3D IMAGE-BASED SURVEYING OF THE SAFE OF THE OBELLIO FIRMO *DOMUS* IN POMPEII

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ABSTRACT:

This paper shows an application of image-based 3D modelling concerning an interesting case study in the field of Cultural Heritage, a safe located in the Obellio Firmo *domus* in Pompeii (Italy), one of the largest and most complex houses in the ancient city. The object was strongly deformed by the eruption of Vesuvius in 79 A.D. and is currently protected by a permanent glass that helps to preserve it over time. The surveying activities and processing methodology is explained, based on Multi-View Structure from Motion technique, as well as the unconventional solution adopted during the images acquisition. Finally, an attempt will be presented to reconstruct the hypothetical original three-dimensional appearance and shape of the safe.

1. INTRODUCTION

The field of Cultural Heritage (CH) has nowadays an increasing interest in modern digital surveying techniques that allow the digital recording of the cultural inheritance. The reason lies in the need for a documentation of the World Cultural Heritage, an essential step for its study, conservation and management, whether they are located in their original location, or maintained in museums. On the other hand, the valuable objects are in constant danger, as they are threatened by various natural and/or anthropogenic factors that can only be partially countered, such as climate change, natural disasters, ongoing wars and vandalism. Therefore, the digitization of CH is a key point for its preservation, management and valorisation (Remondino, 2011; Bitelli et al., 2017; Aliberti and Picazo, 2019; Girelli et al., 2019).

A systematic digitization of the patrimony, in its appearance and with all its geometrical-positional attributes, is now possible thanks to the 3D imaging techniques coming from the Geomatic science: they allow the creation of very realistic 3D digital models that guarantee high geometric accuracy and radiometric fidelity, are suitable for progressive integrations, easy manageable and searchable over time.

As far as the field of CH is concerned, the most used geomatic techniques for three-dimensional digitisation relies on digital photogrammetry and 3D scanning. Both the 3D surveying methodologies, in fact, are non-invasive and contactless, and the whole acquisition process is rapid and objective.

The need for a documentation of the CH is especially felt on the Italian national territory (Cardaci et al., 2019; Tesi et al, 2017; Palestini and Basso, 2017), which owns an enormous and valuable patrimony that need to be preserved. Among the numerous sites of historical and archaeological interest, Pompeii is undoubtedly one of the most important, in Italy and in the world. The ancient city has been recently the subject of a large project, "*Grande Progetto Pompei*", that allowed to document and map, thanks to modern surveying techniques, the structures of the whole archaeological site in a coherent and effective way, within a unique information system.

Among the multitude of objects of great importance belonging to the site, this work is interested in the ancient safe located inside the Obellio Firmo *domus*, a house already the subject of a study conducted by the University of Bologna in agreement with the Archaeological Park of Pompeii (Silani et al., 2017).

The safe, seriously damaged during the eruption of Vesuvius but still well readable in its appearance and function, has been the subject of a detailed survey conducted by the nowadays most used image-based technique, close-range digital photogrammetry by Multi-View Structure from Motion approach. In the specific case, some constraints related to the environment in which the object is located prevented in fact the use of other instruments such as those adopted for 3D scanning (e.g. triangulators or structured-light projection devices). Digital close-range photogrammetry proved to be a suitable survey technique; the derived 3D model has been furthermore the base for an attempt to reconstruct the original three-dimensional appearance and shape of the safe.

2. THE PROJECT AND THE CASE STUDY

The work here described has been carried out in the frame of an agreement signed in 2016 between the Archaeological Park of Pompeii and two Departments of the University of Bologna, the Department of History and Cultures (DiSCi) and the Department of Civil, Chemical, Environmental and Materials Engineering (DICAM).

This project comes after the *Grande Progetto Pompei*, an important initiative funded by the EU. It was born in 2012 from an action of the Italian government to promote the valorisation and preservation of the archaeological area of Pompeii through a programme of conservative and preventive actions, maintenance and restoration. A fundamental part of this large project was the programme named *Piano della Conoscenza*, whose task was to accomplish a modern and complete documentation of the Pompeii city. The *Piano della Conoscenza* aimed to define the most appropriate criteria and methodologies to realise a detailed and georeferenced database storing an immense wealth of information related to the current state of the ancient city. The detailed topographic survey produced a large-scale numerical database (1:50 scale) of all the structures with related information. The project has been a fundamental stage for increasing and reorganising the knowledge of the current state of

the whole Pompeii site, providing an effective basis for the future maintenance and management.
A main topic of the new agreement drawn up in 2016 concerned the study, preservation and valorisation of the House of Obellio Firmo, one of the oldest *domus* in Pompeii, located in the northern sector of the ancient city, Regio IX (Figure 1).
The Obellio Firmo *domus* is one of the largest and most complex houses in Pompeii (Pesando and Guidobaldi, 2006). It is composed by a main entrance through which it is possible to reach a large *atrium* supported by four Corinthian columns. The articulated structure of the *domus* (Figure 2), the oldest original decorative elements and its impressive design indicate the high economic status of the family that built it.
A main aim of the project is to perform a detailed 3D database of this important complex, employing a multi-technique approach for data acquisition using different technologies such as drones, laser scanners, other 3D scanners and high-resolution cameras.

