

JOINT INTERNATIONAL CONGRESS

ARQUEOLÒGICA 2.0
9TH
&

GEORES
3RD

PROCEEDINGS

Digital Twins for
Advanced Cultural Heritage
Semantic Digitization

Online - Valencia
26-28 April 2021



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Proceedings of the ARQUEOLÓGICA 2.0 - 9th International Congress & 3rd GEORES - GEOmatics and pREServation
Lemma: *Digital Twins for Advanced Cultural Heritage Semantic Digitization*.

ARQUEOLÓGICA 2.0 - 9th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation.

GEORES - 3rd GEOmatics and pREServation.

The contents of this publication have been evaluated by the Scientific Committee which it relates and the procedure set out
<http://ocs.editorial.upv.es/index.php/arqueologica20/arqueologica9/about/organizingTeam>

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www.lalibreria.upv.es / Ref.: 6589_01_01_01

ISBN: 978-84-9048-872-0 (print version)

Print on-demand

DOI: <https://doi.org/10.4995/arqueologica9.2021.13259>



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- ✓ Virtual Archaeology International Network (INNOVA)
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Preface

More than 10 years have passed since the first edition of ARQUEOLÓGICA 2.0 (International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation) was held, in 2009. At that time, its promoter, Dr. Alfredo Grande, dreamed of creating a meeting place for all researchers and professionals who were experimenting with the application of new technologies in the field of archaeology. They were years of change and resistance, since part of the academic community considered these new lines of research as something secondary and residual, without connection to true scientific knowledge. People who worked in the field of virtual archaeology did so as isolated units, scattered across different regions and countries and with very little connection to each other. Although in the first decade of the 21st century the number of researchers working in this field had grown exponentially, there was a lack of spaces that would make it possible to make visible what was being done. Thus ARQUEOLÓGICA 2.0 was born, to fill those spaces for the Spanish case but with an international vocation. An open and inclusive congress where it was possible to know what other researchers from different countries were doing but also to forge new contacts and relationships to foster not only the virtual archaeology field but also the widening field of cultural heritage with collateral resources. A congress that favoured the emergence of new collaborations and projects. A congress to know that we were not working alone, encouraging new researchers to join the field of virtual archaeology.

In these years, this congress has evolved at the same time as the scientific discipline that today we call virtual archaeology. During this time, ARQUEOLÓGICA 2.0 has established itself as a meeting forum for professionals from different branches of knowledge. The congress has served to build in Spain and the rest of the world, a link between the latest technological developments and archaeological science. It has promoted the creation of the *International Principles of Virtual Archeology (Seville Principles)* that were ratified by ICOMOS in 2017. It has served as the basis for creating a scientific journal, *Virtual Archaeology Review (VAR)*, which in 10 years has been positioned as one of the most important archaeology journals in the world, and which has allowed, and continues to allow, researchers from around the world to share their progress with the international scientific community in an open and free format.

ARQUEOLÓGICA 2.0 has also demonstrated its commitment internationally and in some editions, Marseille 2013 and Granada 2015, it has joined other similar congresses. This year, ARQUEOLÓGICA 2.0 once again demonstrates its ability to join forces, in this case with the close friendship of the GEORES (GEOmatics and pREServation) community. The previous two editions of GEORES in Italy capture the innovative spirit of the cultural heritage community. In the present edition of the virtual joint international event, the 9th ARQUEOLÓGICA 2.0 & 3rd GEORES 2021, deal with topics related to data acquisition, virtual archaeology, virtual architecture, conservation, cultural heritage, high-end digitization, advanced geomatics, preservation and restoration, through the event lemma, **Digital Twins for Advanced Cultural Heritage Semantic Digitization**. The power of technology, combined with deep understanding of heritage will definitely contribute to increase the scientific level of state-of-the-art technologies applied to safeguarding our heritage, trying to be useful to our society.



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The proceedings report about 87 contributions that have been peer-reviewed by an international scientific committee fully compromised with the advancement of technology. We would like to express our gratitude to the PhD Forum co-chairs, Nannina Spanò (POLITO), Giulia Sammartano (POLITO), Valentina Bonora (UNIFI), Mattia Previtali (POLIMI) & Roberto Pierdicca (UNIVPM), for their active compromise and excellent undertakings in this congress.

