VIRTUAL IN REAL.
INTERACTIVE SOLUTIONS FOR LEARNING AND COMMUNICATION
IN THE NATIONAL ARCHAEOLOGICAL MUSEUM OF MARCHE

P. Clini [a, *], R. Nespeca [a], L. Ruggeri [a]

[a] DICEA, Dept. of Civil, Building Engineering and Architecture, Engineering Faculty, Polytechnic University of Marche, Ancona, Italy – (p.clini@univpm.it, r.nespeca@univpm.it, l.ruggeri@pm.univpm.it)

KEY WORDS: Virtual Museum, Digital Library, 3D Model, Cultural Heritage, Small Artefacts, Edutainment

ABSTRACT:

Today the ICTs are favourable additions to museum exhibitions. This work aims to realize an innovative system of digital exploitation of artefacts in the National Archaeological Museum of Marche (MANaM), in order to create a shared museum that will improve the knowledge of cultural contents through the paradigm "learning by interacting" and “edutainment”.

The main novelty is the implementation of stand-alone multimedia installations for digital artefacts that combine real and virtual scenarios in order to enrich the experience, the knowledge and the multi-sensory perception.

A Digital Library (DL) is created using Close Range Photogrammetry (CRP) techniques applied to 21 archaeological artefacts belonging to different categories. Enriched with other data (texts, images, multimedia), all 3D models flow into the cloud data server from which are recalled in the individual exhibitions. In particular, we have chosen three types of technological solutions: VISUAL, TACTILE, SPATIAL. All the solutions take into account the possibility of group interaction, allowing the participation of the interaction to an appropriate number of users. Sharing the experience enables greater involvement, generating communicative effectiveness much higher than it would get from a lonely visit. From the “Museum Visitors Behaviour Analysis” we obtain a survey about users’ needs and efficiency of the interactive solutions.

The main result of this work is the educational impact in terms of increase in visitors, specially students, learning increase of historical and cultural content, greater user involvement during the visit to the museum.

1. INTRODUCTION

The work in this paper is part of a project that won the national competition “Learning projects in museums, archaeological, cultural and historical sites, or cultural and scientific institutions” organized by the Italian Ministry of Education, University and Research.

This work aims to realize an innovative system of digital exploitation of artefacts in the National Archaeological Museum of Marche (MANaM), in order to create a shared museum that will improve the knowledge of cultural contents through the paradigm "learning by interacting" and “edutainment”.

*, * Corresponding author

The choice of the interactive solutions mainly derives from the need to test the changeover from "learning" to "learning by interacting", that is the overcoming of simple visual experience by stimulating the visitor to do something. These solutions are typical ways of communication, highly developed in interactive museums and science centres. In this project, they are applied to an archaeological museum. The visitors are not passive spectators but become capable of acting with the 3D virtual object in its digital three-dimensional physicality.

The National Archaeological Museum of Marche is the unique "national" archaeological museum of the region; it is the starting point, given the nature of its collections which come from archaeological contexts excavated anywhere in the region.

The enhanced exhibition is characterized by the implementation of a series of stand-alone multimedia installations for digital artefacts that are related to the museum to create a new combination of real and virtual scenarios in order to enrich the experience, the knowledge and the multi-sensory perception of museum visitors. The interactive solutions chosen use multiple communication channels, mainly visual, tactile and spatial ones.

The workflow includes three phases:

1. analysis of user expectations;
2. design of interactive solutions;
3. test of interaction effectiveness.

All the work is based on the Digital Library of 3D models that is shared in a cloud data server and implemented into three interactive technological solutions (Figure 1).

Figure 1. Structure and workflow of the project and its relative solutions and installations.

Therefore, the main goals of this work are:

1. to attract more schools to visit the Archaeological Museum, creating personalized learning paths depending on the level of students' knowledge;
2. to engage students during the learning path by implementing the paradigm of "learning by interacting" with innovative Virtual Reality technologies;
3. to enhance the enjoyment of archaeological heritage whose observation with the naked eye inside of the showcases severely limits their value and the knowledge of the details.

2. STATE OF ART

During the last decades there have been numerous efforts concerning the 3D digitization of Cultural Heritage (CH) and the development of virtual museums, digital libraries and serious games (Skamantzari and Georgopoulos, 2016).

Nowadays, the most common techniques used for three-dimensional (3D) modelling are based on images (photogrammetry) and range data (laser scanning).

