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HBIM for restoration projects: case-study on San Cipriano Church in Castelvecchio Calvisio, Province of L'Aquila, Italy.

HBIM per il progetto di restauro: l'esempio della chiesa di San Cipriano a Castelvecchio Calvisio (L'Aquila).

Although there have been significant developments in research into assigning semantic content to 3D models for the purposes of documentation, conservation and architectural and archaeological heritage management, the application of 3D GIS to individual artifacts has remained rare. Where 3D GIS has been used in this context, it has not been done in a consistent or standardised way. As an alternative to the elaborate construction of 3D GIS, the international academic community has embarked on a process of investigating how HBIM (Historical BIM) might be used in the fields of historical architecture and archaeology. In this paper, we report on experiments carried out at the San Cipriano Church in Castelvecchio Calvisio (AQ) on the basis of the integrated survey of the church, before turning to a discussion of the planning of restoration work in a BIM environment.

Sebbene vi siano stati significativi sviluppi nella ricerca volta ad attribuire contenuti semantici ai modelli tridimensionali finalizzati alla documentazione, conservazione e gestione del patrimonio architettonico e archeologico, le applicazioni di GIS 3D a singoli manufatti sono rimaste per lo più esperienze isolate e lontane dall'essere condotte con omogeneità e sufficienti livelli di standardizzazione. In alternativa alla elaborata costruzione dei GIS 3D, la comunità scientifica internazionale ha intrapreso un percorso volto a comprendere quali siano le possibilità applicative del processo HBIM (Historical BIM) all'architettura storica e all'archeologia. In questo contributo si illustra la sperimentazione condotta sulla chiesa di San Cipriano a Castelvecchio Calvisio (AQ) a partire dal rilievo integrato dell'oggetto sino ad arrivare alla pianificazione degli interventi di restauro in ambiente BIM.

Keywords: HBIM, documentation for conservation, digital survey, 3D modeling, semantic 3D models.

Parole chiave: *HBIM, documentazione per il restauro, rilievo digitale, modellazione 3D, modelli 3D semantici.*

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SEMANTIC 3D MODELS FOR DOCUMENTING ARCHITECTURAL HERITAGE

Deciding which are the most appropriate digital technologies for documenting and managing data concerning built heritage has long been the subject of international debate. Although the question is still open, there is some consensus that three-dimensional digital models that provide layered information in three, and often in four dimensions are most appropriate. In this context, where the focus is shifted from a geometric model to the creation of a comprehensive three-dimensional database which can store various information derived from multidisciplinary fields that the model inherently provides[1], the design of the system storing information on preserving, documenting and managing the project is of crucial importance.
Based on these objectives, researchers have identified two main digital "environments", each with advantages and disadvantages, that fulfil these needs. These are GIS (Geographical Information Systems) and BIM (Building Information Modeling).
In this regard, a thorough review has been set up to analyse each of the key features of both systems, starting from the current state of international research. The results show that, whichever system is chosen, successfully using a semantically rich three-dimensional model to manage information efficiently is dependent on three key prerequisites: (a) the creation of a formal specification of concepts (an ontology); (b) the conceptualisation of relations between them; and (c) the specification of hierarchies. The semantic enrichment of a three-dimensional digital model is the result of a cognitive and technical process that can adapt itself to a tool according to the specific requirements of the case, bearing in mind that both systems aim to provide spatial information[2]. In this paper, we describe the BIM modelling process in an early medieval ecclesiastical building, using hierarchies and criteria already defined following previous experiences of using 3D GIS on an architectural level.

