ARCHITECTURAL INFORMATION MODELLING FOR VIRTUAL HERITAGE APPLICATION

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ABSTRACT:

In today's AEC industry (Architecture, Engineering and Construction industry), there has been a vast evolution in the usage of information and communication technology (ICT) for describing and managing construction projects. During the past years this led to the elaboration of the technique Building Information Modelling or BIM for describing buildings and building information according to their different composing elements. One of the major advantages in this BIM approach is the possibility to use this building information for calculation, simulation and analysis in related, more dedicated ICT applications. Starting from the building information model, these applications are accessible through an interoperability language, namely the Industry Foundation Classes (IFC), elaborated by the International Alliance for Interoperability or IAI. This paper proposes the development of an approach similar to BIM, namely Architectural Information Modelling (AIM), which describes more theoretical and historical building knowledge instead of the explicit and component-based descriptions inside BIM. It illustrates several possible advantages of this AIM approach for application in building documentation for virtual heritage, combined with possible historical analysis tools. It also makes a short comparison of this technique with procedural methods, a similar technique that is gaining much interest during the past few years in the domain of virtual heritage. Finally, this paper proposes future research ambitions and some conclusions of this first, conceptual research about an architectural information modelling approach.

1. INTRODUCTION

The digital archiving process, the management and the providing of accessibility for virtual heritage information has been actively researched over the past two decades. An exemplary organisation that performs active and thorough research on this domain and the possible techniques for this purpose is the World Heritage Centre (WHC) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO). In order to make the world heritage virtually accessible for historical research, numerous disappeared monuments have been reconstructed and digitised under their impulse (Quintero, 2003).

For the digitalisation of our cultural heritage, very diverse ICT techniques can be used, i.e. three-dimensional modelling techniques (Quintero and Jansen, 2002; Müller et al., 2005), digital drawings, maps and plans, reconstruction techniques based on photo material (Van Gool et al. 2002; 2004), procedural modelling, etc.

This paper focuses on one particular ICT technique that can be used in the digitalisation and archiving process, namely the three-dimensional information modelling technique. A possible workflow, corresponding advantages, and new perspectives that can be offered for virtual heritage by this technique, will be illustrated in this paper. This will be based on earlier performed, historical research about the former Casino in Ghent (Boydens, 1986). This building was designed and built by architect Louis Roelandt in 1836 and was demolished in 1945.

A building information model has been constructed in Autodesk Revit Architecture 2008 (Figure 1). This BIM modelling technique and its advantages are shortly commented and illustrated.

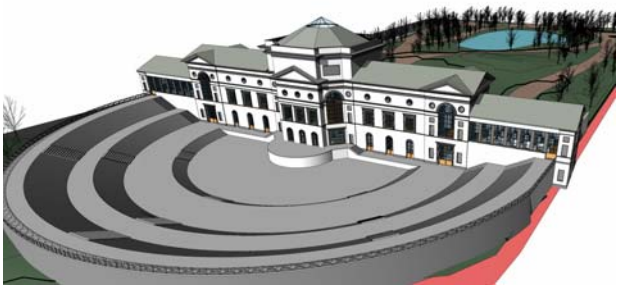

Figure 1: Exterior view of the *Building Information Model* of the *Casino* in Ghent.

1.1 Building Information Modelling

The different objects in the BIM model in Figure 1 (doors, walls, window, spaces, etc.) are modelled and stored in an object-oriented structure, using several proprietary file formats. However, these file formats lack the required interoperability for further simulation, evaluation and analysis.

Through a newly created file format, namely the IFC standard or Industry Foundation Classes, this issue of interoperability is countered. This IFC file format is created as a highly interoperable information structure, that tries to guarantee that the information in this IFC format can be browsed and queried on an object-oriented and semantically rich basis.

By fulfilling this purpose, software creators do not need to develop their applications in correspondence with specific file formats or dataflow structures of existing applications. Instead they only have to rely on this internationally standardised, ontological format, that describes building information of different projects, monuments and buildings in a similar grammar and syntax (Penttilä, 2007; Penttilä et al., 2007).

