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Integration of HBIM and 3D GIS for Digital Heritage Modelling

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***Abstract* — This paper outlines a new approach for digitally recording cultural heritage sites from laser scan data or photogrammetric data. This approach involves 3D modelling stage and the integration of the 3D model into a 3D GIS for further management and analysis. The modelling stage is carried out using a new concept; Historic Building Information Modelling (HBIM). HBIM uses Building Information Modelling (BIM) software with parametric and procedural modelling techniques to automate the modelling stage. The HBIM process involves a reverse engineering solution whereby parametric objects representing architectural elements are mapped onto laser scan or photogrammetric survey data. A library of parametric architectural objects has been designed from historic manuscripts and architectural pattern books. These parametric objects were built using an embedded scripting language within the BIM software called Geometric Descriptive Language (GDL). Using this embedded scripting language, elements of procedural modelling have also been replicated to automatically combine library objects based on architectural rules and proportions. If required the position of elements can be manually refined while overlaying the automatically generated model with the original survey data. After the 3D model has been generated the next stage involves integrating the 3D model into a 3D GIS for further analysis. The international framework for 3D city modelling, CityGML has been adopted for this purpose. CityGML provides an interoperable framework for modelling 3D geometries, semantics, topology and appearance properties [14]. CityGML enables further historical information to be added to the model and allows for efficient management and analysis of all data relating to a heritage site. The aim of this research is to bridge the gap between parametric CAD modelling and 3D GIS while using benefits from both systems to help document and analyse cultural heritage sites.**

Keywords - Laser Scanning; Parametric Modelling; Procedural Modelling; BIM; Semantic Modelling; 3D GIS; CityGML, Cultural Heritage

I. INTRODUCTION

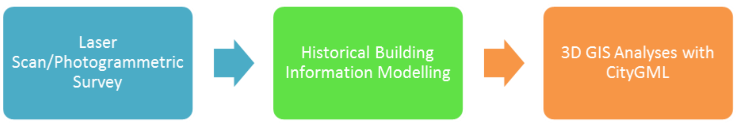
The generation of 3D cultural heritage models has become a topic of great interest in recent years. One reason for this is the more widespread use of laser scanning and photogrammetry for recording cultural heritage sites. These technologies have made it possible to efficiently and accurately record complex structures remotely that would not have been possible with previous survey methods. In addition to these developments, digital information systems are evolving for the presentation, analysis and archival of heritage documentation. These new digital information systems allow for the production of multi-purpose 'nD' models that can be used for more than just visualization.

This paper presents a design framework for the integration of two new developments in this area, Historic Building Information Modelling (HBIM) and CityGML. HBIM provides a solution for parametric and procedural modelling of historic buildings/objects from laser scan or photogrammetric survey data. HBIM includes a plug in library of architectural objects for Building Information Modelling software platforms and a semi-automatic system for plotting these objects to laser scan or photogrammetric survey data.

After the HBIM model has been generated the next stage involves the integration of the 3D model into a 3D GIS for further management and analysis. CityGML, an Open Geospatial Consortium (OGC) standard 3D data format has been adopted for this purpose. CityGML has a detailed semantic framework for city objects and enables further information to be stored as attributes or external references. The aim of this paper is to build on the new concept of Historic Building Information Modelling (HBIM) and to investigate the integration of HBIM into a 3D GIS environment using the CityGML framework for the purpose of cultural heritage modelling.

Section II of this paper shows related works for this research. Section III describes the modelling stage with HBIM and Section IV describes the integration of the model into a 3D GIS with CityGML. Finally Section VI contains a conclusion on the research to date.

Figure 1. Workflow



II. RELATED WORKS

With the exception of [7], very little work has been done in relation to modelling historic buildings and also generating BIM models from laser scan survey data. Their work concentrated on the problems associated with combining laser scanning and BIM and plotting generic library objects onto the scan in a BIM environment. Within the research areas of both procedural and parametric modelling the use of architectural knowledge to inform the creation of models has now developed into a common part of the design approach. Existing research [5], [3] in the area of parametric modelling of architectural heritage has initiated a new direction by examining how architectural historic rules can be exploited to build computer models of structures and their elements. While these works inform the HBIM approach they differ in their way of approach to the analysis of historic data and parametric design.

III. HISTORIC BUILDING INFORMATION MODELLING

A. Overview

HBIM as plug-in for BIM is a novel prototype library of parametric objects built from historic data and a system for mapping the parametric objects onto point cloud and image survey data. As seen in Fig. 2, the HBIM process begins with the remote collection of survey data using terrestrial laser scanning or photogrammetry. The next stage involved designing a library of parametric architectural objects that could be used to digitally model many historic buildings. These parametric library objects are combined with a procedural modelling technique for automatically combining library objects based on architectural rules and proportions. Finally a combination of manual refinement of the automated model and manually placing other required library objects is used to complete the HBIM model.