BIM IN HISTORICAL ARCHITECTURE

Building Information Modelling is already used successfully as a professional planning tool for new architecture. Using BIM for historical architecture management is a strategic objective which remains to be pursued. However, since BIM has obvious potential for working in historical contexts with a wealth of relevant information (e.g. data resulting from direct and instrumental surveys, documents and archival drawings, historic photographs, the results of diagnostic campaigns, documentation of restoration work), the international scientific community has been investigating for several years how it could be applied in the context of historic buildings and building archaeology, adapting its acronym to HBIM (Historic Building Information Modelling[3]). The main difference between the two processes, as described by Simone Garagnani, lies in the type of information which the digital models collect: the BIM process uses three-dimensional models to coordinate the work of the professionals who participate in integrated planning (architects, electrical engineers, structural engineers, etc.), thus also facilitating the planning of the timing and fulfilment of work on the construction site. The HBIM process, on the other hand, is based on geometrical knowledge, knowledge of the materials and history of the building as shown by surveys, and the type and status of conservation materials to be used. It is primarily aimed at the planning of conscientious restoration work[4].


Fig. 1, View from the top of the village of Castelvecchio Calvisio, with its distinctive layout.

CASE STUDY: THE CHURCH OF SAN CIPRIANO AT CASTELVECCHIO CALVISIO, PROVINCE OF L'AQUILA, ITALY.

The Church of San Cipriano, where we tested the

Fig. 2, View of the front of the Church.

Fig. 3, View of the church from behind, with the semicircular apse in the foreground.

techniques described in this paper, is situated on the outskirts of the village of Castelvecchio Calvisio in the province of L'Aquila, within the Barony of Carapelle This territory, located in the high Gran Sasso region surrounding L'Aquila, developed into a significant feudal domain in the late thirteenth and early fourteenth centuries. Until the unification of Italy, it was ruled successively by the D'Angiò, Piccolomini, Medici and Borbone families. The area, which originally included the territories of what are now the villages of Carapelle Calvisio, Castelvecchio Calvisio, Santo Stefano di Sessanio and Calascio, is currently part of the Gran Sasso and Monti della Laga National Park, described as "cultural tourism environmental district of the Lands of the Barony". It also includes the territories of Barisciano and Castel del Monte[5].

The building in question, probably one of the oldest in the area[6], is a small country church. Its internal and external walls contain numerous reused elements from the classical era, which suggests that the church was built near a Roman-Italic settlement, or perhaps on the site of an earlier religious building[7]. Few clues exist as to the original early medieval appearance of the building[8], but thirteenth-century additions can still be seen, although they have been modified repeatedly over time up until the end of the 1980s[9]. The church's nave measures 6.60m by 14m. It has three internal diaphragm arches, behind the last of which is the presbytery. The presbytery is raised, and contains a ciborium made with a structure of columns covered with a cross rib vault, which dates back to the fourteenth century[10]. Its construction involved the demolition of the original apse. To the left of the altar, a pointed arch leads to a chapel built in the first half of the last century, supported by the original building's masonry. To the left of the entrance is a smaller chapel, probably built at the same time as the ciborium; it has a barrel vault ceiling and pointed arches that define two of the four sides, set on modest-sized columns. Next to this is a chapel dedicated to the Annunciation, supported by the perimeter wall and the previous masonry. It is a structure of modest dimensions covered with a barrel vault. The front of this vault has a round arch which rests on two pillars