1.2 Advantages

Concerning information management issues, this characteristic purpose and work method of BIM and IFC is considered to be a solid and useable improvement in building industry. One information model in a standard interoperable data format can be constructed centrally in any small- or large-scale building project, from which every actor in this project can extract the required information. It seems that in today's AEC industry this is particularly used in the construction phase of architectural design and building projects (Penttilä, 2007).

Following the BIM information modelling techniques and the creation of the IFC data standard, numerous ICT applications are being developed, which are capable to read the information of this model via IFC and use it directly to perform automatic analyses, simulations and calculations. It is possible for instance to automatically perform a cost calculation or to compose a time planning proposition for a building project, or for example to perform different heat transfer simulations and building permit analyses.

A more theoretical and historical kind of information could be used as well in this information modelling technique. By giving this small, but very meaningful twist to the actual contents of the present information modelling approach, a whole new range of applications can emerge. An important set of applications can be situated in the preliminary design phase of an architectural project, but also in the work methods and dataflow in the digitalisation and documentation process for virtual heritage projects.

This hypothesis is illustrated and documented in the remainder of this paper, through the architectural information modelling approach. This technique is mainly based on the existing BIM approach, but is using different, more theoretical and historical information instead of the construction-minded, components-based building information of the present BIM approach. The historical context of the Casino in Ghent (Figure 1) is used as an illustrating example.

2. ARCHITECTURAL INFORMATION MODELLING

2.1 Usability in virtual heritage applications

Based on the scarcely found information about a certain architectural building or monument, a three-dimensional information model can be constructed. In this model the different kinds of information, ranging from explicit to more implicit historical and theoretical information, can be appended to the different elements of this model. This information can be added in the form of building features, similar to the BIM work methods (Eastman et al., 2008).

In a cultural heritage application, this could lead for instance to the following workflow. A reconstruction is performed for a specific cultural heritage building or monument of which only a few elements of information are found through historical research. For each recovered building element, information is added to the central architectural information model, continuously expanding the knowledge of this specific cultural heritage building and thus expanding the global virtual heritage knowledge.

On one hand this added information can be concrete geometrical parameters, material characteristics or references to explicit research material, like photographs or scanned documents. On the other hand also more abstract or implicit information can be modelled, such as references to similar projects or projects of significant historical influence, known typological information, environmental constraints or regionally applied regulations that have been followed and are critical in the understanding of that particular project.

2.2 Methodology

As a starting point for a conceptual test-case, it was stated that the modelling technique can be used for describing the building structure of the Casino, not through the composing building elements (doors, walls, windows, etc.), but through the actual spatial structure, a network of spaces. This abstract spatial structure could then form the core structure of the actual architectural information model, to which further architectural information is appended as different kinds of features. These features range from typological information to spatial relations and historical references for instance, as well as the actual geometric building information.

The spatial structure of the Casino for example ('central hall', 'far wing north', …) can then be modelled to its three-dimensional overall shape in an architectural information model (Figure 2).

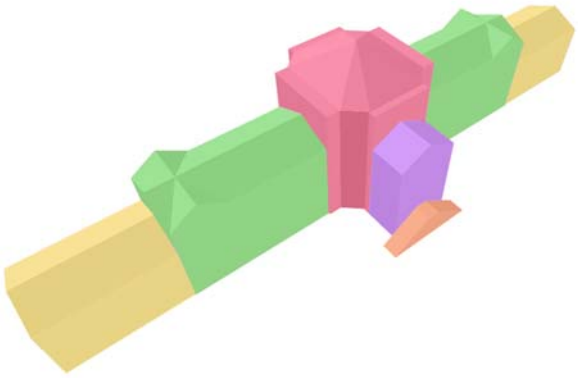

Figure 2: Architectural information model, showing the overall spatial structure of the Casino in Ghent.

