Management of Architectural Heritage Information in BIM and GIS: State-of-the-art and Future Perspectives

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Abstract

Information management technology is widely used in a variety of fields and it proved its great potentials also for the Cultural Heritage (CH) sector. Considering the management of architectural heritage information, there exists a distinctive factor which does not exist in any other field: a multi-layered spatial character in the third (or even fourth) dimension. Moreover the semantical enrichment of three-dimensional (3D) digital models by integrating heterogeneous datasets has a crucial importance. Nevertheless, the organization and structuring of such information is considerably difficult although very useful for better conservation and management purposes.

Accordingly, researchers have recently developed different techniques for the coherent and reliable management of information related to architectural heritage. The approaches so far developed have pros and cons since data processing and visualization is not a simple and straight-forward process. The paper presents a review of the current management approaches for architectural heritage information with Building Information Modeling (BIM) and Geographic Information Systems (GIS) tools, illustrating up-to-date approaches and describing possible future research directions.

1. Introduction

Today there is a great increase in the number of new documentation techniques applied to architectural heritage in order to gather radiometric, geometric, spatial and multi-temporal data. This opportunity gives heritage professionals the possibility to have digital cultural data in three dimensional (3D) forms and process, analyze and display them in different methods or graphical representations as two dimensional (2D) thematic/analytical maps, orthophotos or even four dimensional (4D) models. As stated in Letellier (2007), prior to conservation works and within the long and unique process of documentation and research activities, a large amount of heterogeneous information in both qualitative and quantitative formats is produced. In addition, as conservation is a continuous activity, each time, conservation professionals need to adequately collect and process multi-temporal information. Putting together all the collected and produced information is very crucial and sometimes time consuming as they are spread in various digital platforms and formats in files/folders of offices who produced them or in the archives of related government offices. Furthermore the resulting 3D geometric models, together with other heterogeneous datasets and the supportive material (technical reports, photographs, legal documents, etc.) are very often not able to be stored in a holistic 3D repository in order to be easily accessible and visualized. In this context, recent information management approaches, developed for the continuous and correct maintenance of heritage buildings, play an important role. As these are the facts, the realization of a holistic 3D spatial repository applicable to various scales and heritage buildings and able to allow both information retrieval and visualization, becomes a crucial concern and it is still an open research issue (Manferdini and Remondino, 2012).

Based on these topics, the paper presents a review of Building Information Modeling (BIM) and Geographic Information Systems (GIS) approaches for the management of architectural heritage information. The article will not consider efforts originated in the general construction industry as those solutions consider mainly newly constructed buildings using simple and modern geometric primitives and so are not applicable to heritage structures. Existing research approaches are critically reviewed with a final assessment on possible future research topics.

The structure of the paper is as follows: Section 2 reports the state-of-the-art in heritage information management with a critical evaluation of recent researches and trends in the field. Section 3 gives an assessment of the heritage data to be managed with related conservation aspects. Then, the fourth section includes an example showing how a historical building could be managed with a 3D spatial repository which includes also heterogeneous supportive material. Finally, conclusions wrap up the paper reporting challenges and a future vision to fulfil the gap in the field.

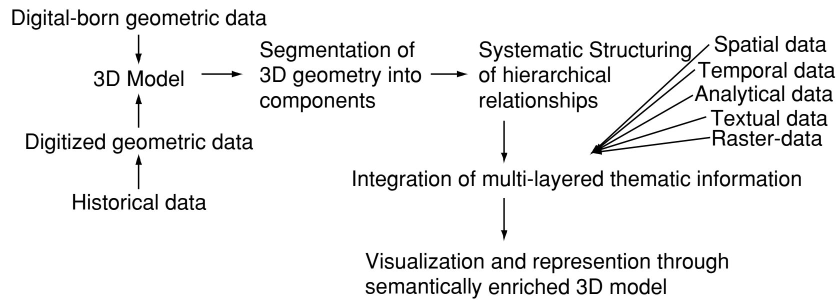
2. State-of-the-Art of Architectural Heritage Information Management with BIM And GIS

Information management systems have great importance for a large variety of disciplines. When it comes to the management of heterogeneous data in three dimensions and their possible correlation with any other geometric dimension (e.g., linear, planar/surface, or adding the dimension of time), there is a great need for a built-in support in information management systems for spatial and temporal operations (Halpin and Morgan, 2008). In fact, the creation of a complete and general 3D repository for efficient management of heterogeneous (2D and 3D) heritage data in a spatial environment, able to manage semantically enriched 3D models, is not a straight-forward task and no commercial solutions are available.