We want to express our gratitude to both the Organising Committee and the Scientific Committee for their compromise in the success of this virtual event during the COVID-19 pandemic era. Hopefully, the next editions will be in a face-to-face format. Last but not least, our gratitude to all the researchers and participants for their positive input that have allowed us to gather this excellent manuscript.

Prof. José Luis Lerma (UPV), Prof. Grazia Tucci (UNIFI), Prof. Raffaella Brumana (POLIMI) & Dr. Víctor M. López-Menchero (Global Digital Heritage)
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ARQUEOLÒGICA 2.0

CONGRESO INTERNACIONAL DE ARQUEOLOGÍA E INFORMÁTICA GRÁFICA. PATRIMONIO CULTURAL E INNOVACIÓN
INTERNATIONAL CONGRESS ON ARCHAEOLOGY, COMPUTER GRAPHICS, CULTURAL HERITAGE AND INNOVATION

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Proceedings of the joint
international event
9th ARQUEOLÒGICA
2.0 & 3rd GEORES,
Valencia (Spain).
26–28 April 2021

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*Proceedings of the joint
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9th ARQUEOLÒGICA
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Valencia (Spain).
26–28 April 2021*

Long scientific papers



INFORMATIVE MODELS OF CULTURAL HERITAGE. THE “UNFINISHED” CHURCH OF BRENDOLA

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Abstract:

The paper is an initial form of dissemination of the research activities carried out by the Università Iuav di Venezia working group which, on behalf of the Municipal administration of Brendola, seeks to delineate the application of a methodology for the study and analysis of the architectural and landscape heritage of significant cultural interest that is in a state of abandonment. The case study application is the church of San Michele Arcangelo in Brendola (Vicenza), known as the “Incompiuta” (“Unfinished”). The case study proposed is an interesting exemplar of ecclesiastical architecture, designed by engineer-architect Fausto Franco, in which its characteristics of being unfinished and in a state of ruin contribute to redefining the image of a work that fits in a historical context of architectural and technical experimentation, where the reference to historical architecture is mediated by contemporary forms and by the use of modern building materials, among which, the use of reinforced bricks is noteworthy. The research activity, which is taking place in the context of the COVID-19 health emergency, aims at putting a series of strategies and operational practices based on the digitisation of data to the test, so as to allow increased interoperability and sharing through the building of an online open data repository addressed to the actors involved in the conservation process and to the community. In the processes of conservation and valorisation, in-depth knowledge and documentation of the materials and construction techniques involves multidisciplinary areas; effectively organising them in a system that regulates their collection, cataloguing, processing and archiving according to shared procedures, therefore becomes a fundamental prerequisite for the development of operational planning of the valorisation strategies. All the instruments that make it possible to collect data and reach a true knowledge of the object therefore become indispensable. From this point of view, the push towards the digitisation of the data that emerged during the pandemic phase plays a fundamental role in the range of application possibilities, from the survey to the mechanisms for the conservation and management of the cultural heritage.

Keywords: cultural heritage, unfinished architecture, interoperable digital documentation, HBIM database, experimental techniques, open knowledge

1. Introduction

The research activity is based on the following Memorandum of Understanding: “*Il limite della Rovina. Procedure di conoscenza, analisi e valutazione dello stato conservativo della Chiesa 'Incompiuta' di Brendola*” (The Limit of the Ruin. Procedures of knowledge, analysis and evaluation of the state of conservation of the ‘Unfinished’ Church of Brendola), stipulated between the Università Iuav di Venezia and the Municipality of Brendola through a funded research contract (file. no. 77-2020 prot. no. 1476 of 20/01/2020). The memorandum of understanding promotes the identification of a study and analysis methodology for the architectural and landscape heritage of significant cultural interest found in a state of abandonment. The applied case study is the “Unfinished” Church of Brendola (Fig. 1). The aim of the research is to attain the creation of a system of knowledge concerning the building’s state of conservation that allows the

identification of conservation and valorisation strategies that can be shared with the bodies that are responsible for its protection as well as with the community of Brendola, acting as a possible reference for the development of operational guidelines in the best practice of the discipline of restoration.

