3D DATA CAPTURE AND VISUALIZATION OF ARCHAEOLOGICAL POTTERY

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ABSTRACT:

The following article discusses the acquisition and the use of 3D renders for the analysis and study of pottery vessels and shards. This article is based on the work develop at the beginning of the 90's concerning 3D models of shards and vessels, and how these techniques have helped to enhance the quality of archaeological visual analysis (this occupies a large part of the time consumed by archaeological researchers).

This article discusses different methods of acquiring, editing and displaying ceramic 3D models. The pros and cons of different methodologies for 3D rendering and analysis are also debated. The aims and purposes of each 3D model are analyzed. The indicators for evaluating each model are: accessibility, user interaction, information about geometric morphology, and the level of automated analysis provided for the study of pottery vessels.

Finally, the article explains the methodology used in the implementation of three-dimensional models which is being developed within the CATA project (Archaeological Wheel Pottery of Andalusia in its acronyms in Spanish). The main objective of the project is the implementation of a graphically oriented database which is accessible from the Internet. The database contains different type of information about pottery vessels and fragments found in Andalusia during different periods. The objective of the CATA system is to create a generalized tool which can be applied to any kind of ceramic found in any geographical location.

1. INTRODUCTION AND OBJECTIVES

The use of 3D models in archaeological pottery is an important development in the pictorial or graphical representation of pottery vessels. These images permit the classification and analysis of the different ceramic vessels and fragments documented in archaeological excavations. The interpretation of artefacts in 3D models is an essential step for visual Archaeological analysis of different objects. This article analyses some of the methodologies used to obtain 3D models, giving importance to all the different aspects of this process. Moreover, the methodology used by the CATA project (Archaeological Wheel Pottery of Andalusia in its acronyms in Spanish) is also explained.

In the CATA project a useful tool is being developed to answer to some of the daily problems that archaeologists have to face by using new technologies. The main objective of the project is the creation of a database which provides information about complete vessels, found in the region of Andalusia, made by a potters wheel. This database can be queried via the Internet, making it a useful tool in comparative research of diverse artefacts found in archaeological excavations. This system combines diverse data (documents, numerical measures, photographs, 2D drawing, 3D models...) in order to additional tools for the acquisition and retrieval of data.

Since the 90's the development of 3D models has greatly advanced, simplifying the storage of images in digital format. Given the above, 3D scanners along with the visual models should be considered as standard tools in the pottery analysis.

As a complement to image acquisition techniques the storage of pottery images in a database table increases the speed of image retrieval and reduces the time required for the drawing process. It also allows advances into the research done about different forms of producing pottery, and the analysis of uniformity and variability of pottery shapes (Karasik, Smilanski, 2008).

II. METHODOLOGY USED IN THE CONSTRUCTION OF 3D MODELS

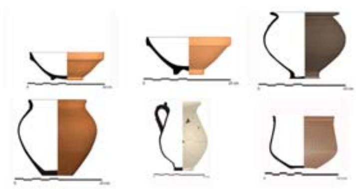
Since the 90's a large quantity of work has focused on dealing with the visualisation of diverse aspect of historical heritage through computer methods. The process used in these new information systems are carried out in three steps (Laudon, K.C.; Laudon, J.P., 1996).

- Data acquisition
- Conversion of the data into models
- User data access: visualization and representation.

2.1. Data acquisition

Data acquisition: the process of digitalization of the data into 3D representations of the pottery vessels. The 3D models can be created from:

- 2D drawings from publications
- Complete vessels



Figures 1 and 2: Drawing and photograph of pottery vessels

The majority of the 3D models are created through the editing of vessel profiles in 3D software (e.g. Autodesk 3ds Max v9). However, descriptions of the vessel's production process, exterior and interior treatments are also taken into account. This information is used to give additional information for a better understanding of the 3D representations. In conclusion, it deals with the capturing of published images of the vessel into a 3D model and the application of additional information to describe this model.

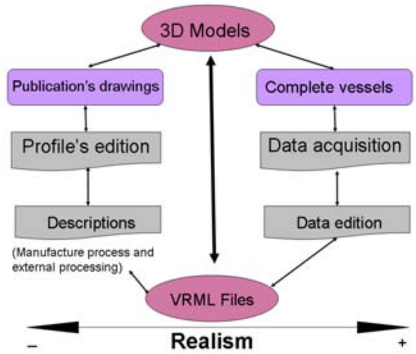


Figure 3: Methodology diagram

When a fairly complete vessel exists a 3D laser scanner can be used (one of the most common technologies used to acquire 3D information).

