus who states that the intervals were based on "… non-Pythagorean frequency ratios", no other scholar in this Music Study appears to provide any further information about al-Farabi's proposition of a tuning system (Marcus, Arab Music Theory in the modern period, 1989, p. 179).

Al-Din's 17-tone tuning system from the 13th century

The next significant epoch occurred in the 13th century and strongly initiated by musician and theorist (quite possibly of Persian origin) Safi al-Din al-Urmawi (and commonly referred to as al-Din) (d. 1294 A.D.). Al-Din appears to be the first person to propose a fully categorised system for the Arabic music scale and evidenced in his treatise *"Kitab al-adwar"* (translated to Book of Modes) which showcase a tone system based on seventeen tones per octave comprising limmas and commas. Touma states that the tones were appointed according to the letters of the Arabic alphabet such as A, B, J, D, H, Ü, Z, H (dot above letter), T (dot above letter), Î, etc.; in addition the rhythmic accompaniment was described as a system of beats within a recurring rhythmic period (Touma, 1996, 2003, p. 10).

Maalouf agrees that al-Din contributions to Arabic music is important and adds that the essential principles of the theoretical writings and the musical system of al-Din has been the basis for further developments during the following centuries (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 19). Although it seems apparent that the Arabs already established a fully categorized tuning system in the era of al-Din, the consecutive centuries would witness a number of changes to these principles and concepts. Whether these specifications in any way resembles those written about Arabic music between the 6th and 11th century still appears unknown.

It should be noted that neither Touma nor Maalouf describes the significance of intonation in Arab music to any great extent and detail, however it appears to be recognized as one of the most important aspects of Arabic music since ancient times. Marcus suggests that a number of musical treatises comprised intonation between the 8th and 13th century, similarly he emphasizes al-Din's (d. 1294) importance during this epoch and attributes his role as "the chief model for subsequent generations" (Marcus, Arab Music Theory in the modern period, 1989, p. 161).

In addition, the principle of a two-octave range appears to have been adopted by Arab theorists at some point during medieval times and is still commonly accepted (in some cases) in modern Arab music theory. Interestingly, the idea appears to derive from the belief that this is the natural range of the human voice in addition to the optimum range on a number of traditional Arabic instruments (such as the 'ud and the nay); Marcus suggests that the two-octave practice is considered to be a continuation of ancient Greek music theory (Marcus, Arab Music Theory in the modern period, 1989, pp. 106-107).

Al-Din's proposition

It is important to address that Safi al-Din's tuning system is different than the 24 tones per octave system currently associated with Arabic music today. As an apparent advocate of the Pythagorean school of ancient Greek music theory, al-Din's concept was based on a seventeen-tone system per octave principle. Al-Din then systemized the tuning into the following principles: the octave comprised two conjunct tetrachords in addition to one whole tone while recognizing five whole-steps per octave the octave, each divided thus - two limmas (90.2 cents) and one comma (23.5 cents) (i.e. limma + limma + comma) all of which concerned fifteen out of the seventeen notes while two undivided limma-sized half step intervals each between B-c and e-f (Marcus, Arab Music Theory in the modern period, 1989, p. 161). An illustration is shown below:

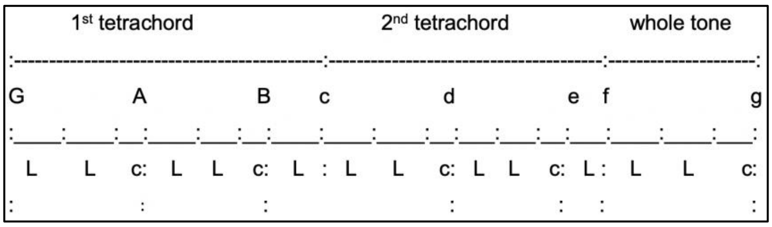

Table A3.3. Displays the al-Din's 17-tone tuning system – including limmas and commas (Marcus, Arab Music Theory in the modern period, 1989, p. 161)

Based on these findings, it appears that the concept of tuning and measurement of intervals changed quite drastically within the timespan of only a few centuries. Marcus addresses that the tuning system originally proposed by al-Farabi's within approximately 200 years would be replaced by a 17-tone system proposed by Safi al-Din (13th century). This conception would be embraced by future scholars in the consecutive centuries, however whether entirely new features and original modifications would be carried over from al-Din's tuning system or whether the contemporary 24 tone system actually appears to be a modification of and derives from either tuning system appears unclear; the main reason for these speculations mainly arise due to very scant information provided about the progress of Arabic music between the time of al-Din's death and up until the 18th century. Traditional Arabic music appears to have gradually deteriorated in the next few centuries until the second half of the 18th century, at which stage when Arabs had become generally dismissive of it. Apparently, it would remain neglected until the beginning of the modern era, a period defined by some scholars to be the start of the aforementioned Three Schools of Arabic music (discussed earlier in this Music Study).

Interestingly, in the intervening period between the 13th century and the 18th century influences from other nearby musical cultures were perceived more favourably and eventually formed strong ties to Turkish and Persian music which would be absorbed and provide Arabic music with a new identity. Marcus suggests that the renewed interest in Arabic music possibly would be initiated through 19th century Turkish music (Marcus, Arab Music Theory in the modern period, 1989, p. 25). This is further confirmed by Walter Feldman who claims that the Turkish author Dimitrie Cantemir wrote a treatise in 1700 which already included the notes "Yegah," "Asiran," and "Irak"; in addition, a sixteenth-century treatise suggests that the scale begins at a fourth below the "first" note which also supports suggestions by other sources on Arabic music (Marcus, Arab Music Theory in the modern period, 1989, p. 83).

The emergence of 24-tone tuning system

The French music composer and theorist Jean-Benjamin de Laborde (1734-1794), appears to be the first source to provide a twenty-four quarter tones per octave tuning system (across the range of one octave). This is documented in his treatise called *"Essai sur la Musique ancienne et modern"* (1780), in addition he also re-conceptualized the seven fundamental notes (including an eight note as the first octave) originally derived from ancient Arabic music and customized these in accordance with this his approach to tuning (Marcus, Arab Music Theory in the modern period, 1989, p. 13).

