Ancient Vase 3D Reconstruction and 3D Visualization

Sorin Hermon
STARC - The Cyprus Institute, Cyprus. *s.hermon@cyi.ac.cy*

Despina Pilides
Department of Antiquities of Cyprus, Cyprus.

Giancarlo Iannone, Ropertos Georgiou, Nicola Amico, Paola Ronzino
STARC - The Cyprus Institute, Cyprus.

Abstract:
The paper describes the process of 3D virtual reconstruction of an ancient fragmented vessel. The work followed several steps: identification of significant potsherds for the 3D reconstruction, the 3D acquisition of the fragments with laser scanner, the analysis of the 3D model (diameter, vertical projection, orientation and thickness), 3D reconstruction and modelling of the vessel, photographic acquisition and ortho-stereoscopic rendering for 3D visualization.

Key Words: *Archaeology, 3D Modelling, Laser Scanning, Open-Source Software, Ortho-Stereoscopy.*

Introduction

Many archaeological finds uncovered during excavations are pottery fragments. Archaeologists select identifiable ones in order to assign their type, to understand cultural, economic, chronological and social aspects of the site under investigation. The main steps of potsherds study are: orientation of fragments, diameter estimation, profile estimation and drawing (diameter, vertical projection, profile). Our case study concerns the study and 3D reconstruction of a set of fragments belonging to one vessel, (roughly and partially) restored by the conservation laboratory of the Archaeological Museum of Larnaca, Cyprus. Since conservators were unable to fully understand the original shape of the vessel, we tried to virtually reconstruct it. The main difficulties related to this type of work are: a large amount of small fragments, inability to place them properly along the 3D surface and the inaccurate physical restoration that forced us to define a virtual error correction (Goel and Priyank 2005). All potsherds larger than 10cm were digitally acquired with a laser scanner (multi-stripe laser triangulation) and open-source software were used for post-processing (MeshLab, Blender). During the post-processing the correct orientation of fragments was calculated through geometric analysis; the potsherds physically restored were virtually separated and repositioned in the right way. Once the 3D virtual shape was obtained, the vessel was digitally rebuilt and textured using photographs with colour calibration. Blender software was used for modelling and for the stereoscopic virtual set up of the vessel in order to obtain the “ortho-stereoscopic” rendering. The final result is the 3D model of the vessel, which was used for 3D stereoscopic vision simulation. Illusionary depth perception and immersive view experience allows to better understand the shape and the volume of an object which is unreadable in the fragmented conditions or in traditional restoration.

Figure 1. Pottery fragments.

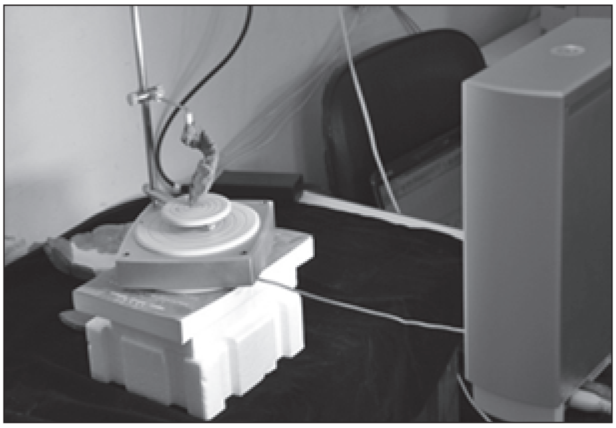

Figure 2. Next Engine laser scanner.

Case Study

The vase was found in 2010 at the 13th – 12th centuries BC site of Pyla - Kokkinokremos, near the south-east coast of Cyprus during the excavation carried out under the direction of Prof. Vassos Karageorghis (Leventis Foundation), Dr. Athanasia Kanta (Ephoros of antiquities, Heraklion, Crete) and Dr. Maria Hadjicosti (Director of the Cyprus Department of Antiquities) (Karageorghis 2011). When discovered, the vessel was extremely fragmented (approximately 60 pieces) (Fig. 1). It had typical handles, of the "elbow reversed handle" type (Sebis 1996). Based on analyses mostly done in Sardinia and adjacent islands (e.g. Lipari), this vessel typology starts from Late Bronze Age (1300-1950 BC) and continues throughout the first Iron Age (900-750 BC) (Campus and Leonelli 2000). After the recovery, all pieces were sent to the Restoration Department of the Larnaca Archaeological Museum, where they reconstructed only three sets of fragments: base, neck and a part of body with the handle. The position of the majority of the pothsherds were uncertain and thus the original shape remained unknown.

