H-BIM and web-database to deal with the loss of information due to catastrophic events

The digital reconstruction of San Salvatore's Church in Campi di Norcia (Italy)

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Nowadays , we are able to produce geometric models of historical buildings at different scales of detail, using photos and measurements. This is true when you are observing something that is still under your eyes. We are faced more and more with lack of preservation actions and maintenance activities, policies framed without foresight, unexpected natural events, etc., that are forcing professionals and researchers to operate without usual data. In such cases, we need a consistent repository to collect and distribute data to produce information.Furthermore, we need to ``give intelligence'' to these repositories, in order to query them with respect to geometrical instances, topological issues, historical features, etc. This last aspect, (archives and databases connected with geometrical aspects), lead our digital model to a new dimension, the informative one (where spatial, temporal, historical and building parameters work together), that should always characterize speculative actions towards the constitution of a wealth of knowledge. We need to work on the efficiency of the process to reach effective methodologies of survey.

Keywords: *cultural heritage, Structure from Motion (SfM), loss information, H-BIM, web-database*

IDEAS FOR RECONSTRUCTION

The work proposed is a part of an ongoing research focused on the application of H-BIM approach for the management of historical building heritage (Murphy 2009; Murphy et.al. 2013). In particular, with regard to the catastrophic event consequences, both the acquisition phase and the archive research process are of great importance, for protecting our undefended building heritage. Following the latest disaster in Italy (Aquila, 2009; Amatrice 2016), most of the historical sources were lost and the artefacts themselves were in a state of total ruin. This fact has lead the scientific community to wonder which approach can be used in this particular case, when all the specific information (survey and historical sources) were unavailable or lost. If the information are missing, it is necessary to gather information through non-coventional methods and reasoning for deduction or analogies with other existing cases: a possibility could be to use the Structure from Motion (SfM) for recreating the digital model from images archived from the network or granted by the local population. Inspired by a similar work of virtual geometrical reconstruction from historical pictures of the Bamiyan's Buddhas (Grün 2004), that were destroyed in March 2001 by the Taliban, we have revised the methodology described in this work and extend, adding the possibility of semantically enriching the model and extending the knowledge beyond the purely metric 3d reconstruction aspect.The mesh model obtained with the SfM techniques can be used as reference for developing an H-BIM model. Although the system seems to be one of the best approaches for managing data and driving the decision-making process, several difficulties arise, due to the amount of effort required in modelling the initial phases (Volk 2014). One of the main issues, still not resolved in the field of H-BIM, is the establishment of the maximum deviation levels from geometrical data survey into the parametric elements that, for their nature, are simplified models, as compared to the complexity survey mesh models achieve with TLS or SfM approach (Lo Turco and Santagati 2015).The model has the dual function of communicative media but, is at the same time, a "virtual prototype" to conduct additional simulation and analyses, which have the primary objective of not endangering the historicity of the monument.In our case, the starting information (amateur sources and material collected from the world wide web) will produce an error, greater than that of a professional topographic approach. In that sense, the procedure should not be interpreted as a method for obtaining forms with a topographic precision but, a qualitative way to rebuild shape and elements. We must be aware that the H-BIM model will include a level of uncertainty.