Laborde's categorization of notes was grouped into three categories 1) fundamental notes, and 2) "half" notes (s. `ansaf, pl. `arabat), and 3) a category of slightly/lower notes which did not coincide with the other two. In order to achieve this, he subdivided the fundamental note names by applying nim (pl. nimat), and tik (pl. tikat) designations in front of note names to signify lower and higher pitched notes (across one octave), respectively. Marcus suggests that the third category of notes appears ten in numbers (across one octave) and with a purpose to "… divide the remaining undivided half-step intervals in the octave scale" (Marcus, Arab Music Theory in the modern period, 1989, pp. 88, 68, 97).

Interestingly, Laborde's perception and understanding of Arabic music clearly exhibit some obvious traits which appears to have derived from European music, among others the conception to start from C to c. Despite no mathematical formulas in which to display the relation between intervals, it appears that his perception of music reflected current (although at the time emerging) conceptual trends in accordance with the Western twelve-tone equal-tempered scale (Marcus, Arab Music Theory in the modern period, 1989, p. 162). Prior to the modern era, the fundamental notes appeared with names of Persian origin (Marcus, Arab Music Theory in the modern period, 1989, p. 74).

However, conflicting opinions arises regarding Laborde's proposition and whether it actually referred to equally divided intervals (through the use of precise mathematical formulas and calculations = i.e. 50 cents apart) or whether he referred to roughly equally divided intervals. According to Marcus, the aforementioned report written by French military officer Francois Baron de Tott (1733-1793) also concur with the significance of Laborde's contributions, crediting him as the first individual to present a twenty-four tone system while also claiming that the conceptualization of intervals to be clearly inspired by the European twelve-tone equal-tempered scale (with a twenty-fifth interval at the octave) (Marcus, Arab Music Theory in the modern period, 1989, pp. 162-163).

However, one major concern arises when closely examining the report; Marcus states that it is difficult to know whether the idea of equally divided intervals was concluded by Laborde or stemmed from de Tott himself, apparently Laborde never specified any exact intervallic values nor pitches although he stated the following: “By comparing [the rab method of dividing the scale] with the division by equal semi-tones, we find there is a clear correspondence. One sees that they divide in quarter that which the Europeans divide in two …” (Marcus, Arab Music Theory in the modern period, 1989, pp. 162-163). Thus, we are not entirely sure about whom to attribute the idea of an equally tempered Arabic scale. Interestingly, de Tott never heard Arabic music prior to writing the report, due to de Tott’s death in 1793 we can definitely conclude that the idea definitely originated back to at least the end of the 18th century,

Arabic versus European scholars about the phenomenon of Arabic tuning and disagreements about its current conception

When examining written works published in and around this era (i.e. the late 1700s and 1800s) some obvious differences between then current contemporary European and Arabic scholars seems apparent; whereas an obvious infatuation with the European equal-tempered scale among many European scholars - the following years also revealed a number of emerging Arabic scholars to gradually show reservations to this approach of tuning.

Despite that the 24-tone tuning system is commonly used by the vast majority of Arabic musicians, arguments are still divided regarding the execution of the intervals. Marcus states that two variants of the 24 quarter-tone scales systems are currently used; one based on intervals equally divided exactly 50 cent apart, while the other is based on intervals divided roughly equal (Marcus suggests that this is considered the oldest) (Marcus, Arab Music Theory in the modern period, 1989, p. 101). Further, Marcus suggests that in the beginning when the quarter-tone system was initially introduced and integrated into Arabic music, the intervals between C-D, F-G, and G-A were described as comprising four quarter steps, while the other intervals from the fundamental scale to contain only three quarter steps (Marcus, Arab Music Theory in the modern period, 1989, p. 12). Based on this, scholars seems to have theorized that the Arabic scale altogether contained 24 intervals per octave (Marcus, Arab Music Theory in the modern period, 1989, p. 12).

In addition to Laborde, Farmer claims that one of the first advocates of Arab influence on theory of music was the French musicologist Guillaume André Villoteau (1759-1839), he believed that Arabic music had been influenced by and adapted the music theory of ancient writings done around the first millennium of modern era by the Italian music theorist Guido of Arezzo (d. approximately 1050 A.D.) and suggested that Arab theory arose out of the Greek system (Farmer, 1930/2015, p. 267).

Modern and medieval tetrachordal theories is often grouped under similar terms, although the former happens to be perceived as a continuation of the medieval tradition by a number of individuals. Marcus states that "… Villoteau found no evidence of contemporary conceptualization in terms of tetrachords: he did not record the existence of even a single term for discussing the phenomenon of tetrachords", during fieldwork conducted in Egypt between 1798-1801 (Marcus, Arab Music Theory in the modern period, 1989, p. 275).

Despite that Laborde appears to have introduced the 24-tone system in Arabic music, Syrian-based musician shaykh Muhammad al-`Attar (1764-1828) is considered the first Arab scholar to write about this particular subject. Among the most important contributions were supposedly documented in his treatise called *Rannat al-Awtar fi Jadawil al-Afkar fi Fann al-Musiqar (The Sound of Strings [arranged] in Rubrics to Bring to Mind What Concerns the Musician's Art) (c.1820).* Marcus claims that al-`Attar presented the Arabic/Persian note names over two octaves (Marcus, Arab Music Theory in the modern period, 1989, pp. 68, 163). Unfortunately, no complete specimen of al-`Attar's original manuscript appears to exist; thus, we need to rely on the work provided by his student Lebanese historian and Doctorate in Music Mikha'il Mashaqah (1800-1889).

A thorough musical treatise called *"al-Risalah al-Shihabiyyah fi al-Sina'ah al-Musiqiyyah"* (The Shihabi Treatise on the Musical Art) was written by Mishaqah, likely between 1829 and 1840 due to no exact published date has been provided (Marcus, Arab Music Theory in the Modern Period, 1989, pp. 44-45). His work seems to provide the first indigenous description of a 24-tone scale extant today, despite that almost all note names match those found in Laborde and al-`Attar's work, he is probably the first author to discuss the scale by referring to tones as rub`(pl. arba`), which literally means "quarter" in the Arabic language (Marcus, Arab Music Theory in the modern period, 1989, pp. 70, 164).