At architectural scale, the most proximate concept is the Building Information Modeling (BIM) (Eastman *et al*., 2011), which is a new paradigm and representation mode derived from the management necessities of architectural and engineering industry. It offers an integrated approach to represent both physical and functional characteristics of buildings and comprises efficient representation tools to obtain semantically enriched 3D models. The primary development of BIM has been based on the support of 3D models derived from design data (as-designed BIM) (Huber *et al*, 2011). Indeed, the requirements for representing any building which does not carry homogenous characteristics and for describing as-found state (as-built BIM) are quite different from the requirements of modern buildings derived from design data. Consequently, the concept of as-built BIM approaches could offer an interesting opportunity in heritage applications to manage geometric 3D information of single components, establish relations between them and attributes and add material properties to the components.

Focusing more into heritage buildings, 3D geometric models showing as-found physical condition of historic buildings are the primary data in architectural conservation. Besides this, an efficient information management in three dimensions for any historic building should take into consideration three main concepts: (a) segmentation, (b) structuring the hierarchical relationships and (c) semantical enrichment (Figure 1). Regarding the segmentation phase, the identification of different architectonical components in point clouds and 3D meshes is of primary importance. There are mainly four type of as-built BIM approaches, based on heuristics (Vosselman *et al*., 2004; Pu and Vosselman, 2006; Pu and Vosselman, 2007; Rusu *et al*., 2009), context (Xiong and Huber, 2010), ontologies (Yue *et al*., 2006) and prior knowledge (Hmida *et al*., 2012). A typical pipeline for as-built BIM generation is composed of the following chain (Hichri *et al*., 2013): (i)

Figure 1. The general workflow diagram for semantically enriched 3D heritage models.



geometric data acquisition and creation of unstructured point clouds, (ii) segmentation into regions using several segmentation algorithms, (iii) production of 3D models and (iv) enrichment using different recognition techniques. However, it is not enough to detect the 3D meshes' sub-parts as architectonical components (walls, windows, doors, etc.). For example, if a wall is identified, it should be specified where this wall is connected, to which walls it is adjacent and is hierarchically part of which space(s). Only in this way it is possible to define mutual relationships of the components with each other in a hierarchical order. In addition, architectonical components of historic buildings often lose their shape similarities over time because of deteriorations and alterations. So, for the production of semantically enriched 3D models of any heritage building, the use of automated segmentation algorithms or shape recognition is in fact not enough.

Recent research interests proved the importance of semantically enriching 3D models to provide a more comprehensive repository of any architectural heritage building. Nevertheless, applications in this field are still in its early stages due to the multiple challenges of the topic. Some researchers (see Table 1) have already focused on obtaining enriched 3D models applied to the case of historic buildings for efficient information management. Regarding the primary concept of gathering semantically enriched 3D models, beside Garagnani (2012), 3D segmented/enriched geometric reproductions derived from unstructured point clouds are very limited. Moreover, the available commercial software, with the exception of Autodesk Revit, is not proposing new functionalities for dealing with dense point clouds. In fact, there is no package ensuring a direct shift from the point cloud to complete 3D models. The drawbacks of many approaches (Apollonio *et al*., 2012; Boeykens *et al*., 2012; Dore and Murphy 2012; Murphy *et al*., 2013) can be very relevant in some specific types of architectural styles. However, such methods are not covering the requirements of historic buildings at all as they are mostly characterized by varied shape components. Moreover, no architectural component is exactly horizontal or vertical in the case of any heritage building, being often tilted. Some elements are even more complex such as carved

Table 1. Current research approaches for obtaining semantically enriched 3D models for architectural heritage information management.

