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The role of 3D modelling for different stone objects: from mineral to artefact

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Abstract **– Over the years, the use of technological tools has increased more and more to encourage the fruition of works of art and artefacts through virtual experiences and the creation of 3D models. Among the various techniques used for the creation of 3D models, photogrammetry has proven itself to be relatively cheap and versatile. Unfortunately, it often happens that many works of art and artefacts of archaeological and cultural importance and value are kept in museum deposits away from the public eye. Through this work, we try to analyse the use of 3D modelling by means of photogrammetry as a rapid and low-cost tool to make those artworks virtually accessible to the public through the use of museum websites and social networks.**

I. INTRODUCTION

Museums, in Italy and worldwide, big and small ones, are rich in findings of interest, many of which are not always easily accessible, due to various reasons. More often it happens that many findings are stored in rooms with no public access, because the institution has not enough space to display them in the showrooms. New technologies and software developments are increasingly accessible, allowing augmented reality [1, 2] and virtual approaches to the findings. The use of 3D modelling offers a chance to virtually see, "handle" and study different objects, like relics, artefacts, crystals, stones, statues, etc., without the need to be physically present in the museum, and to appreciate manufacts or specimens that are stored away through their projected 3D images [3]. 3D modelling of objects is composed of multiple pictures taken with common cameras and/or unmanned systems (i.e. drones), when a wider area needs to be covered, which are then compiled by a specific software for 3D modelling and reconstruction [4, 5]. Today we have two main technologies for 3D close range objects reconstruction: the use of close-range laser scanners and the cheaper, but equally effective, three-dimensional photogrammetry [6].

This study deals with the 3D photogrammetry and modelling of different objects [7], with different sizes and shape complexities, belonging to different museums (cultural or naturalistic heritage) all around Tuscany. 3D modelling surely constitutes a valuable mean to make different materials and artefacts readily accessible. The use of photogrammetry [8] coupled to various 3D modelling software can be easily used to construct 3D models of objects with different complexities and that makes it an easy tool for Museums to make stored objects accessible to public.

II. MATERIALS AND METHODS

We based our work on photogrammetry, a technique that allows to create a 3D model, starting from a rich photograph dataset. For the purpose of this work, we collected and processed a wide dataset of images of the samples studied. We divided these objects in three different categories, from the mineral to the artefact: single crystal, rock sample and artefact. As crystals we used two samples coming from the Mineralogical Collection of the Natural History Museum of the University of Florence: a calcite crystal (Figure 1), and a feldspar one (Figure 2); as aggregate rock samples we used a block of sandstone (Pietra Serena), a block of calcarenite (Panchina Stone, [9]) and a block of white marble, all coming from different areas of Tuscany, not represented in the present paper; as concerns the artefacts we studied a calcarenite head from the Targioni Tozzetti mineralogical collection of the

Natural History Museum of the University of Florence (Figure 3). During the first phase of the work we have taken the photos to build our database for each sample. For the first two categories we acquired several photographs (147 photos for the calcite, 70 photos for the feldspar; 65 photos for the sandstone and 72 photos for the calcarenite), using a LEICA V-LUX 1 camera, while for the latter category we took a more consistent number of photograph (194 for the calcarenite), using a NIKON D500 camera. We took care to create overlaps of 60% between all the images to allow software to easily recognize common points in images by facilitating image alignment and photogrammetric reconstruction of the 3D point cloud. We took all the pictures having the objects laid on a white surface *en plain air* by moving around them, then we moved the objects themselves upside down to be sure to not miss any point of view. In taking all the needed pictures we followed some of the principles used by previous authors [5, 10]. In the second phase, we processed the digital image collection by using a commercial software (Metashape v. 1.6.4 by Agisoft) that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales. The process is semiautomatic, and, in our case, no manual editing or special equipment was needed. The software procedure is user friendly and easily recognizes the features (overlaps) of the images, producing a point cloud of the item and converting it in a 3D model. We must underline that, depending on the number of photos taken, the quality and the detail of the model you want to create, the processing procedure requires very performing computers especially regarding the R.A.M. and the video card used.

Fig. 1. Calcite, var. Iceland spar – Sample MSN-Fi G47378 – Mineralogical Collection, University of Florence. The transparent and reflecting surfaces are clearly visible.

Fig. 2. Feldspar – Sample MSN-Fi G41641 – Mineralogical Collection, University of Florence.