Mashaqah appears to have been a champion of Laborde and al-`Attar in the beginning, Touma suggests that he used the lute as a reference by illustrating the 24 frets on its neck by providing a geometric drawing, thus he divided the value of the intervals thus "…24√2 = 50 cents, where a cent is a logarithmic measurement equal to 1/100 of the semitone in the well-tempered scale" (Touma, 1996, 2003, p. 19). Different to Touma, Maalouf specifies that Mishaqa illustrated the tuning on an ‘ud that comprised seven pairs of strings across the range of two octaves and tuned as follows; the first set of strings tuned to Qarar al-Jaharkah (f) or Yakah (g), the second pair tuned to Rast (c^1), the third one to awa (g^1), the fourth one to Dukah (d^1), the fifth one to ‘Ushayran (a), the sixth one to Busalik (e^1), and the seventh to Nahaft (b^1) (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 204).

According to Marcus, one obvious aspect of Arabic tuning seemed integral to al-`Attar, `Abdullah Muhurdar (a friend of al-`Attar), and Mashaqah which dealt with the incorporation of the twenty-four quarter-tone intervals into musical practice/performance. Al-`Attar and Mashaqah managed to achieve this by referring to fret positions on the tanbur/tanbour which was an ancient long-necked lute instrument that no longer is commonly found in current Arabic music (Marcus, Arab Music Theory in the modern period, 1989, p. 164).

Mashaqah submitted four theories (the first method which was originally proposed by al-`Attar, while the other three by Mashaqah himself) where he demonstrated the exact fret positions on the strings of the tanbur - in combination with string lengths and equidistant frets which correlated with the 24 equally-tempered quarter tones. However, over time it appears that Mashaqah became aware of some animalities and realized that the string lengths and equidistant frets prevented the performer from playing equally tempered notes on the instrument. Thus it appears that Mashaqah rendered al-`Attar's original demonstration of twenty-four equal-tempered scale to be faulty, and stated that "… al-`Attar's scale was, by intention, a quarter tone scale in which the quarter tones were all of equal size, i.e., an equal tempered quarter-tone scale" (Marcus, Arab Music Theory in the modern period, 1989, pp. 163-164, 166). After addressing this issue, Mashaqah proposed another three methods; showcasing both geometric and arithmetic demonstration "… for arriving at the correct fret placements" (Marcus, Arab Music Theory in the modern period, 1989, p. 166). Interestingly, in a study published ca. 1840, while similar to Villoteau, he does not mention tetrachords (Marcus, Arab Music Theory in the modern period, 1989, p. 275).

As a result, Mashaqah determined that the octave contained 24 arba` (quarter tones) and came to the conclusion that the fundamental scale contained three large intervals of four arba` and four small intervals of three arba` (no mathematical theorem was provided to explain the exact placement of the intervals in the scale) (Marcus, Arab Music Theory in the modern period, 1989, pp. 164-166). Mashaqah stated the following "… the [distance between the frets of] the quarter tones diminishes according to a geometric progression and not as the shaykh [al-`Attar] has indicated…" (Marcus, Arab Music Theory in the modern period, 1989, pp. 164-166).

Marcus adds that Mashaqah described the seven fundamental notes as "a ladder" [sullam] where each step appeared above the other, although specified that the intervals were not to be equally spaced but grouped into two different categories, namely larger and smaller intervals; the "… larger is that in which the interval between two adjacent fundamental notes is four arba` [quarter steps]. The smaller is that in which the interval is three quarters. [1840] 1899:220)" (Marcus, Arab Music Theory in the modern period, 1989, p. 84). This approach appears to be accepted among a number of renowned authors/scholars in the twentieth century, such as al-Shawwa (1948), al-Hilu (1946), Fahmi (1965), and Farah (1974) (Marcus, Arab Music Theory in the modern period, 1989, pp. 85-86). Interestingly, on this occasion, some obvious deviations between the answers provided by Touma, Maalouf and Marcus. Neither (with the possible exception of Touma and Maalouf who might refer to the same instrument while not addressing it as such) suggests that Mashaqah used the same instrument in order to demonstrate tuning.

Based on the information provided thus far, scholars appear to concur with the principle of a seven-tone fundamental scale to have remained intact for many centuries and that the quarter-steps tuning system was already is use by the dawn of the modern era (1798). Marcus addresses that this process swept over the Arab world gradually over a period of time, where the earliest adopters of the equally tempered quarter tuning were Syrian-based scholars at some point during the 18th or early 19th century and later accepted in Egypt. The first was Shihab al-Din [1840] who indicated that Egyptians accepted a scale comprising three types of pitches comprising of fundamental notes, `arabat, and nimat/tikat; however, Shihab al-Din claimed that the nimat/tikat pitches were to be fourteen rather than ten although later Egyptian theorists accepted the divisions as originally expounded by Laborde, al-`Attar, and Mashaqah (Marcus, Arab Music Theory in the modern period, 1989, pp. 13, 70-71, 97, 171).

Among contemporary supporters of the Arabic equal-tempered tone system between 19th and 20th century was the archaeologist and linguistic Sebastien Ronzevalle 1865-1937, best known for introducing the twenty-fourth root of two mathematic formula into considerations to Arabic music theory (1899) (Marcus, Arab Music Theory in the modern period, 1989, p. 178). It appears that he was the first writer to describe the phenomenon of tetrachords although only briefly in discussions of Greek and medieval Arabic theory (for instance, a work published in 1904 by Egyptian musician Kamel al-Khula`i (1881-1931) did not mention tetrachords) (Marcus, Arab Music Theory in the modern period, 1989, p. 276).

