Replicating degradable artefacts. A project for analysis and exhibition of Early Medieval objects from the Byzantine village at Scorpo (Supersano, Italy)

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Replicating degradable artefacts. A project for analysis and exhibition of Early Medieval objects from the Byzantine village at Scorpo (Supersano, Italy)

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***Abstract* — Artefacts found in an archaeological excavation are sometimes made of perishable or fragile material like wood, iron, or leather. These present obvious conservation problems. This is the case of various artefacts from the Byzantine village of Scorpo (Supersano, southern Italy) that has been the object of excavations by archaeologists from the University of Salento (Italy) since 1999. In 2007 a number of wooden objects were discovered in a well, while in 2012 a hoard of ferrous objects was found near a drystone wall that perhaps enclosed the settlement. Given the highly fragile and perishable nature of the objects, the questions arise as to how to study these artefacts, preserve them for the future and display them to the public. In this paper we will illustrate the methodology developed at the University of Salento to give an answer to all these questions and we will describe the entire process ranging from the discovery of the artefacts, to their 3D digital acquisition and modeling, the eventual digital restoration, the realization of one or more physical copies using a rapid prototyping apparatus (RP), to their display in a museum. Digital models of artefacts and ancient contexts are increasingly used in museums in order to improve communication, also for the disabled. Furthermore, the resin replica of an object, created from its digital 3D model, can also be useful for its preservation and fruition, especially if it is fragile or in poor condition.**

Keywords—3D imaging; 3D modelling; rapid prototyping; museum fruition, Byzantine archaeology

I. THE BYZANTINE VILLAGE OF SCORPO AND ITS FINDS

Since 1999, the Byzantine village of Scorpo, Supersano (LE, Italy), has been the object of excavations by archaeologists from the Laboratory for Medieval Archaeology, University of Salento (Italy), under the direction of Paul Arthur [1, 2] (Fig. 1). The settlement is one of the most interesting Early Medieval sites excavated in southern Italy over recent years, also due to the building typology of housing found, typical of central and northern Europe.

The excavation to date has revealed evidence of some oval pits with rather vertical sides, interpretable as the bases of sunken-featured buildings. Close by were channels or ditches, perhaps for drainage or the foundations for fences. A long dry-stone wall, found in the northern part of the excavation, may be part of an enclosure wall surrounding the village. A well, about 4.50 m deep, was uncovered close to the wall. Its fill appeared contemporary with the abandonment of the settlement, which probably occurred towards the end of the 8th century or, at the latest, the beginning of the 9th century, less than a couple of centuries after it was first occupied.

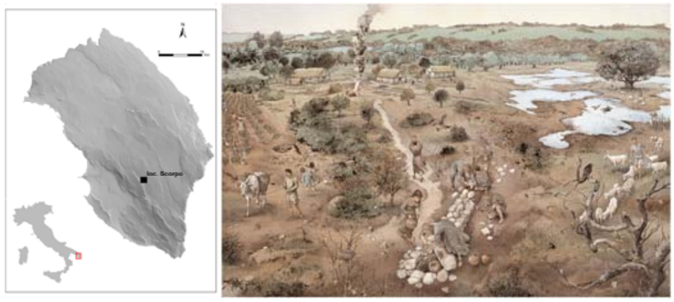

Fig. 1. Left: localization of loc. Scorpo, Supersano in the Salento area. Right: reconstruction of the Byzantine village of Scorpo, Supersano (Inklink, Florence).

The archaeological material from inside the well was of great significance: there were five almost intact ceramic vessels, wooden artefacts including a lathe-turned oak cup, an oak dibber, what appears to have been part of a bow in pear wood, some other wood fragments showing signs of working, a possible shred of leather and many archaeobotanical remains (branches of varying diameter, carbonised wood, leaves, fruit, seeds, and finds related to vine cultivation on the site). Remains of wild plants suggest the presence of a forest characterised by deciduous oak and an area of high humidity around the village [3, 4].

In 2012 a hoard of ferrous objects was found near the dry-stone wall that perhaps enclosed the settlement (Fig. 2). The hoard consisted of nine items including an adze, two hand drills, a possible spur, and the handle of a cauldron or bucket.

