

# Towards Building Information Modelling for Existing Structures

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## Abstract

Capturing and modelling 3D information of the built environment is very challenging. A number of techniques and technologies are now in use such as EDM, GPS, photogrammetric applications, and building surveying applications. However, use of these technologies has not been practical and efficient with regard to time, cost and accuracy. A multi-disciplinary knowledge base, created from studies and research about the regeneration aspects is fundamental: historical, architectural, archeologically, environmental, social, economic, etc. In order to have an adequate diagnosis of regeneration, it is necessary to describe buildings and surroundings by means of documentation and plans. Furthermore, there are a growing number of applications of 3D city models for disaster management, environmental simulations, computer aided architectural design and regional planning, that require more sophisticated models beyond visualization such as multifunctional, interoperable, intelligent, and multi-representational in order to be economical and sustainable. This paper will review the state-of-art techniques and approaches for modelling of existing structures such as 3D laser scanner. Research approach for Building Information Modelling (BIM) for existing structures is introduced. A case study is elaborated to demonstrate how to produce 3D CAD models of existing structures using a semi-automated technique.

**Keywords:** Building Information Modelling, 3D laser scanner, Photogrammetry, object recognition, geo-computational co-planar surfaces, spin images

## 1 Introduction

The regeneration and transformation of cities from the industrial age to the knowledge age is essentially a 'whole life cycle' process consisting of; planning, from the studies

and research about the regeneration aspects is fundamental: historical, architectural, archaeological, environmental, social, economic, etc. In order to have an adequate diagnosis of regeneration projects, it is necessary to describe buildings and surroundings by means of documentation and plans. However, at this point the former is considerably far removed from the real situation, since more often than not it is extremely difficult to obtain full documentation and cartography, of an acceptable quality, since the material, constructive pathologies and systems are often insufficient or deficient (flat that simply reflects levels, isolated photographs,...). Sometimes the information in reality exists, but this fact is not known, or it is not easily accessible, leading to the unnecessary duplication of efforts and resources. The possibility of counting upon catalogues of goods and properties and their associated meta-data, where it is possible to ascertain the possible existence of certain information and to co-ordinate actions between the organizations in charge is a key issue. Therefore, documentation of information of cities during the regeneration for the urban planning, the refurbishment processes, archaeological works, and educational purposes currently faces a real challenge [5].

One of the greater limitations that take place at the moment in the management of building refurbishment process in regeneration projects is the integration of information. It is not only important to have the data, but also it should be available in a digital format because the greater part of the present information remains being provided in a paper format. Furthermore, these digital formats should be compatible with one another, that the data has semantic meaning that they are inter-connected, so that the usual problems of incoherence of information are avoided, that the duplicity of efforts as far as personnel and economic resources are concerned is avoided and that they can altogether be put under analysis.

In regeneration projects, implementation of Information and Communication Technologies (ICT) is still in its early stages. Although there are ICT tools developed for public participation to achieve community based regeneration, these tools have been implemented in ad hoc manner. As a result, the expected achievements have not been fully accomplished for community based regeneration. On the other hand, from EU and UK policy perspective, ICTs is expected to act as the key driver for both, the delivery of the knowledge society and cities. The technical challenge is primarily composed of seeking solutions to the integration and interoperability problems underlying the delivery of the fully integrated systems of the broad scope envisaged for urban regeneration. The use of ICT (e.g. CAD, 3D visualization tools, information modeling and simulations), have demonstrated their value and potential to aid with the digital design and planning process of regeneration projects, however, their capabilities are not fully utilized and only implemented to address specific aspects of urban developments, with little consideration of other factors.

For example, 3D city and building modelling is an emerging field and traditionally modelling has been focused on graphical representations with limited support of semantic aspects, topology, and interoperability. However, there are a growing number of applications of 3D city models like disaster management, environmental simulations, computer aided architectural design (CAAD), and regional planning, that require more sophisticated models beyond visualization.