Even if the potentialities of the image-based 3D reconstruction approach are nowadays very well known in terms of reliability, accuracy and flexibility, there is still a lack of low-cost, open-source and automated solutions for collecting mass of archaeological findings, especially if we consider the real contextual aspects of a digitization campaign in situ. (Gattet et al., 2015)

(Evgenikou and Georgopoulos, 2015) shows different methodology for the three dimensional reconstruction of small artefacts. In (Clini et al., 2016) the authors combine the Structure From Motion technique (SFM) with Focus Stacking for the 3D digitization of small archaeological artefacts, and they verify the accuracy by comparison with 3D model obtained through triangulation laser scanning.

The development of Information and Communication Technologies (ICT) for the visualization of virtual digital object in real museums is nowadays rising rapidly.

Digital technologies are considered generally favourable additions to museum exhibitions. They are often described from the outset as "aids" or "augmentations" to traditional museum experiences (Allen and Lupo, 2012).

In the domain known as "Virtual Museums", (Pescarin, 2014) describes the shift we are assisting in the museum perception and management, including how virtual museums are and can be integrated in exhibits, highlighting positive and negative elements.

Also in the museum we can speak about Edutainment, based on the concept of "education + entertainment". The purpose of (Anikina and Yakimenko, 2015) is to determine the characteristics and methodological potential of technology Edutainment based on a review and analysis of the literature.

3. CRP FOR DIGITAL LIBRARY

The Digital Library (DL) of high quality three-dimensional models presents several positive and beneficial aspects: they are durable and unalterable; they can be used for heritage protection, creation of museum digital archives, documentation

of a great number of pieces; they allow experts to check possible accidental or man-made alterations of the work; finally, as in this case, they can be implemented in the technological interactive exhibitions.

For 3D digitization, we use reverse engineering techniques applied to 21 archaeological artefacts belonging to different categories of dating, material and shape. For the geometric and colorimetric acquisition, we have used the passive technique Close Range Photogrammetry (CRP), with particular pipeline of work for small objects.

In an archaeological museum, where the number of artefacts is very high and their digitization can take a long time, the acquisition phase must be optimized and made expeditious in order to reduce the subsequent times of data processing. So we have developed a quickly and low cost acquisition system that guarantee an excellent photographic quality.

Generally in an archaeological museum and in particular in the National Archaeological Museum of Marche, the artefacts are classifiable in movable, unmovable and very small objects depending on their size and their position into the museum showcases (Figure 2).

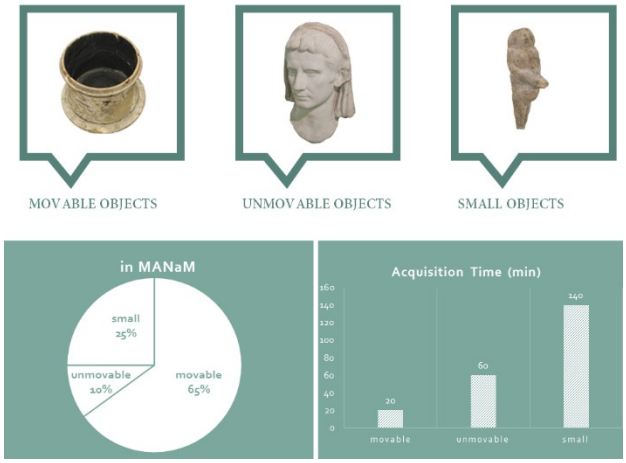

Figure 2. The main categories of archaeological artefacts in the in the National Archaeological Museum of Marche: the percentage of presence (left) and the time of acquisition (right).

The first category is the largest, but also one for which the CRP technique is more effective.

The goal of 3D digitization phase is to obtain a very accurate digital *facsimile*, with the propriety of scalability and the possibility to adapt it to different technological solutions, through the optimization of the interaction.

This kind of 3D allows a large variability of exploitable outputs: 3D printing, stereoscopic view and 3D visualization, etc.

In addition, these 3D models helped also to obtain improvement and enrichment of historical and archaeological knowledge about the artefacts.