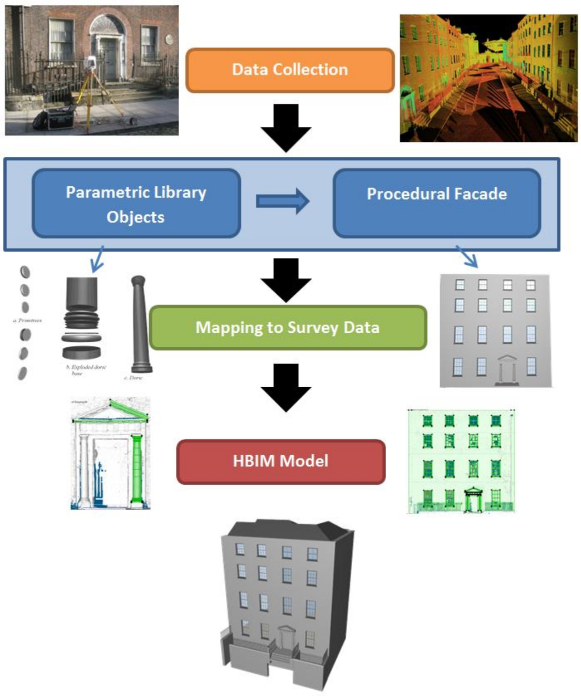


Figure 2. HBIM Workflow

B. Design of Parametric Libraries

A library of parametric architectural objects has been created which are based on the manuscripts ranging from Vitruvius to 18th century architectural pattern books. Classical architectural buildings are made up of decoration in the form of mouldings (Fig. 3) which are combined with cylindrical and planer objects and are brought together, based on a series of rules in relation to space, geometry and aesthetics to create a whole structure. By starting with the design of parametric mouldings as the smallest building block, followed by the parametric design of elements such as columns, pediments, walls, windows, roofs etc. a design framework based on parametric design and shape rules is presented. The library objects were created using an embedded scripting language within the BIM software called Geometric Descriptive Language (GDL). GDL provides access to modelling of objects through a BASIC like language; these objects are specifically constructed for one or many uses and carry the required parametric information for the object's function. Shapes are scripted, based on primitives that represent the simplest solid objects; these are the building blocks of GDL and culminate to create the more complex parts.

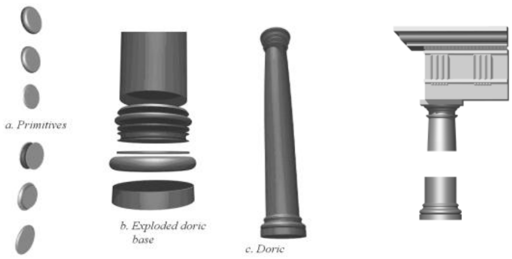


Figure 3. Combined Primitives for Doric Column and Pediment

C. Design of Procedural Building Façade

Procedural modelling is an automated approach to generating 3D content based on a sequence of generation instructions, rules or algorithms that can be repeated with varying characteristics to automatically produce large 3D scenes [8]. These rules are used to modify and transform a defined vocabulary of shapes or shape grammars [8]. For this approach the embedded scripting language within the BIM software, GDL was used to replicate elements of procedural modelling to build a complete wall facade. A new vocabulary of shapes (Fig.4) along with existing library objects are automatically combined based on classical building proportions and architectural rules. An example of these rules can be seen in Fig. 5, which uses circles of the same radius to position windows. A system has also been developed to allow for elements to be subsequently manually refined when overlaid with survey data.

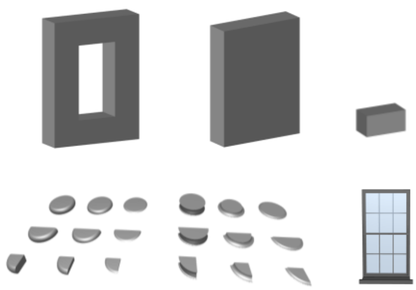


Figure 4. Vocabulary of Shapes and Existing Library Objects

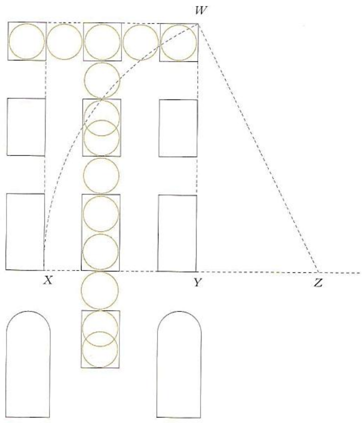


Figure 5. Classical Proportions of a Typical Facade

Using GDL a set of rules has been developed to alter the shape vocabulary (Fig. 4) to represent various arrangements of classical buildings. Rules are developed to repeat tiles in various arrangements depending on user parameters for the general building structure (Fig. 6). Other rules generate window openings based on classical proportions and position additional library objects to build the complete façade. An example of procedurally built elements from the wall façade along with the original shape vocabulary used to create the object can be seen in Fig. 6.