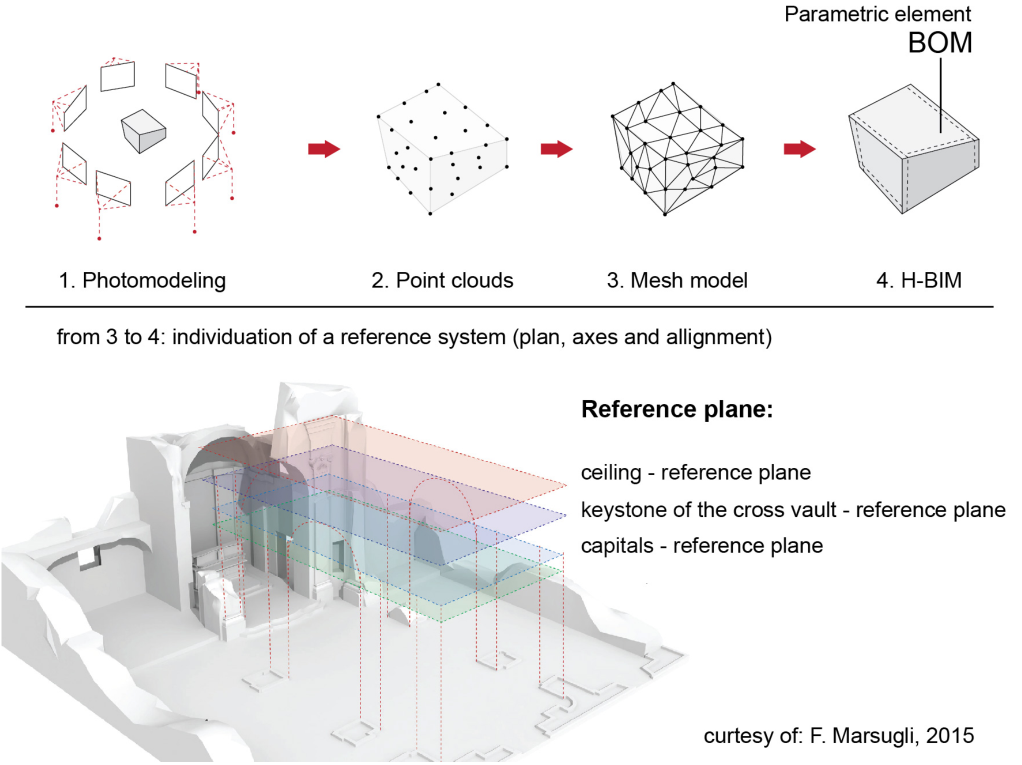
A POSSIBLE METHODOLOGY

The novelty of the method is to gather, elaborate and rebuild missing information from unconventional procedure. The general idea that prompted this work was to find a process that can overcome a lack of access to the ruins and achieve the most accurate digital model from the information available. Moreover, a fundamental aspect is to create a platform where it is possible to manage the information that will vary during the time. The methodology that we are going to present is based on the definition of two main strategies: the modelling strategies (1) and the gathering information involving the local population (social participation) (2).

Modelling strategies

A possibility for gathering or restoring information could be using SfM and extracting metric information from the pictures. The process has been well documented in literature (Lichti 2002, Apollonio 2010, Lo Turco and Santagati 2016), especially when the images are taken by professionals or specialist operator who has knowledge of photographic parameters which vary in accordance with different conditions. Instead, less work has been conducted when the reference material is scarce or has been downloaded from the World Wide Web. The process that we propose starts with the interpretation of the mesh model achieved from SfM that can used as reference for setting the macro element of the preliminary H-BIM model. This model is characterized by a low level of detail and information (LOD 100) and is composed of several main spaces individuated by function (defined at the gross volume of the masonry, floors and roofs). In particular, in the architectural domain, it is necessary to highlight the reference plane and the height of trusses, beams, ceilings, columns, frames, pilasters, niches, tabernacles and other building and all the architectural elements that will characterize the building (Marsugli, 2015) (see figure 1). After exhausting the first phase of modeling, the digital model needs to be enriched by additional, new information. In many cases, not all historical buildings