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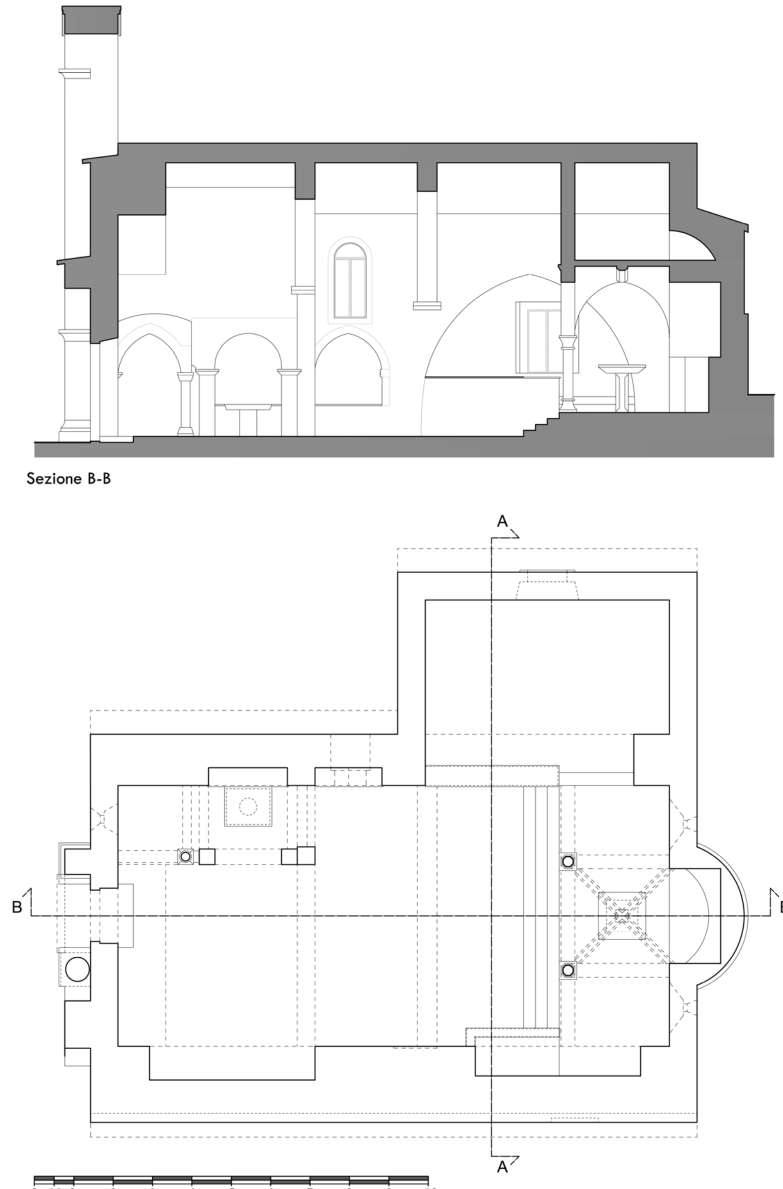

Fig. 4, View of the interior of the Church.

Fig. 5, Building plan and transversal section of the building.

which also support the two low arches that form the sides of the chapel. The arch and pillars are painted, and on the left pillar, the client's name and a date (1429) are still visible[11]. Outside, the church walls' external brickwork is visible. The façade has a bell tower centred on the entrance door, leaning against the wall and flanked by spurs, supported by a pillar and a reused column. The state of conservation of the building is generally good, except for some traces of moisture from rising damp in the apse wall, and some modestly sized damaged sections in the façade and on the inner wall corresponding to the two small chapels to the left of the entrance. The internal painting work has also been generally poorly preserved.

THE PROCEDURE USED FOR THE RESTORATION PROJECT.

To generate a parametric model of the church of San Cipriano, we started by creating a digital photogrammetric of the building using Agisoft's PhotoScan Pro-

