New Achievements on Pottery Reconstruction[1]

Martin Kampel and Robert Sablatnig

Pattern Recognition and Image Processing Group

Institute for Automation, Vienna University of Technology,

Favoritenstr. 9/183/2, A-1040 Vienna, Austria

Fax: +43 (1) 58801 183 92; email: {kampel,sab}@prip.tuwien.ac.at

We are developing a documentation system for archaeological fragments based on their profile, which is the cross-section of the fragment in the direction of the rotational axis of symmetry. Hence the position of a fragment (orientation) on a vessel is important. To achieve the profile, a 3D representation of the object is necessary. The main technical goal of our project is to perform an automated classification and reconstruction of archaeological fragments by using the profile section of the oriented object and additional attributes (type of clay, dimensions, type of vessel and the site) associated with the fragment. The final aim is to provide a tool that helps archaeologists in their formation of their archive of records. This paper gives an overview about new achievements on our potter reconstruction system.

Introduction

Archaeology is at a point where it can benefit greatly from the application of computer vision methods, and in turn provides a large number of new, challenging and interesting conceptual problems and data for computer vision [P01]. In particular, a major obstacle to the wider use of 3D object reconstruction and modeling is the extent of manual intervention needed. Such interventions are currently extensive and exist throughout every phase of a 3D reconstruction project: collection of images, image management, establishment of sensor position and image orientation, extracting the geometric detail describing an object, and merging geometric, texture and semantic data. Improvements in rangefinder technology, together with algorithms for combining and processing 3D data allow us to accurately digitize the shape and surface characteristics of physical objects.

The range- and pictorial information of a pottery fragment recorded by the acquisition system serves as the basis for the further classification and reconstruction process. The profile of a sherd has to be determined by orientation. The term orientation describes the exact positioning of the fragment on the original vessel with the help of the axis of rotation. To automate this process, the profile has to be determined in the same way as in the manual documentation. The generated profile is used to perform the reconstruction and retrieval of fragments of the same type. The reconstruction procedure works if the size of the fragment covers a large part of the original vessel in the vertical direction. The profile is rotated by the original axis of rotation, thus measurements like volume can be estimated. Figure 1 shows the automated archivation process schematically, giving an overview of the intermediate steps.

[1] This work was partly supported by the Austrian Science Foundation (FWF) under grant P13385-INF, the European Union under grant IST-1999-20273, the Austrian Federal Ministry of Education, Science and Culture and by the innovative project ‘3D technology’ of the Vienna University of Technology.

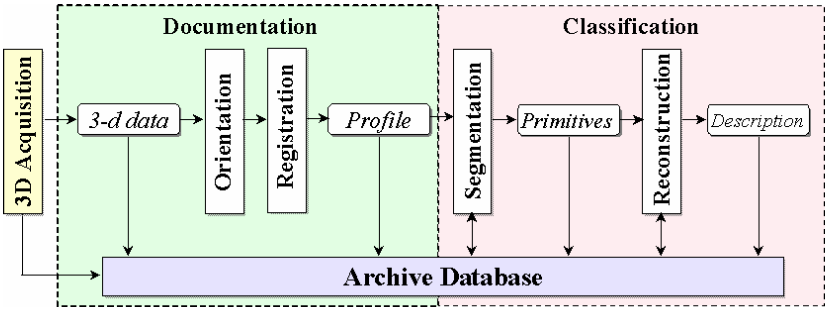


Figure 1: Automated Archivation Process

Furthermore, the process of documenting a fragment is improved, by the automation of the procedures of measuring, drawing, and description. With the help of 3D data, the profile (a cross section in the three dimensional model) of the fragment is constructed. The frontal view is represented with the help of the pictorial information of the surface of the fragment and the surface model. This representation can be used for publication or for retrieval from the database, put on the Internet by other users. This will enable the publication of both the profile of the sherd and a virtual reconstruction of the whole vessel.

Data Acquisition

The *ShapeCam Technology* developed by Eyetronics[2] consists of a Sony TVR-900E digital camera and a Leica slide projector. Figure 2 illustrates the ShapeCam: a digital camera and a specially designed flash device are mounted on a lightweight frame. The flash device projects a predefined grid or pattern onto an object or a scene, which is viewed by a camera from a (slightly) different point of view. The camera also grabs the texture information, which can be mapped on the resulting 3D geometry of the object.


Figure 2: Eyetronic's ShapeCam

The ShapeCam technology is a commercially available technique, which is a based on the structured light approach [KKS96]. It allows the generation of 3D models based on the use of a single image taken by an ordinary camera. As this system is a handheld device, the shapes can be recorded in situ. Within the 3D MURALE [Cos01] project we carried out on site tests to capture 3D potsherds and other finds from the excavation site in Sagalassos [Cos01]. The ShapeCam hardware has been adapted to facilitate such work.