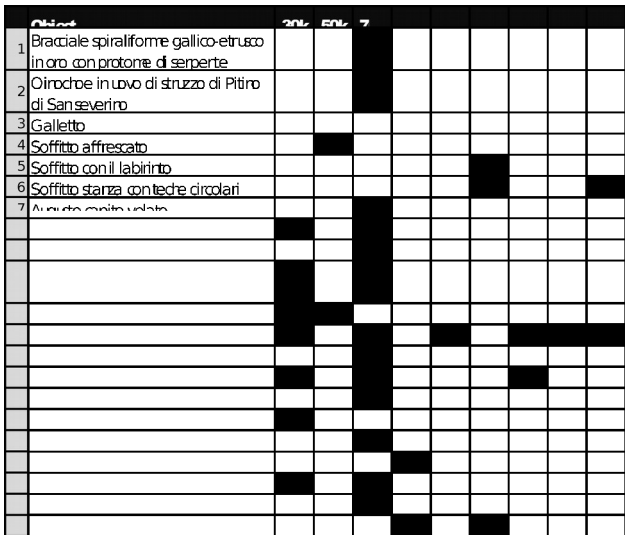

Figure 3. 3D models for Digital Library. Table with archaeological artefacts and model size: different sizes for different features.

Besides the archaeological artefacts, given the historical value of the Ferretti Palace where the museum is, we decided to enrich the digital library of 3D models of its architectural elements, such as coffered and frescoes ceilings.

The CRP pipeline is realized with the acquisition phase, the images orientation and the dense point cloud building.

Depending on the geometry and the size, we made different models with different resolutions: for big and unmovable objects we realized a mesh >100K faces; for others, 30K and 70K are the good resolution for light models.

An exception is the Frasassi Venus, a calcareous little statue of the Palaeolithic, made by combining CRP and Focus Stacking to obtain a very high quality model (for specific and in-depth studies), after decimated in 30K faces (for easy and assisted fruition) (Figure 3).

Chosen the best resolution, particularly important is the texture, that have a significant role in the visualization and the exploration of the artefact.

4. INTERACTIVE SOLUTION: VISUAL, TACTILE AND SPATIAL ROOM

Enriched with other information (texts, images, multimedia), all 3D models flow into the cloud data server from which are recalled in the individual exhibitions. The scalability of DL allows the good user interaction in the sensitive system.

In particular, we have chosen three types of technological solutions: VISUAL, TACTILE, SPATIAL (Figure 4).

Figure 4. Interactive and technological solutions for learning by interaction in the National Archaeological Museum of Marche.

In the first room, the museum visitors can view, rotate, zoom the 3D model and they can learn about them; in the second room, the users can virtually touch the 3D models, to value the roughness of surface and the weight of the object; in the last room, they can move themselves in the virtual scenario of the museum and they can take the artefacts from their showcases.

The new technological area is designed at the beginning of the museum tour to prepare the visit and to introduce the archaeological contents (Figure 5).

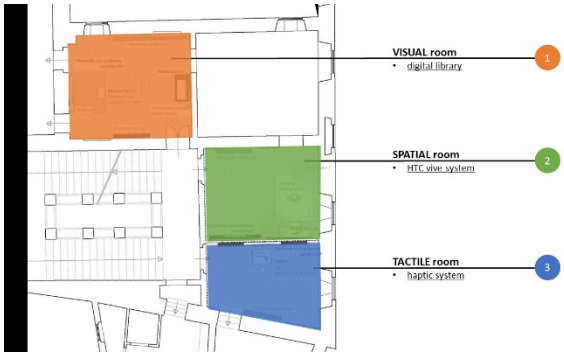

Figure 5. Plan of the second floor of the MANaM.

At the same time, the new interactive solutions do not replace the real tour, but they are the complementary experience for play and learning, to do at the beginning or at the end of the visit. This positioning of the exhibitions has been chosen in accordance with the evaluations of the museum staff and its director.

4.1 Visual room and digital library

The device for the VISUAL room is a PC connected with 4K monitor and a second touch screen (Figure 6).

The monitor allows to view the 3D models and their related information in high definition; the touch screen allows to manage, manipulate and interact with the virtual object.

There are two main components in our system architecture:

- Touch Interface (TI);
- Main Visualization interface (MVI) (4k display).

The TI allows to: a) control the visualization of a spherical panorama; b) control the visualization of Ultra High Definition Images; c) control the visualization of anaglyph 3D model; d) control the visualization of 3D model; e) start/stop multimedia contents related to artefacts. In the Main Visualization Interface (MVI) is possible to view all the contents.