Approach Type	Reference Paper(s)	Applied Case	Used software	Plug-in/ Extension(s)	Advantages	Limitations
As-built BIM	Garagnani (2012)	An Early Byzantine church	Autodesk Revit Architecture	GreenSpider plug-in	The capacity for transtion into segmented 3D geometries from unstructured point clouds.	Enhancement of segmented 3D geometries with the assignment of thematic attributes are not considered.
Integration with As-built BIM	Yajing and Cong (2011)	Stone heritage of Ta Keo Temple	3D MAX, SketchUP, Geomagic, AutoCAD, Autodesk Revit	none	Conceptual classifications and thematic representations.	Routine family classification is not fitting for conservational needs of stone heritage in order to manage attributes.
As-built BIM	Attar *et al.* (2010)	Historic warehouses converted into offices	Autodesk Revit, AutoCAD	gbXML extension, EnergyPlus	Evaluation/analysis of the building performance and energy efficiency.	Pre-defined hierarchical scheme based on structural component types is restricted. Integration of analytical data is not considered.
Hybrid	Achille *et al.* (2012)	Main Spire of Milan Cathedral	Rhinoceros, WEBGL, Back Office, Front Office	Pointools for Rhino plug-in	The use of 3D model as a repository containing photographic catalogue and descriptive images. Ability of web-sharing.	Generation of 3D modell modelling and integrating together the information is a long manual process. Hierarchies are not structured.

Table 1. (Continued)

Approach Type	Reference Paper(s)	Applied Case	Used software	Plug-in/ Extension(s)	Advantages	Limitations
Integration with as-built BIM	Oreni *et al*. (2012), Oreni *et al*. (2013)	Various types of historical vaults	Leica Cloudwork, Autodesk Revit, AutoCAD, Rhino	Leica CloudWorx plug-in	The ability of surface connection with 3D objects.	Emphasis is limited into segmentation rather than indispensable thematic enhancement.
As-designed BIM	Apollonio *et al*. (2012)	Palladian architecture – doric order	Autodesk Revit	none	The capability to re-use/edit geometry in terms of object-based parametric modeling.	Modeling process of complicated geometries is beyond the capabilities. Pre-defined relationships of element families do not correspond needs.
As-designed BIM	Boeykens *et al*. (2012)	Prague Vinohrady synagogue	Graphisoft ArchiCAD, Maxon, Cinema4D	none	The possibility of re-using/editing specific geometries in similar type of architectural style.	Integration of point-cloud into the system is not yet possible. It is limited in adjustments for changing the elements' parameters.
As-designed BIM	Murphy *et al*. (2013)	Various elements of classical architectural style	Graphisoft ArchiCAD	none	Generation of parametric historic components' libraries.	Thematic attribute management is not focused.
BIM-based	Fai *et al*. (2013)	Urban cluster of 19th century heritage buildings	AutoCAD, Civil 3D, SketchUP, Revit, Navisworks	none	Revealing time-based parametric relationships.	It is limited to 3D and 4D modeling. Thematic enhancement is not emphasized.

Approach Type	Reference Paper(s)	Applied Case	Used software	Plug-in/ Extension(s)	Advantages	Limitations
Hybrid	Arayici (2008)	A heritage building under refurbishment	IMMerge and IMEdit modules of Polyworks, Microstation Triforma	IFC plug-in	Innovative for library creation. Pattern matching of new shapes from the existing graphics is useful.	The annotation for large geometric entities is a complex process.
GIS-based	Centofanti *et al*. (2011)	A complex villa and two churches in Italy	AutoCAD, 3D Studio Max, Rhinoceros, Rapidform XOR, Microsoft Access, ESRI ArcGIS	none	Integration of heterogeneous data in a single platform.	Hierarchical relationships in order to do relational queries are not structured.
Hybrid GIS-BIM	José-Alanso *et al*. (2009)	Various heritage objects	PINTA combining CAD and GIS functionalities	none	Combination of CAD & GIS functionalities. Concerns on interoperability. Assignment of thematic layers and keyword annotation.	Volumetric segmentation is problematic. It does not allow the entire perception of the heritage building. The software does not have a wide-range use.
GIS-BIM integration	Dore and Murphy (2012)	A number of heritage buildings	Graphisoft ArchiCAD, Google SketchUp, CityGML	Plug-in for SketchUp	The integration of CityGML model into GIS platforms are promising for efficient management.	Semantic information contained in the BIM model cannot be preserved after translation/conversion processes. Hierarchical relationships are not structured.

Table 1. (Continued)

ornamentations, stone moldings, etc., which have specific characteristics and differentiating architectural styles. Modeling any architectonical component becomes even harder because of their deterioration over time. Indeed, due to all these facts, architectonical elements of heritage buildings having common semantic features lose similarities at the level of their shapes (Yajing and Cong, 2011). Moreover, mutual and hierarchical relationships of architectonical elements are either not focused or not possible within the limits of the tools that are used. In the works of, Often the semantic enrichment of historic building is limited to software specifications and capabilities with lack in adding important attributes such as physical condition and characteristics (like material usage, structural and material characteristics, etc.) or thematic concepts (like alteration types, structural damage, material decay, conservation state, etc.) (Arayici *et al*., 2008; Attar *et al*., 2010; Oreni *et al*., 2012; Fai *et al*., 2013; Murphy *et al*., 2013; Oreni *et al*., 2013).