Marcus states that "… Egyptians did not enter into discussions of exact pitch placement until the late-nineteenth and early-twentieth centuries.", this was triggered by four obvious reasons; 1) the presence of European music in Egypt (many wealthy homes contained pianos and taught in schools of Western military), 2) a monochord (also known as sonometer), a scientific measuring instrument which contained one string and used by Moustapha and al-Khula`i in their studies/work in 1887 and 1904, respectively, 3) a treatise written by the Egyptian Muhammad Dhakir Bey in 1895 (Marcus, Arab Music Theory in the modern period, 1989, p. 171). In this work Dhakir Bey made comparison between fourteen of the Arab notes (i.e. seven fundamental notes and seven 'arabat/ansaf notes) to Western equal-temperament half-tone scale (although previously carried out by Laborde, his work was only published in Paris), and 4) critical intonation studies by Ronzevalle were published in a journal in 1899, which were based on, "…1) Mashaqah's descriptions of al-`Attar's and his own theories for placing the frets in order to achieve equal-sized intervals; 2) Ronzevalle's discussion of the twelfth root of two; and 3) a table by Ronzevalle which contains frequency values, strong length figures, and solfege equivalents for each of the notes of the Arab quarter-tone scale …". (Marcus, Arab Music Theory in the modern period, 1989, pp. 171-172).

Yet, even to this day the opinions among Arabs are still mixed regarding the stature of equal-tempered tone system. The advocates of equal-temperament defends it for a number of reasons: they consider it 1) essential because it flows for free modal transposition, 2) easier to teach (thus considered essential for newly established music institutes), and 3) considered a borrowing from Western music at a time when many considered Western music to be superior to Arabic music (Marcus, Arab Music Theory in the modern period, 1989, p. 173).

Further, a number of supporters believed that Arabic music would steer towards use of harmony and polyphony textures thus regarded this as the next step for Arabic music (Marcus, Arab Music Theory in the modern period, 1989, p. 173). However, 19th century Levantine theorists perceived the situation differently compared to many Egyptian 20th century theorists. Marcus states the following: "The former seems to assume that equal temperament closely matched the reality of Arab music practice. The tempered quarter-tone scale was a new descriptive device that was already inherent to Arab music. The latter seems to accept that the indigenous system was not equal tempered" (Marcus, Arab Music Theory in the modern period, 1989, pp. 173-174).

Calculation of 24-tone near-equal temperament

Syrian scholar and professor Jan Pieter Nicolaas Land 1834-1897) published a series of Syrian texts and studies which was called *Anecdota Syriaca* between 1862 and 1875. His works were published some years prior to the substantial work *"The Sensation of tone"* by Alexander John Ellis/Heinrich von Helmholtz; Land proposed a table with analysis of the pitches (values in cents) on the tanbur, whom alongside composer Baron Rodolphe d'Erlanger (1872-1932) managed to summarize and analyze the Arabic twenty-four tone scale (Marcus, Arab Music Theory in the modern period, 1989, pp. 166-167). A table of this is displayed below.

Key for the following table:	
sol.:	solefege equivalents (not given by Mashaqah).
M. 's i.:	Mashaqah's intervals in terms of a string of 3456 parts.
M. 's f.p.:	Mashaqah's fret positions in terms of a string of 3456 parts.
c.v.i.:	cent value of the intervals between the pitches (provided by Land and D'Erlanger).
c.v.p.:	cent value of the pitches, given cumulatively with Yakah as the starting point

Table A3.4. Key for the following table (Marcus, Arab Music Theory in the modern period, 1989, p. 167)

sol.	Mashaqah's note names (modern names if diff.)	M. 's i	M. 's f.p.	c.v.i.	c.v.p.
sol	YAKAH		3456		0
		95	{ }	48.2	
	qarar nim Hisar		3361		48.2
		93	{ }	48.4	
	qarar Hisar		3268		96.6
		91	{ }	48.9	
	Qarar tik Hisar		3177		144.5
		89	{ }	49.2	
la	'USHAYRAN		3088		194.7
		87	{ }	49.5	
	qarar nim 'Ajam		3001		244.2
	(nim 'Ajam 'Ushayran)	85	{ }	49.8	
	qarar 'Ajam		2916		294
	('Ajam 'Ushayran)	83	{ }	50	
si (b-half flat)	'IRAQ		2833		344
		81	{ }	50	
	Kawasht		2752		394
		79	{ }	50.1	
	tik Kawasht		2673		444.1
		77	{ }	50.6	
do	RAST (RAST)		2596		494.7
		75	{ }	50.6	
	nim Zirkulah		2521		545.3
		73	{ }	50.8	
	Zirkulah		2448		596.1
		71	{ }	50.9	
	tik Zirkulah		2377		647
		69	{ }	51	
re	DUKAH		2308		698
		67	{ }	51	
	nim Kurdi (nim Kurd)		2241		749
		65	{ }	50.9	
	Kurdi (Kurd)		2176		799.9
		63	{ }	50.8	
mi (b-half flat)	SIKAH		2113		850.7
		61	{ }	50.7	
	busalik		2052		901.4
		59	{ }	50.5	
	tik Busalik		1993		951.9
		57	{ }	50.3	
fa	JAHARKAH		1936		1002.2
		55	{ }	49.9	
	nim Hijaz (or) 'Arba'		1881		1052.1
		53	{ }	49.5	
	Hijaz		1828		1101.6
		51	{ }	49	
	tik Hijaz		1777		1150.6
		49	{ }	48.4	
sol	NAWA		1728		1199

Table A3.5. Land and d'Erlanger's proposition for Arabic 24-tone tuning system (Marcus, Arab Music Theory in the modern period, 1989, p. 168)

As proposed in table A3.5., the pitches are roughly equally divided with a deviance of 2.8 cents between the smallest and largest intervals (48.2 – 51). Marcus states that the opponents of an equally-tempered scale, based this on one or a number of the following reasons; "… Pythagorean tuning, idiosynchronic theories based on commas, just intonation, non-Pythagorean frequency ratios proposed by medieval

Arab music theorists (al-Farabi, et al.), and empirical studies" (Marcus, Arab Music Theory in the modern period, 1989, pp. 178-179). Among the strongest opponents to equally-tempered scale was French scholar and professor in physics, Father Xavier Maurice Collangettes (1860-1943) who concluded that the 24-tone scale appeared to be the same scale as the one proposed by al-Din in the 13th century, except for the addition of a number of small intervals. Collangettes stated that "… medieval theorists had already calculated the correct intervals and pitch positions (their calculations based on Pythagorean intervals plus a few additional ratios to account for the half-flat intervals)", thus "… there was no need to establish a new basis—such as equal temperament—for determining the intonation of the intervals of the modern scale", this perception was later shared by Palestinian philosopher Ismail al-Faruqi (1921-1986) (Marcus, Arab Music Theory in the modern period, 1989, p. 179).

