DIGITAL EXHIBITIONS AND FRUITION OF ARCHAEOLOGICAL FINDS

A. M. Manferdini [a,] *, S. Garagnani [a]

[a] Dept. DAPT of Architecture and Territorial Planning, University of Bologna, Viale Risorgimento, 2
40136 Bologna, Italy - (am.manferdini, simone.garagnani)@unibo.it

Commission V, WG 4

KEY WORDS: virtual museums, digital archives, 3d scanning, texture mapping, stereoscopic visualization.

ABSTRACT:

During the last two decades, since digital technologies have become more sophisticated in acquiring real data and building faithful copies of them, their improvements have suggested interesting applications in the field of valorisation of Historical, Cultural and Artistic Heritage, with significant consequences in the share and widespread of knowledge. But although several technologies and methodologies for 3d digitization have recently been developed and improved, the lack of a standard procedure and the costs connected to their use still doesn't encourage the systematic digital acquisition of wide collections and heritage.
The aim of this paper is to show the state of the art of a project whose aim is to provide a methodology and a procedure to create digital reproductions of artefacts for Institutions called to preserve, manage and enhance the fruition of archaeological finds inside museums or through digital exhibitions. Our project's aim is to find the most suitable procedure to digitally acquire archaeological artefacts that usually have small dimensions and have very complex and detailed surfaces. Within our methodology, particular attention has been paid to the use of widely shared and open-source visualization systems that enhance the involvement of the user by emphasizing three-dimensional characteristics of artefacts through virtual reality.

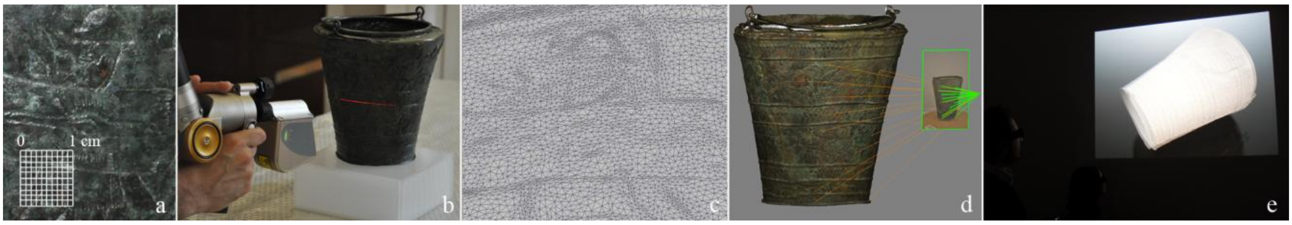

Figure 1. The developed methodology, from the analysis of the artefact and of survey conditions and aims (a), to the selection of the most suitable acquisition technology (b), to the survey of metric information (c), to the addition of radiometric information (d), to visualization (e).

1. INTRODUCTION

During the last two decades, since digital technologies have become more sophisticated in acquiring real data and building faithful copies of them, their improvements have suggested interesting applications in the field of valorisation of Historical, Cultural and Artistic Heritage. In particular, the possibility to digitally acquire and restore reality-based models of artefacts allows to (i) improve digital archives and catalogues by organizing and managing information using 3d models as intuitive graphic interfaces. By restoring the intrinsic 3d characteristics of artefacts, reality-based models facilitate the communication and meanwhile provide accurate and detailed information about shape, as well as chromatic and radiometric appearance of what is represented; (ii) preserve 3d information that are fated to change through time. These data can therefore be considered as references during preservation or restoration interventions; (iii) build virtual reconstructions of sites that have changed through time; (iv) share information among scholars who work in different places and times, and who can access to digital archives using the web. This possibility encourages cross analysis of data among different research teams and suggests interesting applications in different fields.
As a consequence, the recent developments of digital technologies and methodologies and the possibility to create and manage digital *replica* of artefacts allows curators to enrich exhibitions with virtual reconstructions of complex sites, as well as to show objects that are owned and managed by other Institutions and that can be shared and fruited in digital environments. In addition to these aspects, the possibility to produce physical *replica* of finds using digital technologies (i. e. rapid prototyping), provides a significant improvement to physical reconstructions of archaeological sites. The development of these technologies and procedures allows, for example, to collect in the same place *replica* of objects whose original copies are inaccessible because they don't exist anymore or because they are preserved in different locations.
Despite several technologies and methodologies for 3d digitization have been developed and improved in the last two decades (Bernardini and Rushmeier, 2002; Blais, 2004; Remondino and El-Hakim, 2006; Yin et al., 2009), the lack of a standard procedure and the costs connected to their use still doesn't encourage the systematic digital acquisition of wide collections and heritage.

* Corresponding author.

The purpose of this paper is to show the state of the art of a project whose aim is to provide a methodology and a procedure to create digital reproductions of artefacts for Institutions called to preserve, manage and enhance archaeological finds inside museums or through digital exhibitions.