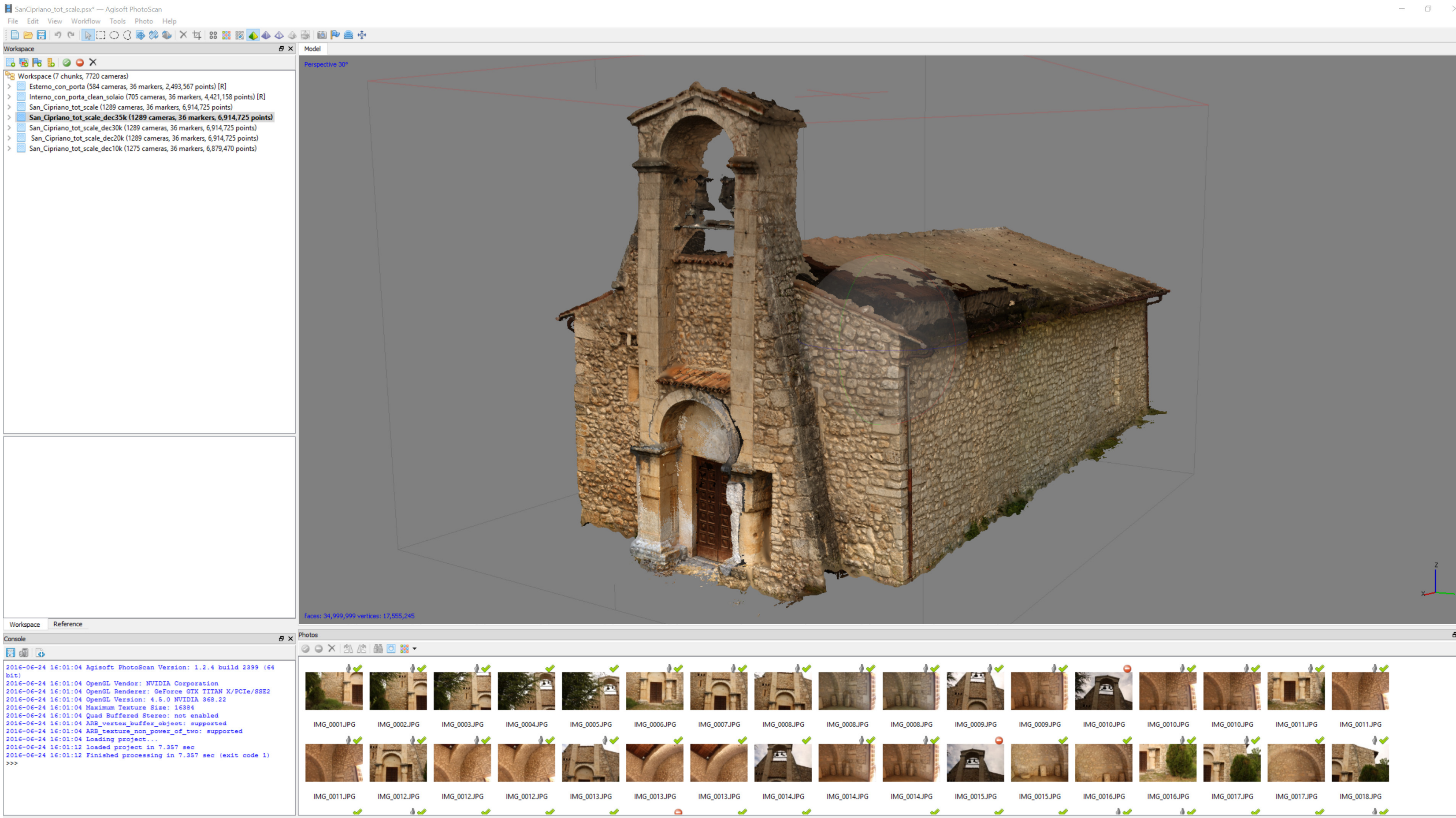

Fig. 6, Screenshot from Agisoft Photoscan with the model of the outside of the church.

fessional Edition software (release 1.2.2). The software generated four clouds of dense points from four different sets of digital images, one for each front of the church. It also created a textured mesh. It created an overall scale model from which we were able to extract four photographic plans of the building's fronts, used for the construction and subsequent texturing of the parametric model. This procedure was repeated inside the church from six sets of images: one for each side, one to model the wooden floor and the diaphragm arches, and one for the adjacent area used as a sacristy. We then used PhotoScan to join the two scale models, one representing each of the inside and outside of the church, using the common points seen from the door aperture.