---

[2] Eyetronics HQ, Kapeldreef 60, 3001 Heverlee, Belgium, www.eytronics.com.

Data processing

Archaeological pottery is assumed to be rotationally symmetric since it was made on a rotation plate. With respect to this property the axis of rotation is calculated using a Hough inspired method [SK02]. To perform the registration of the two surfaces of one fragment, we use a-priori information about fragments belonging to a complete vessel: both surfaces have the same axis of rotation since they belong to the same object. Consequently we register the two views by calculating the axis of rotation and by bringing the resulting axes into alignment. A detailed description of the registration algorithm can be found in [SK02]. The registration of front- and back-view together with the axis of rotation provide the profile used to reconstruct the vessel.

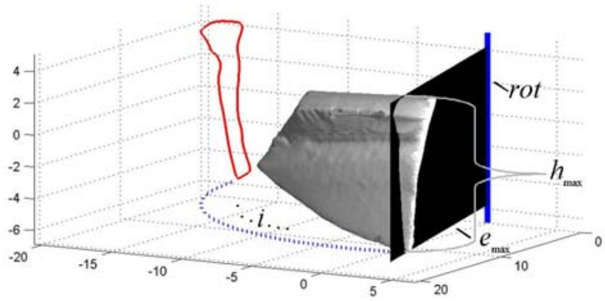


Figure 3: Orientated sherd, rotational axis, intersecting

Figure 3 shows the 3D-model of a sherd and its rotational axis *rot* as a vertical line along the z-axis. The black plane represents the intersecting plane e_{max} at the maximum height h_{max} of the sherd. The longest profile line is the longest line along the surface of the sherd parallel to the rotational axis *rot*. The radius *r* is the estimated mean radius of the profile line. The extracted profile line is shown in the xz-plane. Our algorithm for the estimation of the longest profile line is fully described in [KS03].

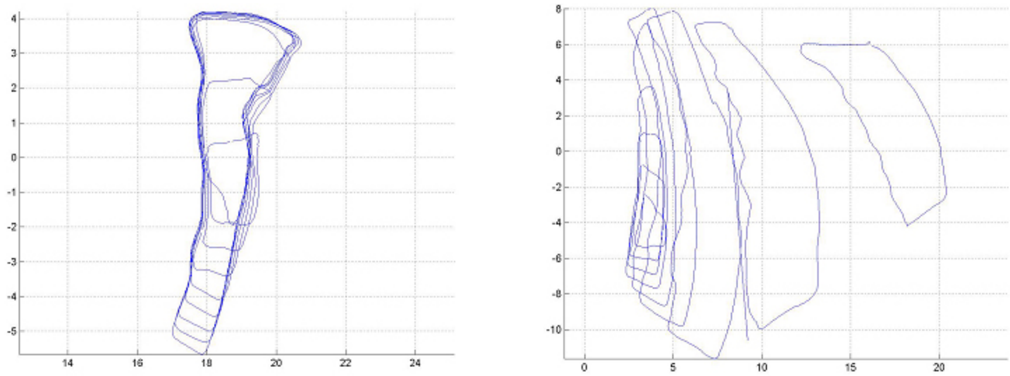
Results

The resulting 3D reconstruction of fragments depends on the correct orientation of the profile section. The evaluation of the 3D representation is rather complicated since verifaction is not available due to the fact that there is no 3rd dimension in archaeological archive drawings and the object is no longer complete. The description of shape is subjective and is not standardized, by archaeologists.

Experiments were done on all fragments of our pottery database. The success rate for correct extraction of the profile line and consequently the percentage of sherds used for further reconstruction is around 50% of the data selected at the excavation site. This should be compared to manual archivation done by archaeologists [OTV93]: for coarse ware around 35% [Deg00] and for fine ware around 50% [Pob99] of the findings are used for further classification. It heavily depends on the shape of the fragment (e.g. handle, flat fragments like bottom pieces, small size, etc.). 18 fragments have been excluded from reconstruction due to incorrect estimation of the axis of rotation.

Experiments with synthetic data have shown that the correctness of the reconstruction depends on the correct estimation of the axis of rotation and on the resolution of the 3D scanner used. The number of vertices in the data used ranges between 4000 and 15000, leading to a profile line with 200 to 300 points. The execution time using a prototype written in MATLAB running on a Pentium III, 1 GHz is less than a minute per sherd. It depends heavily on the computation of the axis of rotation (70% to 80% of the execution time).

