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3D imaging and new ways of making museums interactive and enabling digital discovery and learning

Grazia Maria Signore
Museo Storico-Archeologico (MUSA), Dipartimento di Beni Culturali, Università del Salento, via di Valesio angolo viale S.Nicola. I-73100 Lecce (LE). E-mail: graziamaria.signore@unisalento.it

Adriana Bandiera
Coordinamento SIBA, Università del Salento, via di Valesio angolo viale S.Nicola. I-73100 Lecce (LE).
E-mail: adriana.bandiera@unisalento.it

ABSTRACT
Digital technologies are increasingly used in museums to improve the learning quality and communicative potential of exhibits. In particular, the application of 3D technology not only simplifies the detailed study of ancient artefacts, but also increases the readability of an object, especially if made of perishable materials. The creation of a 3D model can help in planning traditional restoration operations or in carrying out digital restorations for particularly delicate or fragmentary artefacts. Starting from a 3D model you can build physical replicas identical to the original, either full-size or scaled. These can be used for educational activities that require tactile experiences, with children or differently abled visitors (with visual or hearing impairments for example) or to more fully involve the average visitor. It is possible, finally, to create animated digital walkthrough experiences for mobile learning or more generally for remote discovery.
In this paper we will present the 3D modeling project, currently ongoing, for the exhibits of the Historical-Archaeological Museum (MUSA) at the University of Salento, in partnership between the Museum and the 3D Laboratory of SIBA of the University. The project aims to improve the Museum's communicative potential and capacity to interact with the wider general public as well as implement, as soon as possible, an application for mobile devices and a catalog of on-line searchable collections.

Key words:
museum education, 3D imaging, cultural heritage communication.

RIASSUNTO
3D imaging e nuove forme di interattività, fruizione e apprendimento nei musei

L'uso di tecnologie digitali nei musei si sta sempre più diffondendo per migliorare la qualità dell'apprendimento e il potenziale comunicativo delle esposizioni. In particolare, l'applicazione della tecnologia 3D non solo facilita lo studio dettagliato di reperti antichi, ma aumenta la leggibilità di un oggetto soprattutto se in materiale deperibile. Realizzare un modello 3D può essere d'aiuto per pianificare operazioni di restauro tradizionale o per effettuare restauri digitali per manufatti particolarmente frammentari. A partire da un modello 3D è possibile realizzare repliche fisiche identiche all'originale, a grandezza naturale o in scala. Queste ultime possono essere utilizzate per attività didattiche che prevedono esperienze tattili con bambini o pubblico diversamente abile (non vedenti, ipovedenti). È possibile, infine, creare percorsi digitali animati per il mobile learning o più in generale per la fruizione a distanza.
In questo contributo si presenterà il progetto, ancora in fieri, di modellazione 3D dei reperti esposti nel Museo Storico-Archeologico (MUSA) dell'Università del Salento, avviato da qualche tempo grazie alla collaborazione tra il Museo e il Laboratorio 3D del SIBA della stessa Università. Il programma è finalizzato a migliorare il potenziale comunicativo e l'interazione con il Museo e a realizzare, appena possibile, un applicativo per dispositivi mobili e un catalogo delle collezioni consultabile on line.

Parole chiave: didattica museale, 3D imaging, comunicazione del patrimonio culturale.

Fig. 1. Historical Archaeological Museum (MUSA). A view of room 3.

INTRODUCTION

Today museums have more roles and functions than ever before. No longer is their mission simply to conserve, protect and exhibit objects; now they have become privileged places where the public can come to learn and discover and acquire new knowledge.

Every museum, therefore, while continuing with its mission to conserve heritage, at the same time carries out activities aimed at various and diverse groups of users, to enable artefacts to be used and viewed in educational, cultural and recreational contexts.

Interpreting its heritage and making it available to visitors is therefore an integral part of the raison d'être of a museum.

The exploitation of digital techniques - also in immersive visualization and augmented reality- enables the creation of multi-sensory perception mechanisms that actively involve the visitors in the consultation of collections.

