Workshop on numerical acoustic simulation and auralisation as built environment design consultation tools

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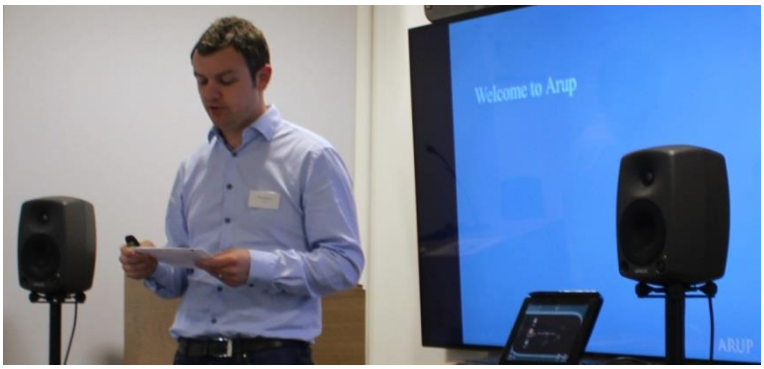
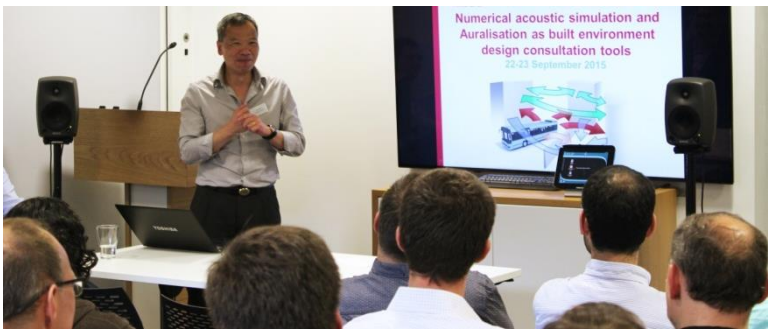
Numerical simulation has for several decades been an important tool for acousticians. Initially it was used primarily as a complement to scale modelling on high-value prestige projects, but it is now being applied extremely widely as a standard step in the acoustic design process. A particularly valuable extension to this development is the use of auralisation, being the reproduction of the acoustic character of a space over loudspeakers or headphones, to communicate to clients the subjective effect of different acoustic design decisions. When combined with simulated or measured acoustic data, auralisation enables design teams, stakeholders and sound artists to listen to soundscapes of the natural and built environment before they are physically created. It allows users to experience how different locations and spaces sound, the impact of architectural form on sound quality, and how physical interventions can alter the audible environment. Auralisation therefore also allows a client or stakeholder, who is unlikely to be au fait in the language and metrics of technical acoustics, to make an informed judgement on whether an acoustic design fits their needs. Again, this process was initially limited to high-value and/or high-stakes applications, but its power to engage and communicate otherwise complex concepts to non-experts means its use is spreading to a much broader range of projects. Arup, for example, have rolled-out their SoundLab auralisation facility to 11 offices internationally, the most recent installation being in their new Manchester office, where the workshop this article reports on was based.



Paul Adams (Arup) welcomes delegates to the workshop

Auralisation however places new and intensive demands on acoustic simulation algorithms, not least that a single full-bandwidth result is required. Most commercially available room acoustics software will produce output data suitable for auralisation, however it is well known that this is unreliable in some scenarios and in particular at low frequencies because the geometric approximation of acoustic propagation which they use breaks down. Other computational methods such as Finite Element and Boundary Element are capable of capturing these low frequency effects accurately, but are typically formulated for analysing single frequency problems and do not at present interface readily with auralisation technology. Hence there is a need for hybridised or unified acoustic simulation algorithms which can process the entire audible bandwidth reliably and output that data in formats suitable for auralisation, ideally with a fast and streamlined turnaround to allow new acoustic design iterations to quickly be experienced by the client.