In order to demonstrate the correctness of the computed profile lines, Figure 5 shows a recorded sherd (dark object) and its computed profile section (vertical line). The computation of the virtual fragment (grey object) is based on the profile section. One can see that the recorded fragment fits into the virtual fragment, which indicates that the computation is correct. Following multiple cross-sections along the perimeter of the virtual fragment - Figure 4a - one can see hardly any deviation from the original fragment. Some deviations are caused by the bumpiness of the surface, as the surface is not exactly rotationally symmetric since it is hand-made pottery. If the fragment was orientated incorrectly, the recorded fragment does not fit into the virtual object and multiple cross-sections along the perimeter of the virtual fragment show large deviations from the original object (see Figure 4b).



(a) (b)

Figure 4: Multiple profile lines: (a) using a correct estimated rotational axis (b) using a incorrect rotational axis

Figure 6 displays a reconstructed pot (grey object) out of a rim- fragment (dark object) based on the profile line (light line) and its axis of rotation (dashed line).

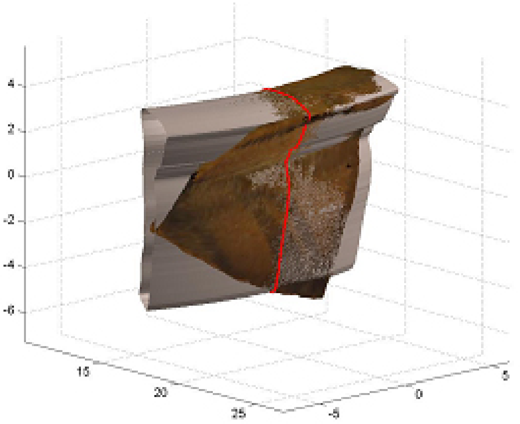


Figure 5: Reconstructed fragment, profile section and recorded fragment

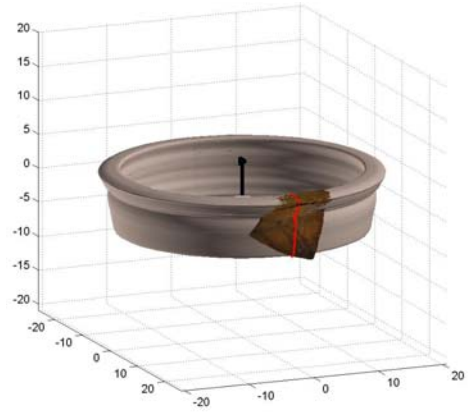


Figure 6: Reconstructed pot

Conclusion and Outlook

We have proposed a reconstruction-method for pottery based on its profile section. The profile, which is the cross-section of the fragment in the direction of the rotational axis of symmetry, represented by a closed curve in 2D, is computed by finding the correct orientation of the fragment.

Comparing the performance of our automated technique to the manual, archaeological approach, the archival process of pottery is accelerated and the quality is improved.

The ceramic documentation and reconstruction system described is currently under further development to be integrated into the virtual excavation reconstruction project 3D MURALE. Future work will be directed towards setting up a pottery database with more then 1000 fragments. Currently we are working on the classification system based on the profile in order to classify all profiles and to find matching fragments from similar vessels and eventually from singular vessels.

Acknowledgments

The authors would like to thank Prof. Marc Waelkens and Roland Degeest from the Katholieke Universiteit Leuven, Eastern Mediterranean Archaeology, and Kristina Adler and Martin Penz from Vienna University, Institute of Classical Archaeology for their archaeological support and contributions in evaluating the profile representation approach and for helpful and inspiring discussions.

References

[Cos01] J. Cosmas and et al. 3d Murale: A multimedia system for archaeology. In *Proc. of Intl. EuroConference on Virtual Reality,* Archaeology *and Cultural Heritage*, Athens, Greece, 2001.

[Deg00] R. Degeest. The Common Wares of Sagalassos. In M. Walkens, editor, *Studies in Eastern Mediterranean Archaeology*, III, 2000.

[KKS96] R. Klette, A. Koschan, K. Schlüns. Computer Vision. Räumliche Information aus digitalen Bildern. Vieweg Verlag, Braunschweig/Wiesbaden 1996.

[KM03] Kampel M., Sablatnig R., "Profile based Pottery Reconstruction", in: "Proc. of IEEE/CVPR Workshop on Applications of Computer Vision in Archaeology", Madison, Wisconsin, USA, June 17, 2003.

[OTV93] C. Orton, P. Tyers, A. Vince. Pottery in Archaeology, 1993.

[P01] P. Martinez, Digital Realities and Archaeology: A difficult relationship or a fruitful marriage, Proceedings *of the International Symposium on Virtual Reality*, In D. Arnold, Archaeology and Cultural Heritage, Athens, 9-15, 2001.

[Pob99] J. Poblome. Sagalassos Red Slip Ware. In M. Walkens, editor, *Studies in Eastern Mediterranean Archaeology*, II. Brepols, 1999.

[SK02] R. Sablatnig and M. Kampel. Model-based registration of front- and backviews. Computer Vision and Image Understanding, 87(1):90–103, 2002.