2. Case Study: The “Unfinished” Church of Brendola

The earliest information found concerning the construction of the church dates back to 1904. Historical events and construction report are collected in the writings of Don Francesco Cecchini (1937), Archpriest of Brendola, reference figure and promoter of the construction of the building. Dedicated to the city’s patron saint, Michael the Archangel, the church rises isolated at the summit of Cerro Hill, in a barycentric position with respect to the nearby communities. As the Archpriest’s

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writings of 1915 clearly express, the temple “which responds to long-standing desires”, was to have been built “out of concordant will and generosity”, “in a place that is convenient to all”, cementing “the scattered districts together in unity of faith and in piety of actions”. The study of the project for the new church “which responds to the noblest ecclesiastical traditions” was entrusted on 10 January 1928 to the young engineer-architect Fausto Franco (1899-1968) who had recently obtained his second degree in architecture. Born in Vicenza on June 19, 1899, in 1922, at the age of twenty-two, he graduated in engineering at the University of Padova. In 1927, at the age of twenty-eight, he obtained his second degree in architecture at the Royal School of Architecture in Rome. (Ministero per i beni e le attività culturali et. al, 2011 and Gazzola, 1968).



Figure 1: General view of the “Unfinished” church of Brendola.

A scholar of the ancient civilisations of the Middle East, starting from 1929, Franco was a student of the Archaeological School of Rome and Athens, taking part in numerous excavation and restoration campaigns with Professor Carlo Anti. In 1930 he was appointed Honorary Royal Inspector of the Monuments of Vicenza, where, in parallel with his archaeological activities, he began to study the work of Andrea Palladio. In 1933 he became part of the Antiquities and Fine Arts Department and was assigned to the Superintendence of Medieval and Modern Art of Milan, and soon after, to that of Venice; in 1939 he became Director of the Superintendence of Antiquities and Art of Venezia Giulia and of Friuli, where he remained until 1952. In parallel with his professional activity, in 1936 he obtained the qualification of professorship in History and Styles of Architecture (1936) and in Stylistic and Building Characteristics of Monuments (1937) at the University Institute of Architecture in Venice (1937-67). Observing the original project (Fig. 2), it is possible to see how the church is characterised by a typological layout that can be traced back to a Latin cross plan in Romanesque style, delineated by a rectangle measuring 53.5m x 22.5m, punctuated by three symmetrical barrel-vaulted naves ending in semicircular apses. The central nave, which is twice as wide as the lateral ones, is defined by columns on pedestals (9 on each side) made of reinforced concrete and clad in pietra di Vicenza stone, connected by a series of round arches. The masonry structure is constituted of core-and-veneer masonry with concrete recesses and is punctuated by the presence of four semicircular chapels that flank the building’s exterior and characterise its composition together with lunette openings located in the upper part of the facing walls.

In the Church of San Michele Arcangelo, Franco manages to combine the architectural language with an experimental use of mixed construction techniques, characterised by the juxtaposition of different materials and techniques; the use of reinforced brick elements in the roof structures is noteworthy.

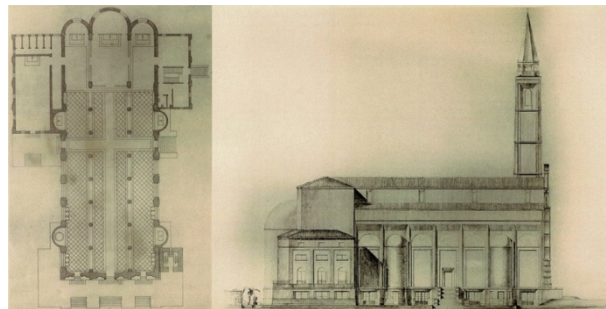


Figure 2: Original drawings made by Fausto Franco.

