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# Valorizing underground cultural heritage through the use of virtual reality

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***Abstract*** **– This paper presents the results of scientific investigations carried out at the Batia Church which is located in the small village of Tortorici (Messina, Sicily, Italy). We performed several geophysical surveys, as well as geomatics approaches, were used in order to reconstruct 2D and 3D digital models of the monument mainly using digital photogrammetry. Previous geophysical investigations have shown the presence of a crypt which was ultimately surveyed and digitally reconstructed. Here, we present the potential of valorizing the site and its underground structures by the means of advanced technologies and digital reconstructions.**

## I. INTRODUCTION

Geomatics techniques have evolved rapidly in the last few years. Progressively, more sophisticated and portable tools are being made available for 3D model generation. Both unmanned aerial vehicle (UAV) and ground-based photogrammetry have been proven to provide a good balance between time, required expertise and results providing accurate digital 3D models which can be largely and easily used [1, 2, 3, 4, 5]. The applications of such techniques span across several fields of sciences and engineering domains (for example archaeology, geology, biology, medicine, civil engineering, geophysics etc.). In general, indirect geophysical approaches are capable of obtaining subsurface information from the surface which can be easily integrated within the 3d digitally reconstructed models [6, 7, 8].

In this study, the authors present a joint research project carried out by the Department of Geosciences at the University of Malta, the Department of Mathematics and Computer Science, Physics and Earth Science at the University of Messina, the *Centro Storia patria* of Tortorici, and the Department of Environmental Engineering at the University of Calabria. The investigated site is the church of the Annunciation or "Batia", located in the village of Tortorici (Messina, Figure 1), which was built on the current site in 1757 at the behest of Bishop Gaetano Galbato. It is referred as "Batia" church because of the abbey of the Clares for noble girls associated with the structure. The abbey was attached to the church complex. The Mass was celebrated in the church until 1963 when, due to its bad state of conservation, it was definitely closed. In the late 1990s, it was recovered and it is now used for cultural activities. Inside the church, there are several important paintings and statutes dated in the period from 1500 to 1700. The Church does not function as a ritual place anymore and it belongs to the Municipality of Tortorici.

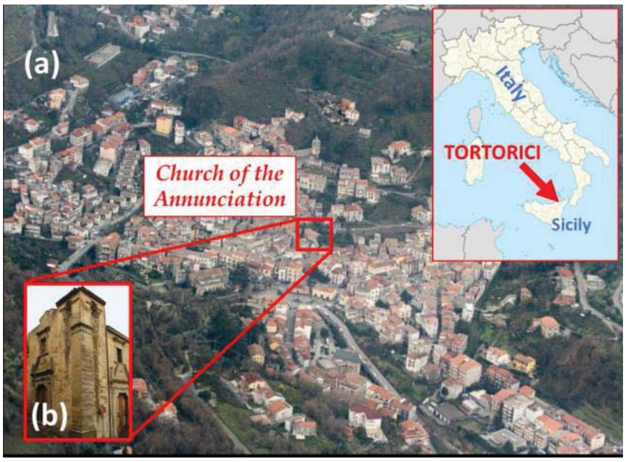


*Fig. 1. Geolocation map (a) of the city of Tortorici, with the investigated Church indicated. The main façades (b) of the Church of the annunciation.*

## II. THE GEOPHYSICAL SURVEY

In order to investigate the site, it was decided to carry out analysis based on non-invasive techniques to identify and map out any potential underground voids or buried structures.

