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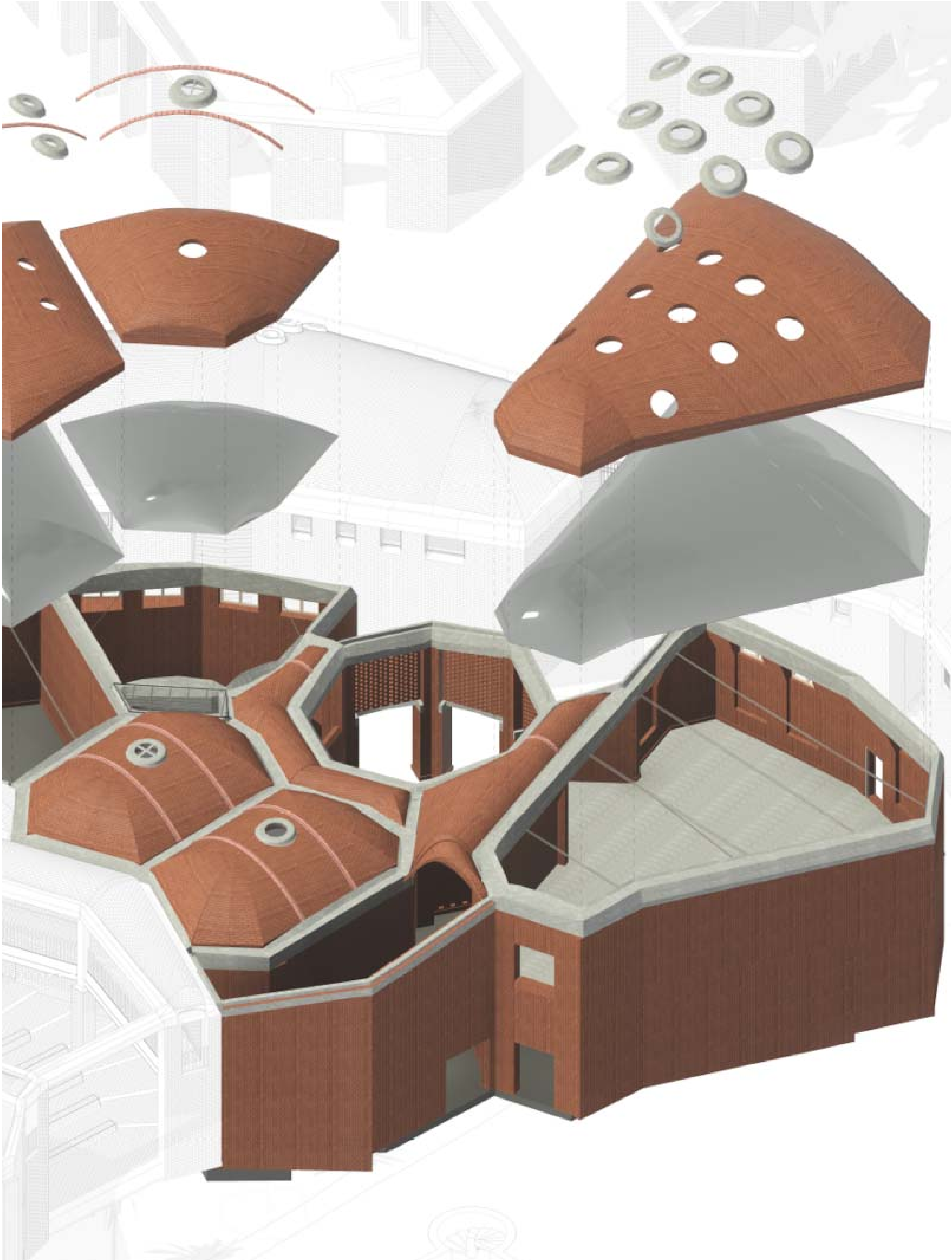

Scan2BIM methodology applied to the Faculty of Theatral Art of La Habana

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Parole chiave: HBIM; LOA; Facility Management; Digital Twin; Geometry validation.