In particular, our project's aim is to find the most suitable procedure to digitally acquire archaeological artefacts that usually have small dimensions but have very complex and detailed surfaces. In some cases, these artefacts have radiometric and reflectance characteristics that do not facilitate the acquisition through instruments that use light as a mean to collect metric information. Moreover, the possibility to visualize artefacts in digital environments using deep enlargements and explorations from unusual points of view, underlines the importance of metric accuracy and faithful graphic reproduction of radiometric and reflectance characteristics through texture mapping. As far as this latter aspect is concerned, texture mapping procedures still present some weaknesses, especially in case of complex shapes with occlusions (Huang, 2010).

Furthermore, another goal of our project is to explore reality-based models of archaeological finds using widely shared visualization systems and meanwhile enhance the involvement of the user by emphasizing three-dimensional characteristics of artefacts through virtual reality.

In this contribution, a description of the complete process, from acquisition to modelling, texture mapping, visualization and virtual applications is proposed (Figure 1).

2. OUR METHODOLOGY

Within the present contribution, in order to support and instance our methodology, we selected the case study of the bronze *Situla* Arnoaldi. This archaeological item, dated to the full V century B.C., was found in an Etruscan tomb of the Arnoaldi necropolis in Bologna with others funerary goods. Discovered in 1881, this *situla* is now preserved in the Archaeological Museum of Bologna and consists in an embossed and engraved bronze plate, with one handle cast apart. In three superimposed orders, spaced out from bands with lotus-buds chain, are represented, from top to bottom, athletic scenes of boxing and chariot racing, a military parade of hoplites and horsemen and a deer hunting scene.

These engravings are realized with great care in the rendering of details and represent topics of an aristocratic way of life. The vase is a precious example of the so-called “Situla Art”, handicraft and artistic production, spread in Northern-east Italy and Central-East Europe from VII up to IV century B.C. *Situla* Arnoaldi is by an Alpine-Veneto artist, probably commissioned by an Etruscan aristocrat; it is supposed to be a prestigious wedding present to a high-ranking woman (Macellari, 2003).

Besides its historical-cultural evidence and artistic value, the *situla* Arnoaldi is significant for our investigation purposes because of the complex micro-scale details of the low marked engravings on its surface and for the dark and reflecting characteristics of its metal surface.

Within the survey process, different technologies and methodologies have been tested, each one showing different characteristics, advantages and disadvantages.

The acquisition of radiometric characteristics and the following texture mapping process highlighted some difficulties mainly due to the dark and pied colour of bronze that doesn't ease the recognition of its shallow engravings. This aspect has been increased by light reflection of metal during shooting. For this reason, particular attention has been paid to lighting conditions during the acquisition phase and to the preservation of the precise correspondence between the images of small engravings and their 3d shapes during texture mapping.

In addition to these aspects, one of the aims of our investigations was to figure out how to effectively exchange information among museum collections, without the need for physical transfer of findings. For this reason, Adobe PDF3D format was identified as a flexible exchange tool for acquired morphological contents. In fact, findings documentation obtained by laser scanning can be stored, prior a proper preparation, within a common PDF file which specifies cataloguing data in alphanumeric mode, while a browser window shows the model that can be interactively explored within its geometric 3D aspects.

Since the digital model is represented by a vector format that can be displayed using a simple reader which can be freely downloaded from the network, heterogeneous information can be embedded into the nested 3D model, providing final users with an easy interface to explore contents.

Within this process, different decimation algorithms have been tested, in order to store different level of detail and meanwhile improve the efficiency in terms of memory consumption and computation time. Particular attention has been paid to preservation of small surface irregularity, in order not to lose information expressed by the engravings.

Within this project, we adopted the Universal 3D (U3D) file format, core of PDF3D technology, which is a compressed standard for computer graphics contents introduced to ease the exchange of different kinds of data using a widely shared archiving format.

After this phase, the digitized models were displayed in active stereo mode in order to better reproduce the sensory experience with the original finding. In particular, the case study presented in this paper with its geometric bas-relief details and its precise texture maps has been considered particularly evocative if appreciated into an immersive stereoscopic environment.

3. REALITY BASED MODELING

Our methodology aims at rebuilding reality-based multi-scale 3d models of small and complex artefacts in order to use them for different purposes, ranging from simple visualizations for popular aims, to accurate metric and radiometric evaluations led by scholars.

In order to reach this aim, each artefact has been analyzed in its dimensions, matter and small scale characteristics; afterwards, different levels of detail of information have been defined. Each of them corresponds to a different degree of complexity and, as a consequence, to different 3d models. Following this rule, 3d models have been conceived as Master Models aimed at collecting the most accurate information. Simplified models have then been derived from the Master Model, showing different levels of detail, corresponding to different communication aims.