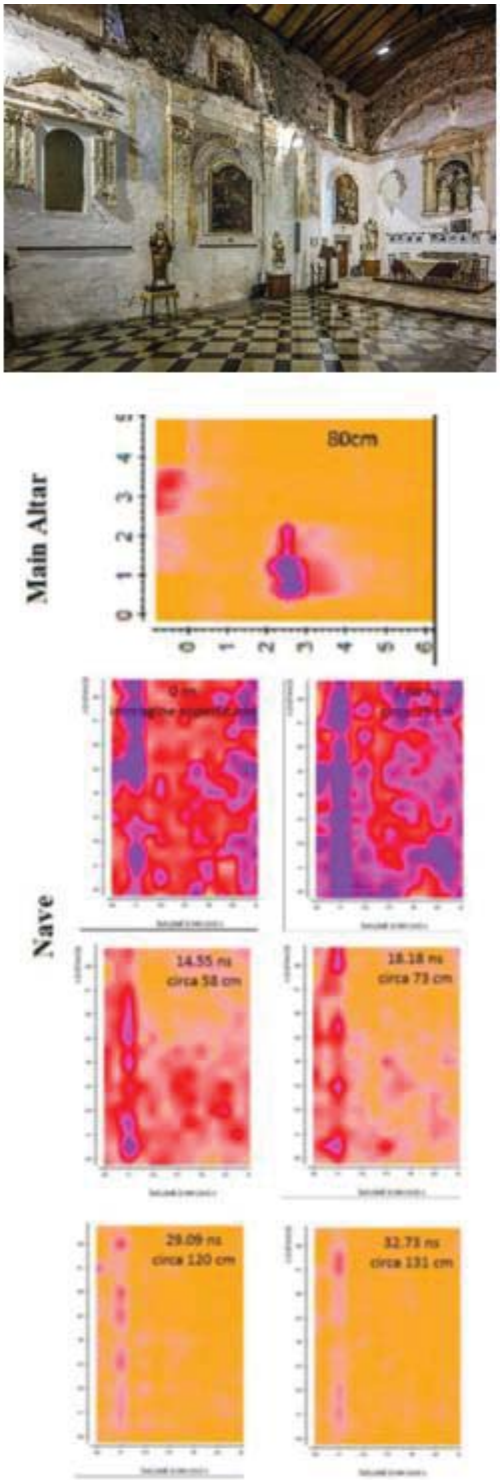


*Fig. 2. Internal view of the Batia Church and main GOR results.*

Ground penetrating radar (GPR) is the most resolutive geophysical method in near-surface geophysics. Figure 2 shows the main results obtained by the use of a Ris Hi-Mode pulsed GPR system equipped with a double antenna at 200 and 600 MHz [9]. The data were gathered along an orthogonal grid size 30x30 cm, and were processed with zero timing, background removal gain vs. depth, 1D filtering and Kirchhoff migration. Slices with a time step of 10 ns were then achieved. The processing was performed with the ReflexW commercial code. Figure 2 shows the results of the investigations on the part relating to the central altar (top part) and the nave (bottom part). In particular, there is a central anomaly corresponding to a funeral site and a lateral anomaly at the left exit that leads to the cloister. This could be due to works that took place over time, but it is not easy to interpret. The anomaly could be linked to a filling to fill a potential height difference. The main anomaly that is found is represented by the long spot on the left side that runs parallel to the longitudinal wall and is placed in front of one of the two entrances to the church. It is certainly a superficial anomaly, but it would not seem to be due to the presence of underground services. It is believed to be a trace of a previous foundation. Finally, there are various other minor anomalies [9]. On the main altar beside the central strong anomaly, there is the presence of a smaller anomaly that at first [9] was considered as not significant. Further investigations, showed that this anomaly can be attributed to the entrance of an old crypt which was used as a burial site for the presumably conventual nuns.

## III. THE PHOTOGRAMMETRIC SURVEY

Photogrammetry is a comprehensive method that enables 2D and 3D reconstruction of terrain. It can be defined as the science of obtaining reliable information about the spatial properties of the surface and objects, without physical contact, by using some kind of image (aerial, terrestrial or subaquatic). To construct a 3D photogrammetric model of a church several optical images were acquired by the mean of RGB cameras that are steered by employing a gimbal in order to stabilize the images and obtain a better final digital reconstructed 3D model. Several hundred photographs were taken at different levels and angles to obtain a high percentage of overlap (above 70%) between successive images to ensure a correct digital reconstruction and Agisoft Metashape [8], a commercial software that uses the Structure-from-Motion technique, was used to process the images. The model was scaled using markers of known dimensions in order to scale the final 3D model. The processing procedure includes five main steps to obtain a complete 3D model (more details can be found in [1]:

1) Image selection: after image acquisition, image selection must be performed, discarding any defective images (e.g., out of focus, bad luminosity) which could impact negatively the final product and increase

processing time.

*Fig. 3. High-resolution photogrammetric model of the external (top image) and internal (below images) of the Batia's church. The yellow areas represent the iso-surfaces of anomalies detected by the georadar investigation*.

2) Camera alignment: the software searches for common points between photographs and identifies the position of the camera in each photograph. The camera calibration parameters are also refined. As result, a sparse point cloud is obtained.

3) Dense point cloud construction: a dense point cloud is generated based on the position of cameras and photographs. Once the dense point cloud is obtained, it is manually cleaned by removing defective points or points outside the area of interest. The scaling of the model can be improved at this point.

4) Mesh generation: a 3D polygonal mesh is generated from the dense point cloud, creating the surface of the model.

5) Texture making: after reconstructing the 3D geometry, the coloured texture of the model is generated.

The final product is a three-dimensional reconstruction of the studied area, on which high-precision measurements can be performed.