In particular, 3D models of artefacts and contexts are increasingly used in museums in order to improve the communicative potential of exhibitions.

MUSA, the Historical and Archaeological Museum of the University of Salento, has always (since it opened its doors to the public) made use of 3D modeling in order to improve communication with the public.

MUSA is the reference museum in the field of studies in ancient history and archeology of the University of Salento and was created in 2007 thanks to the Coordinated Project of the University of Catania and Lecce (IN20). The exhibition is housed in an area of approximately 500 square meters divided into five rooms, which communicate with each other. The executive museum exhibition project sought to combine the scientific and educational purpose of the museum with up-to-date and interactive forms of communication in archeology (fig. 1).

The objects displayed in the rooms come from excavations carried out by our university in the local Salento area. They were chosen and selected for their narrative value and ability to evoke places, contexts, practices and socio-cultural dynamics of the past.

Models, molds, static and moving images are displayed alongside them, to help visitors to learn more about exhibition themes.

The aim was to create not only a simple presentation of objects, but rather an exhibition able to transmit and mediate scientific knowledge (acquired over many decades of research by historians and archaeologists of our university), combining scientific rigor with new tools and communicative approaches.

The exhibition, set up according to the latest and most avant-garde museum criteria, also makes extensive use of Information and Communication Technologies.

MUSA, in fact, is equipped with a Multimedia Exhibition System consisting of twenty video screens placed in different rooms and networked for viewing multimedia content. Some of these make use of 3D modeling, thus presenting the original contexts of the exhibits in a virtual, and therefore more interactive and communicative, mode.

MUSA and the 3D Laboratory of SIBA Coordination of the University of Salento have been actively working together for several years now, with considerable success.
This synergy has launched a digital imaging program of the Museum exhibits; this program is currently under construction. All this is in preparation for an online catalog of the collections and the development of an application for mobile devices that leverages the potential of Augmented Reality. The online catalog and app will provide us with useful tools with which we can improve the learning processes in the museum and especially the public's ability to read and understand both the finds and their contexts.

3D AND MUSEUMS: AN OVERVIEW

The museum's educational function is now recognized as primary and institutional (here we cite the Museum definition given in Art. 2.1 of the ICOM - International Council of Museums Statute) according to which a museum is "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment".
In recent years education has become a crucial activity for museums. Museum Education involves not only students or a specialized audience but, necessarily, must address everybody in the community by implementing educational and diversified communicative approaches, depending on the category of users (De Luca, 2007). This change is the result of a long and laborious process, the result of the growing need for a social use of museums.
Museums have then become agencies for cultural mediation, for intercultural dialogue, for social cohesion (Celi et al., 2013). Now the museum is no longer a place for elite insiders, but instead must be open to all and speak a language that is accessible to different and diverse categories of the general public. Underlying all this is a constructivist conception, where the museum is a place in which every visitor must find the ability to implement strategies of knowledge and personal learning (Hein 1995; Hein 1998). For this reason, the museum must provide space for different points of view and put in the center the experience of each individual visitor, trying to meet their different needs and expectations in order to build a relationship with the public (Nardi, 2004).
Learning and training must be guided by "a local and worldwide training theory within a local and global society of knowledge, which requires us to go beyond closed and separate training systems and replace them with systems that are open and flexible, based on work on structure networks, services and operators, learning processes and knowledge constructs through investigative and participatory methodologies which connect different and diverse relationships and knowledge" (Orefice, 2009).
With this in mind UNESCO has provided clear guidelines on the formative nature of museums and, in general, of cultural institutions which must be capable of "contributing to heightening knowledge acquisition, of intercepting and bringing out unexpressed and latent cultural needs, of interpreting and stimulating the need for knowledge and exchange, so that they (museums) become a dynamic reality, a place for the diffusion of culture, ideas and knowledge, for social cohesion, civil growth and the redefinition of single and collective identity" (Zane, 2016).
Therefore it is essential to communicate effectively so that everyone in the community can recognize themselves in the founding values of the museum. For this reason all Museums should be able to produce, disseminate and mediate information and knowledge, using new languages and new forms of communication.
With this in mind new multimedia technologies undoubtedly play an essential role in improving and strengthening the relationship between museum and visitor (Parry, 2010).
The support of multimedia technologies adds to the interactive potential of the museum, both inside its halls and beyond its physical boundaries, thanks to the internet (Solima, 2008). In addition, "multimedia, used in a targeted manner, and not as an end in itself, provides the opportunity to deepen and integrate information, transforming the visitor, through this interactive exchange, from passive spectator to active protagonist" (Zerbini, 2006).
No doubt, the introduction of mobile technology in museums, through the use of applications for mobile devices (smartphones, tablets), enhances the "cultural enjoyment on site, preserving the centrality of asset exposure and preserving the sensorial richness that comes out of direct contact with products, environments, places "(Spallazzo, 2013).
The traditional visit to the museum is enhanced by additional information, available in real time, without doubt making the visit a richer, more interactive and participatory experience.
The use of this technology, which often exploits features offered by Augmented Reality using 3D content, makes museums more accessible to the general public, and is especially attractive to younger visitors. This technology provides "increased" knowledge about the heritage of the museum itself, enriching it with insights, critical