Before carrying out BIM modelling, it was necessary to design a system hierarchy, organised into categories of architectural components (broken down into constituent materials), on the basis of a simplified version of the model proposed by the Central Insti-

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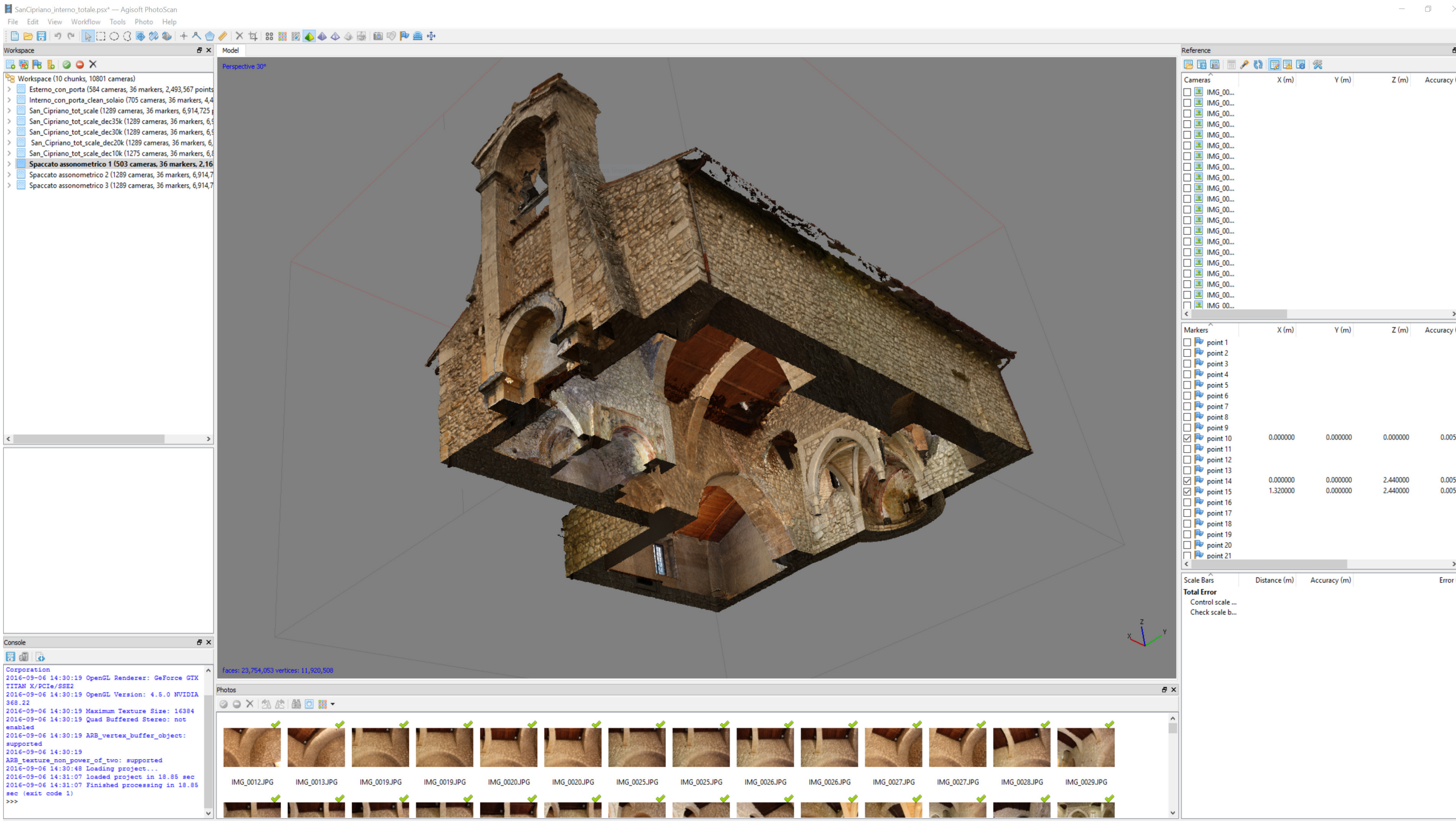