Originally the objects were probably contained in a sack or other container made of organic material.

Fig. 2. The Byzantine hoard of ferrous objects found at Scorpo under excavation.

Given the highly fragile and perishable nature of many of the objects found, the questions arise as to how to study these artefacts, 'conserve' them for the future and display them to the public. Apart from physical restoration of the original items, we believe that detailed reconstructions would preserve much of their information. More immediately, the need to offer the public the results of the excavation and the artefacts unearthed has prompted a project of digital three-dimensional (3D) modelling and the production of physical copies of a group of selected objects in wood, metal and bone. Some of these replicas were at first exhibited in the exhibition "A well of history: the environment and economy of a Byzantine village in the province of Terra d'Otranto" at the Historical-Archaeological Museum (MUSA) of the University of the Salento. Subsequently, they have been put on permanent exhibition at the Museum of the Forest (MUBO) at Supersano.

Apart from the need to reproduce the finds for museum display, the project has permitted the creation of both virtual and real models of the original objects through digital restoration. In particular, as discussed below, is a bent iron sickle which original form could be retrieved through virtual restoration, thus facilitating study and comparison with similar artefacts. In the case of a fragmentary iron cauldron or bucket handle, 3D acquisition and digital restoration has allowed the reconstruction of its original form, and thus the calculation of the original diameter of the container's rim.

II. 3D MODELLING AND DIGITAL RESTORATION

The application of 3D technologies to the documentation of cultural heritage has become more and more common nowadays. Three-dimensional digital models contain a wealth of information that can be examined and analyzed for a variety of conservation, research and display purposes. In addition to facilitating the detailed study of the finds without direct contact with their surfaces, they offer innovative analytical tools that range from the possibility to zoom in on the model in order to examine and measure tiny surface details or to detect traces left by tool marks, to the possibility of creating sections without damaging the artefact (Fig. 3). The 3D technology also allows the preservation of 'exact' digital surrogates of artefacts very often subject to strong degradation processes and alteration over time. A 3D model of good quality is thus the starting point for achieving one or more physical replicas particularly faithful to the original, for purposes of study or education, and for museum display [5].

The 3D acquisition and digital modelling of the artefacts from Scorpo were carried out at the SIBA 3D Laboratory (Fig. 4) [6]. For the creation of the 3D models of artefacts, a 3D laser scanner from ShapeGrabber [7] (configuration AI300 + SG102) for high-resolution acquisition of very small objects was used. This scanner is equipped with a rotating base that allows 3D scans around individual artefacts in a completely automated way and with a micro-radian angular resolution. This in turns minimizes the time for handling fragile artefacts. The structure resolution (as per VDI/VDE 2617.6.1) is as follows: lateral position resolution was set at about 0.1 mm (depending on laser line width, rotation angle and imaging CCD subsystem; *diameter of a human hair is about 0.08 mm*) and the axial resolution which depends on the signal-to-noise ratio, surface roughness and laser penetration, is about 0.01 mm on a cooperative surface but with the current artefacts, it is estimated at about 0.02 mm.

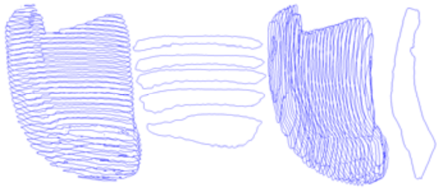

Fig. 3. Sections from one of the 3D models created within the project.

Fig. 4. The real artefacts and the respective 3D model (the white ones).

A very interesting aspect of 3D modelling when applied to cultural heritage is the ability to perform restoration hypotheses in order to restore the artefacts, especially those found in a fragmentary state, so as to look as similar as possible to the originals. Digital restoration does not result in any alteration of the original as it is performed on the polygonal model in the computer memory. Many scenarios of restoration can be applied to the same 3D model and these can be evaluated by scholars before the actual physical restoration. In the case of the wooden cup, polygonal models of individual fragments were created and a further model in which two fragments were assembled virtually was used for exhibition (Fig. 5).

