Validation of geometric data in HBIM implementation processes of Romanesque churches in Sardinia

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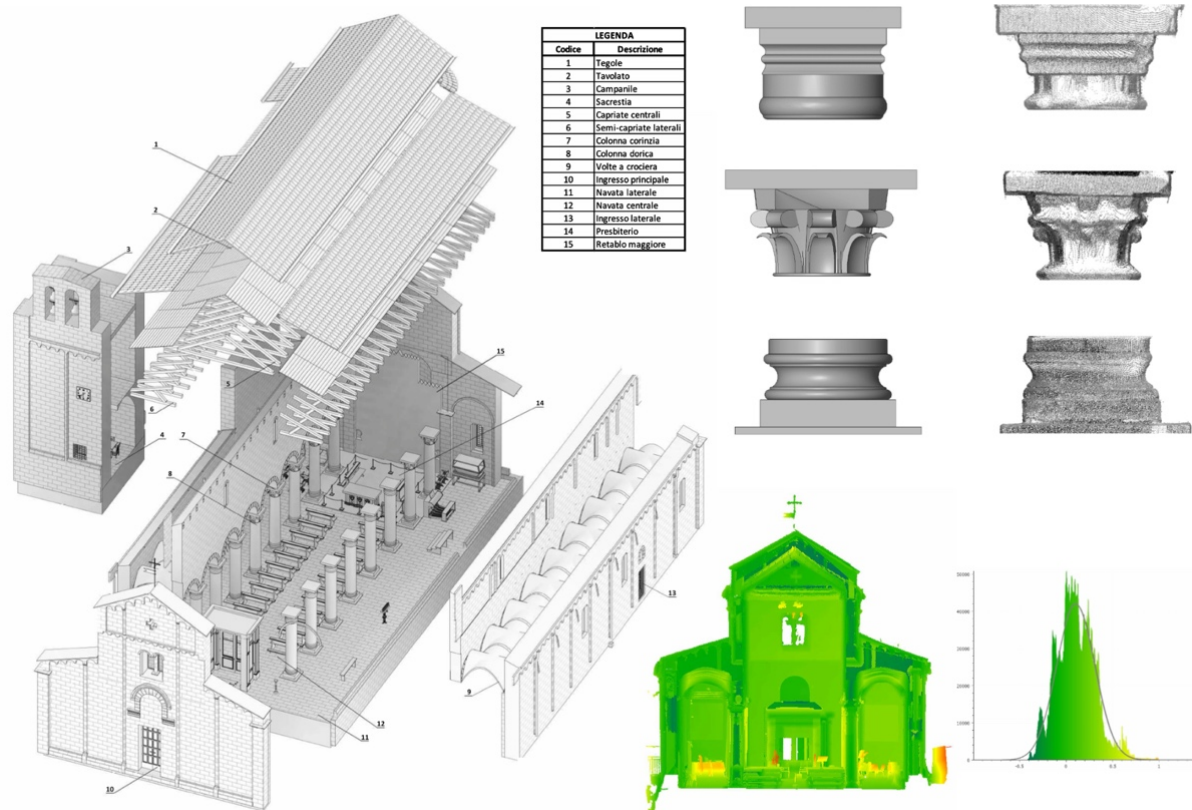*DIDA – Scuola di Architettura, Università degli Studi di Firenze*

Fig. 1. Pastorelli E., Gabrielli L., Riccio S., Ricotti E., H-BIM of the Church of Santa Maria del Regno and deviation map, 2019.

Abstract

The implementation of BIM methodologies for historical buildings presupposes not only the collection of data and information related to its geometric configuration and to the technical parameters of its constituent elements, but more generally the identification of those semantic values which make it part of the historical-cultural heritage shared in a specific context. It is therefore essential that the modelling objectives are explicitly defined in relation to the specific BIM uses required, in order to avoid risks of over-modelling.

This paper proposes a process of geometric validation of building information models of high morphological complexity implemented through Scan-to-BIM procedures. By means of a controlled and interoperable workflow, a chain of software applications is defined that is able to determine the level of geometric accuracy (LOA) of the information model with respect to the numerical model derived from the point cloud. Two case studies of H-BIM modelling of historical monumental complexes dating back to the Romanesque period in Sardinia (Italy) are illustrated: the churches of Sant'Efisio a Nora (Cagliari) and Santa Maria del Regno (Sassari). In the discussion of the results, the need for a prior definition of modelling strategies in relation to the expected BIM uses is highlighted.

Keywords

HBIM, Cultural Heritage, Point Cloud, LOD, LOA

1. Introduction

The implementation of BIM methodologies for historical buildings - HBIM (Murphy, McGovern & Pavia, 2013) - is characterised by its start point, which always occurs at an advanced stage of the life cycle of the architectural asset and presupposes not only the collection of data and information related to its geometric configuration and the technical parameters of its constituent elements, but more generally the identification of those semantic values, which make it part of the historical-cultural heritage shared in a specific context (Volk, Stengel & Schulmann, 2014).