An innovative approach which goes in the direction of BIM for historical monuments is the stand-alone information system NUBES (De Luca *et al*., 2007 and 2011) developed by MAP-Gamsau Laboratory (CNRS Marseille, France). The work presented in Achille *et al*. (2012) is promising too although the presented information system contains only two macro entities and it is not applicable to many heritage buildings notwithstanding the fact that conservation professionals are not specialized in the use of these sort of information technologies. More importantly, hierarchical structures and related query-able characteristics are not covered.

From another perspective, regarding the concept of multi-layered spatial data management in a broader sense (e.g., geology, land use, transportation, etc.), the most common approach for implementing the geometry/object and relation structure is Geographical Information Systems (GIS). In a generic frame, GIS allows dataset storage based on a series of tables where multiple relations between data and elements can be defined (Crosswell, 1991). Centofanti *et al*., (2011) and San José-Alonso *et al*. (2009) have focused on creating semantically-rich 3D objects in a GIS environment for architectural scale. Nevertheless, up-to-date, its great capabilities in efficient enrichment of 3D models dedicated to the management of architectural heritage information has not come into light yet.

3. Assessment of Heritage Data

Databases help separating segments of information and putting these segments together in a structured way for allowing new information to be derived or linked to 3D data (Agugiaro *et al*., 2011; von Schwerin *et al*., 2011). In case of architectural heritage, the use of semantically enriched 3D models is the fact and the criteria for its production process needs:

(i) Definition of specified mutual and hierarchical relationships,
(ii) enhanced attribute management,
(iii) 3D editing functionalities,
(iv) spatial and multi-criteria query-able characteristics,
(v) representation of multi-layered conceptual themes in 3D,
(vi) temporal representations.

Consequently, it is a complex spatial assessment process. Regarding the defined criteria above, it is necessary to go beyond the geometric data composed of either 3D shape files or lines and points and engagement of the very detailed geometric and related spatial information with the other types of data require extended logical process. Consequently, if the capabilities of BIM and GIS approaches are compared, both have pros and cons regarding the criteria for the information management of historic buildings (Saygi *et al.*, 2013).

3.1. Conceptual, spatial and analytical aspects

Reality-based 3D models (Guidi and Remondino, 2012), 2D scaled graphical representations as well as any of the thematic datasets related to architectural heritage are indispensable data for conservation and preservation purposes. But those data alone are neither enough neither very useful. Without the possibility of reaching information in a complete, aggregated and easily accessible way, there is a lack of knowledge and usability - i.e. one cannot exploit all the potentialities hidden behind geometries without the integration and accessibility of such heterogeneous information. Moreover, when explicit semantic and structural characterization among the various geometric features (other than textual annotations) is considered, the use of advanced information management systems is inevitable. Decoding hidden information beyond geometry hence deciding on the most efficient intervention requires a critical evaluation of overlaying all thematic information. During the process, several layers of spatial and analytical information are produced and also a set of key identifiers are formulated specific to each cases' needs. These sets of key identifiers also allow related "attribute" data to be linked and queried.

3.2. Methodological aspects

The management of multi-layered information and the integration of spatial and non-spatial data in a complete 3D platform is not an easy process and it has to carry systematic structuring rules. In order to manage the heterogeneous nature of heritage data beyond 3D geometries, it is fundamental to define in advance the list of the segmented architectonical elements of the heritage building and the respective attributes. Following, hierarchical and mutual relationships between different segments must be identified. With reference to this, generation of geometric data must be followed by the definition of parameters and creation of relations among the different types of data. In order to achieve that, defining ontology is indispensable for covering all attributes related to geometries, relationships and hierarchies (Kolbe and Plümer, 2004). Consequently, there exists some critical methodological issues related to segmentation, structuring and representation phases. The crucial technical issues can be summarized as follows:

(i) *Complete spatial access:* any heritage building cannot be bounded with its exterior shell or simple shape geometries. For conservation and preservation purposes, the inner and outer parts of a heritage building must have a complete connection and representation showing all segments from whole building level to architectonical element level. More importantly, these segments have to be hierarchically structured. Only by this way it is possible to structure mutual relationships.