Hence information models of real world data should be multifunctional, interoperable, intelligent, and multi-representational to be economical and sustainable. Interoperability means that different models and model parts may be smoothly integrated within spatial data infrastructures and may easily collaborate with systems from the domains of CAAD and computer graphics, which denotes an intelligent semantic 3D city and building models where objects know about their structure, thematic properties, and interrelationships with other objects. Furthermore, behaviours might be assigned to objects which, for example, could control the adaptation of geometries when different objects are integrated. Special challenges arise from the need to manage multiple representations of entities in 3D city and building models concerning different scales, evolution over time, and concurrent versions. The new model quality also demands for advanced acquisition tools. These have to cope with the extraction of semantically meaningful features from images and laser scanning data, scale transitions, geometric and topological consistency, and international standards. Therefore, the research explained in the paper aims to develop object recognition and image processing algorithms to convert the geospatial data such as 3D scanning data (vector data) or photogrammetric data (raster data), remote sensing data (raster data) from the real world into the object oriented data models which are recognized nationally and internationally such as IFC (Industry Foundation Classes), city GML (Geographic Mark-up Language) and IFG (Industry Foundation Classes for GIS) and X3D (Xml 3D). Apart from X3D all the data models include semantic information for the existing world.

In the remaining section of the paper, real world data capture and processing techniques are explained. This is followed by describing BIM (Building Information Modelling) and parametric urbanism. Then, a case study for real world data capture and modelling is explained. Then, based on the experience and lessons learnt in the case study, a vision for a way better implementation is described. Finally the paper concludes the paper with result and summaries.

## **2 Real World Data Capture and Processing**

In this section, 3D laser scanning will briefly introduced for real world data capture and processing of the captured data. The 3D Laser scanning technologies have been introduced in the field of surveying and are able to acquire 3D information about

physical objects of various shapes and sizes in a cost and time effective way. While laser scanning based on the triangulation principle and high degrees of precision have been widely used since the 80s, `Time of Flight` instruments have only been developed for metric survey applications in the in this decade [2]. The latter has been optimized for high speed surveying, and a set of mechanisms that allows the laser beam to be directed in space in a range that varies according to the instrument that is being used. For each acquired point, a distance is measured on a known direction: X, Y, and Z coordinates of a point can be computed for each recorded distance direction. Laser scanners allow millions of points to be recorded in a few minutes. Because of their practicality and versatility, these kinds of instruments have the potential to be widely used in the field of architectural, archaeological and environmental surveying [12]. Research studies have been undertaken to investigate the advantages of 3D laser scanning technology over the current technologies available for natural environment, cultural heritage documentation, mining, and tunnel bridge construction and as built survey for defect detection. In addition, 3D prototyping in manufacturing has been carried out for small objects such as car seats. However, the same concept has not been applied in the built environment.

Laser scanner is can be airborne or terrestrial. The main difference of airborne 3D laser scanners from the terrestrial 3D laser scanners is that the scanner is mounted beneath a plane to scan the earth surface while flying. However, the scanning principles and output from the scanning, which is point cloud data, are the same. Airborne laser scanning is an active technique to acquire point clouds describing the earth surface. While early systems generated datasets with an average point spacing of a few meters, modern systems are capable of acquiring several points per square meter. In addition, they offer the capability to record multiple echoes per laser pulse as well as pulse intensities. Originally being used as a powerful technique for the acquisition of data for digital terrain models, airborne laser scanning is meanwhile often referred to as a tool for adding the third dimension to GIS data, and to acquire data for a wide range of 3D object modelling tasks.

To enhance the implementation of built and human environment solutions during the regeneration and transformation of cities, 3D digital mapping tools such as photogrammetry, 3D Laser Scanning technology, can have a significant impact. These tools and technologies can be enablers for effective e-planning, consultation and communication of users' views during the whole lifecycle process of, for example, regeneration.

### **3 Building Information Modeling**

Building Information Modelling is the term used to describe a range of discipline-specific software applications that support all phases of the project lifecycle from conceptual design and construction documentation, to coordination and construction,

and throughout ongoing facility management, maintenance, and operations. BIM is an integrated 3D digital description of a building, its site and related geographic information system (GIS) context. A BIM comprises individual building, site or GIS objects with attributes that define their detailed description and relationships that specify the nature of the context with other objects. BIM is called a rich model because all objects in it have properties and relationships and this information can be for data mining to develop simulations or calculations using the model data [3].

The principal difference between BIM and 2D CAD is that the latter describes a building by 2D drawings such as plans, sections, and elevations. Editing one of these views requires that all other views must be checked and updated, an error-prone process that is one of the major causes of poor documentation today. In addition, the data in these 2D drawings are graphical entities only such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, elements and systems such as spaces, walls, beams and piles [3].