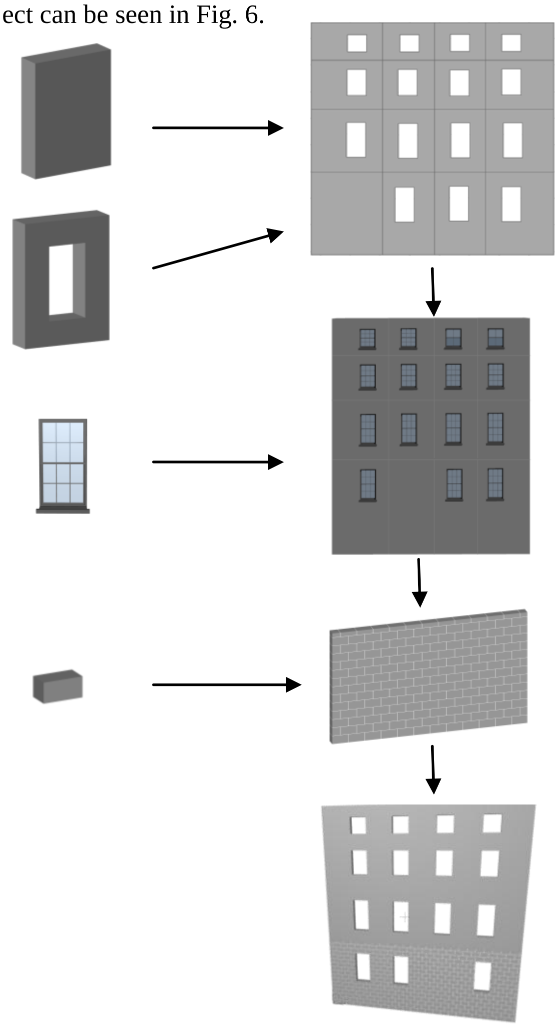


Figure 6. Shape vocabulary (left) & Proceduraly build façade elements (right)

After the wall façade has been automatically generated using classical proportions the user can overlay the results with the original survey data and if necessary manually refine elements that don’t match up. 2D orthographic imagery obtained from laser scan data or image modelling is used for this process. Using GDL scripting certain parts of the model have been scripted to move in a defined, constrained manner. This enables a user to select a part of the building in 2D elevation or 3D and move it to the correct position (Fig. 7). This method allows for very fast editing to refine the position of element in the model.

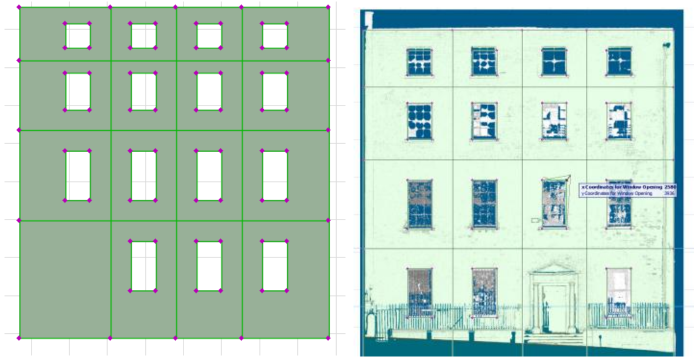


Figure 7. Wall façade with editable points marked (left) & Wall façade overlaid with survey data (right)

An example of a procedurally built wall façade can be seen in Fig. 8 below.

Figure 8. Example of Procedurally Built Wall Facade

D. Mapping Library Objects to Survey Data

A combination of the semi-automatic procedure described in the previous section and manual positioning of library objects is used to complete a HBIM model for a heritage site. For building facades the procedural methods are applied. Other objects can be created by manually selecting the required parametric library object, adjusting their parameters and plotting to survey data. Using BIM software objects are positioned in 2D, first in plan and then in elevations and sections. Orthographic images, sections, plans and segmented point clouds are used during the plotting stage to position library objects.

