BIM-GIS interoperability applied to architectonic heritage: 2D and 3D digital models for the study of the ancient church of Santa Lucía in Seville (Spain).

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ABSTRACT:
This contribution explores the underlying possibilities of interoperability between Building Information Modeling (BIM) and Geographic Information Systems (GIS) methodologies, applied to the management of architectural heritage. This task can be understood as a complex reality, since it must incorporate the contextualization of a specific historical period, the temporal evolution it has undergone and the interpretation based on current parameters.

The paper includes some theoretical notes on the interoperability between both methodologies based on different studied publications with the aim of establishing a reference framework for further developments and conclusions. Additionally, the theoretical basis obtained in this research has been applied to the development of a real case study model. The chosen building for this purpose was the Old Church of Santa Lucía (Seville), now used as *Centro Documental de Artes Escénicas de Andalucía (CDAEA)*. The results of this research show the need to continue working on the integration of both methodologies due to the numerous possibilities it offers.

1 INTRODUCTION

The aim of this article is to draw conclusions about the possibilities offered by the creation of BIM and GIS models for architectural heritage management purposes, taking into account the current viability offered by current interoperability strategies.

The analysis of the different integration processes used has focused on the development of a practical case: the elaboration of a digital BIM-GIS model of the Old Church of Santa Lucía (Seville), currently "*Centro de Documentación de las Artes Escénicas de Andalucía (CDAEA)*".

The interest of this building lies in its belonging to one of the medieval parish churches that were established in the city of Seville after the Christian conquest in 1248. The essential characteristics of this type of architecture were analysed through the creation of spatial databases on an architectural scale processed by GIS systems (Mascort-Albea, 2018). Through this research, a methodology was developed to establish detailed characterizations of heritage buildings using geographic tools and implementing simplified two-dimensional maps that facilitate the management of information related to their preventive conservation (Canivell, Jaramillo-Morilla, Mascort-Albea, & Romero-Hernández, 2019; Mascort-Albea & Meynier-Philip, 2017; Mascort-Albea, 2017) . Taking as a starting point the 2D GIS model of the old church of Santa Lucía, a three-dimensional BIM model of the building has been made, as well as its subsequent export in a 3D GIS environment (Hidalgo Sánchez, 2018). All this allows us to establish the reflections on interoperability that are presented below.

2 NOTIONS ON BIM-GIS INTEROPERABILITY

The concept of interoperability between BIM and GIS can be defined as the ability of the two systems to contact each other, communicate and exchange data in an attempt to achieve a common goal. However, in order to reach this point it is necessary to have a clear and total connection between the data coming from one system and another, as well as the way of interpreting them (Zhu, Wright, Wang, & Wang, 2018).

2.1 Levels of integration

The integration between BIM and GIS can be covered from different levels. Several groups of researchers have carried out classifications that have attempted to synthesize the complexity of this process (Amirebrahimi, Rajabifard, Mendis, & Ngo, 2015). In this work, the following classification is taken as a reference, which is structured in three levels: *data level or data interoperability, application level* and *process level* (Fig.1).

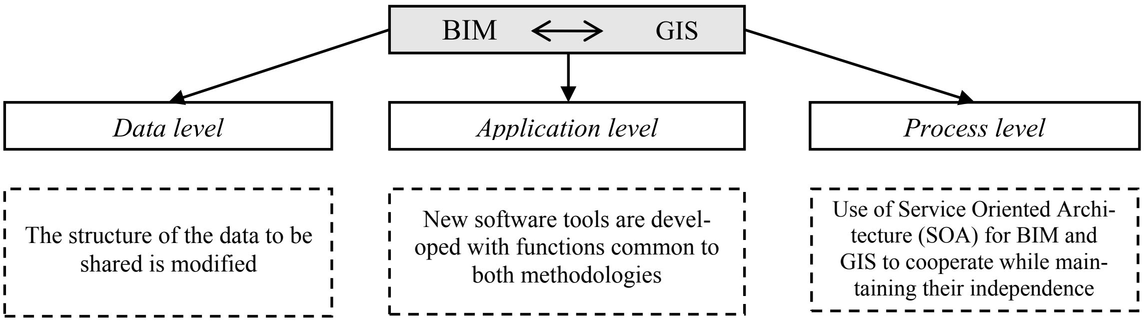

Figure 1. BIM-GIS levels of integration. Source: Prepared by the authors from Amirebrahimi et al (2015).

In this sense, it is essential to emphasize the *data level* or *data interoperability* as a starting point to achieve even more complex objectives, as the other levels depend on correct interoperability at this level. The *data level* in turn is divided into *geometry level* (data visualization) and *semantic level* (data visualization and analysis).

2.2 Commonly Used Data Formats

The flow of information from BIM to GIS, and vice-versa, always implies a change in data structure and format. There are many formats for storing a three-dimensional geometry, such as *3D Studio (.3ds), SketchUp (.skp), COLLADA (.dae)*, etc. However, the formats that by their nature are most likely to obtain better results in this task are *Industry Foundation Classes (.IFC)* and *City Geography Markup Language (.CityGML)*. These formats are capable of storing both geometric and semantic information. An alternative to consider is the *multipatch (shapefile)* standard developed by ESRI, but it only stores data at the geometric level.

2.3 Information exchange of data

The search for interoperability in the *geometry level* is developed mainly for visualization purposes, focusing on the transformation of information related to the geometry of the model, producing a loss of information at the semantic level. The level of difficulty to reach this objective is not too high.

The *semantic level* comprises more complex processes in order to conserve as much information as possible. By allowing the exchange of more information, it makes it possible to carry out analyses based on these, additionally to visualization. The main problem in the semantic aspect for the integration of BIM and GIS lies, on the one hand, in that each one gives different definitions for the same object, for example, a window in IFC is defined as "IfcWindow", while in CityGML is defined as "window", and on the other hand, one of them defines components or classes that the other does not. This situation is problematic for some practical applications, because when switching from the IFC format to CityGML, the relationship between objects is lost, if no procedure is carried out to fix it.