The generic attributes of BIM are listed below:

- Robust geometry: objects are described by faithful and accurate geometry that is measurable.
- Comprehensive and extensible object properties that expand the meaning of the object. Objects in the model either have some predefined properties or the IFC specification allows for the assignment of any number of user or project specific properties are richly described with items such as a manufacturer's product code or cost or date of last service.
- Semantic richness: the model provides for many types of relationships that can be accessed for analysis and simulation.
- Integrated information: the model holds all information in a single repository ensuring consistency accuracy and accessibility of data.
- Lifecycle support: the model definition supports data over the complete facility lifecycle from conception to demolition, for example, client requirements data such as room areas or environmental performance can be compared with as designed, as built or as performing data

The key benefits of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment are listed below [3]

- Faster and more effective processes - information is more easily shared can be value added and reused.
- Better design – building proposals can be rigorously analysed, simulations can be performed quickly and performance benchmarked, enabling improved and innovative solutions

- Controlled whole life costs and environmental data – environmental performance is more predictable, lifecycle costs are understood.
- Better production quality - documentation output is flexible and exploits automation.
- Automated assembly – digital product data can be exploited in downstream processes and manufacturing
- Better customer service – proposals are understood through accurate visualisation
- Lifecycle data – requirements, design, construction and operational information can be used for, for example, facilities management.
- Integration of planning and implementation processes – government, industry, and manufacturers have a common data protocol
- Ultimately, a more effective and competitive industry and long term sustainable regeneration projects

Interoperability is defined as the seamless sharing of building data between multiple applications over any or all applications (or disciplines) over any or all lifecycle phases of a building's development. Although BIM may be considered as an independent concept, in practice, the business benefits of BIM are dependent on the shared utilisation and value added creation of integrated model data.

To access the model data therefore requires an information protocol, and although several vendors have their own proprietary database formats, the only open global standard are IFC (Industry Foundation Classes) that published by the international Alliance for interoperability (IAI) and cityGML (city Geographic Markup Language) that is published by the Open Geospatial Consortium.

### **3.1 IFC (Industry Foundation Classes)**

The need for standard data exchange languages has been widely recognized throughout the AEC/FM IT community and a large-scale international effort has taken up this challenge. The International Alliance for Interoperability (IAI) [6], [1] is a global coalition of industry practitioners, software vendors, and researchers (over 600 companies around the world) working to support interoperability throughout the AEC/FM community by developing the Industry Foundation Class (IFC) standard. The IFCs are a high-level, object-oriented data model for the AEC/FM industry. The IFCs model all types of AEC/FM project information such as parts of a building, the geometry and material properties of building products, project costs, schedules, and organizations, etc [4]. The information from almost any type of computer application that works with structured data about AEC building projects can be mapped into IFC data files. In this way, IFC data files provide a neutral file format that enable AEC/FM computer applications to efficiently share and exchange project information. The IFCs, initiated in 1994, have now undergone four major releases, and commercial software

tools for the AEC industry (such as Autodesk's Architectural Desktop, Graphisoft's Archicad, Nemetschek's Allplan, Microsoft's Visio, and Timberline Precision Estimator) are beginning to implement IFC file exchange capabilities [4].

The scope of the IFCs includes product information: it models the physical parts that make up a building, including the semantic identification of all the building's systems and elements, their geometry, design properties, etc. Within the IFC's, the representation of certain building systems (e.g., basic architectural features such as walls, doors, floors, etc.) is fairly extensive while other building systems (e.g., electrical systems) have received very little development to date (IFC release 2X2, currently in development at the time of writing, will extend many of these areas). The scope also includes non-product information, such as costs, schedules, people and organizations, resources, documents, etc. The largest effort to date in implementing IFCs has been in the area of product information, such as building geometry. Many of the IFC-compatible systems that have been developed to date do work with non-product information. However, in almost all cases, these systems use product information as an input to non-product applications. For example, the product model is used to input geometry into an energy simulation application, or to input a quantity takeoff into an estimating application. Very few systems have written non-product information back into IFC files and used these to exchange non-product data.