Figure 1
Methodology: form SfM to H-BIM



have been archived in official historical archives, as in our case, where an earthquake destroyed all the information (material and immaterial). For that reason, we propose a "campaign of sensitization" of the population: several items of information can be gathered from pictures, documents and historical sources, not published or not stored in official archives. All the information can be collected through a web platform where people can have a registered access. All the information will be uploaded using a logical and quality criteria for organizing and predisposing the material for digital elaborations. This platform is undergoing formalization and will be applied also for a case study in the Norcia area, affected by the earthquake (see figure 2). Once the information is uploaded through the platform, the operator must interpret it and understand how to use it for a semantical enrichment of the H-BIM model. This process will influence the building subsystems that are defined as Building Object Model (BOMs) in literature (Biagini and Donato 2014). The process of their creation could be time consuming, due to the missing of shared libraries available and due to the unstandardized form and shape (Volk et.al. 2014). It is necessary for the users to declare the level of accuracy. There are two main aspects for enriching the element within a H-BIM model: the first relates to the process of converting survey data into parametric elements, parsing the model semantically and decomposing the same, inserting a separation in an element that by its nature does not exist, whilst the second relates to the definition of BIM use that will heavily influence the modeling stage (Kreider 2013). The modeling strategies of BOMs (Building Object Models) could be diversified: if a point clouds is available, it is possible to achieve metric information and trace the elements; otherwise, in the case of missing information, we must use reasoning for analogy and use a deductive process. The information in this last case can be achieved from manuals and historical treatises or from deduction, comparing the information with similar case studies that present similar characteristics (typology, type of construction, era, year of construction, etc) (see figure 3).The LOD (Level of Development), that is expressed by two components: the level of information (LoI) and the level of geometrical detail (LoG); these must be calibrated as a function of the final purposes and if the model is used for analysis purpose, it can only be pure documentative. This can be chosen individuating the goal of the model that can be defined as the "BIM use". Currently, the LoD information is not a normed concept, and will be inserted in the new Italian legislation UNI 11337-2017.

Social crowd-sourcing and Web 2.0 for data management

Representation and its techniques play a fundamental role in the transmission of knowledge. We specifically join the geometrical model to a clever archive of historical data (families of structured and well known elements, intended as the minimal logical part of the whole building). After having put into an interoperability mode a relational database with a repository of "intelligent objects", we create a procedural path that allows users (researchers and professionals) to: (a) interactively select an element of the repository (thanks to a query builder); (b) import the BIM family into the BIM project; (c) associate the elements (BOMs) to the digital geometrical model; (d) link other parameters to elements (alpha-numerical and iconographic documentation; conjectures, other sources); (e) perform a semantic validation of the H-BIM. We have also considered the possibility of distributing database and query builder starting from a