Touma addresses that a rebirth of Arabian consciousness swept over the Arab world in the 19th century and with musical centres divided into different parts of the Arab World such as Iraq, Syria, Egypt, the Arabian peninsula, and North Africa; and each represented through their own approaches towards singing, plucking techniques on lute instruments, structure of scales, rhythmic patterns of the accompaniments, structure of poems and content (Touma, 1996, 2003, p. 13).

In the past 100 years, one of the most prominent writers on Arabic music is the French musicologist named Baron Rodolphe d'Erlanger (1872-1932). His work *"La musique arabe"*, a series of books released after his death are quite possibly the most extensive work written about Arabic music up until that point. The fifth volume of the series (d'Erlanger 1949) dealt with different theories of the Arab tone system and covered a total of 120 modes which were divided into 16 different genres (Touma, 1996, 2003, p. 169). A transcribed taqsim (traditional instrumental improvisations) illustrates the text in each case, followed by an analysis based on the assumption that a mode can be understood as a chain of tetrachords, this theory is as old as Greek music theory (Touma, 1996, 2003, pp. 168-169). Touma states that the main concern about the findings is that "…it cannot explain why modes with the same tetrachordal structure sometimes have different names and are assigned to different genres in d'Erlanger's modal system" (Touma, 1996, 2003, p. 169).

In the sixth volume (d'Erlanger 1959) d'Erlanger dealt with rhythmic-temporal organization of Arabian music and individual musical genres; each of the 110 wazn patterns are analysed and explained; in addition examples of art music is transcribed, in addition to song text examination (Touma, 1996, 2003, p. 169). These two volumes manage to display a comprehensible foundation on modern Arabic music.

d'Erlanger adds that the common ensemble practice which comprised three to five native instruments by the 1920s and 1930s, had been replaced with large orchestral ensembles that featured violin sections, a few cellos, contrabass, and later guitar, accordion, bongos and electric organ (Marcus, Arab Music Theory in the Modern Period, 1989, p. 32). Further, by 1932, a survey revealed that there were far more students and teachers of Western music in Egypt than that of their own music, the Western solfeggio syllables and Western notation had by then profoundly affected the authenticity and identity of traditional Arabic music (Marcus, Arab Music Theory in the Modern Period, 1989, pp. 30, 156). The current music in the Arab world, however, is still closely related to Persian and Turkish influences (Touma, 1996, 2003, p. 15). An apparent supporter of Mashaqah and Collangettes, d'Erlanger addressed Mashaqah's measuring of string lengths and tuning of the tanbur, thus:

> "the most simple of the mathematical methods" (1943:33) supposes that the string of a tanbur is divided into 3.456 parts. The pitch of an open string is called Yakah; the halfway point, at 1.728, gives Nawa, i.e., the octave. The fret positions for the 24 quarter tones in this octave are arrived at in the following fashion: starting at Nawa (at 1.728) and working towards the upper end of the finger board the frets are positioned, successively, at a distance increasingly by two each time with 91, 93, and finally 95, one reaches the 3.456th and last position, equivalent to the open string(Mashaqah [1840] 1899:1073-1074)." (Marcus, Arab Music Theory in the modern period, 1989, p. 166)

Marcus addresses that one of the most significant supporters of Equal-temperament in the 20th century was the Egyptian engineer named Emile Arian. An article published in 1924 called "*Preuve Irrefutable de la Division de l'Echelle Musicale Orientale en 24 Quarts de Tons*", Arian clearly states his objection to previous attempts where scholars defined the scale from a completely different outset than that of the equal temperament – in the same article he also includes a table which to some extent resemble the one previously proposed by Ronzevalle (Marcus, Arab Music Theory in the modern period, 1989, p. 174). Marcus states the following "… in which the quarter tones over one octave are assigned frequency values and string lengths in terms of an open string of 2 meters. His figures for the string lengths are consistently within one-tenth of a cent of those of equal temperament." (Marcus, Arab Music Theory in the modern period, 1989, p. 174). Although Arian used a piano as a template to demonstrate and gain support for his theories and to propose this suggestion to numerous music organizations in Cairo, the piano was specifically customized (or re-constructed) to reproduce 24 equal quarter-tones across a range of six octaves (Marcus, Arab Music Theory in the modern period, 1989, pp. 174-175).

It should be noted that the majority of Egyptian theorists, musicians and scholars did not fully embrace and support the twenty-four-tone system until the 1920s. According to the Syrian `Adnan Ibn Dhurayl, a committee comprising a number of renowned musicians/scholars (such as Mustafá Rada, Safar `Ali, Muhammad al-`Aqqad, Adwar Faris, Najib Nihas, Mustafá al-`Aqqad, Amil Aryan (Arian), Sami al-Shawwa, and Mahmud Zaki) were assembled at the Royal Institute for Arab Music in Cairo and eventually accepted the equal-tempered scale (Marcus, Arab Music Theory in the modern period, 1989, pp. 175-176). In the same period, scholars first started to analyse intervals of different types of maqamat (Marcus, Arab Music Theory in the modern period, 1989, p. 256).