### **3.2 CityGML (City Geographic Mark-up Language)**

CityGML is a common information model for representing 3D urban objects. It defines classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometric, topological, semantic and appearance properties. "City" is broadly defined to include not just built structures, but also elevation, vegetation, water bodies, "sidewalk furniture" and more. Included are generalization hierarchies between thematic classes, aggregations, relationships between objects and spatial properties. These thematic information types go beyond graphic exchange formats and allow users to employ virtual 3D city models for sophisticated analysis tasks in different application domains such as simulation, urban data mining, facilities management, decision support and thematic inquiries [7].

CityGML is an open data model and XML-based format for storing and exchanging virtual 3D city models. It is implemented as an application schema of GML3, the extensible international standard for spatial data exchange developed within the Open Geospatial Consortium (OGC) [13] and International Society of Geographic Information and Geomatics (ISO TC211), [14]. CityGML takes advantage of other open standards and its development has proceeded in careful co-operation with other groups. For example, graphic rendering of data encoded in CityGML can be accomplished using

standardized computer graphics data formats like VRML, GeoVRML, X3D or Universal 3D (U3D) [7].

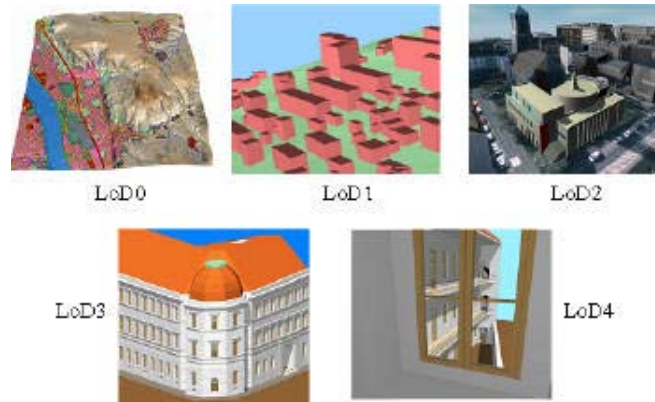


Figure 1: The five levels of detail (LoD) defined by CityGML [7]

CityGML represents the graphic appearance of city models and also the semantic or thematic properties, taxonomies and aggregations of digital terrain models, sites (including buildings, bridges and tunnels), vegetation, water bodies, transportation facilities, etc. The underlying model differentiates five consecutive levels of detail (LoD), where objects become more detailed with increasing LoD, both in geometry and thematic differentiation. CityGML files can - but don't have to - contain multiple representations for each object in different LoD simultaneously. Figure 1 illustrates the LoDs.

## 4 A Case Study Approach for Real World Data Modeling

The case study building is the Jactin house building under refurbishment in East Manchester. The paper explains the point cloud data capture, processing and modelling. A true colour image generated from scanned data is shown in figure 2 below. 3D point cloud data was captured with the Riegl LMS Z210 scanner together with the companion software called RiSCANPro. For scans registration and post processing, RiSCANPro and the Polyworks software were used consecutively based on project requirements and scanning strategy. Once all the scans are registered, a point cloud model of the scanned object is obtained.

A 3D mesh model can be generated using the IMMerge Module of Polyworks software. Meshing parameters such as surface sampling step, reduction tolerance, smoothing and maximum distance, are important to create smooth and filtered high quality mesh model with high resolution. To achieve this, it is important to take into account the scanning parameters. The accuracy and resolution of the model will be dependent on the scanning resolution and the laser scanner accuracy. The output from



ImMerge is a polygonal mesh model of the building, scene or object that has been scanned and merged. The final merged model can then be exported from IMMerge and imported into IMEdit for refining. Figure 3 shows an image of the jactin house mesh model in the IMEdit module.



Figure 2: raw scan data in true colours



Figure 3: The Jactin house mesh model in IMEdit

The editing process is crucial in order to produce a neat CAD model. This is also done in the Polyworks IMEdit software. Several steps exist to complete the editing process to a high standard. This step is illustrated in figure 4 below. The first activity is to orientate and align the 3D Mesh model according to the 3D common coordinate system because the model could be oblique in space. As a result, width, height and length of the model can be viewed horizontally and vertically when the model is viewed from X, Y or Z perspectives of the coordinate system. For example, the script below can automatically align the model XZ coordinate dimensions. In the same manner, the model can be aligned with XY and YZ coordinate dimensions.