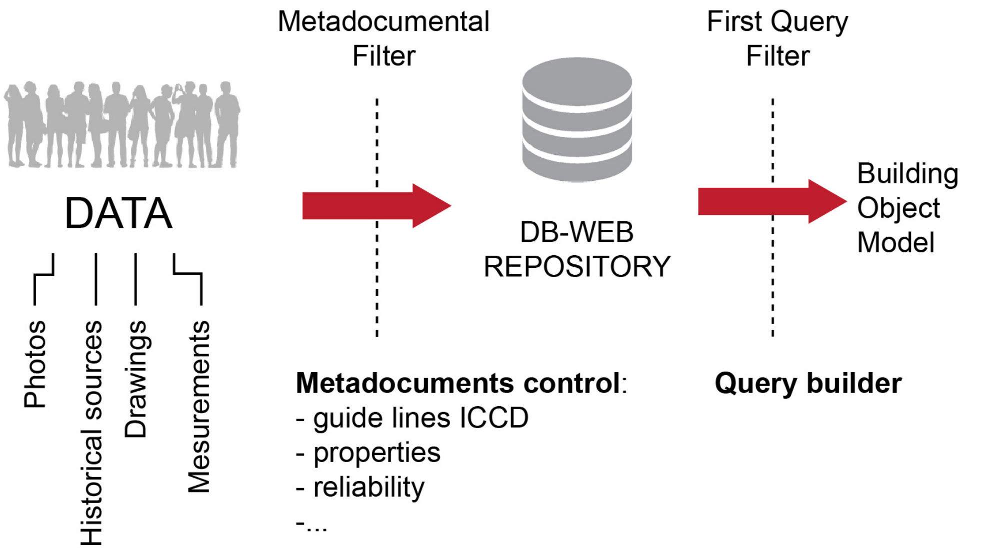


Figure 2
Call for sensitization: data gathering from social participation

web app, using computer technology ordinarily used for social internet site platforms (see figure 2). This digital model was used as a reference to develop an H-BIM. This article demonstrates the feasibility of a whole H-BIM approach for complex architectural shapes, starting from TLS point clouds. In order to improve the framework for 3D modeling, the experience will show the challenges of using integrated procedures to rebuild the historical documentation, when the information has been totally lost.The proposed web platform must consider several aspects: the creation of complex databases of the building must follow the guidelines set out by the Central Institute for the Catalog and Documentation (ICCD) of the Ministry of Cultural Heritage and Tourism; the platform must be user-friendly, to facilitate participation by an enlarged public (institutions, scholars, professionals, citizenry); raising public awareness of the need to supply historical data archives through accessible and transparent tools; the ability to interrogate databases differently, according to different search filters that can be combined (Wei Li et al. 2016).From the above-described requirements framework, the following operational tools (in a prototype version) have descended on the verification of the methodological approach we have outlined. In particular, this platform, which will be operated on distributed computers and on the web, includes two spaces of interaction: one dedicated to the inputs of the database, open to a widespread, appropriately accredited public, and the other turned to certain profiles that work on the digital reconstruction of the building.The open virtual public square provides archiving tools of various types of materials, meta-documented according to what is foreseen in the catalog of cultural goods. It allows the correct sorting of digital materials, functional to the consistent questioning of the sets (Sloane 2011).The main objective is creating an inter-operable and queryable "speaking" three-dimensional models of the built heritage, where the scholars can access and conduct comparison between similar case studies, directly or by analogy, and then associate the results of the document search with specific parts of the model.In more detail, those who work on the building information system provide appropriate parameters for the objects of the model library (general, geographic, and typographical, typological, geometric, topological attributes); The input of these parameters allows their conjunction with "and" and "or" constructs in a query string that is made up of a specific hypertext parameter called "search".The search parameter is compiled within a relational database that has the specific purpose of integrating specific data operations, which are not possible within the building information model (BIM) processing environment. Specifically, the system interacts with model library objects (BOMs) or with their specific formalizations (areas, volumes, or masses).

THE H-BIM FOR SAN SALVATORE CHURCH

The case study that we are presenting is the "Church of San Salvatore" in Campi di Norcia that was affected and extensively damaged by the sequence of earthquakes of 26th-29th October 2016. At the moment, the church is in ruins, with a few remains of the outer walls standing (in particular the southern wall, which was reinforced following earlier earthquakes), and a few sections of the vault near the back walls. The rest - the vaults, the frescoes, the facade and almost all of the ponte (iconostasis) - was all lost. Initial research in the archives of the Diocese of Spoleto-Norcia and the Superintendency of Cultural Heritage did not uncover any surveys of the state of the buildings before the earthquake. The only information available are some photographs and studies of the church, but no drawings. From an architectural point of view, it is clear that a huge amount appears to have been lost: not just the materials, which are currently being gathered, but also the form: the architecture's geometry.This study, starting from the situation described above and with the clear objective of digitally reconstructing the church as it was, involved exploring the outermost boundaries of knowledge of the relevant science, sometimes reinforcing them, and at other times going beyond them.In any case, this