Fig. 5. Left: 3D models of 2 fragments of the same object; right: 3 views of the assembled fragments.

In other cases, the artefacts cannot be simply reconstructed from a physical point of view. Such are the cases of the sickle and the handle of the iron-made cauldron found at Scorpo. The first had been folded before its deposition and oxidation occurred on the contact faces ‘welding’ them together. Instead, the handle has two remaining fragments that cannot be rebuilt physically since on one of them the oxidation had ‘welded’ the attachment of the handle to the loop that was attached to the cauldron’s rim. The restorations performed on the digital models has allowed the restitution, albeit virtually, of the sickle and the fragments of the handle to forms that are close to how the artefacts might originally have looked like (Fig. 6). This allows more efficient research by scholars on the actual function and shapes of the objects in question.

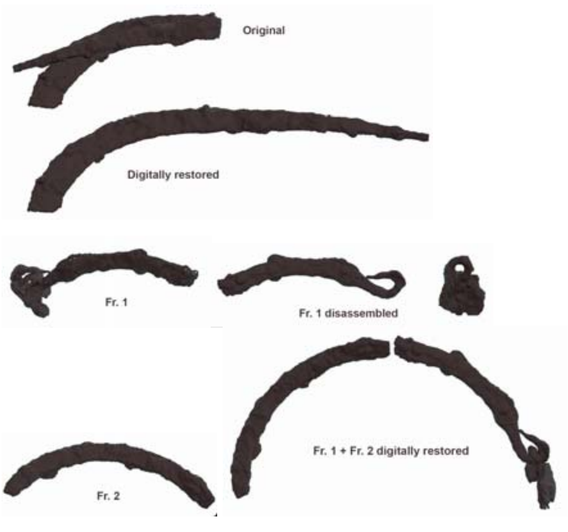

Fig. 6. Digital restoration of the sickle and of the handle.

Texture mapping with high-resolution images, combined with the application of suitable material properties in Computer Graphics (CG) programs, allow for photorealistic renderings and the assembly of virtual displays for remote fruition via the web.

The digital 3D models created were sent to the Laboratory for Polymeric Materials of the Department of Engineering for Innovation for the creation of the physical copies. After the physical copies were made using rapid prototyping technology, a dimensional control was performed between the original and the copy. The comparison showed the excellent quality of the replicas and their correspondence with the shape and size of the original artefacts within the measurement limits of the 3D laser scanner (Fig. 7). This part of the work reassured the team before proceeding with further investment of time and money in the proposed methodology.

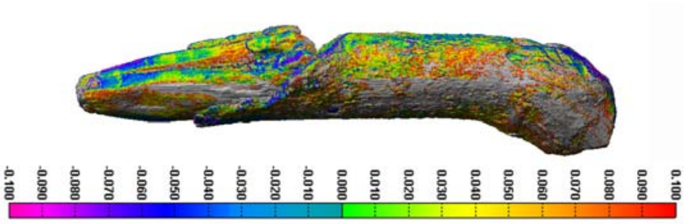

Fig. 7. Error map of the comparison between the real object and its replica (scale mm)

III. Replicas of the Archaeological Finds by Rapid Prototyping

Rapid Prototyping techniques (RP) are devoted to the production of solid 3D parts as an alternative to traditional mechanical manufacturing such as milling or machining. The main difference between RP and traditional technologies is the method used in the production of objects. The former adds material layer by layer, whereas traditional techniques subtract material during the production starting from a bulk. This is why RP are also referred to as additive methods and as a free form fabrication. The most relevant feature of RP manufacturing is given by a fabrication time that is substantially independent of the geometric complexity of the objects.

The first RP technology developed and commercialized was Stereolithography, a method of generation of complex geometries by means of photopolymerization of resin-based material. In this process a laser beam is projected on a vat of resin where the material, under the laser light, solidifies. The item is built solidifying several transversal sections layer by layer. Each layer is a thin solid plastic film, typically 0.1 mm thick.

The object to be built may be drawn using 3D CAD (Computer aided design) software that provides its mathematical representation. Alternatively, an existing object may be modelled with a 3D imaging system in order to obtain a digital representation of its surface shape. In the medical field, the modelling of organs, bones, teeth and so on, will involve magnetic resonance imaging (MRI) or computed axial tomography (CAT) equipment.