Abstract

This paper shows some results of an international cooperation project named "¡Que no baje el telón", funded by the Italian Agency for Development Cooperation and the Ministry of Culture of Cuba (main partners: Department of Architecture, University of Florence and Universidad de las Artes de La Habana) and developed between 2019 and 2023. The Project was divided into two components. Component A (Rehabilitación y Difusión) had its specific objective at the restoration and refurbishment of the building of the Faculty of the Theatral Art (FAT), as well as the dissemination of the results achieved. Component B (Capacitación y Monitoreo) aimed to contribute to the capacity building of all operators in the field of documentation, conservation, management and enhancement of cultural heritage. The FAT was designed in 1961 by the Italian architect Roberto Gottardi and was never completed. It is composed of various pavilions, all of them constructed with facing brick walls, irregular geometric plans and different decorative details. The organic design of the complex is accentuated by the vaulted roof, which uses the traditional "tabicada" vaulting technique, with alternating layers of cement and bricks arranged in slabs. To date, the building is in an advanced state of decay and large parts remain unfinished. The presented research activities concern the creation of a BIM model of the FAT, aiming to the Facility Management of the main assets (spatial and systems items). All the data and information, derived from previous survey and diagnostics activities, were acquired to implement an "AS-IS" BIM model, conceived as a repository of information for the future operational and maintenance phases of the recovery assets. To achieve these objectives, the work was supported by a Building Execution Plan (BEP) for the definition of information exchange operations, coding of elements, materials and project outputs. Within this document, the geometric details and information content were defined at a level of development appropriate to the available knowledge. The open-source software, CloudCompare, was used for the geometric validation of the BIM model. Individual sample elements or their aggregates were compared with the initial geometric data captured from the point cloud to determine the gained level of accuracy. As far as the information part is concerned, we relied on photographic survey, archive documentation, research project elaborations to compile or prepare parameters useful for future management functions.

Introduction

This paper shows some results of an international cooperation project named, "¡Que no baje el telón!", funded by the Italian Agency for Development Cooperation (AICS) and the Ministry of Culture of Cuba (MINCULT), which aims at the conservation

Fig. 1 - Faculty of Theatral Art of La Habana, 3D Model (elaborated by Bongini, A.).

and enhancement of the cultural heritage of the Instituto Superior de Arte de Cuba in La Habana and developed between 2019 and 2023 (Merlo, 2020). In particular the topic of this project was the Faculty of Theatral Art (FAT) (Fig. 2), designed in 1961 by the Italian architect Roberto Gottardi and never completed (Loomis, 2019). It is composed of various pavilions, all of them constructed with facing brick walls, irregular geometric plans and different decorative details. The organic design of the architectural complex is accentuated by the vaulted roof, which uses the traditional tabicada vaulting technique, with alternating layers of cement and bricks arranged in slabs (Paradiso, 2016). To date, the building is in an advanced state of decay and large parts remain unfinished.
The presented research activities concern the creation of an H-BIM model of the FAT, aiming at the Facility Management of the main assets (spatial and systems items). All the data and information, derived from previous survey and diagnostics activities, were acquired to implement an "AS-IS" BIM model, conceived as a repository of information for the future operational and maintenance phases of the recovery assets (Murphy et al., 2016).

State of Art

Facility Management (FM) is a constantly evolving field that is heavily influenced by the efficiency of a company's technological and communication systems. Effective information management is crucial to achieving desired results, and this is facilitated by technological supports. However, the abundance of data available can also lead to challenges, as not all data is properly utilized. Information technology can play a dual role in FM, either directly improving work productivity or coordinating activities. Regardless of its role, information planning and control requires the collection of data from multiple sources, which can be a complex process prone to errors and distortions. To make FM effective, it is essential to rely on technological innovations such as Building Information Modelling (BIM) (Patacas et al., 2015). However, the BIM alone cannot solve all the problems, and there are still many challenges, especially in the Cultural Heritage field (Scianna et al., 2019), such as the types of software used and the individual skills of each actor. Specifically, there are three crucial factors that remain challenging to implement in a BIM process: achieving geometric precision of the model's components, accurately categorizing their meaning, and managing restoration-specific information.
Despite recent developments of procedures for automating digital modelling (Banfi, 2017) and semantic segmentation into building components (Croce et al., 2021) from point clouds, geometric modelling of a building is still largely based on the manual skills of the individual operator (Macher et al., 2014). It is crucial, especially for culturally significant buildings, that the BIM model and its associated measurements are precise. The USIBD Level of Accuracy (LOA) Specification Guide can be used