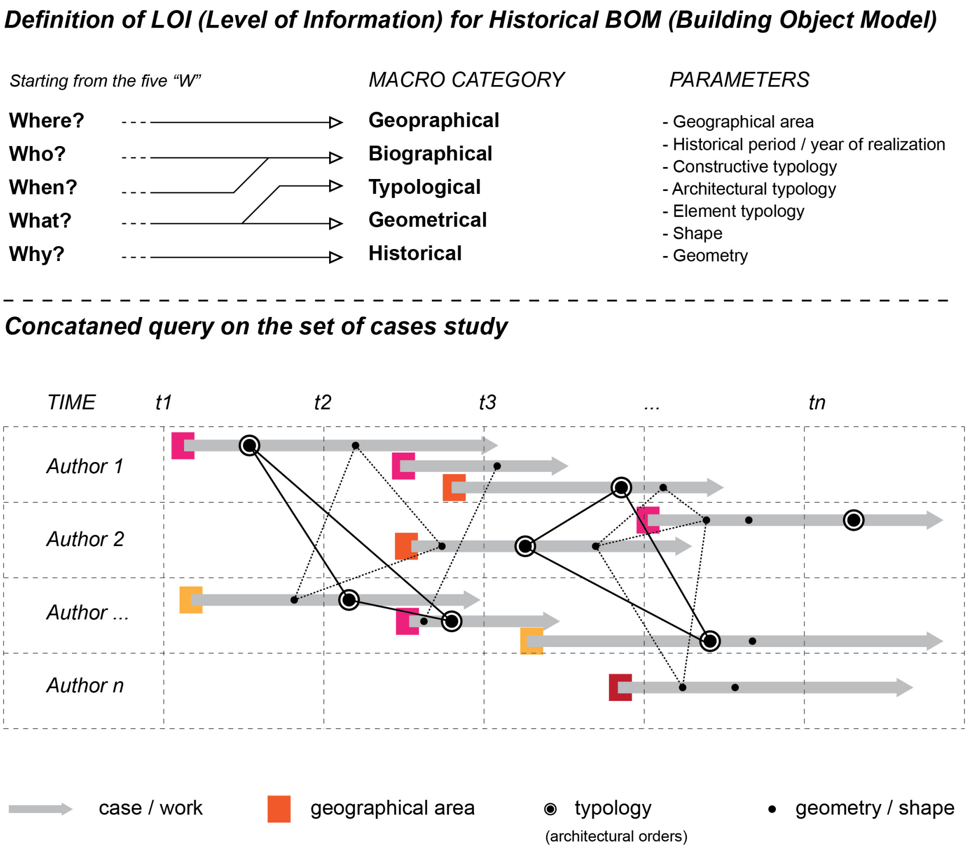


Figure 3
Tool for research and comparative analysis based on rules on a population of case studies: identification of elements analogous or similar on the basis of search criteria

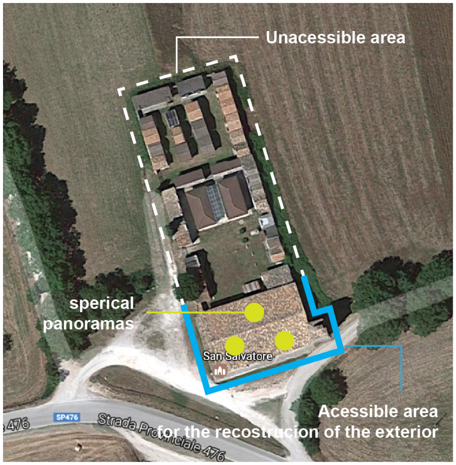
research is only the beginning of a process that is not only much longer, but also much wider in scope. The application outlined here could be repeated to produce an increasingly accurate reconstruction of the collapsed building, and also extended to other parts of the building and to other sites that have suffered the same fate, unfortunately all too common in the region struck by this earthquake.As mentioned before, at the starting point of our work, the only material available was: some spherical panoramas made public on google maps through a virtual tour. No other source of information was available.The first topic was to recreate a geometrical reference (axes, alignment, plane of references) for tracing the geometry of all the building elements. For instance, in the case of the gothic cross vault digital reconstruction, it is necessary to highlight the reference horizontal planes for capitals and the keystone for the transverse arches and the diagonal buttress but, at the same time, it is also necessary to highlight the vertical position of the reference planes for the arches. All the geometrical information were extracted by a 3d mesh model achieved form SfM approach (in particular with the software Agisoft Photoscan) that allows us to extract information from the panoramic photographs.The 3d mesh model was scaled as a function of a topographic measurements taken on site from the surviving masonry, as well as a photo-grammetric survey conducted using a drone. In that sense, the 3d mesh model was geometrically validated.The main issue was that from the photo modelling, using just the panoramic photos, the entire left-hand nave and part of the right-hand nave were recreated with a certain level of detail (approximately one point every 5 cm). However, the extracted model is lacking in other areas, especially the right-hand nave.In this particular case, additional photos could help to fill the voids left by the starting process. Only through a consideration of the original historical measurements and with a recent study of the authors, the 3D mesh model was scaled up and the necessary analysis carried out to