Fig. 3. Carved Calcarenite head, Etruscan period – Targioni Tozzetti collection, University of Florence.

III. RESULTS

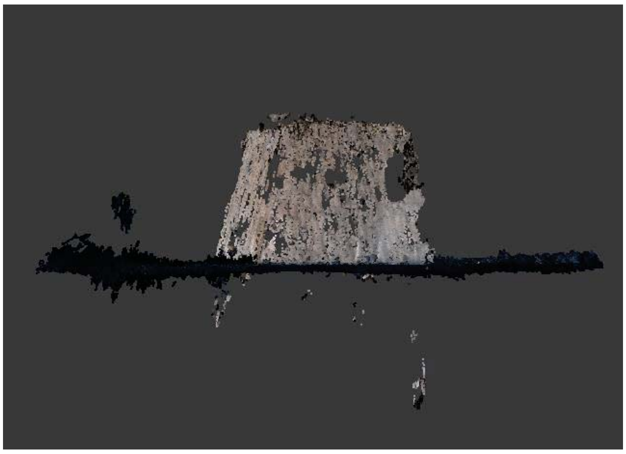
We have been able to create 9 different 3D models: one for each of the analysed objects.

The calcite crystal presented the main problematics during the digitizing process. In fact, despite the carefulness used in taking all the pictures and in preparing the samples, we faced some problems in creating the 3D model for those objects, like calcite crystals, having transparent and/or reflecting surfaces due the light effects that these properties have on camera (i.e., difficulty in focus, light refraction, flare, etc.). Figure 3 presents the poor results obtained in this case. For those objects we had to mark every face/surface with small circular paper labels in order to allow the camera to focus on each surface of the object correctly, and to allow the software to build the 3D model.

The feldspar crystal, together with the calcarenite carved stone, constituted the easiest objects to be digitized thanks to their regular shape and lack of transparent and/or reflecting surfaces and so they required a minimal quantity of pictures in order to create the 3D models (Figures 5 and 6).

4a

4b



4c

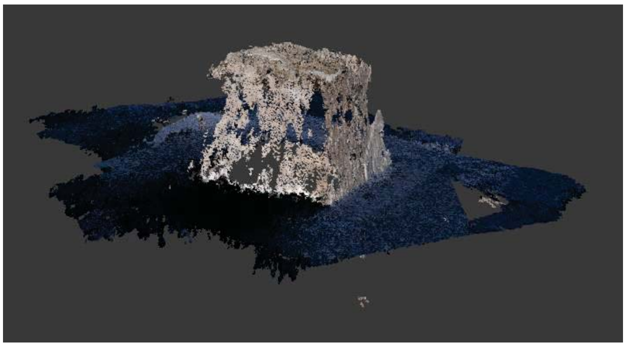
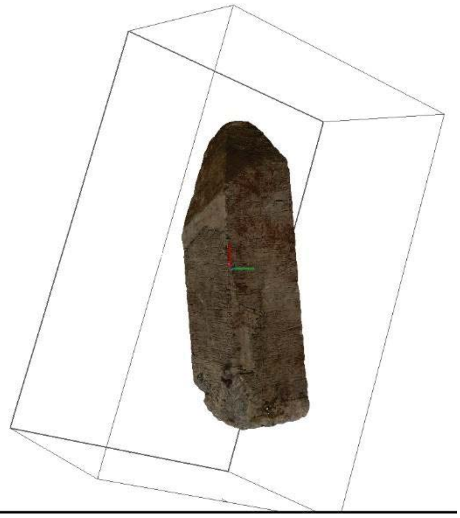
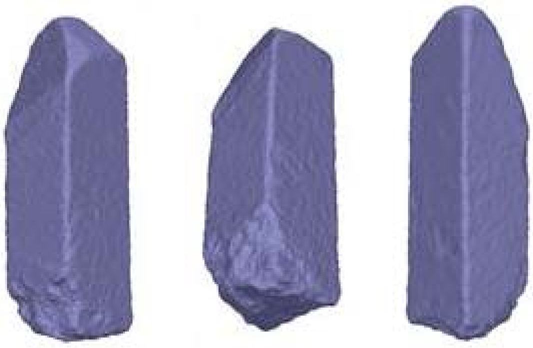


Fig. 4(a-c). Calcite crystal 3D test. 4a, shows the final result after application of the texture given by the taken pictures. It is clear that the program has not been able to properly build the 3D model due to refraction problems caused by the crystalline clear surfaces of the calcite crystal. Figures 4b and 4c show different views of the same calcite crystal dense point cloud. It is here possible to see where the camera, and therefore the software, has failed to capture the crystal details. Note that the software has not been able to detect the difference between the crystal and the surface on which the crystal was laying.