This was the topic of a recent Engineering and Physical Research Council (EPSRC) funded 1.5 day workshop jointly hosted by Arup and the University of Salford. The event was the culmination of a three-year interdisciplinary project, also funded by EPSRC, which saw the Acoustics Research Centre at the University of Salford collaborating with the Applied Maths department at the University of Reading, steered by industrial partners Arup and the BBC. In total the event brought together 37 delegates, 10 from industry and 27 from academia, to discuss recent progress and developments in their respective fields, plus priorities for future research. The programme included technical talks on both theoretical and practical issues, plus structured discussion sessions aimed at promoting better mutual understanding, identifying directions for future development, and opening up possibilities for future collaborations. The programme was interspersed with regular auralisation demonstrations in the on-site SoundLab facility.



Yiu Lam (University of Salford) gives a little background on the project responsible for organising the workshop.

Jonathan Hargreaves (University of Salford) details some of the technical achievements of the project.

Following a welcome to the event by Paul Adams of Arup and Yiu Lam of the University of Salford, Jonathan Hargreaves (also University of Salford) kicked off the technical talks, describing the work the project has done towards creating a new full-bandwidth acoustic simulation algorithm aimed at auralisation. The idea behind this approach is to 'seed' a Boundary Element Method (BEM) with interpolation functions representing the leading order propagation directions suggested by a geometric method, to create a wave method which becomes 'geometrically dominated' at high frequencies. Emmanuel Perrey-Debain (Université de Technologie de Compiègne) spoke next on how similar ideas can be used with the Finite Element Method, after which Jonathan demonstrated a new approach for producing auralisation data from BEM in the first SoundLab demo.

The next set of technical talks focussed on interactive auralisation, with Iain Laird (Arup / Glasgow School of Art) describing, then later demonstrating in the SoundLab, a system for interactive auralisation of stage acoustics. This was based on measured spatial impulse response data of three halls, and allowed a musician to experience playing in them virtually. Rob Opdam and Lukas Aspöck of RWTH Aachen University then gave an overview of the significant related work being done by SEACEN, a large German research project also studying auralisation and acoustic simulation. This was followed by a description, and later a SoundLab demo, of their interactive auralisation plug-in for Sketchup. This allows a user to move around and change parameters of an acoustic space in Sketchup, while hearing an accompanying auralisation which updates in real time.

Ian Laird (Arup / Glasgow School of Art) introduces his work on interactive auralisation of acoustic spaces for musical performance

The last technical session of Tuesday included talks grouped around the topic of Finite-Difference Time-Domain (FDTD) type algorithms, the application of which to acoustics is presently attracting a lot of research interest. First up Maarten Hornikx of Eindhoven University of Technology described his work on a variant called pseudo-spectral time-domain method, which uses the Fast Fourier Transform to quickly and accurately compute spatial derivatives up to a very high order. He described the application of this method to indoor and outdoor scenarios, and his open source framework openPSTD. Following this there was a triple-bill from the Acoustics and Audio Group at the University of Edinburgh. Stefan Bilbao gave an overview of recent achievements by their group, including a way of measuring algorithm stability by considering conservation of energy. Next Brian Hamilton spoke on other developments including adding air absorption and improved approaches for modelling boundaries which do not fit easily with the Cartesian FDTD grid. Finally Craig Webb described some of the significant benefits, and the challenges, of optimising these algorithms to run on modern General Purpose Graphics Processing Units (GPGPUs).

Day two began with a session on geometrical methods. Peter Svensson from the Norwegian University of Science and Technology set the scene with an introductory talk asking what the limitations of geometrical modelling in room acoustics are. Following this Gerd Høy Marbjerg (Saint-Gobain Ecophon / Technical University of Denmark) described their PARISM algorithm, a phased combination of acoustical radiosity and the image source method, and the effect of different choices of angle-dependent boundary condition. David Chappell of Nottingham Trent University then described the new Discrete Flow Mapping approach his EU project MHiVec is applying to predict the steady state response in acoustic and structural vibration problems. Finally Jens Holger Rindel of ODEON A/S gave a talk, and short demo, describing a new feature for simulating the noise from speech in restaurants, specifically how to simulate the people speaking louder in noisier conditions; the so-called Lombard effect. This was followed by Paul Adams of Arup demonstrating what can be achieved using ODEON's new multi-source feature in the SoundLab.