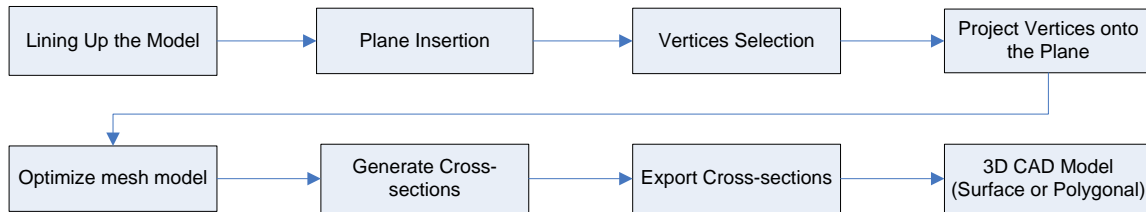


Figure 4: Point Cloud Data editing and CAD extraction process

The script below is to align a mesh model in XZ plane

```

version "4.0"
#VIEW POSE Y_POS
VIEW POSE Y_NEG
TREEVIEW MODEL VIEW DEFAULT_STATIC COLOR VERTEX_COLOR
EDIT PLANE CREATE XZ_PLANE
SELECT ELEMENTS
EDIT PLANE CREATE FROM_3_VERTICES
TREEVIEW SELECT NONE
TREEVIEW MODEL SELECT ( 1, "On" )
DECLARE I
DECLARE J
DECLARE MYPLANEONE
DECLARE MYPLANETWO
TREEVIEW PRIMITIVE PLANE GET_NB (I)
set j expr($i-1)
TREEVIEW PRIMITIVE PLANE NAME GET ( $I, MYPLANEONE )
TREEVIEW PRIMITIVE PLANE NAME GET ( $J, MYPLANETWO )
ECHO (" $MYPLANEONE ")
ECHO (" $MYPLANETWO ")
TREEVIEW PRIMITIVE PLANE SELECT ( $I, "On" )
#TREEVIEW PRIMITIVE PLANE SELECT ( $J, "On" )
ALIGN ROTATE_PLANE_A_TO_PLANE_B ( $MYPLANEONE, $MYPLANETWO )
TREEVIEW SELECT NONE
TREEVIEW PRIMITIVE PLANE SELECT ( $J, "On" )
TREEVIEW PRIMITIVE PLANE SELECT ( $I, "On" )
VIEW VISIBILITY OBJECTS HIDE ( )

```

Figure 5: Code for model lining up

Once the model is lined up, using the script below for each surface in the model, the subsequent steps (plane insertion, vertices selection, and projection of vertices onto the plane) in figure 6 can be carried out automatically. However, this script can be improved by encompassing all the stages in figure 4 to the end of cad extraction. According to the script in figure 6, all the vertices that are 4.5 cm away from the plane are automatically selected and projected on the plane. However, this can vary from cm level to mm level depending on the scan resolution and accuracy of vertex positions.

Following the projection of vertices, it is necessary to optimize the mesh model to make the model consistent and if necessary reduce the number of points at some regions

in the model to reduce the file size and avoid point intensity and heterogenic point scatter. Mesh optimization may be applied to a selection, or to the entire model. There are a number of parameters that need to be adjusted for mesh optimization. These are (i) sensitivity, (ii) minimum number of triangles per vertex, (iii) max number of triangles per vertex, (iv) min inner angle, (v) max dihedral angle. After mesh optimization, the triangulated mesh is more consistent, and the surface curvature is better described. Mesh optimization works best if the polygonal mesh is relatively smooth.

```
version "4.0"  
#CAD LINES EXTRACTION FROM POLYGONAL MESH MODEL  
EDIT PLANE CREATE PARALLEL_TO_PLANE  
#TREEVIEW PRIMITIVE PLANE SELECT ( $I, "On" )  
DECLARE I  
TREEVIEW PRIMITIVE PLANE GET_NB (I)  
#TREEVIEW PRIMITIVE PLANE GET_NB_SELECTED (I)  
#WHILE $I<$I+1  
# ++I  
#ENDWHILE  
TREEVIEW PRIMITIVE PLANE SELECT NONE  
TREEVIEW PRIMITIVE PLANE SELECT ($I, "On" )  
VIEW VISIBILITY OBJECTS HIDE ( )  
SELECT VERTICES USING_PLANES ABOVE_AND_BELOW ( 4.5e-002, "Off" )  
EDIT VERTICES PROJECT ONTO_PLANE  
#EDIT CROSS_SECTION CREATE FROM_PLANE_SELECTION ( 0.0 )  
SELECT ELEMENTS
```

Figure 6: Code Plane insertion, vertex selection and projection onto the plane

Before generating cross-sections, a regular mesh model with planes and defined edges should be in place. Cross-sections are created through the planes inserted into the corresponding surfaces. Each cross-section will create a CAD line on the edges of the corresponding surfaces. This CAD lines describes the characteristics features of the building model.