In this three-dimensional architectural information model, every building block is divided into several underlying abstract spaces, as shown in Figure 3. The building block 'central hall' for example is divided into two building levels, each containing one space, namely a 'storeroom' and a 'reception hall', depending on the information that is found in the performed historical research.

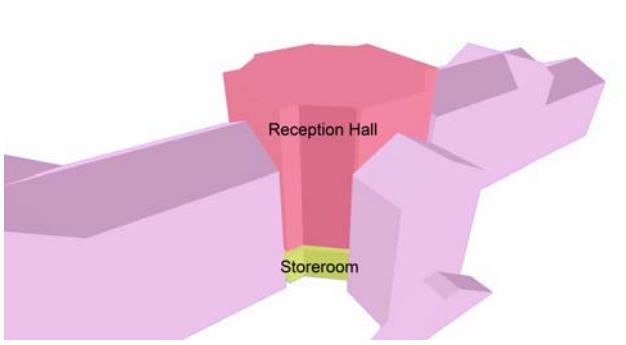

Figure 3: Each building block in the architectural information model is divided in different spaces, like for instance ‘storeroom’ and ‘reception hall’.

Starting from this schematic spatial information model, containing more abstract and spatial than precise and detailed building information as a core structure, a high amount of information is added during different stages of historical research. Each part of information is linked to the corresponding part of the spatial structure in the AIM model. This information can be very diverse, exactly because there is only an abstract spatial model lying at the basis of the model, instead of the actual building components (i.e. complete walls, windows, columns…), that prove to be too complex and detailed to start modelling from the research start (Penttilä, 2007).

The added information covers the actual geometric descriptions of the spatial structure. To each building block or space different annotations are added about the actual building components that are known to limit and form the considered part of the spatial structure. Figure 4 shows the different building components that constitute the ‘central hall’ of the Casino. Each of these geometric building components would then contain further detailed information, as is already happening inside the BIM approach.


Figure 4: Geometric building components that are annotated to the 'central hall' of the Casino in Ghent.

In addition, more abstract theoretical and historical knowledge is also added to this spatial structure, such as references to historical plans or other documentation that was found in the historical research project, or possible relations between spaces and typological annotations. It is also possible to add certain information about a time range wherein the element that’s being considered, existed, or implicitly present environmental or architectural parameters and constraints that shaped the building during different design phases.

The resulting information model contains for almost every part of the building its documentation and information, directly bound and visualised to the actual element it belongs to (a space, an abstract typology, a wall or floor, an historical reference, etc.). In this way, the AIM modelling technique probably improves existing methods for documentation and digital archiving by making architectural, historical and theoretical research more efficient.

The amphitheatre at the backside of the Casino (Figure 1) for instance is probably shaped by a former hill slope with a windmill on top. In case an architectural information model for this windmill existed, it could be referenced in the AIM model for the Casino. In that way, the user who is actually interested in the Casino information, could also have a preview of the information about the windmill, for example the time period it was standing there and information about the way it was built and the way it influenced the conception of the amphitheatre and the Casino.

The information about the windmill would then probably be coming from earlier research projects. By archiving this information linked to the specific correlated elements in a standardised architectural information model, it becomes possible for a user to quickly and intuitively review the information connected to a structure that is somehow related to the building he is actually interested in at that moment, without having to go through a thorough historical research project in order to find all related historical documentation and original plan material of that related building.

2.3 Advantages and possibilities

Besides the advantages which this architectural information modelling approach could give for the process of digitising, documenting and archiving of theoretical and historical building information, the approach could also generate several new perspectives in the creation of applications that can (re)process this information.

When, for example, the more explicit, geometric parameters and the use of different object types (window types, door types, column types, …) are considered, it is possible to develop applications that can look for certain similarities and differences between two different buildings in this global virtual heritage.

Considering ‘Le Palais de Justice’ in Ghent (Figure 5), which was equally designed by architect Louis Roelandt, there are undoubtedly resemblances and similarities to be recognised between this building and the Casino he designed almost at the same time a few blocks further in the city. The five doors for example, which are indicated in Figure 5, are most probably the same as some of the doors he used in the Casino and that can be found at ground level in Figure 1 and Figure 4.