Fig. 2. UAV picture of the FAT spaces (by A. Merlo).

to determine the required level of precision. This guide uses a numerical scale (10 to 50) to define the LOA, along with a confidence level and established tolerance levels that must be consistently met in the BIM model. The second issue is the semantic breakdown of the building into systems and technological units. This process involves theoretically separating elements, but in H-BIM, these separations between Historic Building Object Models (H-BOM) (Donato & Biagini, 2014) are not always clear due to the absence of physical separations. This issue is further complicated by the lack of standardized guidelines for this segmentation. The choice of decomposition criteria should also consider the intended BIM uses, as this will dictate the level of detail and depth for the modelling phase. Finally, to ensure the correct exchange of information among project participants, it is essential that the final output is translated into IFC format, making it compatible with different BIM platforms. This is not an obvious process as not all BIM software has the same read/write capability as a file in the IFC schema and it is likely that some information will be lost in the transition from one software to another (Diana & Rinaudo, 2020). Moreover there is the complexity to insert the information demanded in the just pset, avoiding therefore to use, where possible, parameters of custom type.

Methodology

Starting from the experience acquired in the previous researches (Biagini et al., 2022)

a methodology for the management of the processes of implementation of informative models of historical buildings from point clouds has been conducted through a Scan-to-BIM process (Fig. 3). The point cloud, delivered in format .rcp, was processed and filtered based on the use in the next modelling step, and connected within the proprietary Autodesk Revit modelling software.
To ensure compatibility with future management and functional recovery, a Building Execution Plan (BEP) was used to define information exchange operations, element coding, and project outputs. The geometric details and information content were defined at a level appropriate for the available knowledge. The three-dimensional building model was created using the main geometries, followed by the addition of parametric families. The creation of the architectural objects BOMs 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 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 has been firstly exported from Revit in .fbx format and then converted in .stl format by Blender software. Using the two files the validation process has been 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.

Case study

This work presents the workflow mentioned above applied to the building of the Faculty of Theatral Art (FAT). The process started from the geometric data in the form of a cloud of points (Fig. 4), which, for reasons of optimization of the work, was divided into portions that reflected the natural division of the internal blocks of the building. The different regions of point clouds thus obtained served as input to proceed to the realization of the BIM models. The models representing the various building blocks were then connected in a "master" file used for the coordination of the different working groups. Given the morphology of the work, the workflow adopted provided for the modelling of the architectural and structural elements within a single file, while an ad hoc file was created for the portion of topographic context, also obtained on the

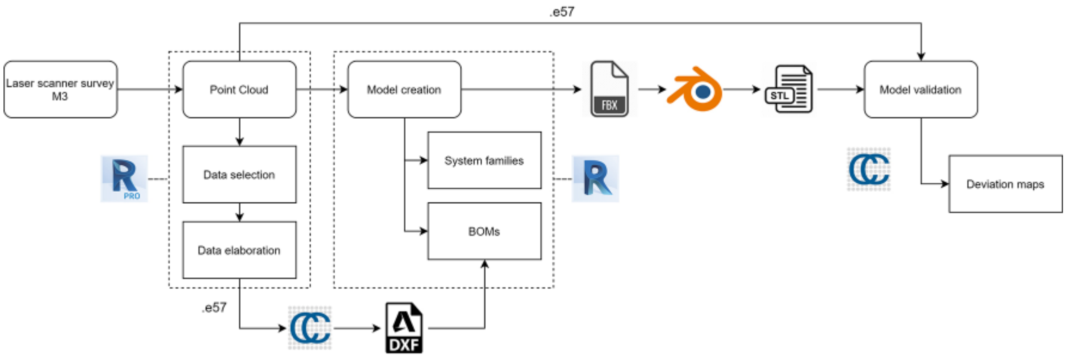

Fig. 3. BIM workflow (elaborated by Biagini, C. and Bongini, A.)

