Pathology detection for HBIM application on a Byzantine church in Axos village in Crete, Greece

Eleni ZAROGIANNI, University of Piraeus, Greece
Konstantina SIOUNTRI, University of Piraeus, Greece
Neoptolemos MICHAILIDIS, Greece
Dimitrios D. VERGADOS, University of Piraeus, Greece

Keywords: HBIM, Byzantine Architecture, Photogrammetry, Laser Scanning

Introduction

Building Information Modeling (BIM) is a revolutionary technology that is characterized as the opportunity of the AEC industry to move to the digital era and improve the collaboration amongst the partners of this industry by exploiting Information and Communications Technologies (ICT). BIM provides automation capabilities for more integrated communication, data exchange and sharing between project actors within a virtual 3D environment (Gu and London, 2010). The designed virtual models are directly linked with databases of geometric and non-geometric information in order to achieve the best possible management in the buildings' life circle, from the design phase, construction, management, maintenance to its demolition. The utilization of BIM as a tool for all relative stakeholders (scientists from multidisciplinary fields, construction and real estate companies etc) is going to grow bigger. Already, many countries such as UK have introduced BIM technology as an obligatory construction process for public buildings. Acknowledging the numerous applications and possibilities of BIM technology to combine various data in a single file, accessible to different scientists and experts, researchers have been trying lately to apply BIM on buildings of historic value (Murphy, 2012). Heritage or Historic Building Information Modeling (HBIM) is a new approach to create intelligent three-dimensional models and databases of historic buildings that integrate information and data, e.g. architectural designs, static analysis, pathology, ICT computing, geomatics, cultural heritage documentation, architectural intervention techniques and maintenance practice, etc. However, the variety and complexity of this information is one of the main reason for its slow integration in the field of restoration of monuments (García-Valldecabres et al., 2016). In this paper a research case of documentation of structural pathology for HBIM implementation on the byzantine church St. John Prodromos in Crete, Greece is presented. The process of diagnosis and documentation using laser scanning and photogrammetric tools will be analysed.

Methodology

Historical analysis - documentation

The church of St. John Prodromos is located in Crete, at Psiloritis mountain, in Axos village near to town of Rethymnon. The surrounding area is listed as a protected historical location by the Hellenic Ministry of Culture, whereas St. John is the best well-preserved byzantine church in the settlement of Axos. Although a written sign of chronological reference has not been yet found, according to Em. Borboudakis, archaeologist and ex Director of Byzantine Ephorate in Crete, based on his study of the internal frescos, the church was probably built in the first half of 15th century. Church of St. Prodromos is a single-aisled arched church (10x5,15m), with two internal stone arcs for additional structural support and a duo - pitched roof with byzantine tiles (Fig. 1). The in-situ research revealed that the church is built on the remains of an older Christian church. Throughout its life history, the monument has undergone some minor interventions. However, nowadays various problems regarding the deterioration of materials i.e. due to environmental causes (humidity) and the structural integrity due to damages caused by earthquakes taking place in the area. In the interior, the church is fully painted with frescos representing numerous instances from St. John's life, as well as other Christian-Orthodox ceremonial subjects and Saints images. The historical frescos nowadays are in bad condition due to humidity. For that reason, a detailed survey and a database with information such as frame dimensions and location, painted forms and pathology has been executed.

Fig. 1. Western view of St John Prodromos Post-Byzantine Church in Axos, Crete.

HBIM Database

Bibliographic research demonstrates that Building Information Modeling (BIM) in the field of cultural heritage is based mainly on practice, as the action places the researcher in a real situation where he must respond to practical and not theoretical problems. As we already mentioned, HBIM platform has a set of different types of objects information pre-determined but also new properties that can easily be added to the specific project needs e.g. authenticity. The information is structured and object-oriented, linked directly to the building element to which it is logically referenced. In order to study the Church of St. Prodromos. It was decided to create an HBIM database that includes both geometric and non-geometric information. The geometric information is indicative of building elements, frescos or plastic decoration, networks, equipment with the required level of development (LOD). Non-geometric data refers to data on building phases, material, colour, cost, model, manufacturer, etc. of the above categories, as well as information on intangible cultural heritage. The 3D model was based on laser scanning and image processing techniques. Then, 3D objects of different elements were edited through graphics and used to create the database. Among other things, database includes information of building components, painting or plastic decoration, networks, material, colour, building phases, authenticity, archival material including historical documents, photographs, etc. as well as information on intangible cultural heritage. The HBIM library that is created will allow moving from the general to the detail and vice versa, as well as categorization / classification of data.