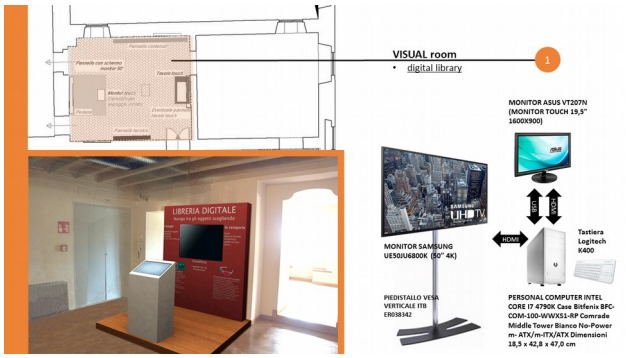

Figure 6. Devices (right) and rendering view of exhibitions for VISUAL room (left).

In the graphic interface is organized the DL (Figure 7), where the artefacts can be chosen by name, by category or by location.

For each object, the users can view the 3D model, the spherical panorama of their original museum room, the positioning on plan, the historical information and the HD images.

The high quality of models and images allows to zoom and to read the small details of the archaeological object as is not possible in the reality, because the showcases are closed and some objects are very small.

Figure 7. Home page of Digital Library in the VISUAL room.

4.2 Tactile room and haptic system

The device for TACTILE room is a PC with Haptic System and big display (Figure 8). The big monitor allows the users group to view the interaction with the haptic device. The Haptic device allows to “touch” virtually the 3D objects, and to play modelling them.

This is a high-precision haptic transmission and feedback device which may be seen as a three-dimensional computer mouse. It is based on a patented mechanical structure that makes it superior to all comparable products in terms of weight and the sturdiness of the design. The combination of mechanics with electronics and software makes the Omega a high-tech input and output device that does facilitate deliberate movements in three-dimensional space and is able to transmit forces and angular impulses to the hand of the user.

It is a completely new instrument within the CH field. Its use by non-expert users is yet to test in situ and definitely needs to be helped by museum staff.

The kind of possible interaction in this room is two:

- the tangible interaction;
- the digital virtual sculpting.

The tangible interaction with this device lets to manipulate the 3D model, to "finger" its shape, size, weight and roughness of material.

The digital virtual sculpting transform the user into an active player that after having seen, read, known and touched the object can play sculpting and shaping it according to his imagination.

The learning experience goes through interaction experience, with the touch and modelling. The distance between the user and the archaeological object is getting shorter, especially with the possibility offered by this device to "create" and to "personalize" the archaeological artefacts.

Figure 8. Devices and positioning of TACTILE room.

4.3 Spatial room and HTC vive system

The device of SPATIAL room is a PC with HTC Vive system and a big monitor. Composed by head-mounted display with a camera near the bottom rim, two wireless motion tracked handheld controllers and two "lighthouse" basestations for "room scale", the virtual reality headset allows to move really in the virtual space and to interact with the 3D models (Errore: sorgente del riferimento non trovata).

In this VR system the user moves himself in the space: he can remake his visit in the museum going easily from one room to another one, but here he can take the artefacts from their showcases and he can look the objects up close.

Unlike previous solutions, the interactive mode immersion provides a very immersive realism turning the manipulation of objects into a fun and exciting experience.

As for the DL, the 3D models and the virtual tour do not replace the originals, but they are a valuable aid to the enrichment of knowledge. The innovative and addicting interaction provides a better experience and learning storage.

In this case, the historical information are visible in a virtual caption that appears according to a specific command.

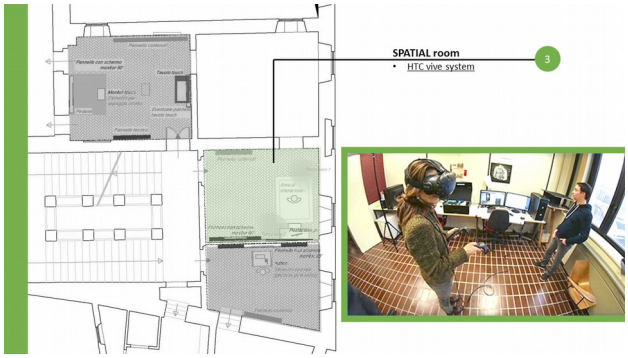

Figure 9. Plan with the SPATIAL room position (left) and photo of HTC vive system interaction in the laboratory (right).

All the solutions take into account the possibility of group interaction, allowing the participation of the interaction to an appropriate number of users, even if the physical interaction occurs inevitably with the individual user. Sharing the experience enables greater involvement, generating communicative effectiveness much higher than it would get from a lonely visit, related both to the immersive perception and to the increase of knowledge about the artefact.