Digital Acquisition and Virtual Reconstruction Pipeline

The curator of the Department of Antiquities Dr. D. Pilides decided to involve The Cyprus Institute in the virtual reconstruction process. After a preliminary visual investigation, all sets of restored fragments and some of the bigger potsherds were acquired with a 3D laser scanner. The device used is NextEngine 3D Desktop laser scanner (Abernathy 2007) based on multi-stripe laser triangulation (MLT). It has an internal calibrated camera that allows the acquisition with the RGB colour. Seven pieces were scanned in Macro Mode, low resolution with 127 micron accuracy. The time spent for acquisition was 15min for each piece at 360°, using a rotary servo-positioner. The operating distance was set at 16.5cm (Fig. 2). After the digital acquisition, the obtained range maps have been processed with the open-source software MeshLab, developed by CNR-ISTI of Pisa, Italy, used for the range maps optimization.

Post-processing

Each piece was meshed with Meshlab software, in order to obtain solid 3D models. These meshes were exported in the software JRC 3D Reconstructor (Sgrenzaroli and Vassena 2007) (complete processing software for 3D data), where we were able to virtually cut the 3D models according to horizontal and vertical plans (Fig. 3). The profile thus obtained was exported in .dxf format for AutoCAD, in order to complete the virtual reconstruction process (Andrews and Laidlaw 2002) (Fig. 4).

From each section of each fragment a cutting plane was obtained, which served to draw an arc from which we were able to define the respective diameter and to build a hypothesized circumference of the potsherds. These arcs were aligned on a perpendicular plane to the central axis of the vessel. Subsequently, all circumferences with an equal diameter were overlapped so as to define an alignment and trace the shape of the object (Fig. 5). Finally using the tool bottom loft, the circumferences were merged together using as trajectory the vertical axis generated from the circumferences.

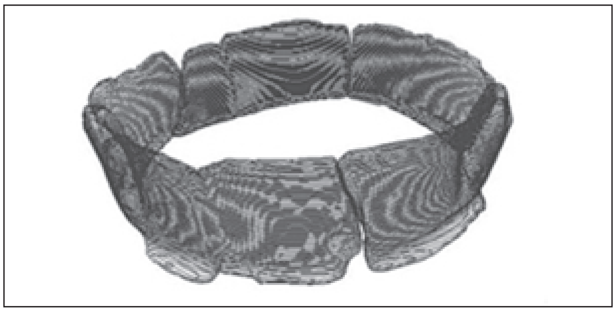

Figure 3. Virtual cut (cross sections).

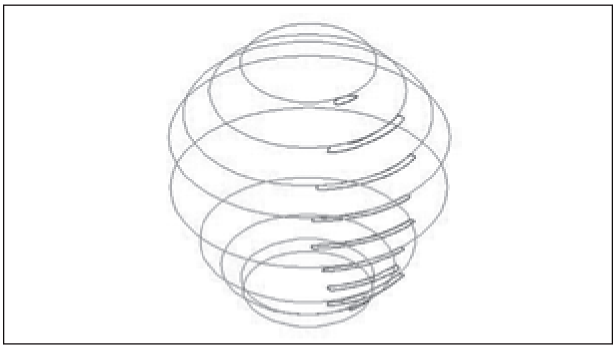

Figure 4. Diameters determined by sections.

Regarding the height of the vessel, it was decided to test four different heights with a range of 5cm. (35-50). The height of 35cm indicates the minimum height obtained by the curvature of the larger fragment. For each possible height, the handles have been re-positioned, in order to find the correct typological position. The final result demonstrated that the vessel had originally an estimated height of approximately 38cm with handles angulations of 92° to 94° to the body.

Reconstruction Process

After the post-processing and the creation of the possible profile (Kampel and Sablatnig 2008) through the CAD system, the profile was exported into the AutoCAD .dxf format, a drawing interchange format for enabling data interoperability between AutoCAD and other modelling applications.