Pathology diagnosis using laser scanning and photogrammetry optimization and filtering

Architectural survey was executed by using Faro's 3D Multisensor Focus Laser Scanner, using spheres as reference points. The accuracy was determined at 6,15 mm and included four repetitions per scan (England, 2018). Finally, 17 scans were produced and the whole procedure was carried out, allowing the engineers to gather all data needed for a restoration study, on a single working day. Faro Scene was used for point cloud optimization, smoothing and filtering, as well as creation of orthophotos, while highly accurate architectural designs were made using Bentley Pointools View, saving a significant amount of effort and time comparing it to traditional methods. As far as the pathology diagnosis, in order to deal with issues concerning the highest possible level of accuracy (cracks, shape of the arches etc), a methodology using digital processing of selected orthophotos was followed. This technique was chosen as the best applicable one since the whole church is covered with frescos inside, making existing cracks difficult to mark and notice. This phenomenon is worsened by the high level of humidity which had created large blackish areas on the facades. Digital processing including removal of the RGB filters and controlling of orthophotos' level of intensity was carried out in all interior surfaces, making frescos disappear and cracks appear clearly on the walls and arches (Fig. 2, Fig. 3). Although the initial intention of the study included using Revit for the whole project, architectural designs of pathology were finally made in AutoCAD, because the highest possible level of accuracy was needed as far as it concerns geometry. This methodology allows scientists in the field of cultural heritage restoration to document accurately a historic building and collect pathology information that can be used on an HBIM central repository.

Fig. 2. Orthophoto of the north facade of St John Prodromos Church in Axos,.

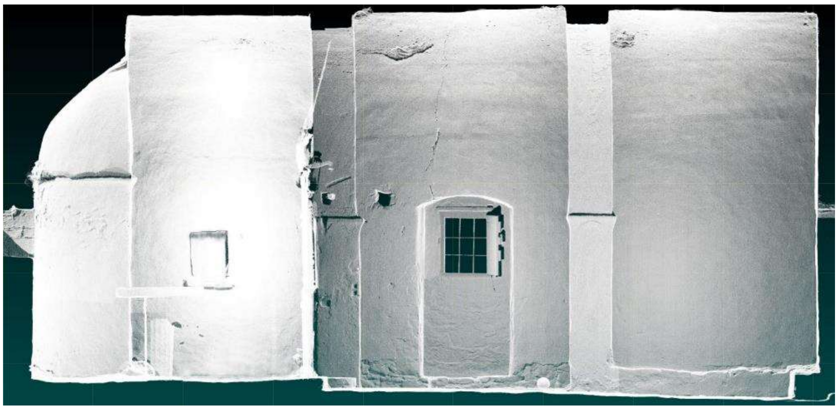

Fig. 3. Orthofoto of the north facade of St John Prodromos Church in Axos.

Conclusions

Digital processing of orthophotos for crack detection can be used not only on pathology survey, but also on monitoring of the structure through time, arriving to significant conclusions about gradual deterioration of a building and necessity of urgent interventions. This methodology allows researchers to reach accurate results, having spent the minimum possible time on site and contribute to the HBIM documentation of cultural heritage.

Acknowledgements

This paper has been partly supported by the University of Piraeus Research Center (UPRC).

References

England, H. (2018) '3D Laser Scanning for Heritage: Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture.'

García-Valldecabres, J., Pellicer, E. and Jordan-Palomar, I. (2016) 'BIM Scientific Literature Review for Existing Buildings and a Theoretical Method: Proposal for Heritage Data Management Using HBIM.' *In Construction Research Congress .*

Gu N. and London K.(2010) "Understanding and facilitating BIM adoption in the AEC," *Automation in Construction, vol. 19.*

Murphy, M. (2012) 'Historic Building Information Modelling (HBIM). For Recording and Documenting Classical Architecture in Dublin 1700 to 1830.' *Handbook of Research on Emerging Digital Tools for Architectural Surveying, Modeling, and Representation*.