Cross-sections can be exported in various formats such as DXF, IGES, and so on. Generally, exporting to DXF is the preferred option because it is CAD exchange format. The export of cross-sections can be done in a variety of combinations such as individual section export, group of section export or all sections export at a time. In addition, the exported model can be either a polygonal CAD model or a surface model depending on the configuration of the export parameters in the Polywork software. Figure 7 shows the cad model extracted of the jactin house building as an example.



Figure 7: Jactin House CAD model produced point cloud data

The object-oriented CAD modelling approach utilises the Microstation Triforma software, which employs the building information modelling concept. All information about a building (or at least as much as possible) is recorded in a 3 dimensional model. Traditionally a given door in a building would be drawn in at least three or four places (plan, building elevation, building section, interior elevation, etc). In the Triforma building information modelling, it is constructed once and these various drawings are later extracted automatically. It requires building objects that are defined, edited and stored in the triforma library.

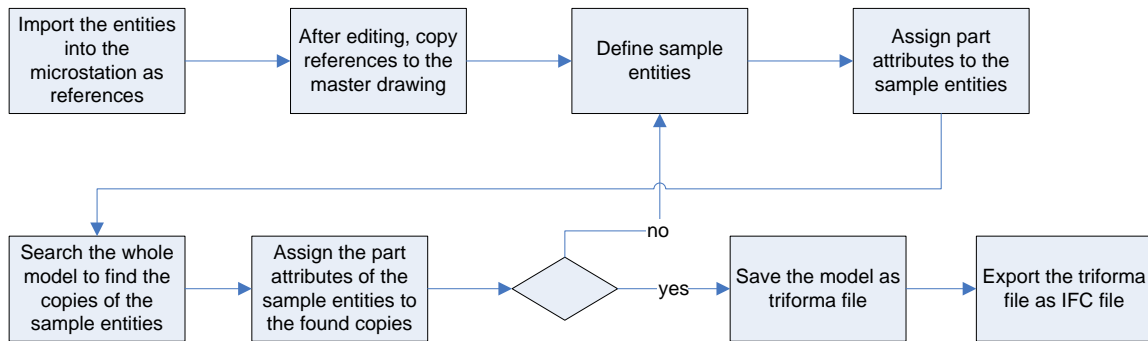


Figure 8: experienced Object Oriented CAD modelling

Since the whole process from the beginning of figure 4 to the end of figure 8 is not fully automated, interaction with the model especially in stages in figure 8 is more than required. For example, individual entities from the Polywork software are achieved by many subsequent exports of group of cross-section that represent a building entity. Furthermore, instead of only assigning part attributes for the sample entities, the former is assigned each entity manually since there is no search engine embedded into the process yet. However, once a search engine is employed, the whole process can be fully automated for OO CAD modelling from the beginning of figure 4 to the end of figure 8.

There have been many researches on shape representation and retrieval at lower level, and semantic retrieval on colour image recently [9]. To semantically annotate a shape database can be very difficult. However, if the objects are the CAD graphics as illustrated in figure 7, it is possible to annotate it automatically. There are efficient techniques available in the literature. However, a simply way is to design some templates representing each type of objects, and then mapping those new objects into templates. If there is already an annotated object database, they can be used to approximate new objects to be created.

The complexity of annotation depends on how large it is and the nature of projects. If a project is new and not large, newly created objects can be manually annotated and stored into database, so that the annotated and stored objects may be reused in the project. That is, whenever an object is necessary later in the project, it can be simply found in the database and manipulated for new situation. If a required object cannot be found in the database, it can be created and annotated before storing into the database. However, if there is a large amount of objects to be defined and annotated, which also need to be stored into the database, these objects can be defined with some object recognition techniques such as the contour based shape descriptors, like elongation, compactness, Fourier descriptors etc, normally those descriptors are size, translation and rotation invariant [9].