4.4 Museum Visitors Behaviour Analysis

Another innovative part of this work is the "Museum Visitors Behaviour Analysis". Its application has concerned the planning phase to obtain a survey about the needs and expectations of the users, and the testing phase to evaluate the impact of interactive solutions on them.

In particular:

Phase 1: The activity was organized in two different opportunities for discussion through the Focus Group technique

appropriately moderated and facilitated, in addition to a free visit to the museum spaces with observant investigation.

Phase 2: The activities consist of the administration of evaluation test using task analysis in order to identify usability issues of the technologies developed.

The main result of this part of the work is to define a set of guidelines to be considered in the implementation of the technological solutions.

The activity was structured and developed during three afternoons (3 hours each meeting) with the participation of three High School Institutes of the Municipality of Ancona.

The total number of participants in the three days was 27 students, including 18 girls and 9 boys.

Each Focus Group (60 minutes long) was supervised by a moderator who, taking active listening, facilitated the discussion. He was supported by a verbalizer that traced the interventions and the relevant aspects that featured the interview and the individual contributions.

The activity was carried out as follows:

- brainstorming (“what do you think if I tell ‘archaeological museum’?)
- our memories (questions about this and other museums)
- metaplan (what I expect, evaluation of expectations)

After has been conducted a free visit (50 min) with an observation survey by the operators, during which there were recorded some behaviour of the boys in relation to the observation of the finds, the teaching aids, the existing multimedia, etc.

Finally, the last part (60 min) dedicated to:

- feedback from the visit
- memorisation of the objects
- game of imagination

In general, the idea of the archaeological museum as a site linked to the past, not active, "static" emerged both before and after the free visit. The museum, moreover, is never associated with the word "fun" and sociality, so the visit is not considered an experience to share with peers.

In the communication with the children clearly emerges the desire to have a direct and personal experience with the object/artefact, going beyond the simple transfer of information. Touching, interacting, recreating finds are definitely useful and desirable ways. There is in fact a need for "subjectivity" of the experience, for appropriation of forms and materials through other senses that are not just the sight, even better by measuring with new abilities and skills, increasing aesthetic abilities (e.g. creating objects). Equally strong is the need to make sense of this "doing" inside the museum, or interacting with objects within a content system that is capable of creating multiple references (multidimensionality of the experience).

The guidelines that have been identified in this first phase are illustrated as follow.

The use of the multimedia device should allow the user to:

- contextualize the find through information contents, easily understandable, suggestive and effective that, in conjunction with the interaction, amplifies its value of experience, provide insights and links with the museum and monumental reality of the city and the territory;
- view the object in its entirety by maximizing its virtual reconstruction in order to visualize its unobtrusive details to the naked eye;
- visualize the original work through a virtual reconstruction of the missing parts (if the exhibit is only partially intact);
- perceive the find by touch and understand its weight, material and texture; simulate the ancient use of the object;
- create a copy or a personal reinterpretation of the finding starting from the virtual modelling of a block that simulates the same material, in order to understand the practical difficulty that had occurred when it was created;
- customize the findings from the virtual modelling of the object; create a 3D print of the object created

In addition, the multimedia device:

- must be easily usable, understandable and accessible for all (for any age, nationality, disability);
- must be installed in close proximity to the exposed exhibit of which there is interaction, or in any case adequately integrate with the space of the Museum;
- if equipped with sound options, volume and playback must be controllable;

- avoid actions with time limits or, if necessary, allow the user to extend the time limit;
- must ensure a fast and pleasant experience (e.g. good resolution, fast loading times ...)

In the second phase, evaluation tests were performed for three different comparison devices:

1. 3D on autostereoscopic screen (not in this project)
2. 3D using 3D red/blue glasses (anaglyph)
3. 2D in High Definition mode.

In (Figure 10), the results are reported.

Key Performance Indicators	autostereoscopic	anaglyph 3D	HD image
quality of view	3,40	3,43	**4,68**
ease to use	3,81	3,68	**4,31**
detail perception	2,38	2,75	**4,71**
emotional impact	**4,25**	3,25	3,93
key performance indicators scale:		0= bad	5=excellent

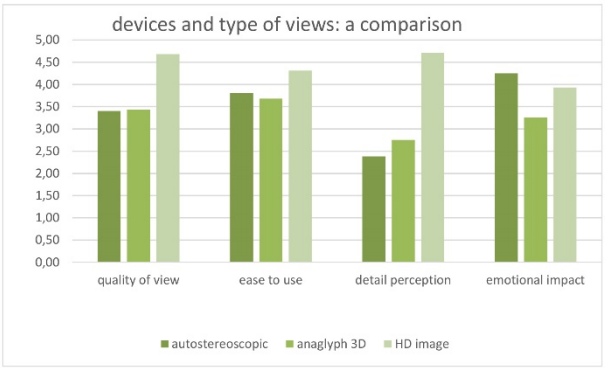

Figure 10. Test results on the usability and preferences about three kind of visualization for 3D models and HD images.