3.1 Range-based survey

The purpose to collect the most accurate and detailed information in a Master Model, required the use of suitable technologies, instruments and procedures. In particular, in the case study of the *situla* Arnoaldi, one of our main goals was to preserve the geometry of engravings, whose width and depth ranges from 0.3 to 0.5 mm (the *situla* measures 25 cm high and has a maximum diameter of 20 cm). As a consequence, a Minolta Vivid 900 and a Perceptron ScanWorks V4i with

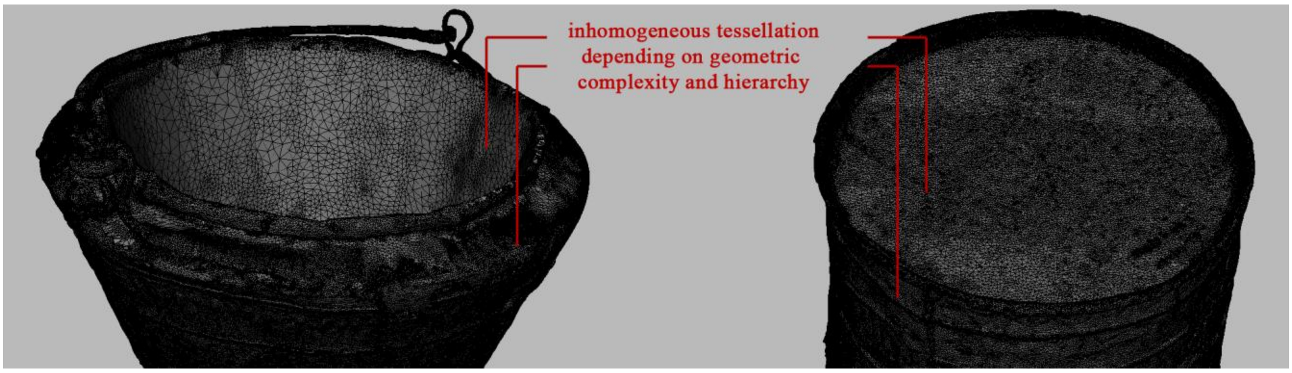

Figure 2. The geometry of the Master Model of the *situla* does not have an homogeneous surface. Smoothed and less detailed areas were acquired using less detailed measurements instruments. In this case, for example, the inner and bottom surface of the *situla* were acquired using Minolta Vivid 900 scanner, in order to ease the management of the derived high polygon mesh.

ROMER Omega bracket laser scanners were used in order to compare precision and accuracy of geometric acquisitions and correlate them with time data processing required by both procedures. Following are the main characteristics of laser scanners:

Minolta Vivid 900 (tele lens - f= 25 mm, fine mode, survey distance 60 mm):
Width of field: 85x114 mm
Accuracy: X ±0.22 mm; Y ±0.16 mm; Z ±0.10 mm
Resolution: XY 0.174 mm; Z 0.052 mm

Perceptron ScanWorks V4i:
Width of field: 34÷73 mm
Depth of field: 109 mm
Accuracy: 0.024 mm (2 sigma corner test)
Feature resolution: 0.0045 mm (2 sigma sphere test)
Mean point to point resolution: 0.057 mm

The Master Model has been conceived to rebuild information with different degrees of detail. As a matter of fact, within the artefact, different resin fillers have been used by restorers in order to hold and connect original pieces, fill the lacks of matter and rebuild the whole shape of the find. For this reason, the geometry of the Master Model does not have a homogeneous tessellation of its surface; these smoothed and less detailed areas were acquired using less dense measurements (Figure 2).
Figure 3 shows an example of the complexity of the acquired mesh. In particular, *a*, *b*, *c*, *d*, *e*, *f* represent a detail of the surface surveyed using the Perceptron ScanWorks V4i scanner Figure 3, *a* and *b* show the density of data of the Master Model (1100000 faces), while *c*, *d*, *e* and *f* represent the derived