IV. INTEGRATION OF HBIM & CITYGML

A. 3D GIS & CityGML

A Geographic Information System (GIS) is used for storing, visualising and analysing geographic data. Information stored in database tables is associated with geographic locations (map data) to analyse data spatially. Traditionally GIS systems are used with 2D map data however recent development such as CityGML allow for the development of 3D GIS systems which have much better capabilities for management, analysis and visualisation of data. Applications of 3D GIS include 3D cadastre, planning, disaster management, noise mapping and also cultural heritage.

CityGML is an international standard data format for representing 3D urban objects. CityGML is an Extensible Markup Language (XML) format which is an application of the Geographic Markup Language 3 (GML3). Unlike many other 3D data formats, CityGML can store more than just 3D geometries. CityGML describes objects in relation to their geometrical, topological, semantical and appearance properties [9]. This enables many more applications than just visualisation. CityGML models can be semantically classified with attributes and external references connected to elements within the model. This allows for very efficient management and analysis of information relating to a 3D model. These benefits are very suitable for cultural heritage modelling as it allows to the geometry of a heritage site to be recorded along with other historical information or records stored as attributes or links to external content. Because CityGML is an XML format it also facilitates visualisation and sharing over the internet. This enables easy sharing of digital heritage models.

B. Conversion HBIM to CityGML

Converting 3D models to CityGML requires converting geometry but also semantic information which describes the classification or sub elements in the model. An initial method for converting models to CityGML was tested using a plug-in for Google SketchUp software which has capabilities for converting SketchUp models into CityGML. Both the Google SketchUp software and the plug in are open source and can be freely downloaded. An advantage of this method is that the geometry is automatically converted to CityGML. However, a disadvantage is that semantic information contained in the BIM model is not retained and so it requires the manual association of semantic classes within Google SketchUp.

Because HBIM models are based on the IFC format the model is already classified into semantic classes. This object orientated model enables a more automated conversion to CityGML where the IFC semantic classes are mapped to the relevant CityGML classes [1]. The open source Building Information Model Server based on IFC provides export functionality directly to CityGML.

1) Linking Data

Once the model has been converted to CityGML the next stage involves adding additional information to the model. This is done by editing the xml file directly and adding the required attributes. CityGML has a number of predefined attributes for each semantic class. For heritage applications the building attributes for *'year of construction'* and *'year of demolition'* are very useful for documenting the chronology of a building or building parts. This allows for modelling the changes of a heritage object over time. This is crucial to assist with conservation and restoration of heritage objects. CityGML also allows for external resources to be connected to a model or specific parts of a model as illustrated in Fig. 9 external resources can include databases or websites. This is very beneficial for heritage documentation as it allows for existing heritage records to be linked to the 3D heritage model.

Figure 9. External References attached to parts of a Building [14].

An example of the entire process applied to a heritage project at Henrietta Street in Dublin can be seen in Fig. 10 below. Fig. 10a shows the point cloud from a laser scan survey, Fig. 10b shows a subsequent HBIM model that was created and finally Fig. 10c shows the model converted to CityGML for additional management and analysis.

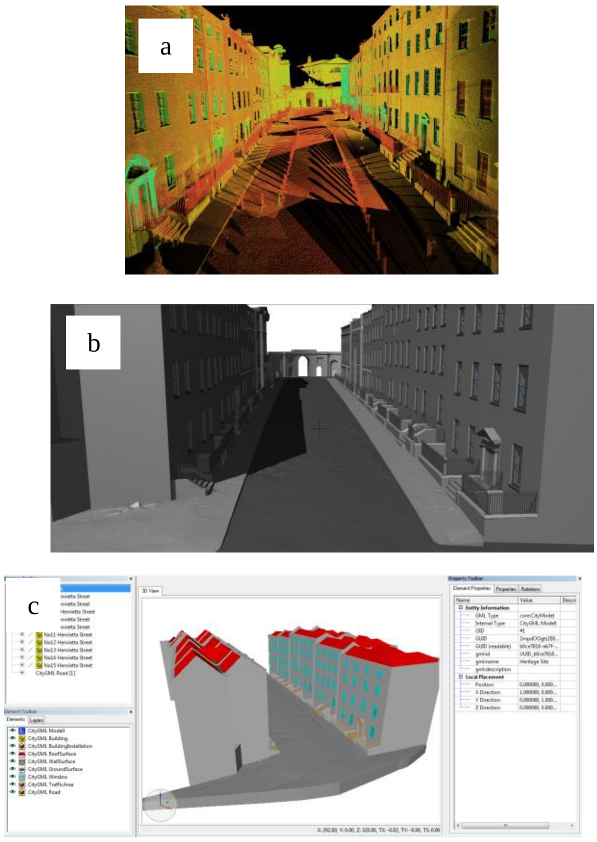


Figure 10. Laser scan point cloud (a), HBIM model (b) and CityGML model (c)