(ii) *Interoperability facts:* during the production of multi-layered spatial information, there would be the need to use a variety of techniques, tools and software. Besides, considering 3D models/meshes creation, there exists a large ontology dependent on each specific software. Accordingly, the complex structure of each software, and exchangeability of 3D spatial information between the combined tools must be taken into account.

(iii) *Translation process:* given the spatial property of the information, there is the high possibility to create different sets of thematic information and to integrate them into non-native environments. The existence of dissimilarities may cause information loose during the translation processes (Delgado *et al*., 2013)

3.2.1. Segmentation of the data

Either digitally-born or digitized data can deliver results in forms of 3D models. In order to be able to assign different attribute data for representing various kinds of thematic information, the initial step is to create a segmented 3D model (Manferdini and Remondino, 2010). This is a bottom-up approach in case of digitized data whereas it is a top-down approach for digitally-born approaches. The models might be drawn from smallest segments i.e., architectonical elements upwards for the former approach while the finalized mesh of the historical building needs to be segmented into the architectonical elements for the latter. Only in this way, it is possible to assign thematic information to the sub-element of the 3D model. The smallest segments i.e., architectonical elements are unique in each, but they have to create a whole coming together for assigning the semantic information to the related architectonical elements. Whether a bottom-up or a top-down approach is used, the final aspect does not differ, all the geometric segments need to be assembled at the end. By this way, the segmented 3D model for the heritage building is produced, and after structuring hierarchical relationships, different analytical information can be overlaid or the temporal phases (4D) of each element can be regenerated by re-using/re-editing the base set of architectonical elements.

3.2.2 Structuring the data

After aggregating an entire heritage building into small segments, it is possible to integrate semantic attributes corresponding to various themes related to conservation and preservation needs. This is not a straight forward action as it is indispensable to create hierarchical relationships specific to the case's needs. In this way, it is possible to correctly relate the small segments and to build up the whole heritage object. Besides the creation of hierarchical relationships, the need to integrate non-geometric/spatial data (e.g. textual, graphical, and pictorial data) must be taken into consideration. Consequently, non-geometric/spatial data need to be categorized according to the key identifiers in order to be able to assign them as attribute data.

3.2.3 Representation of the data

Semantically enriched 3D models give the possibility to do different thematic analysis. Query-able characteristics and integration with 2D analytical drawings are crucial hence different thematic information is structured according to different set of identifiers and need to be assigned different architectonical element(s). For example a 3D representation of different type of cracks/structural damages with different colors/graphical representations, gives a clear understanding for the routes of structural deformation as the model shows variables affecting the decay in a totally perceived 3D environment.

4. A Practical Example

Some tests were done with a 15th century khan (Figure 2), called Kursunlu Khan and located in Manisa (Turkey), a historical building within towns that functioned as a trading center providing food as well as shelter for travelers and traders (Encyclopedia Britannica, 2013). The building, beside its complex geometries, has a series of alterations and different restoration interventions in different periods. These characteristics lead to a layered super-structure which is very common

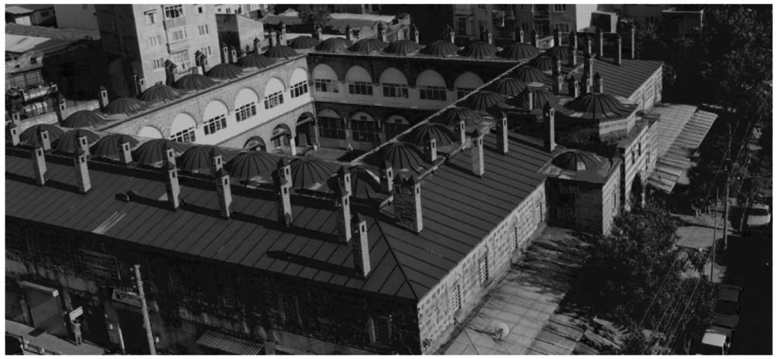


Figure 2. General view of the case study.

in historical buildings. Such an architectural structure, once modelled in 3D and enriched with heterogeneous attributes, cannot be managed and visualized within standard GIS tools nor handle by existing commercial BIM packages. Therefore an integration of in-house methodologies and existing solutions was the only solution. Concerning the pre-processing and geometric modelling, the 3D reconstruction is done with a bottom-up approach, starting from the single architectonical elements to the whole building within the light of the existing archival data. Re-editing some architectonical elements and re-using some of them was possible only in few cases, but as each architectural element carries unique characteristics e.g., dimension, type or deteriorations, it was not applicable for the whole structure. In addition, each architectonical element is tagged individually, with a specific ID during drafting/editing processes in order to assign different types of thematic information. At the end of geometric modeling, a segmented 3D geometric model of the building is created (Figure 3) thanks to the use of compatible modeling software.