references, additional information on the collections in foreign languages, 2D and 3D video, photos, audio, geo-localized content, virtual reconstructions and even games (mobile gaming). All this allows the visitor to build a personalized visit, calibrated on their own interests, through interactive and playful paths of knowledge and exploration.

In Italy, mobile technology has already been adopted not only by major museums such as the Vatican, the Uffizi and the Capitoline Museums but also by smaller museums such as the Civic Museum of Siena or the Archaeological Museum of San Severino Marche.

Many museums all over the world have started digitizing their collections in 3D in recent years.

This is in order to facilitate both the more traditional functions of museums, such as conservation, dissemination and education through the objects in museums, and also to permit remote use of museum collections through websites and social networks.

More recently, some museums have also started to offer the opportunity to print a copy of the three-dimensional model with a 3D printer. For example, the Canadian McCord Museum with its 3D Pilot Project (see web site 1) and the American Smithsonian Institution, which has started to create a digital archive of its findings in 3D (see web site 2).

In English-speaking countries there are many good examples: the British Museum decided to upload Sketchfab, an online platform for publishing and Free 3D models research, some digital reproductions of archaeological and artistic objects from its collections, thus enabling them to display objects from all angles as well as download data and playback (see web site 3).

Thingiverse is another web site that is home to three-dimensional models, especially from American museum collections, such as the Metropolitan Museum in New York (see web site 4).

Once the museum or a visitor uploads a 3D model on this site it becomes accessible to a wider number of people who could potentially be interested in the museum itself. This increases and improves the visibility of the museum and at the same time creates new opportunities and new tools of study and knowledge of cultural heritage by sharing multimedia content with the network's audience.

In Italy, however, according to the latest ISTAT survey of 2011 published in November of 2013 where 3847 museums were surveyed (public and private, open to the public), only 13.3% of museums had a digital catalog available and less than 0.1% published 3D models of their works online (see web site 5).

There are examples, such as the European project 'European Virtual Museum' (Leonardo da Vinci), carried out a few years ago, in which the Pigorini Museum was involved in digitizing its collections together with other museums in Europe (see web site 6). And more recently, the MAO Turin (Oriental Art Museum) made over 120 3D models of objects stored in its collections on Google Art Project platform available online (see web site 7).

However, a certain reluctance can be seen in Italy in allowing online access to collections, probably due to the rules which existed until recently in our country in terms of prohibiting photographic reproduction of objects and works of art in museums. Only recently have these rules been repealed by art. 12, c. 3 of Bonus Art Decree, which entered into force on June 1 of 2014, authorizing the free reproduction of cultural heritage.