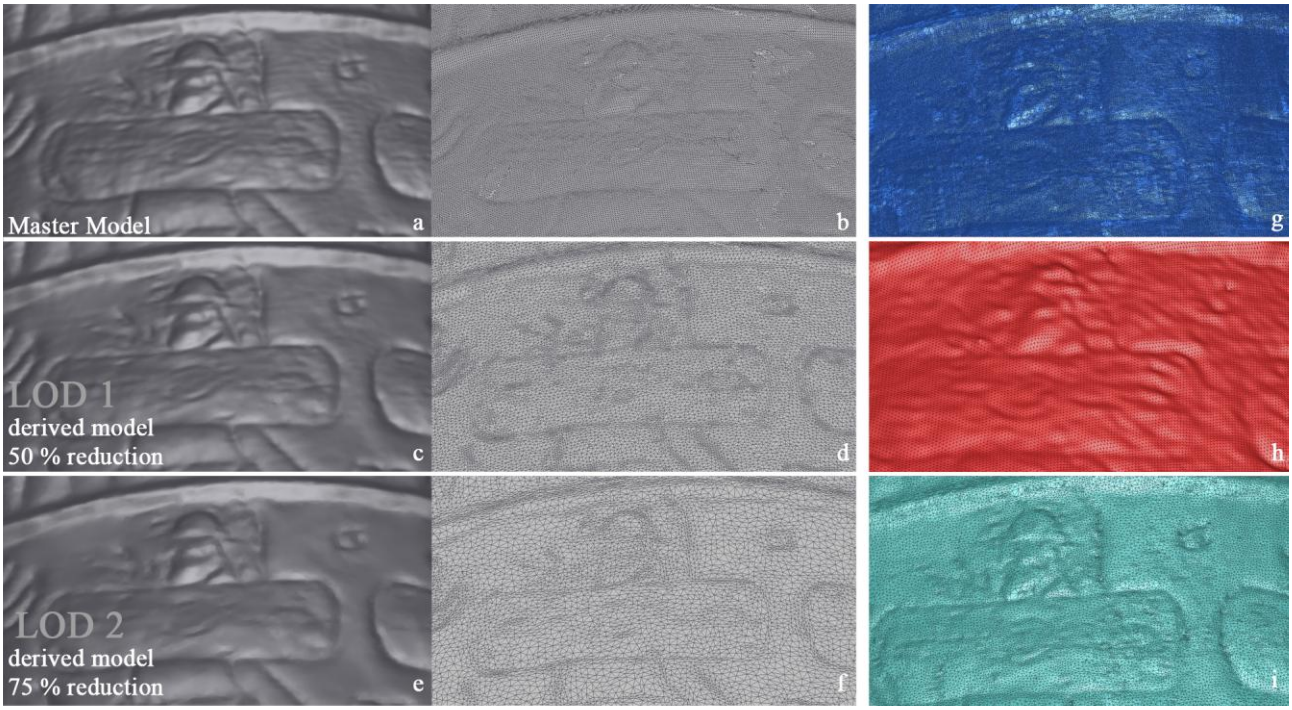

Figure 3. Left, Master Model (*a*, *b*) and simplified models (*c*, *d*, *e*, *f*) derived using the Perceptron ScanWorks V4i scanner. Right, Master Model acquired using the Perceptron Scan Works V4i (*g*, 1100000 faces); (*i*) decimated model derived from *g* – 80% reduction; (*h*) 3d model acquired using a Minolta Vivid 900 scanner, highlighting the noise due to laser power required in order to measure points location on dark and reflecting surface of the find. *h* and *i* have the same number of faces.

Figure 4. Texture mapping of the 3d model of the *situla*, using Adobe® Photoshop® (*a*, *b*, *c*). In *a*, imported 3d model; in *b*, overlapping of 2d image and 3d model. The alignment between 2d images and 3d model requires manual deformation of the image. In *d*, 2d image projection using 3d Reshaper®. The software calculates camera calibration parameters through the recognition of homologues points on 3d surface and 2d image.

models associated to two degrees of complexity: LOD 1 (50% reduction) and LOD 2 (75% reduction). In order to preserve the detailed information of engravings, simplified models have been derived from the Master one using the quadric edge collapse decimation algorithm. Figure 3 also shows the differences between the acquisition through Perceptron ScanWorks V4i laser scanner (*g*) and the Minolta Vivid 900 (*h*) one. The noise on the surface derived from this latter survey (*h*) is mainly due to the high power of laser required by the dark colour of the bronze surface. Figure 3, *i* shows the mesh acquired using the ScanWorks V4i laser scanner that was decimated in order to manage the same density and therefore compare it with the one surveyed using the Minolta scanner.
Thanks to these tests and observations, the main characteristics of the two triangulation laser scanners were considered as resources from which we derived benefits for different uses: ScanWorks V4i scanner was used for the acquisition of the outer engraved surface, while Minolta Vivid 900 was used to acquire areas that do not need to be documented using complex and redundant data that would have overloaded the models.