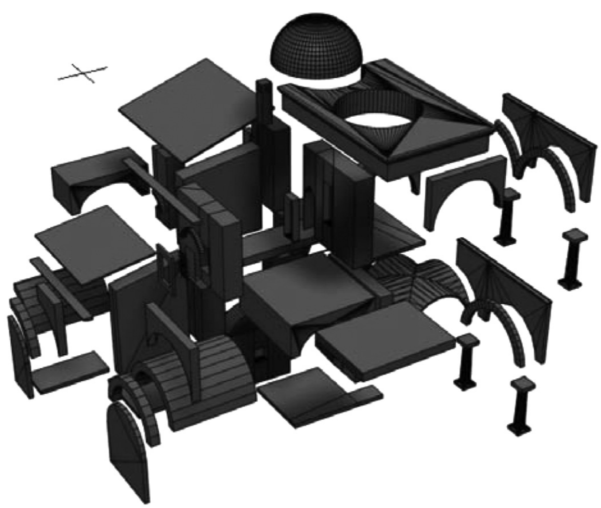


Figure 3. The exploded 3D model showing some interior architectural elements.

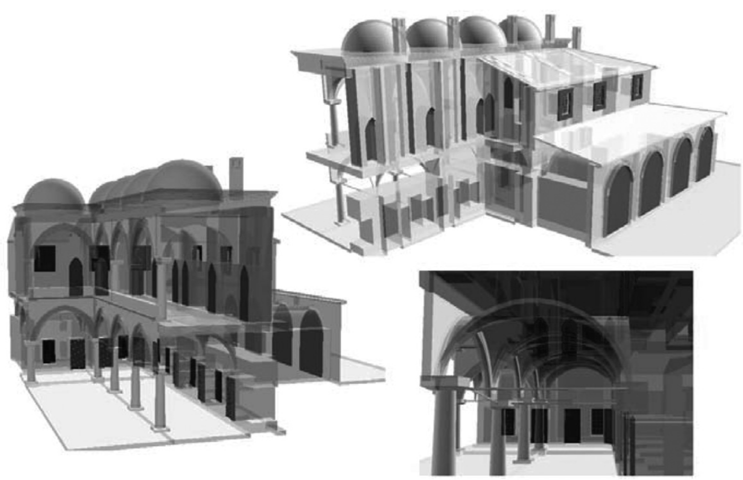


Figure 4. Some views of the segmented and enriched 3D model of the khan.

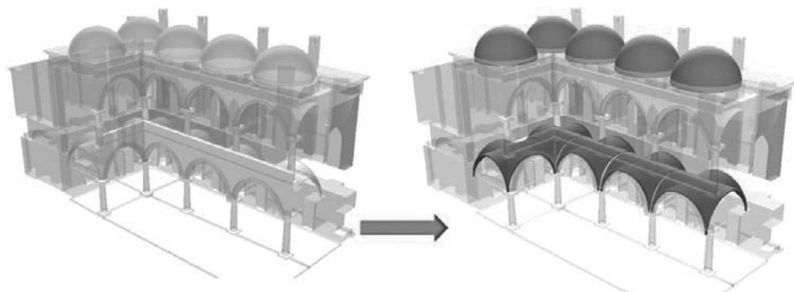


Figure 5. Extracting horizontal structural components of porticos.

The use of various tools was indispensable as none stand-alone tool was successful in geometrically modelling and segmenting such a complex heritage building. Using datasets organized in different themes, the key parameters are identified for each thematic layer thus giving the possibility to enhance the model with semantic information. After all, tables consisting a variety of attributes are created in PostGIS environment after structuring hierarchical and mutual relationships for assigning different themes of information and organizing non-spatial data. It should be underlined that the logical process for structuring relationships and identifying different classes is fully manual. Finally, in a GIS-like environment, spatial and non-spatial data are integrated and different thematic attributes are joined to the related geometric features. Figure 4 and Figure 5 show different representations according to different query criteria throughout on-going researches. In this way, any thematic information can be queried or analyzed in a holistic 3D environment.