Figure 1. Pompeii city map: the red circle indicates the location of the Obellio Firmo *domus* (http://pompeiisites.org)

In this framework, a complete in-depth survey of the *domus* was performed, in a multi-scale approach that starts from the main structural components and goes to the detail of the single elements composing the furniture. The last were surveyed using the 3D structured-light projection techniques and digital photogrammetry, achieving in 3D modelling a sub-millimetre accuracy.
Among the elements of the furniture, a very interesting and rare object is a safe, located in the *atrium* next to the main entrance (Figure 2), where the owner used to receive guests or business customers and representing the high social status of the family living in the *domus.* The safe (size about 1.50 x 1.20 x 1.00 m) is located at the entrance of the house (Figure 3) as a sign of power and wealth of the family.
In the Roman world the safes were extremely valuable and precious objects. The number of objects of this type still visible today is very limited and then they are worthy of special attention, both in terms of conservation and valorisation.
In literature, there are very few references to the safes of the Roman period for this area (e.g. Prisco et. al, 2014), but from them it is possible to notice that the characteristics and materials do not differ considerably from one to the other. Considering the work of Pernice (Pernice, 1932), it describes seven safes found in the cities near Vesuvius, including the Obellio Firmo *domus* one.
The safes are made of a wooden base structure and covered by bronze and/or iron, and all have the same connection system made of a huge amount of round nails covered by studs. However, the Roman safes of the Vesuvius area differ in their ornamental decorations, varying according to what the client wanted to be represented.

Figure 2. Top: Floor plan of the Obellio Firmo *domus.* In red the location of the safe, in the right side of the *atrium tetrastylum* (Campedelli et al., in press).
Bottom: a view of the *atrium* (Silani et al., 2017).

Figure 3. The main *atrium* at the entrance of the Obellio Firmo *domus*: the safe is clearly visible in the background (from pompeiisites.org official Twitter account).

The safe of the Obellio Firmo *domus*, fixed on a masonry base, is characterized by unusual decorations that reminds to a knit basket, and the round applications are the mentioned characteristic elements of this kind of safes, which have the function of connecting nails between the wooden base and the metal cover (Figures 4 and 5).

As can be noticed in the two figures, the safe currently has an irregular shape: during the eruption of Vesuvius in 79 A.D. in fact, the iron surface was partially melted by the heat of the lapilli that reached the urban area of Pompeii and the safe also suffered a strong deformation. However, its shape and distinctive characters are still well readable.

Figure 4. The safe inside the protective case
(photo P. Giorgi, from Sassatelli and Giorgi, 2017)

Figure 5. Detail, from the left side, of the external surface.

As shown in Figure 4, to preserve and protect the historical object from atmospheric events and vandalism, a permanent glass case has been installed, whose structure consists of a metal frame. This protection, although indispensable for the good conservation of the safe, was an obstacle for the photogrammetric survey, which could not be carried out with a traditional approach but required an unconventional solution.

The described work aims to highlight the effectiveness of digital photogrammetry and 3D modelling for a high-fidelity documentation of the current state of the object; in addition, since no evidence about the precise original shape of the safe is available, it will be described a first attempt to reconstruct its original undeformed appearance.

3. IMAGE-BASED MODELLING

3.1 Planning of the photogrammetric survey and images acquisition

The acquisition planning is a fundamental step for the success of the photogrammetric reconstruction. The factors to be considered when planning a photogrammetric survey are the desired final resolution and detail, the characteristics of the object – i.e. dimensions, materials, shape – the environment and the logistic constraints, the time limitations, the budget and the available instrumentation.

This survey was characterized by bad weather conditions and limited time, and a major limitation was the environment in which the object is located. As mentioned, the safe in fact is surrounded by a protective glass case installed on a non-removable metal frame. For logistical reasons only the left and right side of the case could be opened at the moment of the survey.

Given these conditions, the survey strategy adopted was to introduce a compact small digital camera (Panasonic TZ60, 1/2.3" CMOS sensor) between the glass surface and the object, moving the camera by a monopod and remotely controlling the acquisition phase.