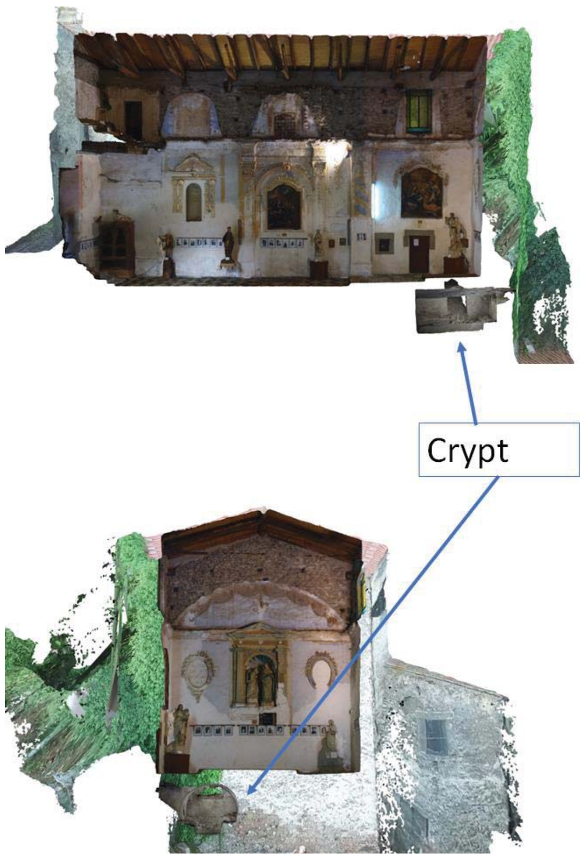

*Fig. 4. Cross section of high-resolution photogrammetric model of the church of Batia. The 3D digital model of the crypt has also been integrated.*

Figure 3 shows the final 3D digital model of the internal and external parts of the Batia church. Figure 4 shows the integrated model of the church and the underlying crypt. The latter was digitally reconstructed by inserting small endoscopic cameras as well as LED light system from a small aperture located at the back of the church. The crypt seems to be in a good state of health, but the entrance is completely blocked by rubbles and material presumably belonging to the collapsed adjacent conventual structure.

## IV. RESULTS AND CONCLUDING REMARKS

In this study, we present a combined geophysical and photogrammetric study of a small conventual church in the Municipality of Tortorici (Sicily, Italy). The creation of the 3D digital model is used for promoting the built heritage of one of the main cultural heritage sites of the village. The non-invasive investigations also offer information on the history of the monuments, possible architectural changes and changes in use, as well as restoration works that took place in the past and/or can detect the absence of foundations of pre-existing structures. All this information is integrated within the digital platform and data and results can be easily made available to practitioners, site curators as well as general public (Figure 5). In Figure 5, we report an example of a digital platform used for integrating all the gathered scientific information as well as historical information related to the sites and artefacts that are located within the church. By clicking on each number specific information related to the selected item will be available to the user. The same information can be used to create virtual tools that can help in exploring the site and its hidden beauties also from remote locations through the use of Virtual Reality (VR). This can be effectively done by the means of VR headset which is a head-worn apparatus that completely covers the eyes for an immersive 3D experience (Figure 6). VR tool can also contain specialized information related to the historical site and serve as a repository for the results of different scientific investigations [e.g. 11].

In general, this method aims at promoting balanced and sustainable approaches for the conservation of the cultural heritage site with particular attention to underground heritage. In this case, the approach valorizes the potential of important underground space in urban and rural area which is made virtually accessible to the public. Furthermore, the 3D digital model can facilitate the sharing of best practices, action planning, stakeholders' involvement in the management etc. In addition, the collected information will be the basis for developing new research and training, open and accessible to all parties interested in the conservation of the site, and it will provide knowledge on main technical and organizational solutions also in relation to the underground space. The results will disseminate knowledge on underground culture and assist the local community in planning the restoration and potential fruition of the site. From a scientific point of view, three-dimensional reconstruction of the site represents a great advantage over other survey methods as it enables different measurements and volumetric estimations to be carried out on the site.

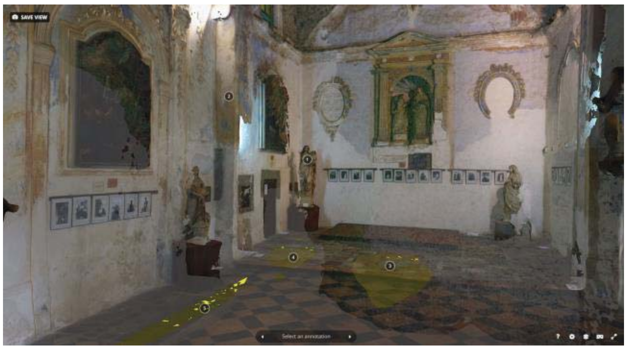

*Fig. 5. Example of the integration of the 3D digital model and information to be used by the mean of new technologies (e.g. Virtual Reality, use of smart phones etc).*

*Fig. 6. head-worn apparatus that completely covers the eyes for an immersive 3D experience*

In conclusion, the presented example and holistically the proposed approach can be considered as a valuable resource to celebrate and preserve cultural heritage sites. They can be made accessible to the public in a virtual form if other means are not possible. Indeed, it represents an important tool to valorize the full potential of the site as well as be a valuable support for the local communities' development.

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