In the light of what has been said above, this paper presents the work in progress which started some time ago at the MUSA Museum of the University of

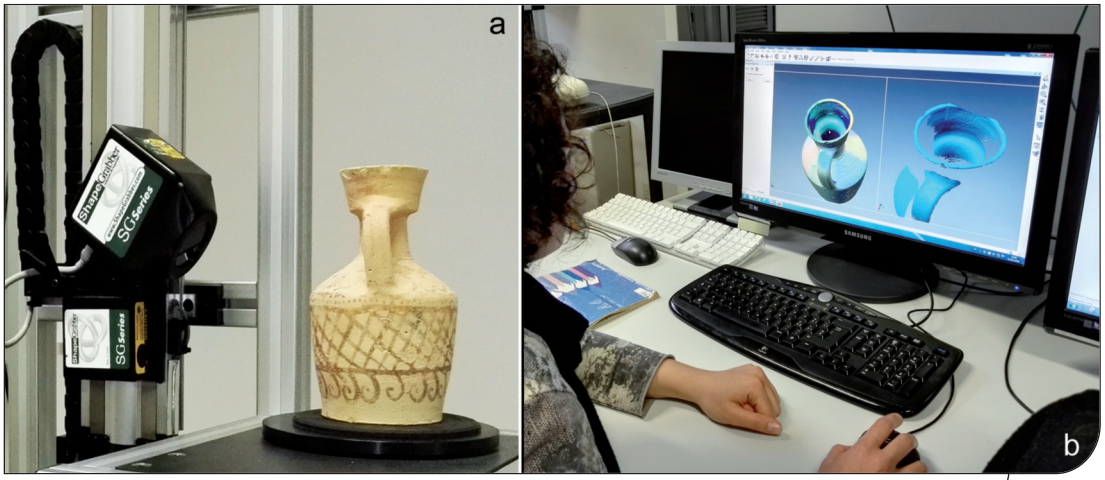

Fig. 2. 3D scanning (a) and modelling of an artifact (b).

Fig. 3. Late antique amphora with engraved text and related 3D models: the left made with Photoscan, the right constructed with laser scanner.

Salento: the 3D digitizing and modeling of its archaeological finds.

The program grew out of the need to upgrade and increase the communicative potential of the museum in conveying information about its contents to visitors. Furthermore it was essential to cater to the new modes of communication and informal learning dedicated especially to young people (particularly given that 80% of the MUSA audience is made up of the students of the University and those of local schools).

METHODOLOGY

The 3D scanning and modeling work was carried out at the 3D Laboratory of SIBA, which has been working in this field for several years now. The Laboratory is equipped with 3D laser scanners, digital cameras for texture mapping and photogrammetry, software and professional tools for modeling, digital restoration, animation and 3D visualization of archaeological artefacts, fossils and objects available at the University, or object of interest by teachers, researchers and museum curators.

The creation of the 3D models of MUSA artefacts was done with a 3D laser scanner from ShapeGrabber ®. This scanner, suitable for high-resolution acquisitions of small objects, is equipped with a rotating base which allows 3D scans all around individual artefacts in a completely automatic way. This, in turns, minimizes the time in handling these fragile artefacts. The lateral position resolution was set at 0.1 mm (diameter of a human hair is about 0.08 mm).

For the 3D modeling InnovMetric PolyWorks® was used, a professional software also used in automotive and aeronautics, that permits management of the different stages of 3D modeling, from the alignment of individual point clouds to the creation of a high quality metric model, to its possible inspection (fig. 2).

Recently, to speed up the creation of a 3D model process, the digital photogrammetry software Agisoft PhotoScan® has been adopted. This software, starting from a series of pictures taken according to specific rules, enables the creation and export of 3D models with texture. However, laser scanning was found to be the best solution in order to highlight slightly visible surface details, as is evident from the comparison of the 2 amphora 3D models created with laser scanners and PhotoScan respectively (fig. 3).

Where necessary, with the support of the scholars, it is possible to perform digital restoration operations, especially on 3D models of objects or fragments that cannot be reassembled because of their incomplete state. Since digital restoration does not cause any alteration of the original artefact, different restoration hypotheses can be applied to the same 3D model, and these can be evaluated by experts prior to a possible physical restoration (fig. 4).