In any case the file representing the geometry is converted in a particular standard format used by every RP apparatus: the "*.stl" format (solid to layer) that reproduces the object as a mesh of triangles. This file is processed with a mathematical algorithm to generate the files of all the layers required to fabricate the part in the RP apparatus. This operation is also known as slicing. After this step, resulting files are uploaded on the apparatus of RP and the fabrication starts.

In this work, the reproduction of two archaeological objects, i.e. a sickle and an adze, using a rapid prototyping apparatus, is reported. The technique can be used to make copies of items of cultural, archaeological and historical significance, for many purposes such as exhibitions and recording of their features even after possible damage.

A photoreactive resin, acrylic based and commercialized with the trademark "EnvisionTEC SI 500", was used in a standard rapid prototyping equipment able to build 3D solid plastic objects. EnvisionTEC Ultra apparatus (EnvisionTEC GmbH, Gladbeck - Germany) was used to fabricate high precision copies of two of the archaeological finds. In order to maximize the speed of production, this machine uses a light projector instead of a laser. The equipment starts the building procedures with thin supports that fix the part on a moving platform. After solidification of a first layer this platform is moved downward along a vertical axis (called z-axis) and the layer is covered with a film of liquid resin. Then a new solidification process starts, selectively photopolymerizing the resin film according to the shape of the section (fig. 8).

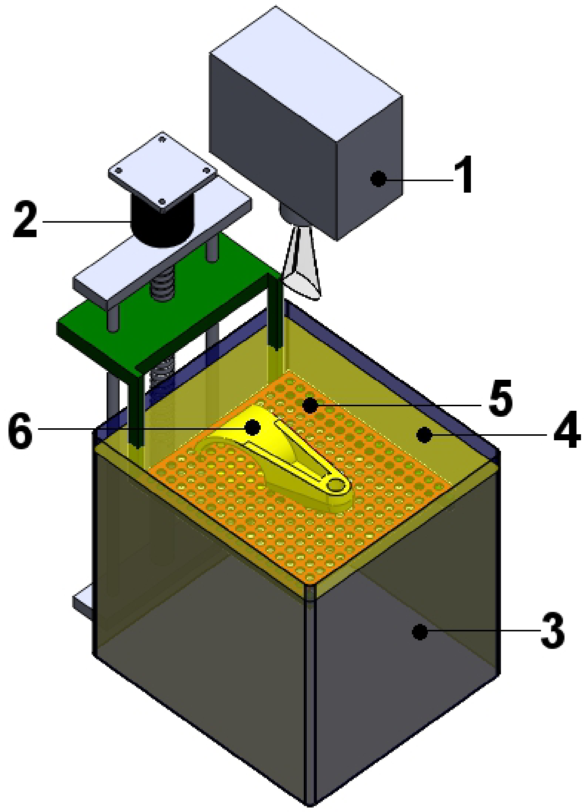

Fig. 8. Envisiontec Ultra Apparatus: 1. Light projector; 2. Motor – Z Axis Elevator Mover; 3. Vat; 4. Resin; 5. Platform; 6. Part in construction.

Magics14 software (Materialise, Leuven - Belgium) was employed to process the CAD files for the reproduction of the objects in the prototyping instrument. The latter step was carefully performed in order to obtain the best surface finish of the replicas, making them suitable for a museum exhibition. Very detailed copies were obtained, ready for post-processing operations such as painting, shading or artificially aging them.

The reproductions of the sickle and of the adze shown in fig. 9 are obtained applying the described procedure without any further machining or painting [8].

Fig. 9. Replica of the sickle and of the adze made of an acrylic resin

IV. FINISHING AND COLOURING THE REPLICAS

The copies produced for museum display have had their surfaces coloured, using colours obtained through reference to Kodak Color Control Patches placed next to the objects during digital photography. This had enabled us to obtain a coded colour scale that could be referred to the RGB gamut and thus to the range of colours provided by Pantone Inc.