Blender (Blender 2011) is open source software suitable for our needs supporting the necessary formats for the efficient communication between the two modelling applications. It supports Python scripts for the revolution of the profile around its vertical axis and the 3D stereoscopic simulation of the final result.

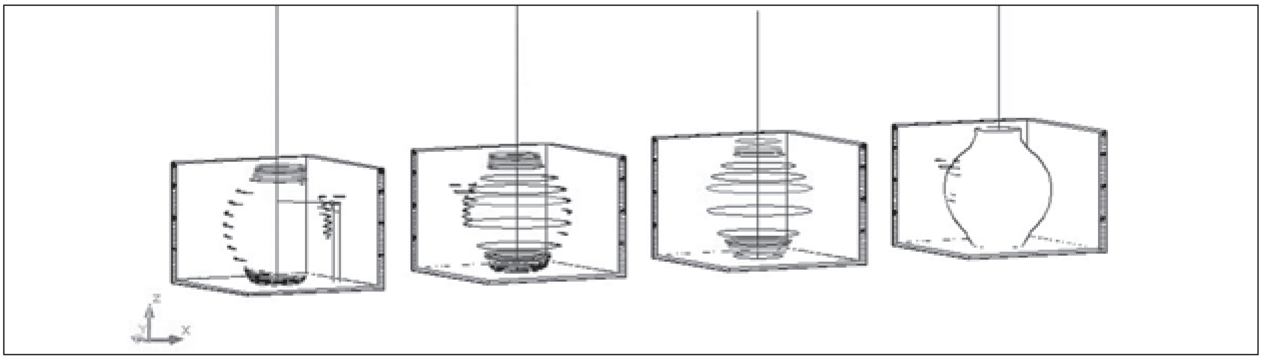

Figure 5. Overlapping sections.

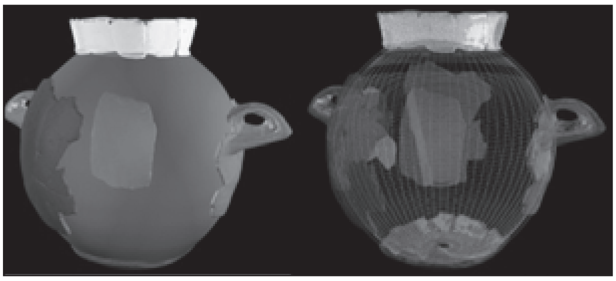

Figure 6. Snapshot showing the final outcome of the revolution of the profile around it vertical axis and the alignment of the sherds on its surface.

Inside the 3D application environment, "spline primitives" are drawn on top of the profile cross-sections by following the path of the line of each digital drawing imported from CAD. This step simulates the half silhouette profile of the vessel represented as NURBS curves. A genetic algorithm "Lathe" was then applied by compiling a Blender experimental Python Script, which creates the vessel's volume, leading to a robust reconstruction of its whole. Each scanned piece was then aligned along the surface of the reconstructed vessel in order to check matching and find its probable original location (Fig. 6).

Texturing Process

A High Resolution camera (Nikon D3x) was used for the photographic acquisition of the fragments using a standard colour reference, determining an optimal exposure index and dynamic range.

The images were used to create the texture map of the model and to create a 'template map' from which the colours were extracted. The template map has been applied to the 3D model using the UVW mapping technique, preventing graphic artefacts which accompany more simplistic texture mappings such as planar projection (Fig. 7).

Visualization

The visualization process follows an "ortho-stereoscopic" (Schneider 2011) approach to the simulation of the vessel by animating the still left/right imagery captured from the Blender (Blender 2011) environment through real environment calculations, such as the horizontal size of the projection screen and the average distance of the viewer to the projection screen (Fig. 8). This is done by running and compiling a Python script for creating two off-axis virtual cameras with the analogous adjustable attributes for the correct visualization of the artefact, without distortion of geometry, having a 1:1 ratio of real and virtual spaces, thus conveying the correct visual perception to the spectator.

Conclusions

In this article we have described a method of virtual reconstruction by the digital acquisition of the fragments using a very cheap laser scanning: NextEngine 3D laser scanner (Guidi et al. 2007). The post-processing work has been done with MeshLab, open-source software with a relatively easy-to-use interface but with a wide community of users and excellent technical support. Once we have obtained the 3D models of each fragment, the virtual restoration and visualization were performed within CAD and

Figure 7. Texture application on the 3D model.