Fig. 7, Screen shot from Agisoft Photoscan with the axonometric cross section of the whole model.

tute for Restoration (ISCR) in the Risk Map of Cultural Heritage, previously used for the construction of three-dimensional architectural information systems (Continenza 2015).
We then used the Revit 2015, by Autodesk, to generate a parametric model. With this software, we modelled the different parts of the building, always making reference to the reality-based models described above, supplemented with data from direct detection, following the hierarchical structure described above. Each architectural component was modelled completely within the software. This involved the creation of suitable "families", which we gradually populated with attributes related to their state of conservation and the fields required by ISCR cards. We also used the software to analyse the degradation of the building, carrying out modelling on the basis of the representative photoplane surfaces available of the various damaged areas, quantifiable through the data generated by the software.
Finally, we exported the model in .dwf format (Design

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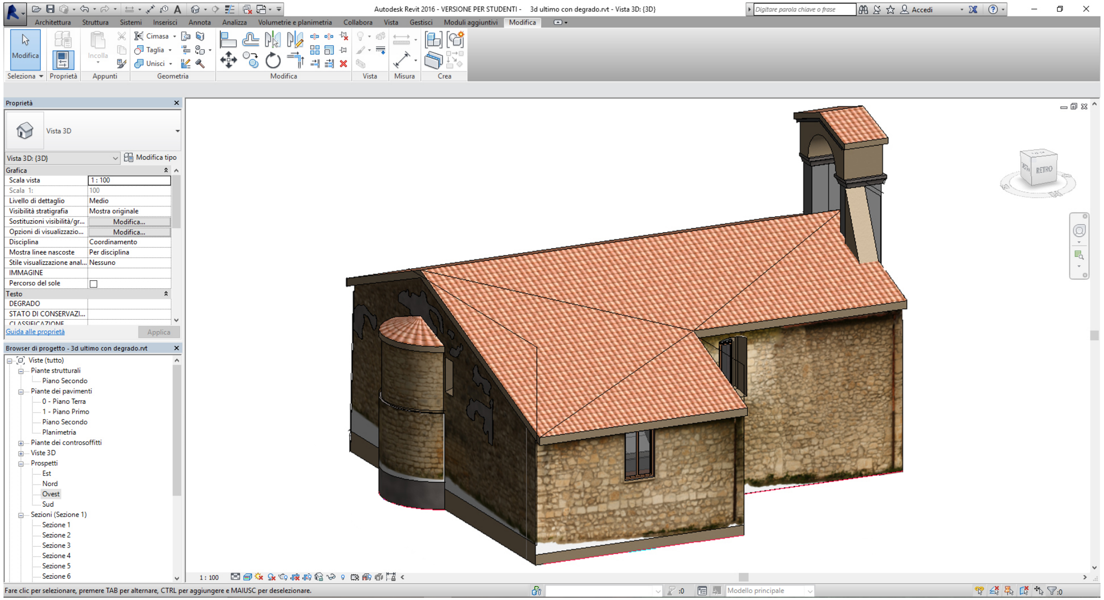