A common usage of a 3D scanner is the achievement of digital replicas of ancient sculptures. This technology is most adequate to obtain, for example, a 3D model of a statue (Bernardini *et al.* 2002; Fontana *et al.* 2002; Levoy *et al.* 2000; Pollefeys *et al.* 2001; Stumpfel *et al.* 2003). For our purposes we have obtained digital models of pottery vessels. The scanner used was a Konica Minolta VI 900, which produces a triangular mesh of the scanned object. The process phases of the scanner can be summarized as follows:

- Capture alignment. All the captures of the scanned object occupy the same surface, so they are aligned in homogeneous spatial coordinates.

- Fusion of the scanned surfaces assembles a complete model of polygonal mesh.

- Mesh simplification to reduce the complexity of the model, and to produce different levels of detail and representations with different resolutions.

The scanning process is simple and fast, and produces an accurate 3D model of the object with different captures. In some cases two different scanner models have been used, depending on the size of the object (Razdan et alii 2001). In this case only one scanner has been used, since it is possible to modify the distance of the scanner from the object, and it is also possible to change the target of the scanner depending on the object's size. The software used for the first data capture has been the Polygon Editing Tool (PET).

Figures 4 and 5: Acquisition system with the Konica Minolta scanner VI-900

2.2. Conversion of the data into models

The polygonal mesh obtained can be exported in different formats for its later treatment (Wavefront OBJ, VRML, STL, IGES ASCII, DXF, and Maya ASCII). For our purposes the polygonal mesh has been exported in VRML or DXF, formats compatible with the software Autodesk 3ds Max v9. Once the model has been imported in this software, different views of the objects can be attained (top view, front view, perspective view…) and different types of visualization (wire frame, with texture…).

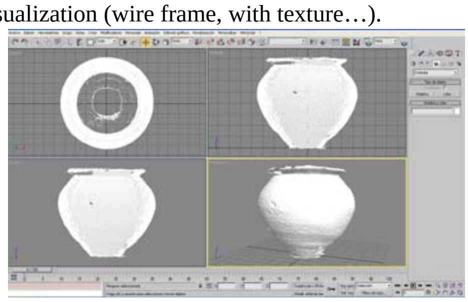


Figure 6: Import of the 3D models into Autodesk 3ds Max v9 software

Once the profile is edited, it is possible to determine the capacity of the complete vessel, a measurement that corresponds geometrically to the internal volume of the vessel's form. One of the methods used to find the capacity is through the revolution of the internal profile (Louise and Dumbar 1995). In this case it has been applied to the drawing of the sections with the program 3D Studio Max, which incorporates the measurement of the volume as a utility.

The capacity of a vessel must be estimated taking into account the morphology, and bearing in mind that it must not be full to the rim. Therefore, a maximum capacity of the vessel must be calculated, which in reality was not always used.

With some forms it is possible to calculate the capacity of the vessel and find the external volume (useful in estimating the number of vessels that can fit in storage area or recipient). The volume of the material which is used to construct the vessel can be obtained by subtracting the internal volume from the external volume. This gives the relation between the volume and the estimated weight of the vessel (the density). The density can be used for the study of technological aspects of the ceramic materials. (Karasik and Smilanski, 2006).

The calculation of the volume can be inexact principally due to the inaccuracy of the drawing of the profile, especially when it is drawn by hand. In this case the problem is solved with the use of the three-dimensional scanner to draw the complete vessels (Sablatnig and Menard 1996; Leymarie et al. 2001; Razdan et to. 2001). There also exist problems with original deformations of the vessels, in which case there should be more than one estimation of profile of the vessel to try to find the volume. These distortions usually appear in non-rotary produced vessels. In rotary manufactured vessels the materials usually do not present the above mentioned deformations. When vessels are made by wheel or mould there exists a greater uniformity in the manufacturing process.

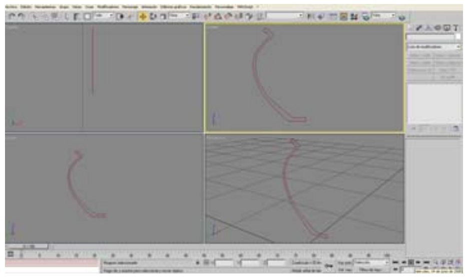


Figure 7: Profile of the vessel

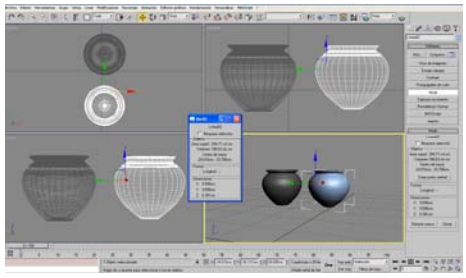


Figure 8: Calculation of the capacity and the volume of the vessel

Although image acquisition software fuses the different views extracted by the scanner, it is necessary to review the polygonal mesh, in case of imperfections in the surface of the mesh that are necessary to correct.