APPLICATIONS

The 3D modeling project is still in its initial phases and so currently covers some exhibits that are part of the permanent MUSA exhibition. These are those objects that pose reading problems or are fragmentary, or are in a not good state of preservation. They also include items that deserve to be observed from different points of view but their placement in a display case does not allow one to fully appreciate all the wealth of information they provide.

For example, a Mycenaean cup from the Bronze age settlement of Roca (Southern Apulia, Italy) has been digitized. The object is exhibited in Room 2 of the museum, in the section dedicated to Roca in the Bronze Age. The cup is incomplete: lacking the lugs and the foot and part of the bowl and rim. From the fragments recovered from the excavation only two

Fig. 4. Digital restoration hypothesis applied to the 3D model of a Eucharist mold (X-XI cent. A.D.) exhibited at the MUSA.

Fig. 5. 3D model of the of Mycenaean cup: frame of the 3D animation.

non-connecting parts could be reassembled. However, it was deemed worthy of exhibition in the museum for its historical value, since it is an imported object documenting exchanges between Roca and the Aegean world in the fifteenth century B.C.

Once we had identified the cup reference prototype, based on a comparison with the best-preserved specimens from other contexts, it was possible to embark on its complete reconstruction.

The 3D model has not only provided a greater understanding of the object but it has also proved to be of great help in improving the display of the find. Initially, in fact, only the larger part of the cup was visible in the window. Having a three-dimensional model of the object made it possible to create a plexiglass support capable of supporting both sides of the container and simulating the presence of the lugs and the missing foot.

Furthermore, we created an animated digital walkthrough to be used on the web and more generally for remote discovery (fig. 5). 3D animation offers in fact a more attractive and less conventional approach to learning.

Virtual technology, used as a methodology that integrates and verifies analytical research data, clearly plays an important role both in the cognitive recognition and in the conservation of ancient artefacts.

This can also be seen in the digital modeling of other exhibits of our museum.

Another example is a cup with relief decoration of Corinthian production (Brindisi, Roman imperial age). The cup has a battle scene between knights shown in relief. The convex surface of the vase and its location in the cabinet - showing only its front view - makes it impossible to follow the narrative of the relief decoration. Thanks to 3D digital modeling the scene could be unrolled on a flat surface, making it clearer and more legible (fig. 6).

In the same way, the understanding of an inscription on the surface of late antique amphora, from a tomb of the early Christian necropolis of Vaste (southern Italy) and exhibited in the MUSA Late Antiquity section, was improved. In this case the digital model allowed us to free the engraved text from the painted decoration grid that covers the belly of the container thus providing a better understanding of the text (fig. 3). On a 3D model in fact you can see the details of the surface of an object, without the distraction of color, and thus notice little details that otherwise are not very visible through direct observation of the original (brushstrokes, traces of tools, inscriptions, etc.).

Finally, the 3D model of a clay mold mask that adorned an Apulian red-figure krater (second half of IV century BC) made it possible to carry out positive virtual restoration, returning the artefact to its original function and helping to tell the story of this ancient object (Signore, 2016), hitherto apparent only to specialists (fig. 7).

The 3D digital model also offers another great benefit, that is the opportunity to accurately reproduce the object and manufacture a physical copy. The model obtained can be used to present a copy of artefacts found in bad condition, such as those made of wood or metal, which might not otherwise be exhibited.

The advantages of this method can be fully appreciated in the exhibition "The history in the well. Environment and economy of a Byzantine village in Terra d'Otranto ", realized in 2011 by MUSA, with the exhibition of resin replicas of some wooden artefacts from the Byzantine village of Supersano (LE). The replicas of the objects were produced by the Laboratory for Polymer Materials of the Department of Innovation Engineering of our university through rapid prototyping technique, starting from the digital models made by the SIBA 3D Laboratory (Bandiera, Arthur, Leo Imperiale, 2013).