The inclusion of the project in the landscape was the object of evaluation, on 2nd October 1931, by the artistic commission composed of important figures in the national panorama of conservation such as Ferdinando Forlati (1882-1975 one of the protagonist of the post-war reconstruction of monuments after the First and Second World Wars) of the Royal Superintendence of Monuments of Venice, Luigi Ongaro, Vice President of the Provincial Monuments Commission and Director of the Civic Museum of Vicenza, and Giuseppe Stocchiero, Commissioner of Sacred Artworks for the diocese of Vicenza, all of whom were called to “consider the project and the orientation of the church in relation to the landscape requirements”. The construction officially began on 3rd October 1931, with the blessing of the foundation stone by Bishop Ferdinando Rodolfi and continued as planned until 1934, a year that marked a turning point, characterised by the suspension of the construction site due to the Archpriest’s replacement for reasons of health. On 20th March 1939 the Bishop authorised the resumption of the construction works at Cerro, but with limited resources, insufficient for the completion of the work. In 1940, in support of the continuation of the work, Fausto Franco intervened and, addressing the Bishop, pointed out the critical issues that the interruption of the construction works would have entailed, stressing how the failure to build the roof would have rendered futile the work completed up to that point. Notwithstanding the economic difficulties, in October 1940, permission was granted for the roofing of the building, which was completed in 1941. The impossibility of receiving new funding and the death of Father Cecchini on 18th May 1949 brought the construction site to a standstill, leaving the sacristy area, a chapel and the bell tower unfinished. Following its abandonment, the church was purchased by the Municipal administration of Brendola in 1997, with the commitment of using the building for social or cultural purposes of public utility. Since 22nd June 2009, the church has been under the protection of Legislative Decree no. 42 of 2004, which defines it as “the only evidence of the activity of an architect with an original and eclectic personality, fully integrated into the Italian culture of the 1930s and, in particular, in the architectural debate that was emerging following the great archaeological campaigns in Africa and Asia”.

3. Method

The fields of investigation of the research activity have entailed a first phase of historical-critical investigation aimed at identifying the information useful for developing a critical knowledge of the cultural property, together with a campaign of inspections aimed at carrying out the geometric survey of the building and the analysis and cataloguing of the vulnerable elements and the mechanisms of deterioration. This first phase involving the gathering of information makes it possible to compare and interpret the data obtained and to reach different levels of knowledge, making it possible to delineate strategies for the valorisation of the cultural property through the use of digital technologies for data sharing and dissemination by building an online repository and an HBIM database. The collection of documents involves the gathering of elements belonging to different contexts; given the above, it has been decided to orient the structure of the database towards an architectural study aimed at identifying those documents that can retrace the construction phases of the building and that can bear witness to its architectural value. For each of the documents scanned and catalogued, wherever possible, optical character recognition has been performed in order to make the contents searchable by means of computer devices.

3.1. Field acquisitions

The data acquisition and processing campaign, led by the CIRCE photogrammetry laboratory of the Università Iuav di Venezia, was conducted with the use of different types of surveys related to specific theoretical and operational procedures. The necessary instrumental and methodological apparatus was evaluated, in relation to the complexity of the building and to the scale of representation required for the subsequent multidisciplinary analyses. The survey operations were carried out through the implementation of topographic, laser scanner and photogrammetric surveys (Castagnetti et al. 2016), programmed according to an effective data acquisition campaign that made it possible to complete the acquisition operations in a single day. The first operation carried out concerned the design of the polygonal structure, leading to the definition of six cornerstones upon which to position the full station. The conformation of the church and the presence of natural obstacles made it impossible to make some of the points of the polygonal structure visible from several points of the station. In order to overcome the problem and to allow a good stiffening of the grid, it was decided to place some passage points on the building in positions visible from several station points. Once the structure of the grid was defined, the cornerstones were materialised in the field and 87 support points were marked with special paper targets (checkerboard) applied to the building. The support points positioned, together with architectural points identified on the building, facilitated the orientation of the photogrammetric survey and the various scans carried out by means of the laser scanner. The topographic observations of the detail points were collected by irradiation with a Leica TCR 1103 full station with Hz and V precision of 1 mgon and 3 mm ± 3 ppm in distance measurement.

The photogrammetric survey was carried out using digital cameras and software based on Structure from Motion

(SfM) and Multi View 3D Reconstruction algorithms, using the commercial reference software: Agisoft Metashape Pro. The photogrammetric images were recorded using Nikon D800 type digital terrestrial cameras with a focal length of 20 mm and 36 megapixel full frame CMOS sensor, and aerial cameras using DJI Mavick 2 Pro type RPAS (Remotely Piloted Aircraft Systems) equipped with Hasselblad L1D-20c camera with 35 mm focal length equivalent to 28 mm and 1" 20 megapixel CMOS sensor, and DJI Phantom 4 Pro equipped with FC6310S camera with 35 mm focal length equivalent to 24 mm and 1" 20 megapixel CMOS sensor. The imaging positions were divided into two macro-groups, one dedicated to the survey of the internal façades and one dedicated to the external ones; each macro-group was then divided into sets with different imaging modes and distances: the farthest sets made it possible to identify an overall view, while those closer to the object made it possible to acquire data with a higher resolution for the detailed representation of the façades. Overall, the operations led to the recording of 1,533 images. As far as the laser scanner survey is concerned, the acquisition operations were carried out using two phase-measurement instruments, Faro Focus 3D S120 and Focus S 150, which are characterised by their high precision and the speed of their data acquisition (up to 976,000 points per second). The scans, 34 in all, have been acquired by positioning the instrument in such a way as to minimise the formation of shadow cones as much as possible and to ensure an adequate overlap with the previous scans. The individual scans were orientated in the local reference system thanks to the previously positioned targets. The distance between the instrument and the object of the survey was evaluated in order to guarantee a density of about one point every centimetre at a distance of 10 metres.