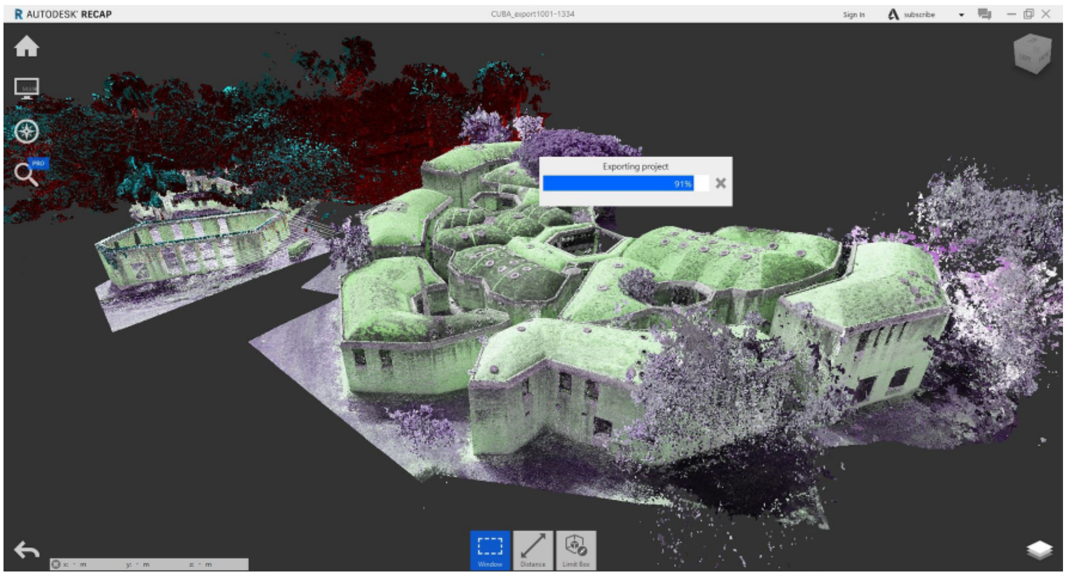

Fig. 4. FAT Point Cloud (elaborated by Bongini, A.)

basis of the relevant data. In order to ensure optimal coordination between the models, a project file was initially generated, leveraging the support of point clouds and CAD files, to create a system of reference grids for the entire property. These grids were obtained by tracing the external surface of the perimeter walls and using the axis line of the inner walls as a reference. Since the points of the cloud were not perfectly aligned, an optimal interpolation of the points was found by finding a direction for each single line. Each element of the grid was then assigned an identification code related to the relevant block. Additionally, the levels of the various blocks were set in the file, starting from the point clouds. Just like the grid, the levels were given identification codes related to the block or blocks, in the case of homogeneous levels. The individual models were then created based on this reference file. To ensure accurate placement of the blocks during the reconstruction process, a shared reference system was established

Fig. 5. 3D exploded view of block 5 (elaborated by Bongini, A.)

from the outset. This system allowed the models to respect the expected positions and coordinates in the grid and layer file. To make the reference systems consistent, each group connected the grid file and acquired the coordinates before beginning modelling operations. A similar procedure was followed in creating the total coordination file, allowing for immediate positioning of the individual models when they were imported using shared coordinates.