In the next session the spatial audio requirements of auralisation were considered. Filippo Fazi of the University of Southampton spoke first, giving an overview of the pros and cons of performing wave-field reconstruction and translation using spherical harmonics compared with equivalent plane-wave statements. Jonathan Sheaffer (Ben-Gurion University of the Negev) spoke next, describing challenges which occur when using (or simulating) spherical microphone arrays, and an approach to compensate for the high-frequency attenuation and aliasing which naturally occurs due to an array's finite number of microphones and encoding order. Finally Angelo Farina of the University of Parma presented Spatial PCM Sampling (SPS), his new alternative to high-order Ambisonics, which represents a sound field as multiple highly-directional microphone feeds instead of spherical harmonics. Following this session Jonathan gave a binaural demonstration of his technique and Angelo gave a demonstration of SPS in the SoundLab.

The final technical session welcomed Damian Murphy from the University of York, who gave an overview of the work they've done developing FDTD simulation algorithms and studying the subjective response to their results. Next Alex Southern of AECOM, who is currently seconded to the University of York, described his Spatial High-frequency Extrapolation Method (SHEM). This is a post-

processing algorithm capable of extending band-limited spatial room impulse responses from wave methods to include realistic higher frequency components without the use of geometric modelling methods. Following this session there were SoundLab demonstrations from both Alex and Steve Oxnard (York), who showed how multiple 2D FDTD simulations can be combined to create realistic simulations of a 3D space at reduced computational cost.

Alex Southern (AECOM / University of York) in the Arup SoundLab experiencing the interactive auralisation of acoustic spaces for musical performance demonstration prepared by Ian Laird (Arup / Glasgow School of Art).

After lunch it was the turn of the delegates from industry to lead the discussion. A panel was assembled including Paul Adams and Vincent Jurdic of Arup, Laurence Evans from the Defence Science and Technology Laboratory, Jens Holger-Rindell of ODEON A/S, Jim Smith of AECOM, Perttu Laukkanen of Ramboll Environ, and Richard Muir of Sandy Brown. One strong theme emerging from the discussion was the extent to which auralisation has impacted on the way in which acoustic consultants are able to discuss design outcomes with their clients and manage their expectations, as mentioned at the beginning of this article. However various shortcomings were also identified, the majority being either to do with accuracy and reliability of the numerical simulation algorithms or streamlining of the simulation / auralisation process; e.g. such that changes to a design may be trialled while a client is still present. Another area where significant progress remains to be made is in the quality of input data for computer models, since this is not typically known exactly and can cause drastic changes in the results. Suggestions for 'game-changing' developments included accurate low-frequency auralisation and the ability to accurately include structure-born sound.

Yiu Lam (University of Salford) chairing the industry panel discussion, comprising (left to right) Paul Adams (not visible) and Vincent Jurdic of Arup, Laurence Evans from the Defence Science and Technology Laboratory, Jens Holger-Rindell of ODEON A/S, Jim Smith of AECOM, Perttu Laukkanen of Ramboll Environ, and Richard Muir of Sandy Brown.

The workshop concluded with an open discussion on how research might be progressed so that these goals were met. Plans were discussed for seeking funding to organise further such networking events (in a survey afterwards 100% of respondents said they had found the industry / academia networking aspect of the workshop beneficial, and that they would like to see more such events in future) and to coordinate joint publication and benchmarking initiatives, the latter being aligned to complement the parallel work

being done by the European Acoustics Association technical committee for computational acoustics and the SEACEN project in Germany.

For more information on the workshop and videos of the technical talks please visit:

http://hub.salford.ac.uk/acoustics/workshopSept2015/

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