3.2. Materials analyses

The building of the church of San Michele Arcangelo is characterised by a strong presence of modern construction techniques juxtaposed with traditional techniques (Fig. 3). Among the historical documents related to the construction of the church, it is possible to find descriptions of the building materials used, including those of the stone elements, which can be traced back to the use of "*pietra bianca di san Gottardo*" (white San Gottardo stone), "*pietra gialla dei Berici*" (yellow Berici stone) and "*Trachite Euganea*".



Figure 3: View of the interior spaces of the church after the abandonment.

An element that opens an interesting field of investigation in the understanding of the vulnerabilities found in the masonry is represented not so much by the quality of the stones used, mainly due to the use of “*pietra di Vicenza*” (Vicenza stone), but rather by the quality of the mortars and the stone cladding. In this sense, the subsequent phases of characterisation of the masonry will be oriented where, through assays and laboratory analyses, the quality of the mortars and the relative critical points that may have influenced the behaviour of the masonry over time will be identified, also in relation to the presence of different construction techniques.

4. Results obtained

The use of laser scanner and photogrammetric survey methods has allowed a considerable reduction in acquisition times and has lessened the possibility of operator error. The laser scanner survey has been the most effective methodology for the survey of the architecture in its complexity, thanks to its high acquisition speed and the considerable amount of information it was able to collect. The photogrammetric survey, on the other hand, made it possible to integrate the portions of the building not directly accessible from the ground, such as the roof structures, and at the same time, made it possible to acquire data with a high photographic resolution useful for the detailed representation of the façades by means of orthophotos generated by the three-dimensional model obtained. The local reference system generated by the topographic survey made it possible to orient and join together, thanks to the topographic support points, the point cloud obtained by joining the different laser scans with the point clouds obtained by means of photogrammetry.

From the point of view of the precision obtained, the processing of the laser scans led to a difference of about 0.5 cm while, as far as the point cloud obtained by photogrammetry is concerned, a precision in the region of one centimetre was reached, perfectly in line with the expected scale of representation. An experimental element introduced in the processing of the large number of images is the use of a cloud processing service. This has made it possible to drastically reduce processing times, making post-processing and rendering operations possible on a normal computer. The processing of the point cloud (Fig. 4) will make it possible to evaluate the actual geometry of the components of the structure, identifying possible deviations from the plane of the facing walls or of subsidence, described by a continuity of points and not by a discretisation operation carried out by the surveyor. The point clouds obtained, together with the analysis carried out on the building, established the basis (Bruno et. al. 2013) for the development of the informative model of the church that collects its identity data and its vulnerabilities, configuring itself as a useful project tool for the delineation of hypothetical guidelines for a conservative design project.

4.1. HBIM Database

Through the critical analysis of sources and data collected, the in-depth study of cultural heritage allows looking at these cultural assets as fragments of stratified memory (Augé, 2004) that meet the criterion of uniqueness. Associate the construction of BIM models to the cultural heritage means to weave different knowledge

composed by material and immaterial values that sometimes hardly fall within the concept of standardization and parameterization that is usually associated with the construction of informative models for architecture (Attenni, 2019). In the construction of informative models for the cultural heritage, every object, even if defined by characteristics common to other elements, is configured as a *unicum* defined by a rigorous semantics.



Figure 4: Final point cloud.

The construction of HBIM models, as in the case of the unfinished church of Brendola (Fig. 5), deals with managing a large amount of data. The collection of this data presupposes a philological reconstruction of the information that allows reconstructing of the archival and bibliographic sources used in the association of the data to the geometric model.