This setup ensured the survey to be carried out safely as the camera was protected from the rain by the glass case in which it was inserted; the distance between the lens and the object was, however, very limited.

It was planned to acquire each side of the safe separately and the scheme consisted of strips of nadiral and convergent images (acquired in separate steps). Nine coded targets were positioned around the safe at its base, and distances measured between couples of them were used to scale the final model.

The team that realized the survey consisted of two operators: one in charge of holding the camera-monopod system and moving it to make the strips of images, and the other one to remotely control the camera through a smartphone with a dedicated app (Figure 6).

The object surface is very irregular, due to both the folds of the deformed metal covering and the rounded applications on all four sides of the safe.

In order to obtain a 3D model capable of accurately describing these peculiarities, a high number of images was acquired. Moreover, the non-conventional remote-controlled camera-monopod system is less immediate and slower than the classic methodology for taking the pictures. These elements adversely affected the duration of the survey, which took longer than a traditional survey.

598 images were acquired, characterized by 4896 x 3672 pixels, with a 35 mm equivalent focal length of about 25 mm and a pixel size of 1.27 x 1.27 μm. The average distance between the camera and the surface of the safe varies from each side depending on the presence (or absence, in the case of the two lateral sides) of the protective glass. Considering the top and the front of the safe, where the acquisition was hindered by the protective glass, the distance has been quite limited; at an acquisition distance of 20 cm, the resolution on the object is in the order of 0.15 mm/pix and one picture covers a very small area.

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Figure 6. One operator during the survey holding the camera-monopod system inside the glass case.

3.2 Data processing and 3D model generation

The photogrammetric reconstruction of the safe was performed using the Multi-View Structure from Motion approach implemented in the software ContextCapture by Bentley.
The data processing overall involved 569 camera stations (almost the entire data set, only few images belonging to the top and front sides were in fact not-aligned) and 9 coded targets for scaling the model. Figure 7 shows the very dense photo coverage on the top of the object.

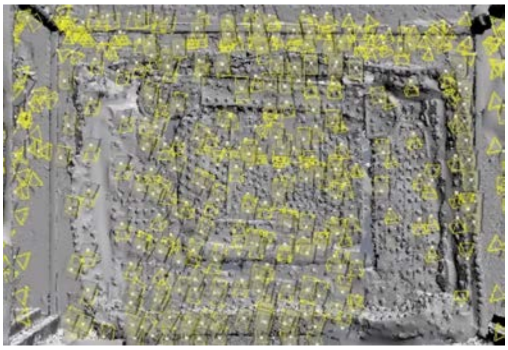

Figure 7. The photo positions from the top.

The distortion grid calculated by the program shows a quite good behaviour (Figure 8), despite being a consumer camera with a wide angle arrangement of the lens. The processing of the whole model reached good results in terms of accuracy, with a reprojection error (RMS) of 0.87 px. The total number of tie points was around 90 thousand, with a very high average number of points per photo (Figures 9 and 10).

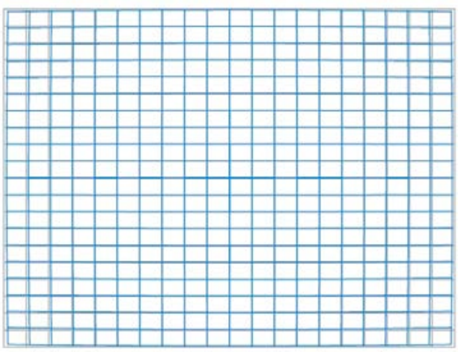

Figure 8. The calculated distortion grid.

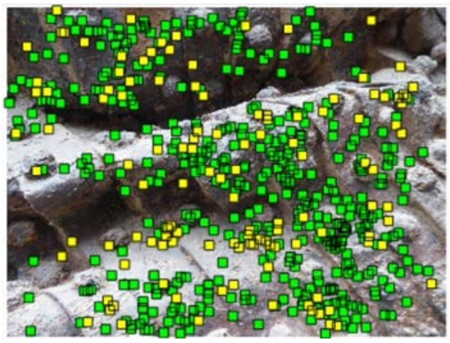

Figure 9. Example of a picture with the relative tie points.