5a



5b



5c

Fig. 5. 3D polygon meshes and 3D model of the feldspar crystal: a) 3d model completed into the virtual space; b) three different view of the same crystal 3d polygon mesh; c) same view of the crystal as in 5b, after application of the texture given by the taken pictures.

Other more complex objects, like the artefacts studied, necessitated a higher number of pictures in order to elaborate the 3D model correctly.

Fig. 6. Carved Calcarenite head, Etruscan period – Targioni Tozzetti collection, University of Florence. Different views of the 3D model of the calcarenite head built by means of photogrammetry

Although the complexity of the artefacts was quite similar between the studied objects, the calcarenite head was the easiest object to digitize, followed by the stele from Pontremoli, while the capital was the hardest one. In general, we noticed that, especially for the more complex objects, it is better to have a higher quality of the pictures than just a higher number.

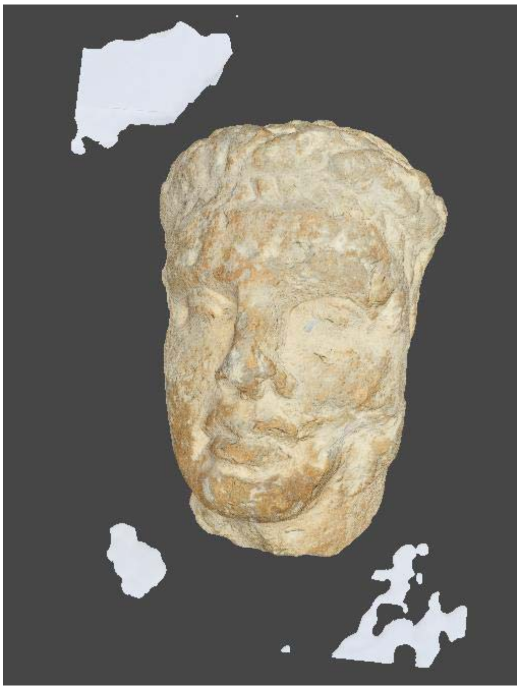


Fig. 7. Carved Calcarenite head, Etruscan period – Targioni Tozzetti collection, University of Florence. 3D model with traces of the white background used.

Using different types of surfaces on which to lay the studied object may also affect the final processing the 3D model. We noticed that using a plain, uniformly coloured surface with no irregularities, like a white paper sheet, does not allow the software to properly work and process the dataset of pictures in order to build the 3D model, therefore resulting in a fake 3D model which includes part of the used background (Figure 7).

Moreover, the same effects result when using a background like a green or white screen, like the ones commonly used for photography or cinema (Figure 8).

We have been able to get around the problem by adding some unconformities to the paper surface, like a pen mark, but it can also easily been overcome with some photo editing when a great picture dataset is not used..

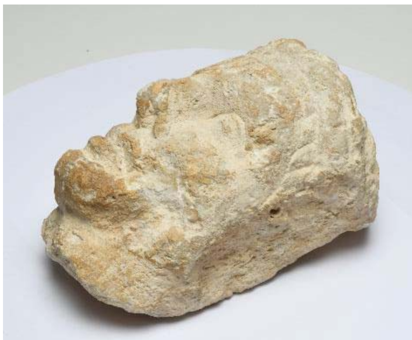


Fig. 8. Carved Calcarenite head, Etruscan period – Targioni Tozzetti collection, University of Florence. Calcarenite head laying on a blank white surface with a white background.

IV. CONCLUSIONS

3D modelling of small objects by using the tool of photogrammetry, coupled with software for digital images processing, without using any kind of post-production or editing work, can be an easy-access, low budget, short-time, way for Museums and Private Collections to make accessible objects not shown to public. The possibility offered to visualize and virtually manipulate objects that are even thousands of kilometres away, allows experts and general public to study and enjoy any specimen or artefact that would otherwise remain inaccessible. The difference with a simple photo is that in addition to the detail we can have the perception of the object in its three dimensions as well as having the chance to measure its volume. A further advantage is given by the possibility of creating virtual exhibitions [13-19], with objects from different parts of the world, all gathered in a single virtual site easily reachable by anyone who has an available personal computer and internet connection.

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