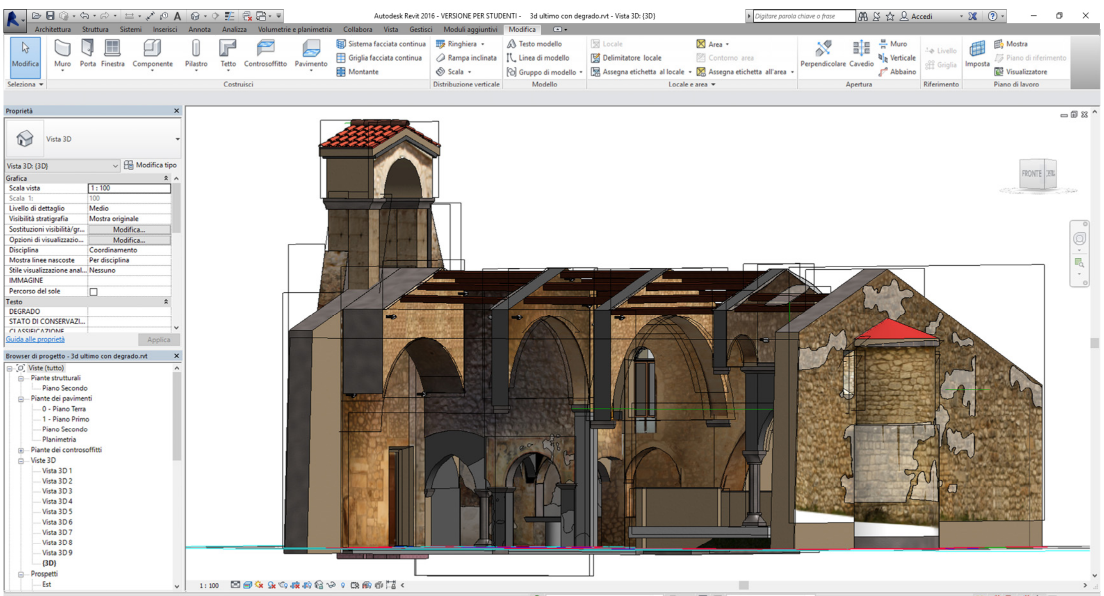

Fig.8, Screenshot from Autodest Revit 2015 with an external view of the parametric model of the church.

Fig.9, Screenshot from Autodesk Revit 2015 with mapping of the interior degradation of the church.

Web Format) so that it could be widely shared viewed and measured using free viewing software (we used Autodesk Design Review).
The project, which is still being finalised, aims to overlap the parametric model of the church with the results of the stratigraphic-structural analysis conducted in parallel on the building by a multidisciplinary team, as well as representative models of the various church life stages identified through the stratigraphic analysis of the church's walls.

CONCLUSIONS

The investigations described above allowed us to carry out tests (not without difficulty) in an architectural context on previous research carried out using 3D SIArch (three-dimensional architectural information systems). Specifically, our work allowed us to investigate whether it is possible to connect topologically heterogeneous data to a representative 3D model of a historic building. Although the results of the investigation are still to be verified (because the work is still in progress), it can be stated with confidence that, compared to similar experiments conducted previously, the modelling procedure is not significantly affected by the format interoperability issues experienced when using 3D GIS. As in that case, here as well it is clear that the major issues encountered are the result of using software created for another purpose (BIM, for example, was designed for creating new buildings rather than for restoring and managing existing built heritage). Therefore, the irregularities inherent to archaeological contexts and historical buildings is poorly compatible with the automatic nature of the functions of the software, and with its orientation to the geometrically regular forms which characterise contemporary architecture, and making it impossible to fully exploit the potential of the software in terms of seriality, equality of proportions, and repetition. In historical contexts, it is constantly necessary to use manual procedures (implementation of ad hoc families); this necessarily involves an increase in the time needed for the procedure. The fourth dimension of the semantic model (the time management of the building, carried out through the planning of maintenance programs, the documentation of exceptional operations and all monitoring activities in the broadest sense) still requires further research.

NOTE:
This work was conceived jointly by the authors. Romolo Continenza wrote paragraphs 1, 2 and 5; Ilaria Trizio wrote paragraphs 3, 4 and 5. Alessandro Giannangeli carried out the photogrammetric survey of the entire process of the case study and developed photoplane models, and Alessandra Tata created the parametric model and analysed the degradation of the case study.