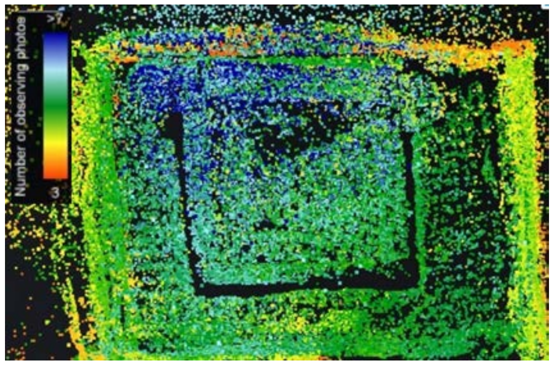

Figure 10 - Number of observing photos per tie point.

The obtained final 3D model is composed by more than 16 million of triangles, and characterized by a very high geometric and radiometric detail; it was subsequently simplified to 8 million faces in Meshlab (Cignoni et al., 2008), using a Quadric Edge Collapse Strategy. A cleaned model is presented in Figure 11.

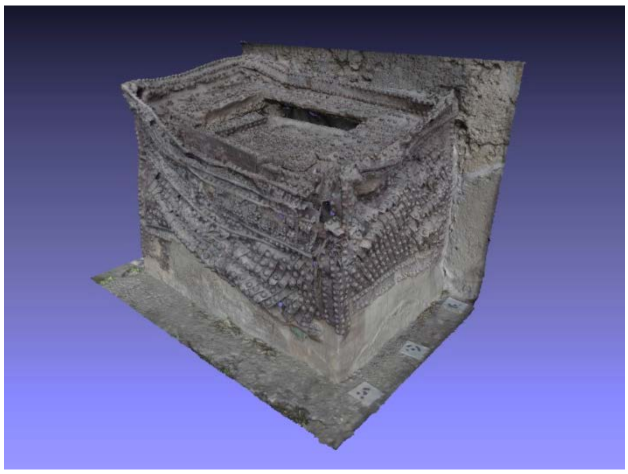

Figure 11. Final 3D model of the safe.

4. 3D RECONSTRUCTION OF THE ORIGINAL APPEARANCE AND SHAPE

Since the original appearance and shape of the safe is unknown, the last part of the work aimed at reconstructing it, as it was before the Vesuvius eruption.
The model was created on the basis of initial researches on a few other Roman safes in the area. Due to the lack of documentation about the safe we are dealing with, it has been assumed the way of opening, as well as some details and the colour. The 3D

reconstruction was generated in Rhinoceros; the figure 12 shows two sides of the safe.

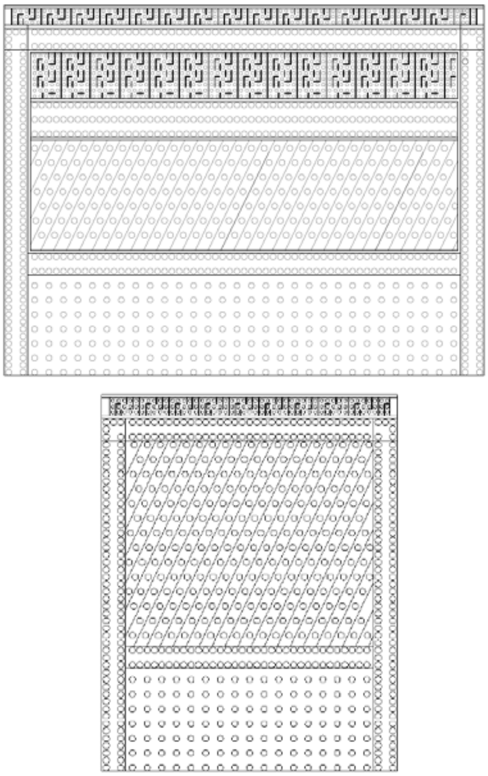

Figure 12. Vector drawing of the reconstructed front (top) and side (bottom) of the safe.

It is important to underline that this reconstruction is only a first attempt. Although made trying to maintain a certain degree of fidelity and rigour, it requires further documentation and knowledge about the ancient Roman safes, which are the starting point for an accurate reconstruction of the details, the decorations and the opening mechanism, features that in the Obellio Firmo safe have been almost lost.
Such an analysis could be significant also to support investigations about methods and technologies for producing this type of objects in Roman times.

5. CONCLUSIONS

This work is a further proof of how digital surveying techniques represent a strong support to the CH field. This applies especially when the heritage is particularly valuable and needs a proper documentation for its preservation and valorisation, as the case of the safe of the Obellio Firmo *domus* in Pompeii.
For the photogrammetric survey of this rare object we adopted an unconventional approach and still succeeded in achieving a high detailed 3D model contributing a rigorous detailed documentation of the precious object.
Finally, an initial attempt was made to reconstruct the original shape of the safe as it was before the Vesuvius eruption. Although the result is promising, this part of the work should be further developed in order to achieve a more rigorous reconstruction.

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