Therefore, in order to proceed smoothly for an informative modelling process of existing buildings, following an effective workflow, it is essential that modelling objectives are explicitly defined in relation to the specific BIM Uses required. This avoids the risk of over-modelling and creates a lean model that contains only the information need for the intended use. The information content of a model and its components are defined by the LODs (Levels of Development), which is divided into level of graphical detail (LOG) and level of information detail (LOI).

2. State of art

According to Historic England, 3D geo-spatial data derived from surveys based on laser scanner techniques offer many advantages over traditional approaches. Brookes (2017, pp. 21-22) reports a classification of the most frequently used survey techniques according to their cost, acquisition range and accuracy.

Despite recent developments in automation processes (Banfi, 2017), it must be considered that the reconstruction of a building geometry from a point cloud is still largely based on manual operations and the quality of the model thus comes to rely on the skills of the operator (Macher et al., 2014). This necessarily implies the introduction of a level of simplification of the information model with respect to the numerical model of the point cloud, i.e. an error, which has to be specified from the beginning of the process.

In these cases we are helped by the modelling tolerance, i.e. the accuracy with which the model "comes

close" to the building scan (this can vary depending on the areas and components of the model).

In fact, in the "USIBD Level of Accuracy (LOA) Specification Guide" (2016) we find the term Level of Accuracy (LOA), which can be applied to both the traditional survey and the information model. Through a classification in which each level corresponds to a range of values, the level of reliability of a represented/modelled object is evaluated and the appropriate level for the individual building elements is defined.

In the text "Common BIM Requirements - Series 2: Modeling of the starting situation" (2012), although it refers more to modern than to historical buildings, it is found a distinction of the data acquisition techniques in three levels of accuracy, with values related to the measurement error admissible with the various acquisition techniques and the definition of an Accuracy Levels, i.e. the levels of accuracy of a BIM model with respect to geo-spatial data

3. Metodology

Starting from the analysis of some researches that have dealt with the application of BIM methodology to historical buildings (Del Giudice et al., 2017; Quattrini et al., 2015; Santoni et al., 2015; Scianna, Gaglio, La Guardia, 2018), a methodology was developed by the authors for the management of implementation processes of information models of historic buildings from point clouds (fig. 2), i.e. through Scan-to-BIM procedures. The registration of the scans and the selection of the points was carried out with the software ReCap. The point cloud was then exported in .rcp format and linked within the proprietary modelling software Autodesk Revit. Based on this, the three-dimensional model of the building was recreated starting from its main geometries and then moving on to the insertion of parametric families.

The creation of the architectural objects BOMs (Biagini & Donato, 2014) was the most complex step; in fact, the authoring software does not allow the direct import of the point cloud within the project of a family (.rfa format). To solve this problem, the open source software CloudCompare was used, which allows to create a region of the point cloud, imported in .e57 format, and to export it in .dxf format, which is the only format readable within a
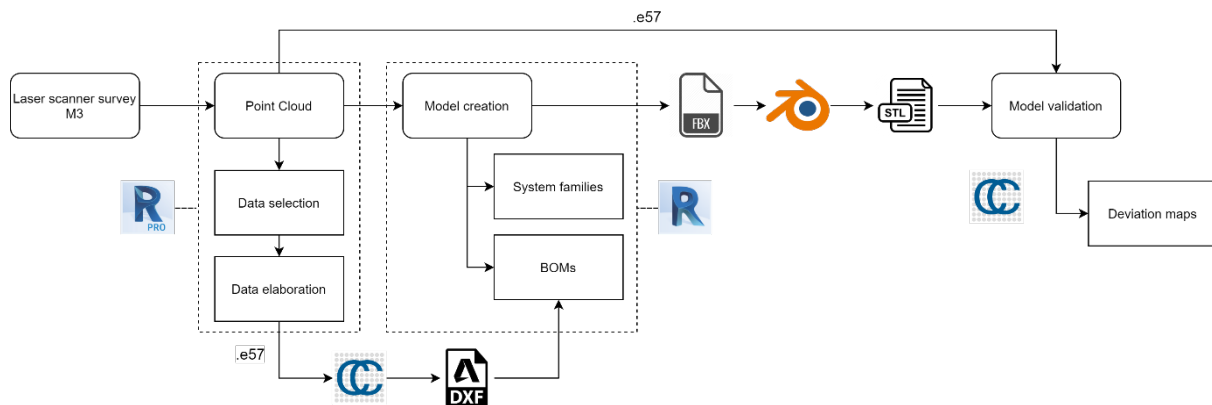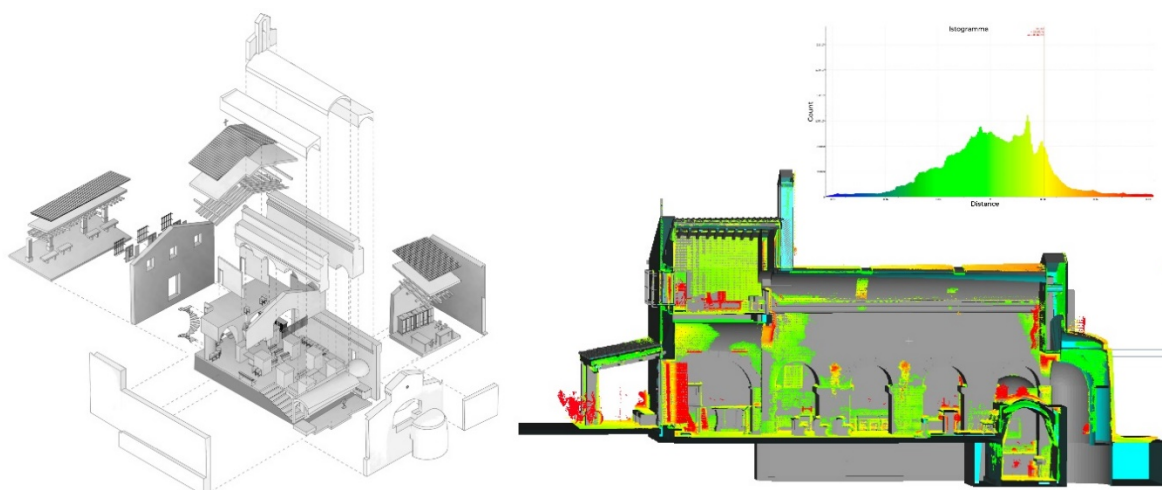