These imperfections may be reduced by automated error correction software of the modeller which generated the mesh. But, there exists no homogeneous format or format converter which can translate the image file format for use in diverse programs. Thus, the polygonal meshes must be converted to other file formats by auxiliary applications different from the one that generated the original file format. This type of conversion process is slightly inefficient, and in extreme cases it must be carried out “point to point " which result in slightly distorted file data.

2.3 Information transfer

The visualization of these 3D models will be carried out using standard formats, which allow their visualization by any user in the Internet. Some standard formats are being investigated to test which of them are more appropriate for the visualization of 3D models.

In this sense, the formats that are the most developed are related to Virtual Reality. These systems develop 3D scenarios of entire or partial immersion of the spectator with the shaped objects. The computer, according to the position and control of the user, uses a database of the virtual environment, and calculates the appropriate visual presentation to present to the user.

The system must be capable of supervising all the actions undertaken by the user; for example, the change of perspective when the user requests such changes. Therefore, the user could receive a feedback that imitates the average responses before the actions are carried out.

The VRML (Virtual Reality Modeling Language) programming language which recreates virtual environments was developed with the purpose of allowing three dimensions image navigation over the web and has become an official standard of these types of applications.

III. IMPLEMENT OF BOTH METHODOLOGIES

The starting point determines the methodology used for the achievement of 3D models. At this point it is necessary to specify that both methodologies have advantages and disadvantages that can be specified in the following points:
1- 3D acquisition methodology. The use of 3D scanner enormously improves the capture of the vessel's morphology, since it is a system that captures the information without need of surface contact. This system allows capturing of an object's morphology and colour, the resulting image is quite accurate when compare to the original object. In the case of incomplete vessels it is possible to obtain the entire image from a given section.

Nevertheless it is necessary to clarify that the obtained mesh has a high resolution making the digital model difficult to manipulate. In this sense it is necessary to mention the existence of works aimed at the treatment of polygonal meshes of high resolution (Callieri *et alii.* 2008; Borgo, Cignoni, Scopigno, 2001).

Another disadvantage of this system is that the obtained image and texture depend on the light with which the information is acquired. Also it is necessary to point out there are no standards as of yet in these type of acquisition system. Thus, there is no regularization of the 3D acquisition methodology.

2. Creation of 3D models from drawings of complete vessels. The obtaining of 3D models through the edition of the profile in Autodesk 3ds Max v9 is a quick and effective way to obtain 3D models of pottery vessels, allowing volumetric and capacity calculations. These 3D models contribute to a new way of visualization that allows the user to interact with the model choosing several views and parts of the object. This constitutes a more precise and interactive form of visual knowledge of the vessel.

The development of 3D models in three-dimensional edition softwares has been used by several researches (Prieto, Irujo 2005; Moitinho, 2007), obtaining quite real 3D models.

Nevertheless, the 3D models produced are not completely realistic, different levels of realism can be obtained using descriptions of the piece and applying textures to the polygonal mesh with an appropriate library of materials.

Figure 9: Ideal and realistic 3D representations

IV. CONCLUSIONS AND FUTURES WORKS

This article has described the methodology used for the achievement of the 3D models that integrate the reference collection of the CATA project. This collection can be consulted by professional archaeologist and by everybody interested in archaeological pottery.

Basically, it is necessary to emphasize two principal data sources will be incorporated into the CATA database: two-dimensional drawings of pottery vessels or complete vessels. As expounded, both methodologies have advantages and disadvantages that facilitate or add difficulties to the process of development of 3D models.

It is also necessary to consider some factors in the development of the 3D models of archaeological pottery:

- Acquisition data system
- 3D mesh edition
- Acquisition and exportation of textures
- Export to VRML format without quality loss
- Purpose for which the models are elaborated

The 3D models allow not only a new form of visualization, but also an exhaustive analysis about manufacturing processes.

The 3D models are going to be integrated into an accessible database in the Internet. The above mentioned models not only allow a virtual manipulation of the vessels, but can be analyzed manufacture process.