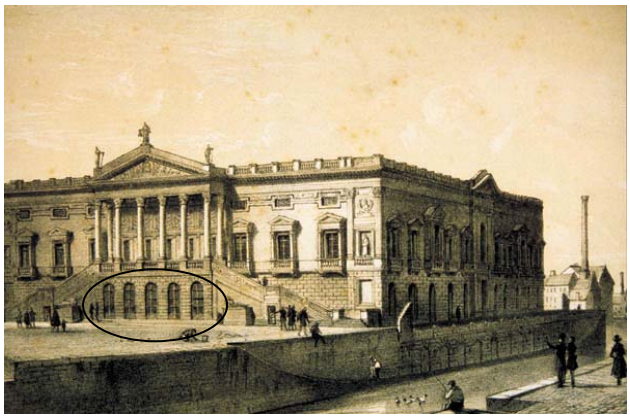

Figure 5: 'Le Palais de Justice' in Ghent, by architect Louis Roelandt in 1836.

By modelling more abstract theoretical and historical information, in addition to the pure geometric information, it is possible to search for similarities between this sort of information as well. If the AIM approach can make it possible to explicite information about how architect Louis Roelandt conceptually designed both the Casino and 'Le Palais de Justice', this information could be (semi-)automatically queried by dedicated applications to find out if there are similarities or remarkable differences in the design methods and decision-making that shaped the two buildings, or maybe if one design obviously influenced the other design, etc.

If these research possibilities are extended towards different architects and different time periods for instance, the AIM approach can probably generate several more advantages, which can hardly be foreseen at this moment, for the use and research of design and theoretical or historical information in the virtual heritage domain.

3. INFORMATION MODELLING OR PROCEDURAL MODELLING

A technique that is quite similar to the AIM approach and that has gained remarkable interest during the past few years in cultural heritage research, is procedural modelling (Parish and Müller, 2001). One of the variants of this procedural modelling technique, namely the procedural modelling approach based on style grammars, shows a great resemblance to the presented architectural information modelling technique. This grammar-based procedural method is already used in several application domains, such as urban modelling (Parish and Müller, 2001) and modelling for virtual heritage application (Müller et al., 2006).

In this grammar-based procedural modelling technique it is made possible to define sets of meaningful parameters and functional rules to three-dimensional models. These are capable of describing different building styles, with which several 'similarly styled' buildings can semi-automatically be generated, to form a complete urban landscape, a possible alternative formalism in a cultural heritage monument (Müller et al., 2006), etc.

The procedural modelling technique is at this time mainly used to facilitate the three-dimensional modelling process of big and complex datasets (i.e. infinite urban landscapes, highly detailed and complex heritage monuments, etc.). Therefore, the amount of information that is subject of this technique is kept to a minimum.

In (Müller et al., 2006) for instance, a procedural modelling workflow is elaborated for the Mayan Puuc buildings in Xkipché. It shows very effectively how a lot of modelling and alteration work can easily be done in a procedural method by common archaeologists. However, also several encountered problems have been situated in (Müller et al., 2006), of which one is stating that the model is detailed only to a certain level and lacks an amount of precision for the actual documentation purposes needed in virtual heritage (i.e. imprecise door locations, missing GIS data, etc.).

Despite the several resemblances between the architectural information modelling and the procedural modelling approaches, the two techniques are quite different at this specific point. At this time of research for the information modelling approach, the accent namely lays on the actual information of the building itself and less on the resulting visual appearance or the way how archaeologists could create and alter this building model.

This means that much more parameters and information is archived and made accessible in the architectural information modelling approach, not only of a pure geometric or visual kind, but also of more abstract and implicit building knowledge of a theoretical and historical kind. An AIM model for the Puuc buildings in Xkipché would for instance contain more detailed instances of doors and windows than is possible at this moment using procedural methods. Also detailed information such as the materials used in this temple or for instance the actual reasoning of the Mayans in the conception and the building process of the temple in question, could be added for documentation of the actual cultural heritage information.