Notation was not commonly found in Arabic music until the latter half of the 19th and early 20th century when it was finally accepted among Arab musicians who then began to notate their music by using Western notation. Similar to the Western system, tones were given corresponding names although this approach proved not to translate well into Arabic music since Arabic tones showed a certain level of inaccuracy (Touma, 1996, 2003, p. 18). According to Touma, Arabs would then need to approach the Western system differently and figure out which tones that would correspond to tones in the Western system; thus the lowest tone yakah was fixed to the position of D, then later to G – although yakah has nothing to do with the absolute pitch of G (Touma, 1996, 2003, p. 18).

One of the most essential musical principles found in Arabic music are the jins/ajnas, which are the Arabic equivalent to tetrachords. As we have pointed out prior in this Music Study, the theories of tetrachords appear to have their roots in Greek; however, the focus and concept of tetrachord (by its "Greek" name) did not seem apparent to most Arabic scholar until the 1932 Congress publication in Cairo. Marcus states that five aspects of these ideals appear to be important to scholars of the modern era; 1) concerns about the actual size of the different tetrachords, alternatively pentachord, trichord etc, 2) the intervallic structure of the tetrachords including schemes for classifying tetrachords based on their structure, 3) placement of different tetrachords within the overall gamut, sometimes leading to other names to express the same tetrachord when its placement is different and further leads to the classification of particular tetrachords based on tonic pitch, 4) the amount of tetrachords used in modern Arab music, and 5) putting together two or more tetrachords to establish larger modal scales which leads to separate terms for the first and second tetrachords in a particular scale – while further overlapping of composed tetrachords (Marcus, Arab Music Theory in the modern period, 1989, pp. 275, 277, 280).

Cairo Congress and the ongoing dispute regarding the conception of the Arabic 24-tone tuning system

Later on in history, the aforementioned Cairo Congress of 1932 would occur and as previously stated, the outcome of this Congress would eventually rejected the 24-tone equal-tempered scale system (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 220). An acceptance of this system grew stronger within the next few decades and today is generally favoured among a large group of Arabic musicians, although within certain circles of the Arab community this approach is not rendered acceptable. A number of works written within the last 90 years might provide some interesting perspective on further developments of Arabic music between late 20th – early 21st century.

Touma points out that another three significant books about Arabic tone system appeared in the late 20th century. The first, called *“Qiyas assullam al-musiqi al-‘arabi”* (1969) was written by Egyptian musicologist Yusuf Shawqi Mustafa (1925-1987) and focused on determining precision and exact measurement of the Arabic scale by proposing exact value on intervals and discussing the number of intervals per octave (Touma, 1996, 2003, pp. 169-170). The second is called *“Das arabische Tonsystem im Mittelalter”* (The Arabic Tone System in the Middle Ages) and written by Indonesian musician and theorist Liberty Manik. This book was based on a critical examination of fifteen musical treatises originating between the 8th and 13th century;

Manik compares the mode rast from the Middle Ages and the modern form – in which he comes to terms with the Arabic division of octave being different than the Turkish and Persian (Touma, 1996, 2003, p. 170).

The third book was written in 1979 by Argentinian/Syrian scholar and Professor of Musicology Amnon Shiloah (1928-2014) and called *"The Theory of Music in Arabic Writings (c. 900 A.D. to 1900 A.D.)".* This has been considered the most extensive work done on Arabic music theory and covers such topics as acoustics, call to prayer (adhan), literature (adab), earth science, dance modes, musical speculative, musicians, notation, phonetics, rhythm, and meter (Touma, 1996, 2003, p. 171).

Other important propositions for tuning occurred in the 20th century, among others by Syrian author, composer and violinist Tawfiq al-Sabbagh. According to Racy, he used Pythagorean-based comma (roughly, one-ninth of a tone to measure), based on principles which he borrowed from medieval Arab treatises. In this work the octave was divided into 53 commas where some of the sizes were described as whole-step, half-step, neutral-step, and augmented-step intervals (Racy, Making Music in the Arab World, 2003, p. 107). There are similarities to his analytical methods and those provided by Turkish theorists, while fellow Syrian theorists suggested that it makes the maqamat's structure and ethos comparable with Byzantine counterparts; thus contains the following, whole-step comprising 9 commas, half-step 4 commas, the perfect fourth 22 commas, the perfect fifth 31 commas etc (Racy, Making Music in the Arab World, 2003, p. 107).

So far in this Music Study, we have examined many different important changes to occur in Arabic music. On this occasion, we have witnessed a number of different propositions/conceptualizations of tuning systems to emerge and followed the gradual development through centuries before the eventual arrival of the current 24-tone tuning system. However, the remaining part of this section will be devoted to concepts of tuning which have been provided by late 20th – early -21st century scholars.

Description about the Arab tones of how they are separated

Evidentially as previously addressed prior in this Music Study, the most commonly used approach in Arabic music is the concept of twenty-four equally-tempered quartertones per octave (50 cents). Marcus states that musical compositions are mostly based on the fundamental scale comprising seven notes per octave; all seven notes, except the third (‘iraq) and seventh (sikah) intervals (neither natural or flat keys) are equivalent to tones commonly found in Western music; the scale starts with the fundamental tone of C, the third tone appears somewhere between E natural and E flat, while the seventh between B natural and B flat - these are both often referred to as half-flats or neutral tones (Marcus, Arab Music Theory in the modern period, 1989, p. 12).

Some debates have occurred about the key tone which is considered the tonic in Arabic music, some advocates G as the rightful fundamental note, while others (most likely affected by modern principles associated with the West) suggests C. According to Touma the following order in Arabic tone system and maqam is supposed to start with the key of G (the notes in the scale have been assigned Arabic/Persian names), thus; yakah (G), ‘ushayran (A), ‘iraq (B𝄳), rast (C), dukah (D), sikah (E𝄳), jaharkah (F), and nawa (g) (Touma, 1996, 2003, p. 28). It should be noted that the structure of the descending cadential sequence of seconds eventually leads to the final tone being a crucial part in the determination of one particular maqam row (Touma, 1996, 2003, p. 28).