3.2 Texture mapping

Last generation of laser scanners has recently been improved and equipped with high-definition cameras that allow to acquire good quality colour and radiometric information and directly relate them to 3d geometry. Unfortunately, some of the most sophisticated range-technologies in terms of metric accuracy and definition, still do not offer the opportunity to acquire colour information, so that texture mapping is still an important procedure within surveys aimed at reality-based modelling.
Texture mapping consists in the acquisition of high definition images that need to be post-processed in order to correct geometric and radiometric distortions, establish a connection with 3d geometry and therefore faithfully reproduce the characteristics of the artefacts.
Texture mapping connects 2d images that are defined through (u, v) coordinates with 3d surfaces defined by (x, y, z) coordinates. This process usually consists in a projection that can be performed following different procedures and using widely spread three-dimensional modelling packages.
The unfolding of a 3d mesh, for example, consists of the projection of the faces of a polygonal mesh on a plane whose (u, v) coordinates range from 0 to 1. This procedure requires the following superimposition of 2d images on the unfolded geometry, in order to connect mesh faces to image pixels. This methods is usually very effective if used with models that do not have evident geometric complexities, such as deep convexity or intricate shapes.
Another procedure consists in the orthogonal projection of the image plane on the 3d mesh. This method presents evident lacks if used with models with complex shapes with occlusions. In addition, it usually needs the separation of the mesh of the whole model into portions that correspond to areas covered by each single image, as well as post-processing manual correction of tone differences (i. e. using blending procedures) among adjacent textures.
A more effective method consists in the geo-referencing of 3d models with respect to 2d images. Generally, through the recognition of homologues points on image and model, it is possible to derive the bundle adjustment parameters and therefore align cameras within the 3-dimentional reference system (Abdel-Aziz and Karara, 1971; Huttenlocker and Ullman, 1990; Jacobs, 1997; Remondino et al., 2008). This procedure allows a more precise correspondence between the projected image and the 3d model. As a drawback, many software packages that actually allow to use this methodology, as well as automatic blending between images, are proprietary.
In the case study of the *situla* Arnoaldi, we tested 3DReshaper®, that offered good quality results in terms of precise correspondence between geometry and images, as well as in blending (Figure 4, *d*).
Aiming at testing widely used software and therefore find a solution that could reduce costs connected to software equipment, we also tested Adobe® Photoshop®, whose last releases allow to manage 2d and 3d objects in the same environment.
In our case study, we overlapped each single image on the 3d model by defining a point of view for the model (*a*) that followed camera location and orientation of each image. Afterwards, we superimposed the photographs on the model (*b*) and manually deformed images in order to refine the overlapping. This procedure (*c*) highlighted a good quality results in terms of geometric correspondence between image and model. If compared with the previous methodology, one of the main differences is the time required for the manual alignment in the Adobe® Photoshop® environment. On the other hand, this aspect is balanced by cost containment in case the software is already owned by the Institution in charge of survey. Figures 5 and 6 show the unfolding of the texture of *situla* Arnoaldi that has been performed in order to ease the observation of small details of engravings and therefore read the narration of various life scenes and mores. Some graphic procedures, such as ambient occlusion shading and Canny algorithms, highlighted surface irregularities and therefore eased the recognition of contours of single figures (Figure 6).

Figure 5. Unfold of the texture of the 3d model of *situla* Arnoaldi. Top, detail of the bronze lamina projection on a flat surface. The narration is represented through engravings and figures stacked in three superimposed registers, representing different life scenes and mores. Centre, shallow engravings have been highlighted using graphic procedures that ease to recognition of figures and scenes that are not evident because of the dark and pied colour of bronze.

Figure 6. Graphic effects, such as the use of ambient occlusion shading and Canny algorithms, highlight surface irregularities and ease the recognition of contours of single figures.

4. VISUALIZATION

One of the most important consequences due to the development and improvements of 3d digitizing technologies is the possibility to use computer graphics as a powerful medium for education, communication and knowledge sharing aims.
For this reason, an easy and effective exploration of archaeological finds was one of the main goals of our investigations.
In particular, in order to host and share digital content related to *situla* Arnoaldi, we selected the Universal 3D (U3D) file format, a standard released by ECMA International in 2004, an industry association dedicated to standardization of information and communication aims, together with the 3D Industry Forum (3DIF), because of its multiplatform operational capabilities and its on-line content sharing facility.
Originally aimed at becoming a compressed file format standard for 3D computer graphics data, U3D is supported by PDF Portable Document Format, since it can be inserted into PDF documents and visualized using Adobe® Reader® on several platforms even by different non-proprietary applications and meanwhile provide a high quality viewing experience (Majorov, 2005). Adobe System Incorporated® adopted U3D in 2005, featured it, also including binary encoding, animation support and extensibility to address evolving visualization needs.
For this reason, 3D PDF files guarantee continuous level of detail and good compression ratio; they are fitted for progressive streaming and therefore allow user interaction during downloading.
In addition, Adobe® PDF can be considered as a sort of improvement of PostScript, the page description language developed by Adobe in 1983, aimed to describe graphics and text in a device and resolution independent way. But differently from the PostScript, which is more similar to a programming language, PDF defines a structured binary format which is optimized for high performance in interactive visualizations.
Within PDF files, annotations like hypertext links and comments can be added to 3d views by associating them to geometry in the form of information layers rendered over 3d models.
3D PDF allows tree structures for model's components, so that semantic organization of 3d models is allowed. In addition to this aspect, with version 8 of Adobe® Acrobat® Standard, PDF files are geospatially conceived, so that it is possible to use measure tools that help to get information about the dimensions of 3D models.
Figure 7 shows a cross section of the *situla* through which information about its inner shape is clearly highlighted.