These references have been used for the physical colouring of the replicas, manually executed by a skilled restorer employing both tempera and oil colour paints, matching the material of which the original object was made (wood, iron, bronze, bone, etc.) (figs. 10, 11) [9].

Fig. 10. Coloured replicas of the sickle and of the adze.

Fig. 11. Original artefact (adze) photographed near its respective replica: left) a top view, right) a side view.

V. About Fruition: the case of the Museum of History and Archaeology (MUSA)

It has been possible to appreciate some advantages thanks to the display of replicas of wooden items in an exhibition organized by the Museum of History and Archaeology of the University of Salento MUSA [10]. The exhibition, entitled "A well of history: the environment and economy of a Byzantine village in the province of Terra d'Otranto" [11] (Fig. 12), was part of a project aimed to promote and divulgate recent research in ancient history and archaeology by the University of Salento [12].

Fig. 12. Poster of the exhibition.

The exhibition presented the context of the well and the finds within it as an aid to reconstructing the environment and the landscape around the Byzantine village of Supersano and the productive activities of its community. The display included artefacts and ancient plant remains, together with explanatory texts and scale models of the village huts and of the well (Fig. 13). The possibility to replicate the wooden artefacts found in the well through digital 3D models allowed the exhibition of the entire group of finds, that otherwise would have been necessarily deprived of the more fragile remains (Fig. 14). However, this would have limited the scientific content of the exhibition, both in quantitative and qualitative terms. Resin replicas of the relics can also be useful in order to set tactile paths in displays that care for particular types of visitors, such as children or the visually impaired.

Fig. 13. Scale model of the well by Fabrizio Ghio and Alberto Guercia

Fig. 14. The exhibition of the replicas of wooden artefacts (nos. 7-9).

VI. Expanding our capabilities

In order to improve the area of 3D image acquisition, 3D surface modelling and replication, we will have a closer look at latest multi-view stereo photogrammetry “metric” packages available either commercially or in the public domain, and at commercial RP equipment.

With recent improvements in computing power and efficient algorithms, 2D image-based techniques have emerged as a real contender to replace active 3D imaging systems in situations where well-textured artefacts are to be inspected and modelled. Here we will rely on current literature with proven application in order to evaluate an easy and flexible solution for the 3D reconstruction of the artefacts on-site (at the moment of the discovery) and in the laboratory. This solution will add a new tool to our "digital continuum" tool-kit.

A number of recent publications summarize solutions for automatic selection of 2D images, generation of 3D point clouds, 3D surface models and texturing. Both low cost commercial software packages and open source solutions including web services have appeared. These publications are complemented with actual accuracy tests where multi-view stereo photogrammetry results are compared to laser scanner data and reference materials [13, 14, 15, 16, 17, 18, 19].

There is even a proposed solution for artefacts with sizes in the range 10 mm-100 mm where problems related a reduced depth of field and a loss of contrast due to diffraction with passive 3D imaging techniques are minimized. The method uses a sequence of multi-focused images. Active 3D imaging based on laser scanners has dominated that range of sizes because of the increased depth of field and the controlled diffraction of the laser propagation within the measurement volume. Further testing of these methods, often based on image fusion algorithms to extend the depth of field of the images used in the photogrammetric process, will provide solid accuracy data that can be then applied in the field of cultural heritage [20].

As presented in recent technical literature and company press releases, there is a real potential of 3D printing technology to transform manufacturing by creating new opportunities for large to small organizations and even Do-It-Yourself (DIY) creators. It is anticipated that prices for DIY equipment will see an even lower drop with many patents due to expire in the next few years. The introduction of colour in the RP process will also create new ways to expand museum exhibits and experience [21].

VII. Conclusion

To sum up, digital 3D models of artefacts and contexts are increasingly used in museums in order to improve the communication potential of exhibitions. The exploitation of digital techniques (immersive visualization and augmented reality [22]) is able to create multi-sensorial perception mechanisms and is able to actively involve visitors in the consultation of the collections. Furthermore, the tactile relationship with the objects contributes in improving the fruition of the archaeological heritage, and helps the construction of an interpretation of objects, creating and transmitting meanings in a more engaging fashion.

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