5. CONCLUSION AND RESULTS

The innovation of the work in this paper is to make the technologies effective for the communication in the museums. The main goal is the valorisation of the Real Museum with Virtual Reality and Edutainment, through interactive technologies. The proposed solutions take advantage of the latest opportunities available by ICT technologies in the visualization of three-dimensional prototypes and visual and immersive models. In particular, with the digital content it is possible to implement the 3D Digital Library also for social share. The physical aids instead amplify the visual and multi-sensory possibilities in the learning of archaeological artefacts.

The results of this work mainly concern the educational impact that can be measured in terms of increase in visitors of schools and educational institutions, learning increase of historical and cultural content, greater user involvement during the visit to the museum.

Through the interactive solutions that increase the multisensory perception, this work demonstrates how the digital documentation of archaeological artefacts is effective for learning and communication in the archaeological museum.

More in general, for archaeological finding it is possible to obtain a great magnification of their characteristics thanks to ICT tools. The 3D virtual replicas make culture accessible to the mass audience. The Cultural Heritage collection, conservation and access in novel, need accessible and attractive ways for digital documentation of museums and archaeological/historical sites, as well as for designing methodologies to represent, manage and exploit CH data at different levels. The use of virtual "*facsimile*" of artworks or architectures can unify the scattered elements of them, allow public access to inaccessible places, allow the visitor to interact with perishable objects and promote the preservation of fragile sites and simulate damaged or lost objects. The availability of semantically reach data is a promising filed for smart applications devoted to fruition, preservation and study of Digital Cultural Heritage (DCH) collections.

ACKNOWLEDGEMENTS

We thank the departments DII and DIISM, that have worked with us to realize the entire project. In particular, the professors Emanuele Frontoni and Adriano Mancini for the ICT support and professor Maura Mengoni, the research fellow Silvia Ceccacci and Ph.D. students Andrea Generosi and Alma Leopardi for the development of the haptic system.

Thanks to the Polo Museale of Marche, its director Dr. Peter Aufreiter and the National Archaeological Museum of Marche in Ancona and its director Dr. Nicoletta Frapiccini.

The tests were carried out by Marchingegno in the project "Percorsi didattici interattivi, multisensoriali e multiutenti attraverso tecnologie di Virtual Reality: il Museo Archeologico delle Marche".

REFERENCES

Allen, J., Lupo, E., 2012. Representing museum technologies.

Anikina, O. V., Yakimenko, E. V, 2015. Edutainment as a Modern Technology of Education. Procedia - Soc. Behav. Sci. 166, 475–479. doi:10.1016/j.sbspro.2014.12.558

Clini, P., Frapiccini, N., Mengoni, M., Nespeca, R., Ruggeri, L., 2016. SFM technique and focus stacking for digital documentation of archaeological artifacts. Int. Arch.

Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch. 41, 229–236. doi:10.5194/isprsarchives-XLI-B5-229-2016

Evgenikou, V., Georgopoulos, A., 2015. Investigating 3D reconstruction methods for small artifacts. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch. 40, 101–108. doi:10.5194/isprsarchives-XL-5-W4-101-2015

Gattet, E., Devogelaere, J., Raffin, R., Bergerot, L., Daniel, M., Jockey, P.H., De Luca, L., 2015. A versatile and low-cost 3D acquisition and processing pipeline for collecting mass of archaeological findings on the field. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch. 40, 299–305. doi:10.5194/isprsarchives-XL-5-W4-299-2015

Pescarin, S., 2014. Museums and Virtual Museums in Europe: Reaching expectations. SCIRES-IT - Sci. Res. Inf. Technol. doi:10.2423/i22394303v4n1p131

Skamantzari, M., Georgopoulos, A., 2016. 3D Visualization for virtual museum development. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch. 41, 961–968. doi:10.5194/isprsarchives-XLI-B5-961-2016