Starting from the available photographic material and point clouds, a preliminary survey was conducted on the types of architectural elements and furnishings present within the entire complex. Due to the state of semi-neglect, significant furnishings or plant equipment were not found, and the detail modelling was limited to architectural components. This initial inventory of objects to be modelled allowed an estimate of the modelling operations and their complexity. Modelling elements such as load-bearing walls, partitions, interplane floors, stairs, and floors can be created using system

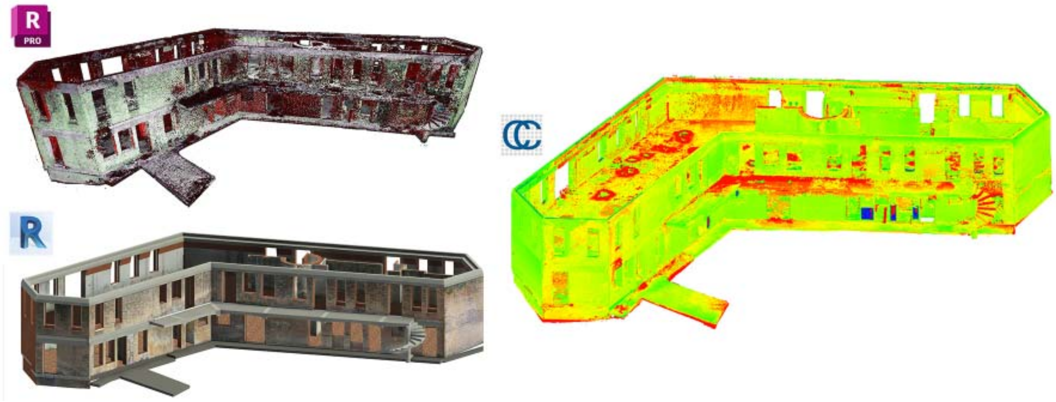

Fig. 6. Validation of block 12 by ClodCompare software (elaborated by Bongini, A.)