Fig. 6. Cup with relief decoration unrolled on a flat surface.

Fig. 7. Clay Gorgon head mold and its virtual restoration.

Undoubtedly having physical copies of objects that could not be exhibited because of their state of preservation allowed us to better display the materials from the well of Supersano, further enriching, both quantitatively and qualitatively, the scientific reach and communicative potential of the exhibition.

CONCLUSIONS

3D technology applications are ever more widely used in museums to increase the communicative potential of exhibits. The creation of 3D images helps us to study, conserve, exhibit and educate through ancient objects. Thanks to this technology we are able to provide objects with a better narrative and thus encourage our visitors to discover more and to explore. Furthermore, from a conservation point of view, together with the opportunity to virtually restore a damaged or partial artefact, as seen above, the analysis of differences in 3D data can also tell us about the changes which the artefact has undergone with respect to the past.

In particular the use of these images in immersive visualization and augmented reality is able to create multisensorial perception mechanisms that actively involve visitors in the consultation of collections. Since the images are superimposed on the real artefact they provide the viewer with extra information, information which is immediate as well as being easier to understand when presented in this format.

The 3D digitizing project started by MUSA Museum in partnership with the 3D Laboratory of SIBA at the University of Salento is still in its early stages, but has clearly shown its advantages, especially in improving the knowledge and interpretation of the individual objects. However, it has not yet been possible to ascertain the wider public's reaction to this application since the models are not yet on display in the museum's rooms but only, together with other digital content, in the adjacent SIBA 3D Theater, and so far only open for viewing during organised cultural events or by booking in advance.

Recently, digitization activities have been intensified with the involvement of university students doing internships at the 3D laboratory. During the internship, students are trained in the use of hardware and software equipment, and guided during all phases of the creation of a 3D model, from the 3D acquisition by laser scanners or photogrammetric techniques to the three-dimensional modeling, through to the realization of a 3D model or of a computer graphic video, viewable in stereoscopy. For the future we expect to create an application for mobile devices that uses Augmented Reality to make 3D models which work well for visitors to MUSA and for its educational activities, we are certain that mobile technologies can be adapted to different styles and ways of teaching and are particularly suitable for personalised learning pathways, and for ensuring lifelong learning.

Finally, we are evaluating which web platform would be most suitable for hosting 3D reproductions, so that they can also be accessed via web by the public so that the museum does not provide simply a finite learning experience but instead represents just a fragment of a wider exploratory path, one which exploits the potential of digital storytelling.

We also hope to create a tactile pathway through the museum by creating physical replicas of some of the objects by using digital models as a starting point. The replica of a relic, realized thanks to its digital 3D model can thus be functional to the study and conservation of archaeological artefacts, especially those in poor condition, but, perhaps even more importantly, it can also improve the scope for discovery and interaction with a larger public. A physical copy, in fact, offers the opportunity to interact directly with the artefact and this opens up a range of possibilities in making cultural heritage accessible to visitors with disabilities (visually impaired, blind) or to different age groups.

A tactile relationship with the objects, in particular with archaeological ones, often fragmented and therefore not easy to read, represents a further form of knowledge and can thus help in the interpretation process of the objects and in creating and transmitting their meaning in a more engaging way. Recently, the more widespread use of 3D printers is encouraging full-scale printing of artworks copies or even scaled-down architecture, to be used in museums for didactic activities and for the deployment of tactile discovery tour paths. As 3D printers become more affordable this trend will continue.

However, amidst the general excitement regarding the use of this new technology, it is important not to lose sight of some important aspects in its use. Namely the need for rigor in the construction of the 3D model that allows exact replicas of the original to be created and, above all, taking into account the needs of the visitor and how they can be met. The tactile path must be designed and built taking user

needs into account. Models will be tested and gradually improved in response to visitor reactions and comments. In addition, it will be essential to conduct an investigation to verify the effectiveness of the exhibition and the public's expectations before, during and after (Miglietta, 2013). Only in this way can a museum be genuinely inclusive, participatory and accessible.

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