Touma suggests that the tone system should be structured as follows; three tones found between yakah and ‘ushayran thus: qarar nim hisar, qarar hisar (where the middle tone is the most important among these), and qarar tik hisar (qarar refers to the lower octave, nim and tik means slightly lowered and slightly raised pitch, while hisar specifically relates to pitch and is perceived to be more of an abstract sound compared to either of the three possible fret positions on the lute) (Touma, 1996, 2003, p. 27). In order to adapt and transcribe the tones of Arabic tuning into a Western notation system a few alterations have been necessary. Thus, the solution has been to use accidental marks in original and modified forms; 𝄳 lowers a tone by a quarter-tone, ♭ lowers a tone by a half-tone, ♭𝄳 lowers a tone by a three-quarter-tone, 𝄲 raises a tone by a quarter-tone, ♯ raises a tone by a half-tone, 𝄲♯ raises a tone by three-quarter-tone (Touma, 1996, 2003, p. 24).

Frequently occurring	less frequently occurring	seldom occurring
1. yakah G		
		2. Qarar* nim† hisar G#/Abb
	3. qarar hisar Ab/G#	
		4. qarar tikǂ hisar Aǂ/G ǂ#
5. 'ushayran A		
		6. qarar nim 'ajam Aǂ/Bbb
7. qarar 'ajam Bb 8. 'iraq Bb 9.qawasht B		
		10. tik qawasht Bǂ
11. rast C		
		12. nim zirkulah Cǂ/D bb
13. zirkulah Db/C#		
		14. tik zirkulah Cǂ#/Db
15. Dukah D		
		16. nim kurdi E bb/Dǂ
17. Kurdi Eb 18. sikah Eb		
	19. busalik E	
		20. tik busalik Eǂ/F bb
21. jaharkah F		
		22. nim hijaz ('arba') Fǂ/g bb
	23. hijaz F#/Gb	
		24. tik hijaz gb/F#
25. nawa g		
		26. nim hisar gǂ/a bb
	27. hisar g#/ab	
		28. tik hisar gǂ#/ab
29. husayni a		
		30. nim 'ajam aǂ/b bb
31. 'ajam bb 32. awj bb 33. nihuft b		
		34. tik nihuft bǂ
35. kurdan c		
		36. nim shahnaz cǂ/d bb
	37. shahnaz c#/db	
		38. tik shahnaz cǂ#/db
39. muhayyar d		
		40. nim sunbulah e bb/dǂ
	41. sunbulah eb	
42. buzurk eb		
	43. husayni shadd e	
		44. tik husayni shadd eǂ/f bb
45. mahuran f		
		46. jawab 'arba' fǂ/g bb
	47. jawab hijaz f#/g'b	
		48. jawab tik hijaz g'b/fǂ#
49. ramal tuti (saham) g'		

* qarar = lower octave
† nim = slightly lowered
ǂ tik = slightly raised

Table A3.6. An overview of the first and second octave of Arabic tuning system (Touma, 1996, 2003, pp. 25-27)

The concept of three tones in-between each fundamental scale notes eventually adds up to 24 intervals per octave (as indicated in table A3.6.). Further, it is important to address that the concept and names of the tones presented here would appear at a much later time period than that of the fundamental scale tones, most likely in between the era of al-Din (13th century) and the beginning of modern era (1798).

The music scale also contains a set of principal tones across a range of two octaves which are equally important to understand. These are ‘iraq, sikah, awj, and buzurk (B𝄳, E𝄳, b𝄳, e𝄳), which includes the following intervals ‘ushay-ran-‘iraq, ‘iraq-rast, dukah-sikah, sikah-jaharkah, husyani-awj, awj-kurdan, muhayyar-buzurk, and buzurk-mahuran (A-B𝄳, B𝄳-C, D-E𝄳, E𝄳-F, a-b𝄳, b𝄳-c, d-e𝄳, and e𝄳-f). Touma states that these can be turned into “…a second that is neither major nor minor but rather constitutes a medium second approximately the size of a three-quarter-tone” (Touma, 1996, 2003, pp. 27-28).

It should be noted that the fundamental scale in the current-day 24 tones per octave scale still retains some of the individual note names associated with 13th century Arab theory, among others Rast (fourth note), Dukah (fifth note), and Sikah (sixth note) are still commonly associated with current Arab music. In addition, Professor of physics, Father Xavier M. Collangettes believed that the “… lower range already existed in the theories of the thirteenth century scholar Safi al-Din” (Marcus, Arab Music Theory in the modern period, 1989, p. 84).

Touma claims that the position of a tone within the scale and the distance between the next and closest tone is much more significant than for the tone itself to appear in absolute perfect pitch - the approach to tune the lowest tone is in accordance with the lowest tone of a singer’s register and the next two octaves (Touma, 1996, 2003, p. 18). Further, Touma states that modes are named accordingly on certain characteristic tones of the scale; usually this refers to the fundamental tone of the scale in a particular mode (Touma, 1996, 2003, p. 18).

Arabic tuning appears to have been pulled in a many different directions – at one end the Arabic tuning system can be interpreted as straightforward and comprising fundamental concepts that are easily intelligible to Western scholars and musicians. On the other hand, it is apparent that the approach to the 24 equally-tempered tuning system shares obvious similarities to the Western/European tuning which applies to established rules regarding divisions of octave and exactly measured values of tones/intervals; however, even though the concepts appears simple at first - Arabic tuning is much more complicated than this.

Conclusions

We can conclude that Arab concepts of tuning have changed drastically over the course of its history. The concept of the fundamental seven tone scale appears to have been established dating back at least 1000 years (if not earlier) and is still an integral part of Arabic music today (although significantly modified), we have also established that the fundamental seven note scale was greatly influenced by ancient Greek and Indian music.

Among the concepts of tuning system provided in this Music Study, the earliest known proposition was provided by al-Farabi, whose concept of 25 tones per octave tuning system appears to have been established in the 10th century. Approximately 300 years later, Safi al-Din proposed another tuning system which comprised 17 tones per octave. In-between al-Din up until 1780 and Laborde's proposition of a 24-tone tuning system, it appears that no new propositions were offered. Further, the exact position of Laborde and whether he was the originator of the equally-tempered Arabic scale appears to be debatable among scholars. In the following century, Mishaqah came to the conclusion that the Arabic tuning system should appear with roughly equally divided intervals. Thus, the following conceptualized tuning systems appears to have been part of Arab music throughout history; 1) 24 tone equal tempered system, 2) 24 tone roughly tempered system, 3) the 17 tone system from the 13th century, 4) 25 tones per octave system from the 10th century.