Figure 8. Rendering frame of the animation. Stereoscopic composition of the vessel with sherds aligned on surface; side-by-side output.

Blender systems (for profile extraction of each fragment and its location in the Euclidian space). Future works will consist of creating a methodology that solves the problems related on understanding the correct location of the pottery fragments on the original vessels and on finding a semi-automated way to obtain the original shape of very fragmented vases based on pottery fragments.

The study reconstruction of objects such as ceramic vessels today can make a productive use of 3D technologies and advanced display systems, achieving results that were unthinkable only a few years ago. The study of an object in every detail, seeing colours and shapes in three dimensions, has become an indispensable support for researchers in this field. Thanks to technology, the case study proposed here allows you to open a window to our past and investigate typologically a more or less absolute chronology (in this case involving the elbow reversed handle). In any case, the real goal is that thanks to virtual reconstruction historical and archaeological research can be narrated and represented as never before.

Acknowledgments

The authors want to thank prof. Vassos Karageorgis (director of the excavation), for allowing us the digital acquisition of the potsherds and for his support in the interpretation process. This study is the result of collaboration between: STARC (*Science and Technology in Archaeology Research Center)*, Cyprus Department of Antiquities, The A.G. Leventis Foundation. This research benefited from the support of the EU-funded project 3DCOFORM (www.3d-coform.eu) (FP7/2007-2013) under grant agreement n° 231809.

Bibliography

Abernathy, D. 2007. "Review: The NextEngine Desktop 3D Scanner." *CSA Newsletter* 20:11.

Andrews, S., and Laidlaw, D. H. 2002. "Toward a framework for assembling broken pottery vessels." Paper presented at *the annual meeting of the Association for the Advancement of Artificial Intelligence (AAAI), Edmonton, Alberta, Canada, October 27.*

Blender. 2011. "Blender software." Accessed November 11. http://www.blender.org/

Blender Documentation. 2011. "Online Wikibooks: Blender Documentation." Accessed November 11. http://de.wikibooks.org/wiki/Blender_Dokumentation:_UV-Editor_und_Face_Select_2.37a

Campus, F., and Leonelli, V. 2000. *La tipologia della ceramica nuragica. Il materiale edito*. Viterbo: BetaGamma.

Goel, S., and Priyank, S. 2005. "Computer vision aided pottery classification and reconstruction." Paper presented at *the INDO US Science and Technology Forum on Digital Archaeology, Mussoorie, India, November 11-13.*

Guidi, G., Remondino, F., Morlando, G., Del Mastio, A., Uccheddu, F., and Pelagotti, A. 2007. "Performance evaluation of a low cost active sensor for cultural heritage documentation." Paper presented at *the annual conference on Optical 3D Measurement Techniques, Zurich, Swiss, July 9-12.*

Kampel, M., and Sablatnig, R. 2008. "Profile-based Pottery Reconstruction." Paper presented at *the annual meeting of Computer Vision and Pattern Recognition Workshop (CVPRW) Madison, Wisconsin, USA, June 23-28.*

Karageorghis, V., and Kouka, O. 2011. "On cooking pots, drinking cups, loomweights and ethnicity in Bronze Age Cyprus and neighbouring regions." Paper presented at *the annual International Arhcaeological Symposium, Nicosia, Cyprus, November 6-7.*

Russo, M., Morlando, G., and Guidi, G. 2007. "Low cost characterization of 3D laser scanners." Paper presented at *the annual meeting for the International Society of Optical Engineering, San Jose, California, USA, January 29-30.*

Schneider, S. 2011. "Stereoscopic Rendering in Blender." Accessed November 11. http://www.noeol.de/s3d/

Sebis, S. 1996. "Il Sinis in età nuragica e gli aspetti della produzione ceramica." Paper presented at *the annual conference La ceramica racconta la storia, Oristano-Gabras, Italy, October 25-26.*

Sgrenzaroli, M., and Vassena, G. P. 2007. *Tecniche di rilevamento tridimensionale tramite laser scanner vol. 1.* Brescia: Starrylink Editrice.