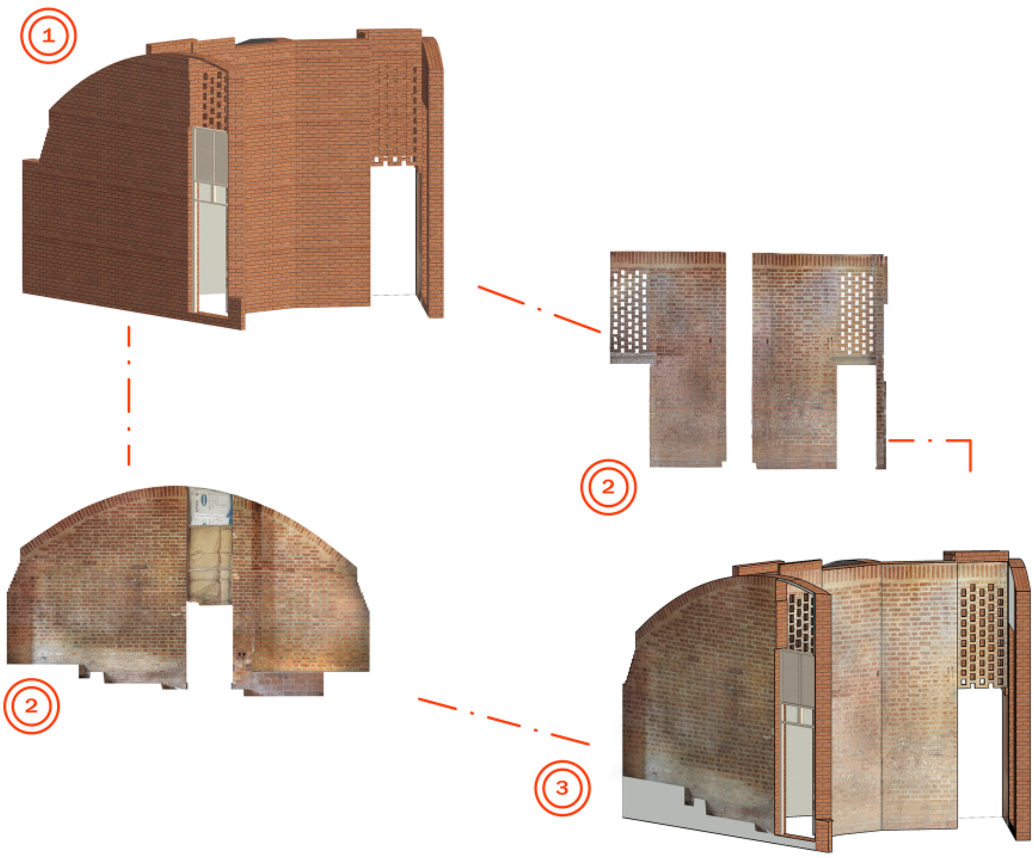

Fig. 7. Application of texture inside the BIM model (elaborated by Bongini, A.)

families. To guide modelling, the use of local models to return components in place was excluded, except where necessary, to avoid excessive dimensional burden in the final models. After these considerations the modelling phase was carried out starting from system families and then moving on to the introduction of simple loadable families, such as, up to the use of adaptive families for the reproduction of complex geometries such as organic shapes of roofs (Fig. 5). And in this context, the architectural elements that have found the most critical for their modelling have been the arched roofs. In these portions, in fact, at the end of the modelling, the maximum deviations from the cloud of reference points have been recorded as certified by the subsequent geometric validation.

For the geometric validation of the model, CloudCompare software was used to compare individual sample elements, or their aggregates, with the initial geometric datum obtained from the point cloud. For this operation an intermediate step with export through the Blender software, as it was said, was necessary to avoid data loss. The following example demonstrate the results obtained for the entire block (Fig. 6). The results can be observed in the three-dimensional representation of the model, where the green indicates correct modelling, including small details. This is also confirmed by graphical results showing that approximately 98% of the analyzed points have global deviations within the predetermined margin of +/- 5 cm. For instance, the mean deviation of block 1 is around 4 cm, while the curve is slightly dispersed with a deviation value from the mean of 1.5 cm.

The information part is determined by the evidence provided by either photographic material or literature. In addition, stratigraphies of walls, floors and roofs have been applied where possible by assigning the materials specially created (Fig. 7). Schedules and calculations related to surfaces, materials and building components were subsequently extracted. Finally, the insertion of photoplanes and reliefs regarding degradation and cracking framework through the definition of appropriate shared parameters has been arranged. The actual population of the model was currently only possible for limited portions (Fig. 8).

Conclusion

Developing a parametric model for historical-cultural heritage involves creating a complex information management process that can handle both geometric and non-geometric data. There is a focus in many studies on accurately capturing spatial data using 3D imaging/Scan-to-BIM techniques. However, geometric simplification may be necessary in later stages of building performance simulations for different BIM uses to ensure compatibility between authoring and specialized software. This often involves a trade-off between accuracy and simplification.

This paper emphasizes the importance of managing information and operational phases during H-BIM modeling, with a focus on validating the information management process to prevent data loss during phase transitions. By mapping out the activities involved, we can identify and address potential information losses, ensuring that the models are reliable and suitable for their intended uses.

The experience confirms that the current approach to managing information during

Fig. 8. Interior render from the BIM model (elaborated by Bongini, A.)

phase transitions in H-BIM modeling still heavily relies on manual control by individual operators, with automated procedures available only for certain tasks. The level of geometric accuracy required depends on the intended use of the BIM model. In fact these models are increasingly used as databases for archival documentation, surveys, and photos, providing structured information management not only for future restoration and conservation efforts, but also for cultural heritage appreciation.

Credits

The acquisition of point clouds with the laser scanner and the processing of photoplanes was carried out by a research group led by prof. A. Merlo.
Author Contributions: Conceptualization, B.C; methodology, B.C. and B.A.; data acquisition B.A.; data processing B.A.; writing—original draft preparation, B.C. and B.A.; writing—review and editing, B.A.; supervision, B.C.. All authors have read and agreed to the published version of the manuscript.

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