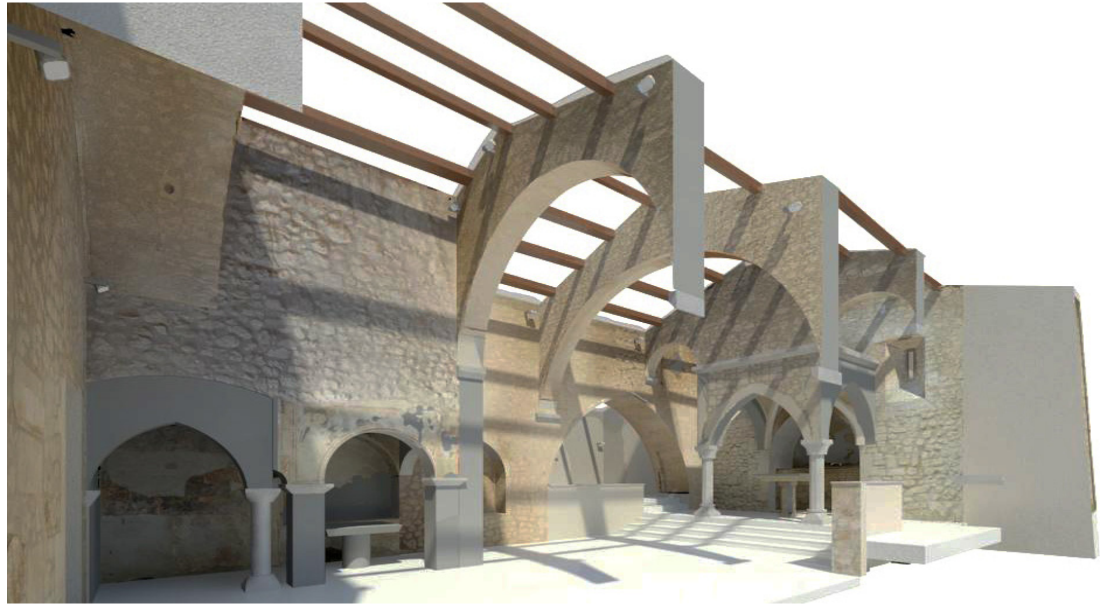

Fig.10, Render of the interior of the church with mapping of the surfaces degradation.

Figg.11 e 12, Render of the facade and view from north-east of the church with mapping of the degradation.

NOTES

[1] Saygi and Remondino 2013, p. 697.

[2] Saygi and Remondino 2013.

[3] This acronym was coined in 2009 in an article by M. Murphy, E. McGo-McGovern and S. Pavia. “Historic building information modelling (HBIM)”, in “Structural Survey”, 2009 27/4, pp. 311-327.

[4] S. Garagnani 2015.

[5] Cifani and Cialone 2012, p. 17.

[6] The first documentary evidence is from 779, according to the *Chronicon Volturnense*.

[7] Staffa 2000, p. 76 and Mattiocco 1988, p. 117.

[8] A recent stratigraphic-structural survey, conducted by a multidisciplinary group of researchers from the CNR-ITC and archaeologists from the University of L'Aquila, has sought to highlight the evolution of the building over time, from its early medieval beginnings to the changes made during recent restoration work (Redi et al., not yet published).

[9] In 1478, the church was changed from a parish church to a rural church used only for burials. From this time, it was probably maintained less frequently; this is suggested by the pastoral visits that continued regularly as early as 1589 (Mattiocco 1988, p. 118) and various documented appraisals (Antinori, 29, vol. 2, 488 and ASA, Intendenza, S. I, Cat. X, B. 1229A) which were followed by renovations and repair work to the building.

[10] The construction date of the Gothic-style raised area has been determined on the basis of comparisons with similar features of the nearby church of San Pietro in Valle Caporciano (Moretti 1971, pp. 269-301).

[11] Antinori’s chorography (Antinori A.L., Corografia Storica degli Abruzzi, vol II, 478, ms, Library Salvatore Tommasi, L'Aquila) can indeed be interpreted to understand that the aedicula and its decorations were commissioned by Luccia Jaba.

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