Fig. 2. Workflow

Fig. 3. Siddi V., Sant'Efisio Church 3D model and validation using Cloud Compare, 2019.

Revit family.

In order to verify that the modelling had been carried out within the required accuracy range, a validation of the model was carried out with respect to the starting point cloud. For this comparison, the CloudCompare software was used, which allows the creation of deviation maps between the points of the numerical model and the geometry of the information model. The point cloud can be imported, as already mentioned, in .e57 format, while the geometric model can be exported from Revit, through a special plug-in, in .stl format (format interoperable with CloudCompare); this step represents a critical moment of the entire process since in some cases it can lead to loss of geometric data (especially in the case of generic models) or reference coordinates. This problem has been solved with an alternative process, which involves exporting from Revit in .fbx format, opening the file in the open source software Blender and exporting it in .stl format. In this way, the resulting model will contain the reference coordinates and geometric information need for importing into CloudCompare and overlaying with the point cloud. This validation was carried out not only for the overall model but also for individual architectural elements such as walls or floors. This allows a better control of the irregularities present or due to simplifications in the modelling phase. The validation was also carried out at the level of the single family, so that a descriptive parameter of the relative level of accuracy could be evaluated for each of them.

3.1 Case studies

In the present work, two monumental architectural complexes with high geometric complexity, dating back to the Romanesque period in Sardinia, were analyzed: the Church of Sant'Efisio in Nora (Cagliari) and the Church of Santa Maria del Regno (Sassari).

The modelling of the first building involved the restitution of all the architectural components including the liturgical furnishings inside. The validation process of the entire model showed a deviation between point cloud and geometric model of less than 8 cm for 85% of the analyzed points (fig. 3). This result is quite high, but a more precise

analysis shows that the greatest deviations are due to the presence of both internal and external disturbance elements. For a more precise evaluation, the model elements were subsequently taken out of context and returned results of less than 5 cm.

The second building, on the other hand, has a wider nave and a greater number of complex architectural elements, which required ad hoc modelling as they were not available in the standard libraries of the authoring software. In this case too, a validation of the model was carried out both for the building as a whole and for individual elements (fig. 4).

4. Conclusioni

The proposed validation methodology of the information models makes it possible to verify the reliability of the geometric information contained in them by means of a direct comparison with the numerical model derived from the point cloud acquired by scanning survey.

In this way, the geometric development level (LOG) characteristic of a specific development level (LOD) of the information model can be attributed with high precision.

The irregularity of the surfaces in these particular architectures (stone degradation, out of plumb of the vertical structures, etc.) and the presence of occluding vegetation represent the main causes of the peaks of deviation between the information model and the numerical model.

In particular, the requests to reach development levels higher than LOD C, will have to be carefully evaluated in the context of global strategies of informative modelling in relation to the expected BIM Uses.

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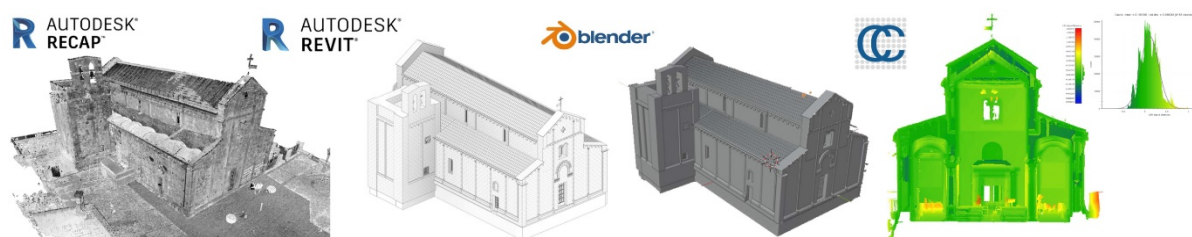
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