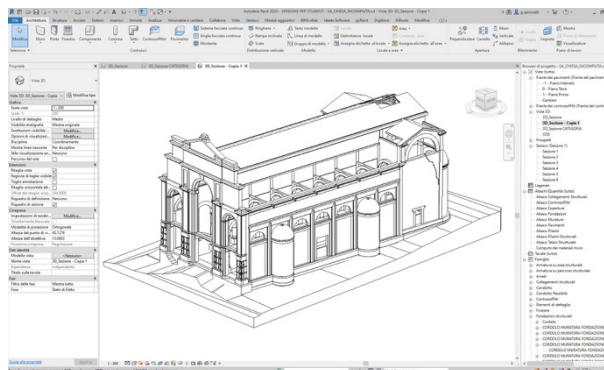


Figure 5: View of the HBIM model of the “Unfinished” church of Brendola.

This method of comparative study, which embraces technique and cultural humanism, was the basis of the decision to structure the information in databases (Fig. 6) that would act as a system for an archival and constructive investigation (Acierno, Cursi, Simeone, & Fiorani, 2017) of the architectural elements in parallel with the assessment of the state of conservation and the design choices. This assumption was the base to develop an HBIM model connected to a repository that can be consulted and implemented (even by non-specialized personnel). The analyses carried out, within the archival documents, are associated with each architectural element. This tool wants to be the key to a multi-level interaction of knowledge and data sharing structures over time, being a vehicle for historical investigation and design.

The digital model's construction took place within the Autodesk Revit 2020 work environment, one of the sector's leading reference software. The choice of

conservation status. (Fig. 9). As reported in Baldwin (2019), IFC is not an exchange format but a hierarchical structure that provide the organisation and the transportation of digital data. In this schema each object is defined and described by relationship and property.

The operation resulted in the search for the identity information necessary to describe the architectural element observed and its conservation status encoding them in a series of synthetic attributes associated with the model elements by introducing a series of "shared parameters" linked with the different categories of the model. This operation made it possible to combine the attributes, commonly available in the software, with specific features that refer to the heritage data.

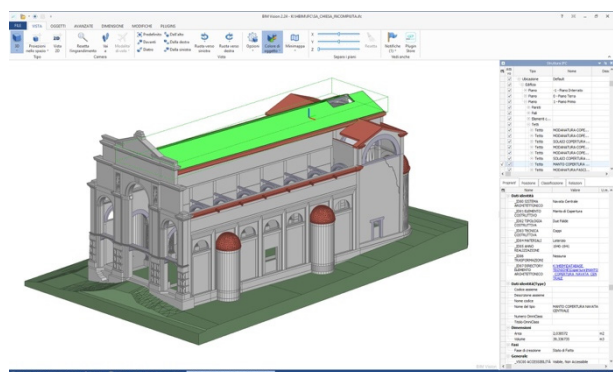


Figure 9: Example of the visualization of the data contained in the HBIM model within the open-source BIM Vision application.

The use of "shared parameters" has made it possible to collect information within specific schedules referring to the different architectural systems, ensuring high interoperability and allowing for the possibility of one-to-one modification between model and schedule. The interoperability is ensured by the open-source plugin *SheetLink* (2020) developed by "DiRoots" company, which enables the export of the information in the form of spreadsheets with the possibility of being modified, also

by non-specialized persons, in any application that supports its editing. This operation will allow a progressive advancement of knowledge linked to the asset and the possibility of managing the aspects related to conservation.

5. Conclusions

The studies carried out so far on the church show how the acquisition and processing of three-dimensional models supported by high-resolution digital images, together with the use of CAD tools and HBIM methodology, contribute to providing valuable support to the preliminary knowledge of the building. This instrumental premise interfaces with the theoretical and methodological assumption of recovering and enhancing the intangible value of the abandonment and the state of ruin of the Church, as well as its being an unfinished fragment (Augé, & Meneguzzo, 2013), crossing the balance of the relationship between material traces and collective memory in an attempt to grasp the limits and opportunities of transmission.

Acknowledgements

We would like to thank: the Municipal Administration of Brendola for the great helpfulness it has shown us; the CIRCE Photogrammetry Laboratory for its willingness to carry out the activities and for having made the laboratory equipment available to us; the Superintendence of Archaeology, Fine Arts and Landscape for the provinces of Verona, Rovigo and Vicenza in the person of Silvia Dandria for the continuous support in the acquisition of data and the evaluation of conservation strategies; and Professors Mauro Marzo, Ettore Muneratti and Claudio Bertocco for their advice. Finally, we would like to thank Architect Gaetano Cecchini and Martino Albiero, for providing us with some of the historical data on the Church.