5. Conclusions and Outlook

In order to carry out investigations and analyses, conservation professionals need to make use of different thematic, heterogonous and overlapping information (e.g. architectural, spatial, analytical and temporal data) to better understand the physical state of heritage objects and their specific characteristics. Therefore for a deep and holistic understanding of multi-layered spatial information, the use of semantically enriched 3D models stands as the best solution. Nevertheless as it is not only geometric information, but also a huge amount of geometry-related semantic information, a crucial problem is the integration of semantic attributes into the geometries as well as the successive access and visualization. Therefore the use of semantically enriched 3D models for the management of architectural information (giving the possibility to do a simple navigation or queries or integration of different data like photographs, textual descriptions, 2D thematic drawings) plays a crucial role not only for archival purposes but also for supporting decision-making phases of conservation. This gives also the possibility for better comprehension.

New information technologies give the possibility to produce detailed 3D geometric models and other types of graphical representations. But, up-to-date, there is no stand-alone approach for information management and integration of complex and multi-layered data of heritage monuments in 3D environment. Moreover the aspect of semantically enriching a 3D model for any historic building is quite differentiating from a new industrialized/standardized one. So far, historic buildings require different hierarchical segmentation, not pre-defined ones and non-standard attribute types. Therefore, any of the fixed structure inside single software might be applicable for a few specific purposes, but it does not correspond to the conservational needs.

In this context, the implementation of semantically enriched 3D models does not only provide us to build a spatial information system but also help us to assign and understand heritage data beyond geometric features. Regarding the first drawbacks of the experimentation and the results of the current approaches, semantically enriching a 3D model must be based on three crucial concepts as: (i) creation of an ontology, (ii) conceptualization of relationships and (iii) specification of hierarchies. As a whole, it is indeed a complex cognitive and technical process, and requires the use of combined tools which brings along conversion and compatibility issues as well as the related translation processes.

Normally there is a general consideration that BIM and GIS are distinct worlds, but both of them deal with “spatial information”.

Criteria for Information Management Process	BIM	GIS
Definition of specified mutual and hierarchical relationships	7	3
Enhanced attribute management	7	3
3D editing functionalities	3	7
Spatial and multi-criteria query-able characteristics	7	3
Representation of multi-layered conceptual themes in 3D	3	7
Temporal (4D) representations	3	3

Table 2. Comparison of BIM and GIS capabilities for the semantically enriched 3D model creation (Saygi *et al.*, 2013).

Nevertheless considering the needs of historic buildings, both approaches have some restrictions due to their specifications (see Table 2 for a comparison). On one hand, BIM has pre-defined criteria for structuring hierarchical relationships and restricted 3D modeling possibilities and attribute management of any architectonical component are based on mainly new building technologies according to their technical specifications. On the other hand, GIS do not allow detailed 3D editing possibility as GIS products are still limited with regards to 3D editing functionalities. They generally only allow construction of simple 3D elements as geometric primitives, so it requires outward software support. However once 3D geometrical modeling is done with compatible software, GIS show the possibility to identify key aspects for representation of different thematic layers for analysis, enhancement with any type of attributes, and query or visualize any thematic concepts in 2D/3D/4D forms Moreover, taking the conceptual idea of GIS, i.e. representation of multi-layered information in a spatial environment, the approach is promising for the use in creation of semantically enriched 3D model prior to use as a central platform as representation of historic buildings, and as holistic repositories for navigating inside other types of thematic information (text, images, tables, etc.).

Semantically enriched 3D models in response to the question of "how to store the information produced in a systematic and relationally structured spatial platform" carries a crucial importance. During the information management phase for the conservation of heritage buildings, the combined use of ad-hoc software and tools remains the best solution. Correspondingly, there cannot be a common model in heritage conservation, as each heritage object is unique and carry individual characteristics. Though, the described on-going research experimentation results are promising and it is possible to adapt and calibrate it to other singular models, according to each case's specific needs.

Regarding GIS's thematic layering concept, it is coherent with architectural heritage as it is possible to identify different types of datasets. More importantly, not only the definition of relations but also description of hierarchies for controlling the database is offered.

Consequently, GIS allows users to create interactive queries, analyze and edit spatial information. In this context, it can be a very useful and powerful tool in managing semantically enriched 3D models.

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