V. Conclusion

The initial results from this research have shown the capabilities for semantic modelling and analysis from the proposed workflow from laser scan, HBIM to CityGML. The workflow provides new tools and methods for 3D virtual heritage modelling, documentation, management and analysis. The use of laser scanning and photogrammetry can record very high and accurate levels of detail in the field for heritage documentation. The HBIM process can automate and speed up the modelling stage by using accurate parametric objects and procedural modelling techniques. As a result of HBIM automated conservation documents such as plans, section and elevation can be produced. Finally the integration to CityGML can provide further capabilities for linking the 3D heritage model to information systems. The CityGML model can be integrated into GIS platforms for efficient management and analysis that is required for maintaining important cultural heritage sites.

References

[1] Berlo, Lv & Laat, Rd 2010, 'Integration of BIM and GIS: The Development of the CityGML GeobBIM Extension', paper presented to 5th International 3D GeoInfo Conference, November 3-4, 2010,, Berlin, Germany, Berlin, Germany.

[2] Boehler, W & Heinz, G 1999, 'Documentation, Surveying, Photogrammetry', paper presented to XVII CIPA Symposium, Olinda, Brazil, 3rd - 6th October 1999,<http://cipa.icomos.org/text%20files/olinda/99c601.pdf>.

[3] Chevrier, C, Charbonneau, N, Grussenmeyer, P & Perrin, J-P 'Parametric Documenting of Built Heritage: 3D Virtual Reconstruction of Architectural Details', *International Journal of Architectural Computing*, vol. 08, no. 02, pp. 131-45.

[4] D'Andrea, A 2008, 'Sharing 3D Archaeological Data: Tools and Semantic Approaches', paper presented to 14th International Conference on Virtual Systems and Multimedia, Limassol, Cyprus, October 20th - 25th, 2008.

[5] De Luca, L 2012, 'Methods, Formalisms and Tools for the Semantic-Based Surveying and Representation of Architectural Heritage', *Applied Geomatics*, no. 1866-9298, pp. 1-25.

[6] Delgado, F, Martínez, R, Hurtado, A & Finat, J 2010, 'Extending functionalities of Management Systems to CityGML', in *eWork and eBusiness in Architecture, Engineering and Construction*, CRC Press, pp. 409-15.

[7] Fai, S, Graham, K, Duckworth, T, Wood, N & Attar, R 2011, 'Building Information Modelling and Heritage Documentation', paper presented to XXIII CIPA International Symposium, Prague, Czech Republic, 12th-16th September, <http://cipa.icomos.org/fileadmin/template/doc/PRAGUE/047.pdf>.

[8] KELLY, G. and MCCABE, H. (2006). “A Survey of Procedural Techniques for City Generation”, Institute of Technology Blanchardstown Journal, Vol. 14: 87–130.

[9] Kolbe, T, Gröger, G & Plümer , L 2005, 'CityGML – Interoperable Access to 3D City Models', paper presented to International Symposium on Geo-information for Disaster Management, Delft, The Netherlands, 21 - 23 March 2005.

[10] Kolbe, T 2007, 'CityGML Tutorial', Technical University Berlin. <http://www.citygml.org/fileadmin/citygml/docs/CityGML_Tutorial_Kolbe_Internet.pdf>

[11] McEnroe, GD 2009, 'A Feasibility Study on CityGML for Cadastral Purposes', Eindhoven University Of Technology. <http://alexandria.tue.nl/extra1/afstversl/wsk-i/dsilva2009.pdf>

[12] Murphy M, McGovern E & Pavia, S 2011, 'Historic Building Information Modelling - Adding Intelligence to Laser and Image Based Surveys', paper presented to 4th ISPRS International Workshop, 3D-ARCH 2011: "3D Virtual Reconstruction and Visualization of Complex Architectures" Trento, Italy, 2-4 March 2011.

[13] Murphy, M, McGovern, E & Pavia, S 2009, 'Historic Building Information Modelling (HBIM)', *Structural Survey*, vol. 27, no. 4, pp. 311 – 27.

[14] Open Geospatial Consortium Inc. 2008, *OpenGIS® City Geography Markup Language (CityGML) Encoding Standard*, Open Geospatial Consortium Inc., Berlin.

<http://www.opengeospatial.org>

[15] Ulm, K 2010, 'Virtual 3D City Models - satisfaction through sustainability', *Geomatics World*, vol. 18, no. 6, pp. 16-8.