A more extensive comparison between this procedural modelling technique and the proposed architectural information modelling technique is needed, but exceeds the scope of this paper. Both approaches have their advantages and disadvantages, and probably none of them is the 'perfect' or 'right' approach. If the advantages of both techniques however, could be combined in one integrated approach, archaeologists, as well as building modellers, architects and people from many other scientific domains would benefit.

4. FUTURE WORK

At the time being, the AIM research has been preserved to merely conceptual research activities. As a start, the different aspects that may be needed in an architectural information modelling approach have been shaped to a conceptual completed scheme. In this conceptual shaping process, the different possibilities and advantages which the information modelling technique can generate in combination with dedicated virtual heritage ICT applications, have been identified and denominated.

However, to make this conceptual AIM approach actually work in a virtual heritage environment, two fundamental steps will be taken in further research.

The first step is the definition of an appropriate equivalent of the existing IFC Classes in the BIM approach, for application in the AIM approach. The IFC classes that are used in the BIM approach, are namely limited to machine-readable, concrete

information, i.e. financial costs, material names, construction phases, etc. and don't describe more theoretical and historical information, which is necessary in an architectural information modelling approach.

The second step in future research also applies on this distinction between concrete building information and more abstract, theoretical and historical information. Where the more concrete building information can be rather easily identified and uniquely denominated, the description of more theoretical and historical information is difficult. For instance, while the description of a concrete wall into physical characteristics and exact measuring data is precisely known and therefore easily made machine-readable, a lot of theoretical concepts and historical knowledge stays locked in images and sketches or between the lines of texts for example, and therefore explicitly require human interpretation and intelligence.

When the aim is to unlock this knowledge as well, there will be a certain amount of machine intelligence needed. At the time of writing, several international research projects are performed to improve this machine intelligence. One of these research projects for instance is performed by (Berkhahn and Tilleke, 2008), who use neural networks and topological models to recognise dimensions and common lines out of 2D images and plans. After this recognition process a three-dimensional model can be built in IFC, using the recognized information.

However, this is only one of the possible ways to improve machine intelligence and computer vision for the recognition of information out of images, text, video and other multimedia. Further research has to be done on this subject to evaluate the possibilities in using and possibly further improving these techniques.

5. CONCLUSION

Different kinds of ICT digitalisation techniques and applications can be used for the digitalisation, documentation and archiving of virtual heritage information. In this paper, one of these techniques is highlighted, namely the three-dimensional information modelling technique that is known as Building Information Modelling or BIM in architectural design practice. This technique describes the different composing building elements according to their composition, characteristics and other kinds of information. Using a standard IFC (Industry Foundation Classes) file format, this information can be stored in a highly interoperable structure. This makes it possible for other ICT applications to perform simulations, calculations, etc. based on this information.

The same modelling technique, that has proven its documentation and archiving advantages already in architectural design practice, can possibly be used as well to model more theoretical and historical information which can be useful for virtual heritage application. An alternative information modelling technique is proposed, namely Architectural Information Modelling or AIM for the digitalisation, documentation and archiving of the international cultural heritage.

By using this modelling technique, new ICT applications can emerge, based on the information in the central architectural information model. Several possible applications and the corresponding advantages of using these applications have been highlighted in this paper. The exact possibilities and advantages of using the proposed architectural information modelling technique for virtual heritage purposes are at this moment however rather unclear and still depend largely on the results of the development of the architectural information modelling technique itself.

In the further development of this architectural information modelling technique, first attention will go to the delineating and structuring of the actual theoretical and historical information in this AIM approach. Since there are no 'Architectural' Foundation Classes available at this time, these classes will be developed during further research. The combination of the AIM techniques with related techniques, such as procedural modelling methods and techniques that try to improve machine-readability of documents and the actual machine intelligence, will be researched.

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