References

- Acierno, M., Cursi, S., Simeone, D., & Fiorani, D. (2017). Architectural heritage knowledge modelling: An ontology-based framework for conservation process. *Journal of Cultural Heritage*, 24, 124–133. <https://doi.org/10.1016/j.culher.2016.09.010>
- AIA. (2013). AIA Contract Documents. G202-2013 Project BIM Protocol (aiacontracts.org). Retrieved March 15, 2021, from <https://www.aiacontracts.org/contract-documents/19016-project-bim-protocol>
- Attenni, M. (2019). Informative Models for Architectural Heritage. *Heritage*, 3, 2067–2089. <https://doi.org/10.3390/heritage2030125>
- Augé, M. (2004). *Rovine e macerie. Il senso del tempo.* (Ruins and rubble. The sense of time) Bollati Boringhieri.
- Augé, M., & Meneguzzo, M. (2013). Non-finito, infinito. Paolo Delle Monache film di Benoit Felici. (Unfinished, infinite. Paolo Delle Monache film by Benoit Felici). Mondadori Electa.
- Baldwin, M. (2019). *The BIM-Manager: A Practical Guide for BIM Project Management.* Beuth Innovation.
- Brumana, R., Georgopoulos, A., Oreni, D., Raimondi, A., & Bregianni, A. (2013). HBIM for Documentation, Dissemination and Management of Built Heritage. The Case Study of St. Maria in Scaria d'Intelvi. In *International Journal of Heritage in the Digital Era*, 2(3), 433–451. <https://doi.org/10.1260/2047-4970.2.3.433>
- Bruno, N., & Roncella, R. (2018). A restoration oriented HBIM system for cultural heritage documentation: the case study of parma cathedral. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2, 171–178. <https://doi.org/10.5194/isprs-archives-XLII-2-171-2018>
- Brusaporci, S., Maiezza, P., & Tata, A. (2018). A framework for architectural heritage hbim semantization and development. In *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-

2, 179-184. <https://doi.org/10.5194/isprs-archives-XLII-2-179-2018>

- buildingSMART. (2021). buildingSMART - The Home of BIM. Retrieved March 15, 2021, from <https://www.buildingsmart.org>
- Castagnetti, C., Dubbini, M., Ricci, P.C., Rivola, R., Giannini, M., & Capra, A., (2016), Critical issues and key points from the survey to the creation of the historical building information model: The case of Santo Stefano Basilica. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-5/W1*, 467-474. <https://doi.org/10.5194/isprs-archives-XLII-5-W1-467-2017>
- Cecchin, F. (1937). *Il giubileo arcipretale nella parrocchia di San Michele arcangelo in Brendola: 19 Maggio 1912 - 19 Maggio 1937* (The archpriest's jubilee in the parish of San Michele Arcangelo in Brendola: 19th May 1912 – 19th May 1937). Tipografia commerciale.
- Del Giudice, M. & Osello, A. (2013), BIM FOR CULTURAL HERITAGE. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XL-5/W2, 225–229. <https://doi.org/10.5194/isprsarchives-XL-5-W2-225-2013>
- Diara, F., & Rinaudo, F., (2018) Open source hbim for cultural heritage: a project proposal, in The International Archives of the Photogrammetry. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2*, 303-309. <https://doi.org/10.5194/isprs-archives-XLII-2-303-2018>
- Gazzola, P. (1968). In Memoriam. Per Fausto Franco: 1899-1968. *Arte Veneta, XXII*, 217–218.
- Murphy, M., McGovern, E., & Pavia, S. (2009). Historic building information modelling (HBIM). *Structural Survey*, 27(4), 311–327. <https://doi.org/10.1108/02630800910985108>
- Nazarena, B., & Roncella, R. (2019), HBIM for Conservation: A New Proposal for Information Modeling. *Remote Sens.*, 11, 1751. <https://doi.org/10.3390/rs11151751>
- Quattrini, R., Pierdicca, R., & Morbidoni, C. (2017). Knowledge-based data enrichment for HBIM: Exploring high-quality models using the semantic-web. *Journal of Cultural Heritage*, 28, 129–139. <https://doi.org/10.1016/j.culher.2017.05.004>
- Sheetlink (1.2.2). (2020). [Free Revit plugin that allows you to sync the model data back and forth between Revit and Excel]. DiRoots. Retrieved March 15, 2021, from <https://dirroots.com/plugins/sheetlink-revit-to-excel>
- Tommasi, C., Achille, C., & Fassi, F., (2016) From point cloud to BIM: A modelling challenge in the Cultural Heritage field. In *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLI-B5*, 429–436. <https://doi.org/10.5194/isprs-archives-XLI-B5-429-2016>
- UNI – Ente Italiano di Normazione. (2017). UNI 11337-4:2017. <https://www.uni.com>. Retrieved March 15, 2021, from <http://store.uni.com/catalogo/index.php/uni-11337-4-2017.html>