One obvious advantage attributed to Arabic music in comparison to a few other foreign traditional music cultures is that sufficient attention on details of current-day tuning system, practices and measurement of intervals has been sufficiently provided. Thus, this has been of great help in order to establish a basic understanding on execution of current Arabic tuning system. Despite that the 24 equally-tempered quarter-tones per octave tuning system currently appears to be the most popular and commonly used conception by many Arabic musicians, the main problem is that it is not widely accepted in the Arab World.

The main challenge with this Music Study revolved around a number of divided opinions and debates about defining an authentic Arabic tuning system, among Arab musicians and scholars. Evident from what has been discussed so far in this Music Study, it may appear that Arabic music has been significantly victimized by Western notational system and music theory which again has made an impact on intervallic values of tones. Longer periods of neglect towards its own music and musical culture appears to have allowed this to happen, through the dawn of European influences especially in Egypt and other part of the Arabic World at the beginning of the 19th century.

Another challenge during this Music Study occurred when establishing a sufficient overview of the traditional core instruments found in maqam and art music. Apparently, some radical changes occurred in Arabic music during a time when the oral tradition was the main source for information. Thus, it is quite possible that a number of instruments have been completely forgotten. However, the other significant challenge was to select a core group of instruments due to differing opinions among various scholars and as a result the instruments were chosen (and displayed in figure A3.3.) on the basis that they were accepted by all or most authors (two exceptions are the santur and buzuq – each only covered thoroughly by one scholar).

Lastly, the final challenges which was encountered in this Music Study are opposing ideas of specific occurrences in the history of Arabic music. According to Touma the current tone system appears to be based on the original Arabic tone system provided by al-Farabi in the 10th century, while Turkish and Persian tone system appears to derives from the Pythagorean system of Safi ad-Din al-Urmawi from the 13th century (Touma, 1996, 2003, p. 170). Maalouf, on the other hand, calls this statement unelaborated and misleading, thus questioning whether Touma originally intended to state that al-Farabi's proposition of a tone system actually derived from the Pythagorean system, and al-Din's tone system possibly was entirely of Arabic origin; Maalouf further states that the statement about al-Farabi is not entirely true and that the tone system of al-Farabi may have been inspired by the ancient Greeks, although certainly not merely reducible to a Pythagorean origin. (Maalouf, History of Arabic Music Theory - Change and Continuity in the Tone Systems, Genres, and Scales, 2011, p. 32)

Sufficient information about the origin of Arabic instruments and understanding the core group of Arabic instruments in traditional maqam and art music also proved to be challenging. A large selection of different books (by different authors) on the topic of Arabic music was used for this Music Study, although significantly more difficult to obtain books on this subject (at least by Western authors) in comparison to cultures such as Indian music. None of the scholars on Arabic music were capable of providing an entirely complete “overview” (red thread) of Arabic music and Arabic music history, due to several gaps in the history which have not been accounted for and none of the scholars were entirely capable of filling in these gaps of missing information.

One of the major reasons why no exact or approximate time period has been provided may be attributed to the lack of proper documentations found in present day regarding historical happenings in relation to music. The other two major musical cultures examined as part of a PhD thesis, namely Indian and Indonesian music; managed to account for several examples of ancient musical activities, and evidenced through stone carvings, paintings, or information carved into palm leaves which provides us with a possible origin or timeline of certain instruments; however only scant information about this can be accounted for in Arabic music.

Despite a selection of different sources were used in particular eight authors were crucial during the development and eventual completion of this Music Study. Touma provided a very good overview of Arabic music and managed to cover most aspects to some extent, in particular across a variety of different subjects such as historical works, maqams, instruments, and tuning. Farmer and Hitti (although somewhat older sources) provided some of the basic history about the Arab culture to a greater extent; whereas the former also contributed some necessary information related to music. Maalouf provided some information related to written history, as well as some additional information about tuning. Racy, provided the majority of information regarding musical instruments, while Farraj and Shumays provided the majority of information about maqams as well as some important contributions in terms of tuning on separate melodic instruments. Lastly, Marcus was a completely indispensable source who provided the majority of thorough in-depth information about the various tuning systems known throughout Arab history.

Despite that the aforementioned authors covered different aspect about Arabic music, the majority of information explored for this Music Study only managed to provide sufficient information in order to establish a comprehensive overview of Arabic music. It should be noted that the information provided by the authors appeared less complete than anticipated prior to examining the Arab music culture (although they are not to be blamed for this), as neither seems to cover every single aspect of Arabic music which would have rendered a complete and thorough Music Study (analysis) on Arabic music. Unfortunately, "the missing gaps" in the history of Arabic music leaves us with extensive periods which completely lacks any physical evidence or documented progress.

There could be many different reasons due to this lack of evidence; most likely it can be attributed to different happenings in the course of Arab history. It is impossible know whether many important works or documentation across the centuries were destroyed during very significant change of rule, or wars – whether musical ideals possibly opposed to or challenged the beliefs set by the new rulers. Earlier in the Music Study, it was stated that any written work on Arab music prior to the 8th century has not survived, whether this could be directly related to the emergence of Islam would yield even more speculation.

It is arguable whether parts of the tradition have been lost due to the reluctance to stray away from oral tradition. Throughout the history it appears that Arabs have acted in good faith and content that ideas and concepts of Arab music would remain intact, although not taking into consideration that the music could possibly go through phases where it potentially could be rendered outdated, unfashionable or lost due to neglect or by sheer accident.

However, one likely argument for lack of documentation in Arabic music stems from the Qur'an, which neither except nor dismisses music. It is quite possible that longer periods under certain types of rule or rulers interpreted this differently from one another, thus resulted in reigns and/or periods where music was considered forbidden or excepted.