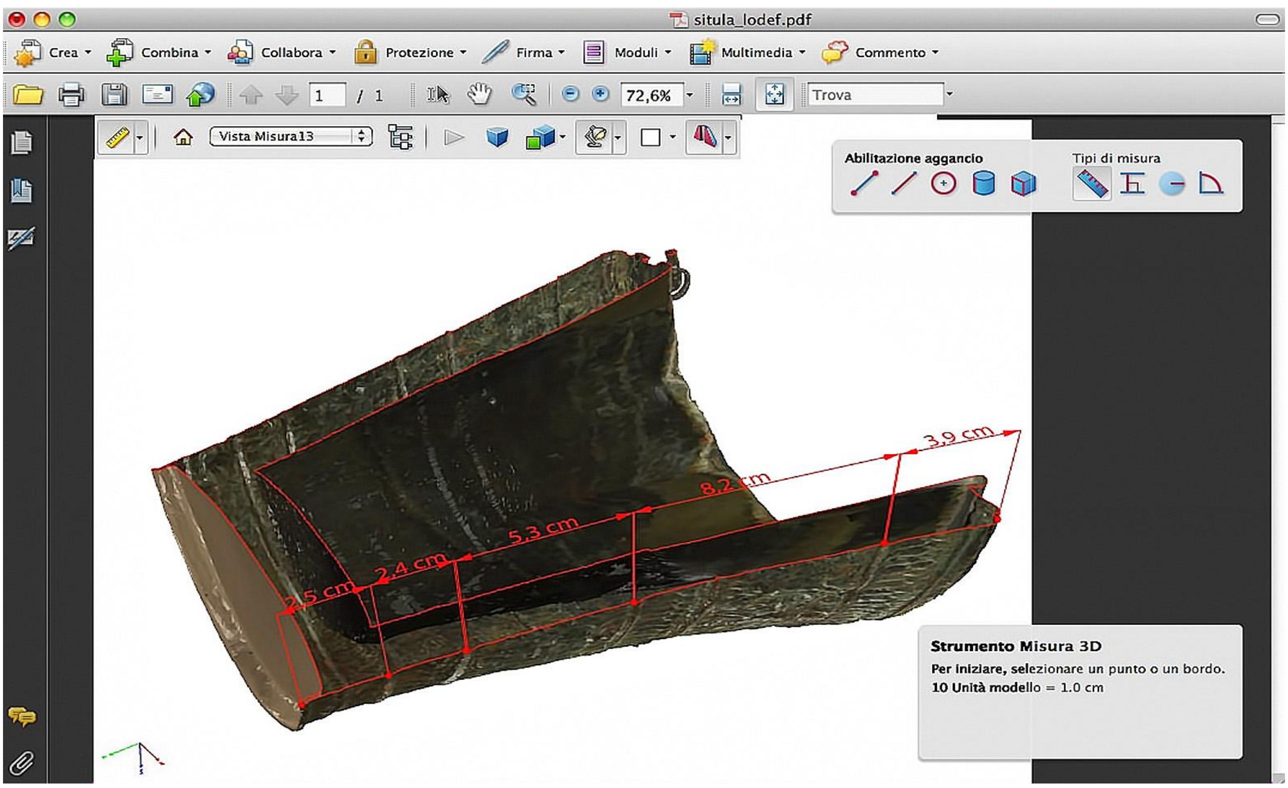

Figure 7. Exploring the *situla* through cross sections: an interactive U3D model embedded in 3D PDF can be easily visualized from different points of view and shaded using different light source in order to optimize contrast and better evaluate geometry.

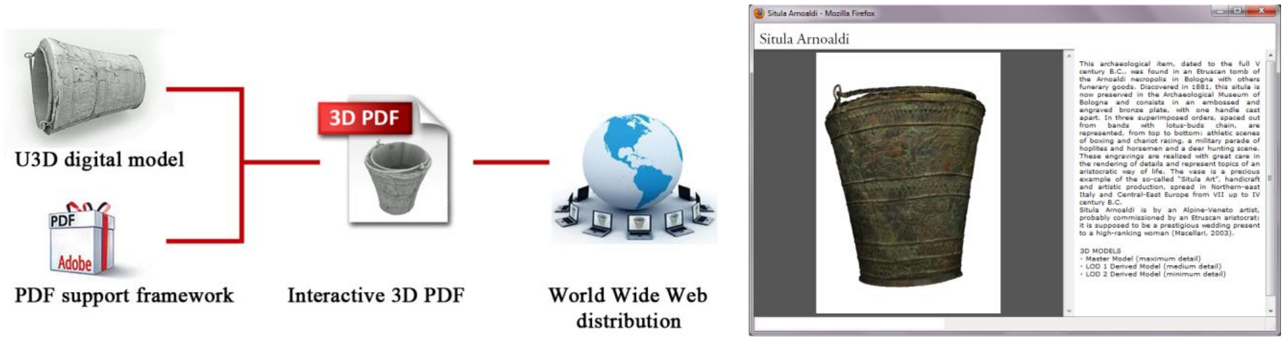

Figure 8. Left, schematic pipeline of 3D PDF document generation and distribution. Right, example of the visualization of the 3D PDF *situla* Arnoaldi model inside a browser window.

Furthermore, PDF files can be inserted as hyperlinks into on-line HTML pages so that connected Internet browsers can automatically show their contents in windows, allowing a fast and well distributed fruition (Figure 8).

As a consequence, the artefact *replica* becomes expression of a personal experience for every single user, who can customize the access to its information independently from its location.