V. REFERENCES

Bernardini, F.; Rushmeier, H.E.; Martin, I.; Mittleman, J.; Taubin, G., 2002. Building a digital model of Michelangelo's Florentine Pieta , *IEEE Comp. Graphics & Aplications* 22, 1, pp. 59-67, Jan/Feb, 2002.

Borgo, R., Cignoni, P., Scopigno, R., 2001. An Easy to Use Visualization System for Huge Cultural Heritage Meshes, *Proc. Virtual Reality, Archeology, and Cultural Heritage (VAST) 2001*, D. Arnold, A. Chalmers, and D. Fellner, eds., ACM Press, 2001, pp. 121–130.

Callieri, M., Ponchio, F., Cignoni, P., Scopigno, R., 2008. Virtual Inspector: A Flexible Visualizer for Dense 3D Scanned Models, *IEEE Computer Graphics and Applications*, vol. 28, no. 1, pp. 44-54, Jan/Feb, 2008.

Fontana, R.; Greco, M.; Materazzi, M.; Pampaloni, E.; Pezzati, L.; Rocchini, C.; Scopigno, R., 2002. Three-dimensional modelling of statues: The Minerva of Arezzo, *Journal of Cultural Heritage* 3, 4, pp. 325-331.

Karasik, A.; Smilanski, U., 2006. Computation of the Capacity of Pottery Vessels Based on Drawn Profiles, *Excavations at Tel Beth Shean 1989-1996*, vol. I, Mazar A. (ed.), Jerusalem (Israel).

Karasik, A., Smilanski, U., 2008. 3D scanning technology as a Standard archaeological tool for pottery analysis: practice and theory. *Journal of Archaeological Science 35 (2008)* pp. 1148-1168.

Laudon, K.C.; Laudon, J.P., 1996. *Management Information Systems, Organization and Technology* (B.4) Prentice-Hall, Inc., New Jersey (United States).

Levoy, M.; Pulli, K.; Curless, B.; Rusinkiewicz, S.; Koller, D. Pereira, L.; Ginzton, M.; Anderson, S.; Davis, J.; Ginsberg, J.; Shade, J.; Fulk, D., 2000. The digital Michelangelo Proyect: 3D scanning of large statues, *SIGGRAQH 2000, Computer Gaphics Poceeding*, Annual Conference Series, Addison Wesley, pp. 131-144 .

Leymarie, F.F.; Cooper, D.B.; Sharp Joukowsky, M.; Kimia, B.B.; Laidlaw, D.H.; Mumford, D.; Vote, E.L., 2000. The SHAPE Lab.- New Technology and Software for Archaeologist, *Computing Archaeology for Understanding the Past CAA2000. Computer Aplications and Quantitative Methods in Archaeology (BAR Int. Ser. 931)*, pp. 79-89. Stancic, Z. y Veljanovski, T. (eds.), Oxford.

Louise, M.S. ; Dunbar, P.B., 1995. Accurately Estimation Vessel Volume from Profile Illustrations, *American Atiquity* 60/2, pp. 319-334.

Mitinho, V., 2007. The Roman Villa in Rabaçal Virtual Museum, *Proc. The 8th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST) 2007*. D. Arnold, F. Niccolucci, A. Chalmers, eds., pp. 74-78.

Pollefeys, M.; Gool, L.J.V.; Vergauwen, M.; Verbiest, F.; Tops, J., 2001. Image-based 3D acquisition of archeological heritage and applications, *VAST 2001 Conference Proc*. Arnold, D.; Chalmers, A. y Fellner, D. (eds.), ACM Siggraph, pp. 255-261.

Prieto, M.P.; Irujo, D.J., 2005. Aplicaciones del 3D en cerámica prehistórica de contextos arqueológicos gallegos: Un estudio sobre percepción visual. *Arqueoweb: Revista sobre Arqueología en Internet.* 1139-9201, Vol. 7, Nº. 2.

Razdan, A.; Liu, D.; Bae, M.; Zhu, M.; Farin, G.; Simon, A.; Henderson. M., 2001. Using geometric modeling for archiving and searching 3D archaeological vessels, *Proc. Conf. on Imaging Science, Systems and Technology*. Las Vegas (United States).

Sablatnig, R.; Menard, C., 1996: Computer-based Acquisition of Archaeological Finds: the First Step towards Automatic Classification, *3rd International Symposium on Computing and Archaeology*.

Stumpfel, J.; Tchou, C.; Hawkins, T.; Debevec, P.; Cohen, J.; Jones, A.; Emerson, B., 2003. Assembling the sculptures of the Parthenon, *VAST 2003* D. Arnold; A.C. Niccolucci F. (eds.), Eurographics, pp. 41-50.