Contour shape techniques only exploit shape boundary information. There are generally two types of very different approaches for contour shape modelling: continuous approach and discrete approach. Continuous approaches do not divide shape into subparts; usually a feature vector derived from the integral boundary is used to describe the shape. The measure of shape similarity is usually a metric distance between the acquired feature vectors. Discrete approaches break the shape boundary into segments; called primitives using a particular criterion [9]. Discrete approaches differ in the selection of primitives and the organisation of the primitives for shape representation. Common methods of boundary decomposition are based on polygonal approximation, curvature decomposition and curve fitting [8].

Based on the logic above, the pattern matcher in figure 8 will access the triforma library with the criteria in hand to do search and match. Two different type of matching can be done such as exact pattern matching and approximate pattern matching. Exact pattern matching consists of finding the exact pattern looked for. In the case of approximate pattern matching, it is generalisation of the pattern looked for and a determined number of differences between the pattern looked for and the objects found in the library is allowed.

As a result of various matching techniques based on which the search, object recognition can be worked out for the interested building frames in the 3D CAD model. Attributes of the objects matched in the library will be assigned to the building frame in the CAD model, which result in the building frames to be building objects defined. Subsequently, object-oriented (OO) CAD model will be obtained. This OO CAD model will be mapped into IFC schema to save the model in IFC data model. After all the entities are defined as triforma part objects, the file can be saved as a triforma file and it is now ready for IFC generation from triforma parts. The image in figure 9 shows the IFC model of the Jactin house in the Microstation triforma environment that has IFC 2X plug-in installed.

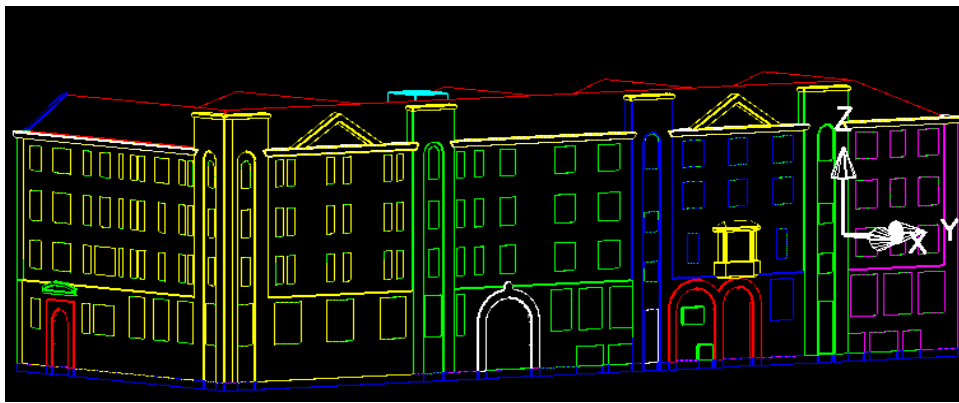


Figure 9, The Jactin House building IFC model in Microstation Triforma

## 5 Conclusion

The research is ongoing and the experience is aimed to expand to apply into various buildings including historical buildings that have intensive architectural details. Therefore, the spin images generation [10], Hough transformation [11], candy edge detection [11] are investigated to be embedded into the algorithm.

The paper shows that Building Information Modelling (BIM) can be achieved for existing structures by modelling the data captured with 3D laser scanner from the existing world. This can be achieved by adapting appropriate automated data processing and pattern recognition techniques through applied science research. This information modelling will enable automatic and fast data capture and enrichment for not only in urban design and planning, regeneration but also disaster management, environmental analysis, assessment and monitoring, GIS implementation, sophisticated simulation environments for different purposes such as climate change, regeneration simulation for complexity and uncertainty and so on.

It can be a way forward for parametric design approach from building level to urban level. The concept of Building Information Modeling (BIM) for parametric design is an evolving object oriented design concept for building design. For example, this concept can be improved Urban Information Modeling with varies level of details concentrated on regeneration projects at building and urban level. As a result, it will increase the capability for fast production of virtual reality models and comprehensive and sophisticated simulation platforms to utilize when needed in the regeneration projects in order to achieve long term sustainable built environment for living and working in the knowledge age.

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