Even if users can appreciate the 3-dimentionality of the *situla* viewing 3D PDF files, the irregularities of the engravings can be perceived in a more efficient way in a stereoscopic environment. Taking advantage of a computer workstation equipped with a suitable card and carrying active glasses which are synchronized with the screen, some *situla's* images were rendered under two different points of view (just like human eyes) and displayed one after the other at 120 Hz frequency (60Hz for each view). Synchronized glasses, which control LCD shutters on lens, make possible for each eye to have its own point of view at a frequency which allows the brain to perceive this spatial phenomenon.

Situla's static stereo images (Figure 9) were obtained using two separate virtual cameras in Autodesk® Maya® 2010: after rendering the first one, the second one was generated by horizontally translating the camera along a plane which is perpendicular to the first view's optical axis. Even if Autodesk® Maya® offered the *StereoCamera* option, which automatically creates a proper rigging, since release 2009, this solution was discarded due to anaglyph passive output. Camera's optical axis for both views were almost parallel since this emulates human retinal images in the best way (Howard and Rogers, 1995). This parallel configuration, considering a 6.5 cm lens offset, avoids depth plane curvature and keystone distortion (Woods et al., 1993) if the whole 3D object is visible by both cameras.

Couples of rendered raster image were stored on hard disk in JPS format (JPEG Stereo) and visualized through a high frequency video projector using Nvidia® software, connected to a workstation equipped with an infrared emitter in order to control glasses sync.

Within our approach, another aspect that still needs further developments is the possibility to give access to 3d models of archaeological finds and their related documentation using mobile devices. In this direction, a further more decimated model (down to 135.000 polygons) of the *situla* has been built in order to visualize it on systems powered by Apple® iOS 4.2.1 through Safari Mobile web browser and McNeel & Associates® iRhino 3D® (Figure 10).

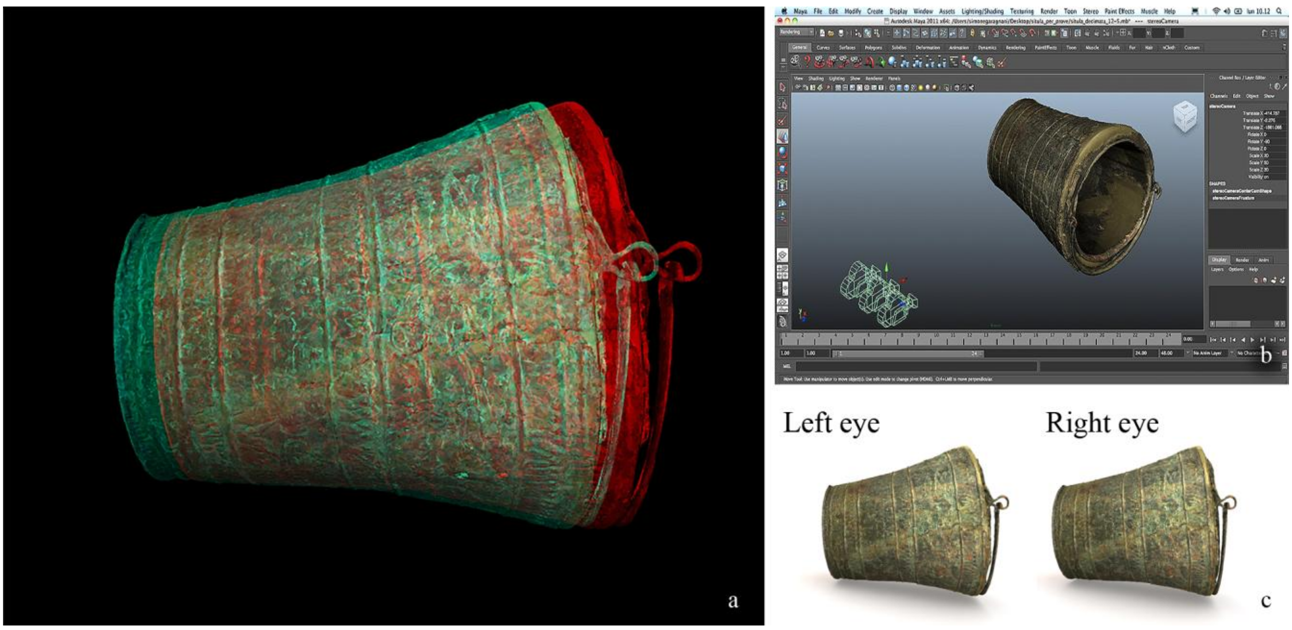

Figure 9. Studies on stereoscopic visualization of *situla* Arnoaldi: red-cyan glasses were experimented to view anaglyph images correctly through passive techniques (a), using the StereoCamera rig option in Autodesk® Maya® (b). Then, taking advantage of Nvidia® 3D Vision® active technology, eye-splitted renders of the textured model were composed as intended in a typical JPS format layout (c) and displayed with synced glasses, with neutral saturation and full spectrum colors.