Apart from the creation of specific methodologies and processes (creation of ontologies, modification of "schemas" of the formats IFC and CityGML, etc.), there are commercial software working on the integration between BIM and GIS, such as *BIMServer, IfcExplorer, Feature Manipulation Engine (FME)* and *Data Interoperability (DI)* for ArcGIS. However, none of these tools achieves a complete transfer of information at the geometry and semantics level between BIM and GIS (Donkers, 2013).

3 STRATEGIES APPLIED TO THE CASE OF STA. LUCIA´S ANCIENT CHURCH (SEVILLE, SPAIN)

3.1 General procedure

In this type of practice, BIM tools are often used in the 3D modelling phase, usually using photogrammetry and laser scanners to capture data and obtain point clouds that serve as the basis for the model survey. In this case, these techniques have not been used because they suppose a high cost in relation to the pursued aims. The graphic survey has been carried out using the BIM *Graphisoft ArchiCAD* software, based on the planimetric information obtained during the research. Once the BIM (or HBIM) model has been built, an attempt has been made to include it in a 3D GIS environment.

3.2 BIM model of the Sta. Lucía´s ancient church

When approaching the BIM modelling of a heritage building, it is important to carry out a formal, structural and spatial preliminary study, which allows us to group elements to simplify the model and facilitates the possibility of linking heterogeneous data for subsequent analysis and management. To such ends, in this case the effort to segment the model is reduced, since it has been taken the constructive and spatial characterization of the church developed through a 2D GIS previous model (Mascort-Albea, 2018). This division groups different elements of the building into certain categories, assigning them a common coding.

Based on this structure of the architectural information of the building, the BIM model was elaborated. The construction process of the model is too extensive to be included in this article, but it can be consulted in its entirety in the Final Degree Paper that serves as the basis for the drafting of this contribution (Hidalgo Sánchez, 2018). Some images of this model are shown below (Fig.2). Finally, it is exported to IFC format using *Graphisoft's ArchiCAD* general translator. During this export process, there is a slight loss of information referring to the geometry level, mainly in those elements of the model derived from Boolean operations (subtraction, insertion, etc.). Notwithstanding, in the semantic information section, the attributes that had been linked in the original BIM model remain intact when exporting to IFC.

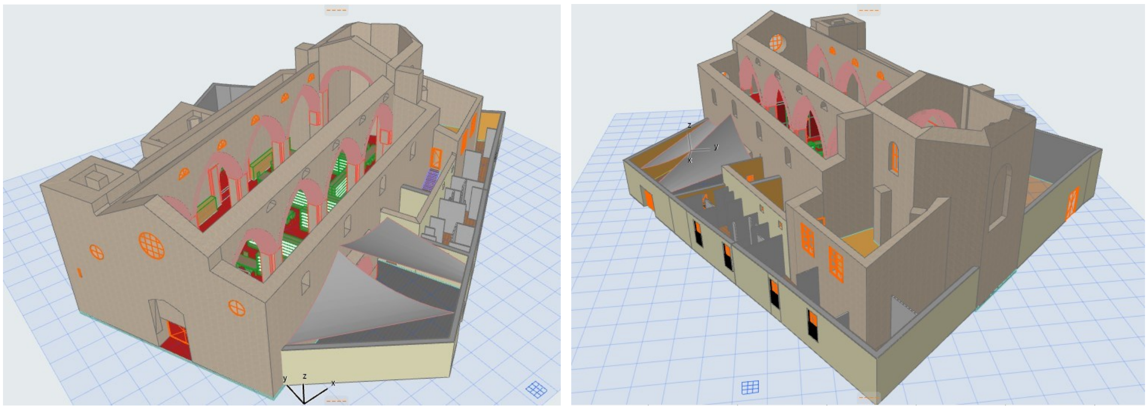

Figure 2. Santa Lucía´s BIM model images. Source: Prepared by the authors

3.3 BIM - GIS interoperability

As developed in section 2.2, interoperability between BIM and GIS can be conceived from the conversion between IFC and CityGML formats. It should be remembered that the main procedures for achieving interoperability between the two are basically divided into two groups. On the one hand, the use of commercial software developed especially for this task. On the other hand, the use of specific procedures, such as the creation of ADEs (Application Domain Extension), use of own ontologies, etc. Within the framework of the research carried out, both options are discarded, because of the reason previously mentioned (Hidalgo Sánchez, 2018).

In this sense, it was considered a third option, a combination of the two previous ones (Dore & Murphy, 2012). It consists of using a *Trimble SketchUp* plug-in to convert the BIM model of a heritage building to the CityGML format. This plug-in converts the objects of the BIM model taking into account the semantic classes defined by the CityGML format. It seems a good method, however, it has the disadvantage that some elements of the model, such as the pointed arches of the Church, do not present a semantic class equivalent in CityGML, which would force to create it through the development of ADEs, returning to the second of the initial options, therefore, it is also discarded.

4 CONCLUSIONS

BIM-GIS conversion currently involves tedious processes, and in spite of this, full interoperability is not guaranteed. Depending on our purpose, it would be more convenient to choose the construction of a 3D model which semantic properties are not assigned (not BIM), and then to link them in a GIS environment, or to make a BIM model with semantic starting information, being complemented and managed in the GIS environment. Which method is better will depend on the development of the standards used by BIM and GIS to communicate with each other. On the other hand, the development of both methodologies of tools enables the construction and the work with models of buildings with patrimonial characteristics, will be a very important factor, in order to facilitate and speed up this workflow.

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