Figure 4
The San Salvatore Church: before and after the earthquake - the spherical panorama: the only information available


1.The Church of San Salvatore in Campi di Norcia before the earthquake


2. The Church of San Salvatore after the earthquakes

Information available: spherical panoramas



3. Localization of the information


4. One of the nine equirectangular images of the church interior (photographer Emanuele Persiani)

5 3D mesh model created - Retrieving the elevations and sections with Agisoft Photoscan software

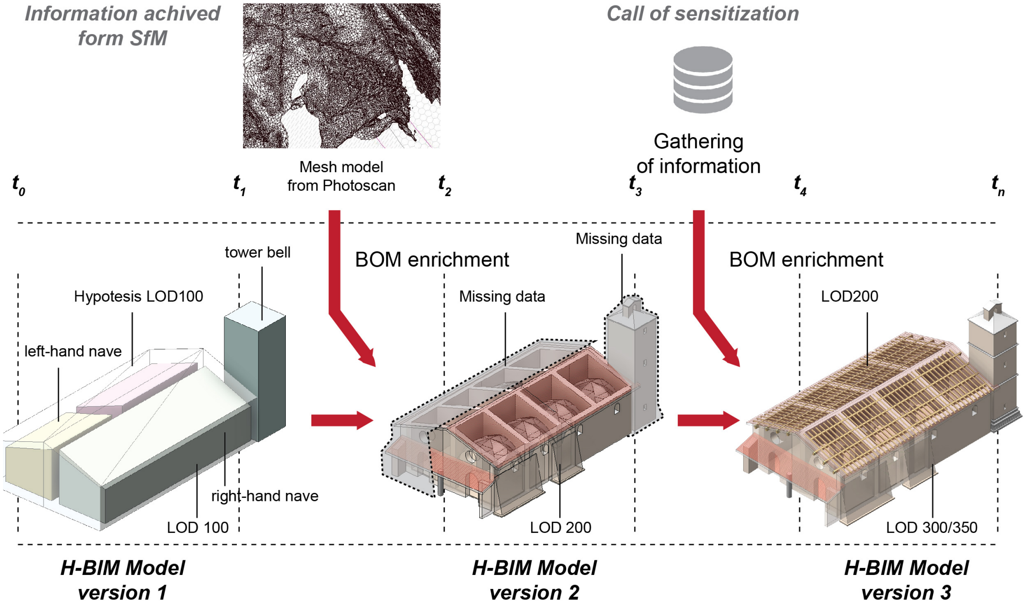


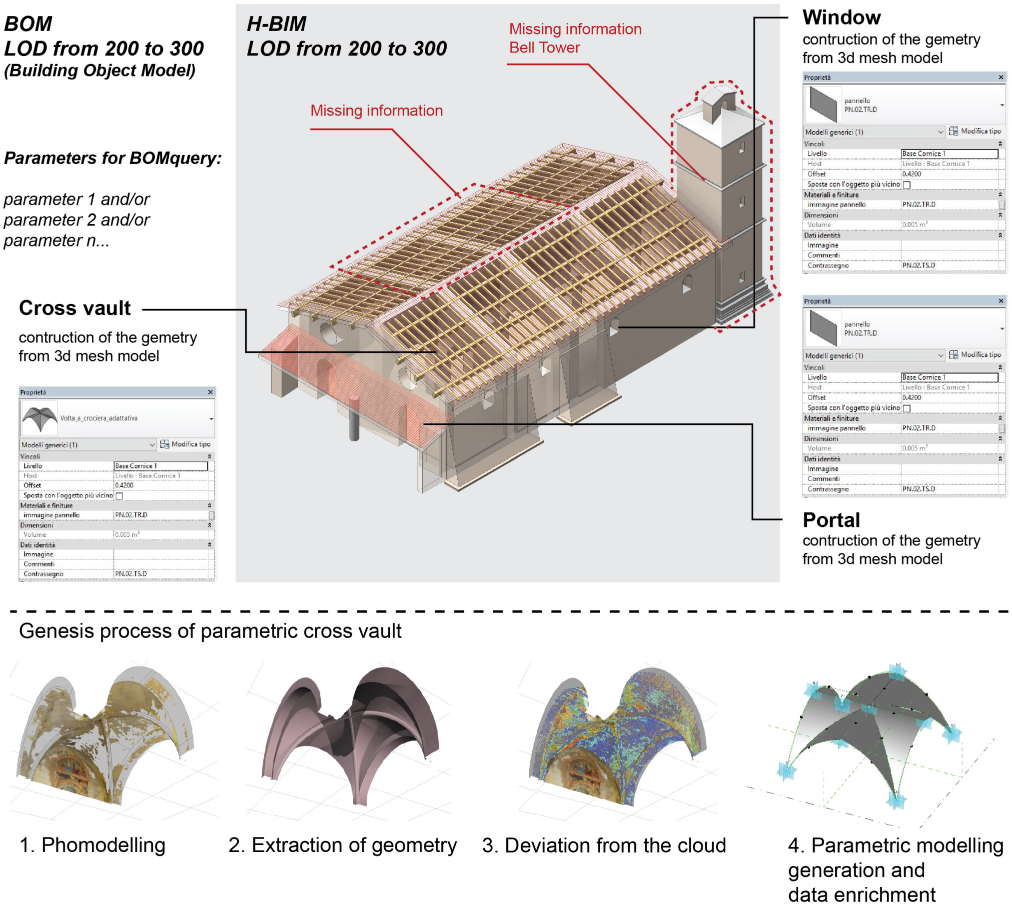
Figure 5
Process of data enrichment

reconstruct the creative process.The model was decomposed in the subsystem, starting from the load-bearing element, going till the roof and defining the rib vault and hypothesizing the traditional composition of the roof made by the main beams and secondary beams. This information can be obtained by observing the internal spherical panorama that allow us to look in the left nave. Unfortunately, due the low level of detail of the images, is not possible to extract metric information.Another step was the definition of the vaults. Before the earthquake in October, both naves were covered by raised rib vaults, with the keystone of the ribs higher than the arches surrounding the vault. Another observation is that the centre-to-centre distance of the aisles is not consistent, and they are laid out along a straight line, which is not parallel to the floor. These characteristics, typical of Italian Gothic architecture, should not be attributed to haphazard building techniques, but rather to an artisanal approach typical of mediaeval architects.For this, we have developed a parametric rib vault that can be adapted on the mesh model, inserting 9 control points (4 for the lower level of the arcs, 4 keystone of the arcs and 1 keystone for the vault).For this research, as a case study, the left-hand nave was modelled at the LOD200. Other parts of the church were modelled based on the picture extracted from google maps at the LOD100 due to the absence of information. Proportional relationship between elements were obtained through the inverse perspective method.

CONCLUSION

The research conducted until now demonstrates the potential of H-BIM applied for driving the process of reconstruction after the seismic event due a loss of information. Although the procedure shows high potential in general, from another perspective, it shows limitations, especially the difficulties of populating a virtual library of case studies (churches, for

Figure 6
H-BIM model for the San Salvatore Church - model version 2 towards version 3



instance) and elements (BOMs for historical building heritage).Further work will be conducted in presenting the platform officially in the town of Norcia and starting with the phase of "sensitization" and gathering of information for developing the third version of the model. The final objective will be to achieve a complete "as-it-was" model, including all the architectural and technical notices necessary to guide the reconstruction phase of the church.

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