Proceedings of the
joint international event
9th ARQUEOLÒGICA
2.0 & 3rd GEORES,
Valencia (Spain).
26–28 April 2021

Received: 15/12/2020
Accepted: 09/04/2021

LOST GEOMETRIES - A METHODOLOGY FOR THE DIGITAL RECONSTRUCTION OF HISTORIC ARCHITECTURAL RUINS¹

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Abstract:

The present study aims to define a digital reconstruction methodology for ancient architectural ruins. The research has been applied to the six Mannerist altars and the main portal of the church of Santa Maria de Monasterio Albo, located in the ancient village of Misterbianco (Sicily). These artefacts partially destroyed during the 1669 eruption of Mount Etna and brought to light after various excavation campaigns conducted in the 2000s, represent a rare example of Mannerist art in eastern Sicily.

To document their extraordinary artistic value, the researchers digitally reconstructed the altars and the main entrance portal, ideally bringing them back before the eruption. This goal was achieved through a workflow that started from a cognitive phase, consisting of harvesting the documentation and data to support the reconstruction process. Then, the following steps were followed: in-depth archival research (focused mainly on archival documents dating back to the years between 1300 and 1666); an analysis of Classic and Renaissance treatises, useful to understand the geometric rules underlying the proportions of the architectural orders; two integrated digital survey campaigns (laser scans and SFM photogrammetry) aimed at acquiring the configuration of the ruins and the photogrammetric textured models of 28 isolated fragments belonging to the decorative apparatus.

The 3D digital reconstruction of the altars and the portal, carried out after the cognitive/interpretative phase, was characterized by the ethical principles of transparency of the intervention, recognition of non-original additions and distinction between evidence and hypothesis (according to the London Charter and the Seville Principles). The base of the virtual reconstruction is represented by the seven photogrammetric meshes of the ruins (re-topologized by means of ZBrush 2019 software). In general, the 3D digital reconstruction was carried out using the following criteria: 1) The ruins of the altars and the portal, which survived in their original location, were re-proposed in the form of photogrammetric meshes; 2) 15 of the 28 isolated fragments have been located into the 3D reconstruction as photogrammetric meshes and have been reassembled in their original likely location by means of a virtual anastylosis. Specifically, the researchers identified: contiguous fragments separated by a sharp crack; fragments that are contiguous but whose contact surface has been eroded; and, finally, fragments that belong to the same artefact (altar or portal) but are not contiguous; and 3) The elements no longer existing or no longer recognizable have been 3D modelled as NURBS surfaces based on Classical and Renaissance treatises (which provided information on the correct proportioning of the architectural orders) or in analogy with other coeval altars and portals, which are supposed to be similar to the ones to be reconstructed.

This methodology has proven its remarkable potential in the documentation, conservation and promotion of cultural heritage. In this regard, for the first time, it was possible to elaborate reliable theories on the dating of the altars and the portal, and to get an idea of the original configuration of the entire decorative apparatus. The virtual reconstruction also allowed a more precise classification of isolated fragments whose original location was not accurately hypothesized so far. These new hypotheses can consequently provide valid support for possible restoration interventions, partial anastylosis or new museum exhibitions. Finally, the collected information allows for developing a digital archive of the site, with free access to all the sources used for the virtual reconstruction, thus making explicit the arguments at the base of 3D modelling and the different levels of accuracy of the reconstruction itself.

Keywords: architectural ruins, documentation, 3D reconstruction, digital cultural heritage, digital photogrammetry, architectural treatises, virtual anastylosis

¹ Please check its full version at the *Virtual Archaeology Review*: RETRACED MEMORIES - VIRTUAL RECONSTRUCTION OF AN ARCHITECTURAL LANDMARK. <https://polipapers.upv.es/index.php/var/article/view/15302>

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