5. CONSIDERATIONS AND CONCLUSIONS

In this article, we presented a complete pipeline aimed at building reality-based models of archaeological finds to be used for different purposes within digital exhibitions. A brief description of the whole process, from acquisition to modelling, texture mapping, visualization and virtual application has been proposed, in order to highlight peculiar characteristics of different methodologies and procedures and therefore suggest the most suitable ones, depending on artefacts characteristics, costs and communication aims.
Further developments of our methodology could be singled out within the acquisition process, by exploring different procedures which use less expensive technologies and meanwhile guarantee high quality results in terms of metric precision and accuracy.
Collecting data from findings and presenting them in a graphical 3-dimensional environment can significantly improve users experience for museums and institutions, over the Internet or through public podiums equipped with standard web browsing software. For this reason, the application of some well-known stereoscopic techniques to digital models of archaeological artefacts or showing them through a widespread visualization tool such as 3D PDF, leads to simple ways to share knowledge.
Further developments are planned to be carried out with stereoscopic real time rendering in order to add radiometric information to 3d models and improve their immersive fruition.

Figure 10. Stereo visualization of situla Arnoaldi on mobile systems.

5.1 References and/or Selected Bibliography

References from Journals:
Bernardini, F., Rushmeier, H., 2002. The 3D model acquisition pipeline. *Computer Graphics Forum*, 21(2), pp. 149-172.

Blais, F., 2004. A review of 20 years of range sensor development. *Journal of Electronic Imaging*, 13(1), pp. 231-240.

Huang, Y.-H., 2010. The Digital Archive of Sculptures of Tien-Shen Poo in Early Taiwan History, *Lectures Notes in Computer Science*, 6436, pp. 343-355.

Huttenlocher, D., Ullman, S., 1990. Recognizing solid objects by alignment with an image, *International Journal of Computer Vision*, 5(2), pp.195-212.

Jacobs, D. W., 1997. Matching 3d models to 2d images, *International Journal of Computer Vision*, 21(1-2), pp. 123-153.

Remondino, F., El-Hakim, S., 2006. Image-based 3d modelling: a review, *The Photogrammetric Record*, 21(115), pp. 269-291.

Remondino, F., El-Hakim, S., Gruen, A., Zhang, L., 2008. Development and performance analysis of image matching for detailed surface reconstruction of heritage objects, *IEEE Signal Processing Magazine*, 25(4), pp. 55-65.

Yin, X.,Wonka, P., Razdan, A., 2009. Generating 3d building models from architectural drawings: A survey, *IEEE Computer Graphics and Applications*, 29(1), pp. 20-30.

References from Books:
Howard, I.P., Rogers, B.J., 1995. *Binocular vision and stereopsis*, Oxford University Press, pp. 736.

Macellari, R., 2003. *Il sepolcreto etrusco nel terreno Arnoaldi di Bologna (550-350 a.c.).* Marsilio, Bologna, pp. 692.

References from Other Literature:
Abdel-Aziz, Y. I., Karara, H. M., 1971. Direct linear transformation from comparator coordinates into object space coordinates in close-range photogrammetry. In: *Symposium on Close-Range Photogrammetry Proceedings*, Falls Church (VA), American Society of Photogrammetry, pp. 1-18.

Barceló, J. A., 2000. Visualizing what Might Be: an Introduction to Virtual Reality Techniques in Archaeology. In: Barceló, J.A., Forte M., Sanders D.H. (eds): *Virtual Reality in Archaeology*, Oxford, Archaeopress, pp. 9-35.

Majorov, A., 2005. Universal 3D (U3D). In: *International Conference Graphicon 2005*, Novosibirsk Akademgorodok, Russia, Proceedings on CD.

Woods, A.J., Docherty, T.M., Koch, R., 1993. Image distortions in stereoscopic video systems. In: *Stereoscopic Displays and Applications IV*, Proceedings of the SPIE, Vol. 1915, pp. 227-238.

References from websites:
Programme of work in U3D format development:
http://www.ecma-international.org/memento/TC43.htm
(accessed 7th Feb. 2011).

Adobe Systems Incorporated. ISO 32000-1:2008 - Portable document format Part 1: PDF 1.7, 2008:
www.adobe.com/pdf/pdfs/ISO32000-1PublicPatentLicense.pdf
(accessed 7th Feb. 2011).

5.2 Acknowledgements

The research project on the *situla* Arnoaldi has been made possible thanks to the precious collaboration of the Archaeological Museum of Bologna, in the person of its Director Paola Giovetti and archaeologist Federica Guidi.
The authors would like to reserve a special thank to Federico Uccelli of Leica Geosystems and Gabriella Giacomoni who supported this project and whose contribution was indispensable to its success.
The research has been held thanks to the equipment made available by Roberto Mingucci, Scientific Responsible of the Silab Laboratory of the Department of Architecture and Territorial Planning of the University of Bologna. The authors would like to thank Giovanni Bacci of the Silab Laboratory for his precious support during survey operations.