Automated Documentation System for Pottery [1)]

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Abstract:
Motivated by the requirements of the present archaeology, we are developing an automated documentation system for archaeological classification and reconstruction of ceramics. Our system works with the profile of an archaeological fragment, which is the cross-section of the fragment in the direction of the rotational axis of symmetry. Ceramic fragments are recorded automatically by a 3D-measurement system based on structured (coded) light. The input data for the estimation of the profile is a set of points produced by the acquisition system. Classification is based on the segmentation of the estimated profile line. We demonstrate the method and give results on synthetic and real data.

1 Introduction

New technologies are introduced to old research areas and provide new insights for both the researchers and people interested in this field. This statement can be proved especially in the field of archaeology, since there are many researchers in that area who already use new technologies and there are many people interested in the field of archaeology since so-called archaeo parks have an increasing number of visitors [2, 13].

Motivated by the requirements of the present archaeology, we are developing an automated system for archaeological classification of ceramics. Ceramics are among of the most widespread archaeological finds, having a short-period of use. A large number of ceramic fragments are found at nearly every excavation (Figure 1) and have to be photographed, measured, drawn and classified.

Because the conventional methods for documentation and classification are often unsatisfactory [9], we are developing an automated archivation system [11, 5] that tries to combine traditional classification methods with new techniques in order to get an objective classification scheme.

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Figure 1: boxes filled with ceramics stored in archives

Late-roman burnished ware, which was found during the excavations from 1968 to 1977 in the legionary fortress of Carnuntum [7, 8], was chosen as the basis for our research [3, 4]. In addition to these sherds we enlarged our material basis with published pieces from other pannonian sites.

In the next section we give an overview about the archivation system and explain each intermediate step. In Section 3 results are presented and in Section 4 we conclude with an outlook for future research.

2 Automated archivation process

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 [6]. The profile of a sherd has to be determined in the so-called orientation step. The term orientation describes the exact positioning of the fragment on the original vessel with the help of the axis of rotation. The main objective is to perform an automated classification and reconstruction of archaeological fragments by using the profile section of the oriented object and additional attributes (fabric, dimensions, type of vessel and the site) belonging to the fragment. 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. However, if only small fragments (with respect to the vertical size) are available, a reconstruction based on the fragment is not possible. In this case, the fragments have to be classified correctly in order to determine matching fragments. Figure 2 shows the automated archivation process schematically, giving an overview of the intermediate steps.

Furthermore, the process of documenting a fragment is improved since the important steps measuring, drawing, and describing are automated. With the help of 3-D data, the profile (a cross section

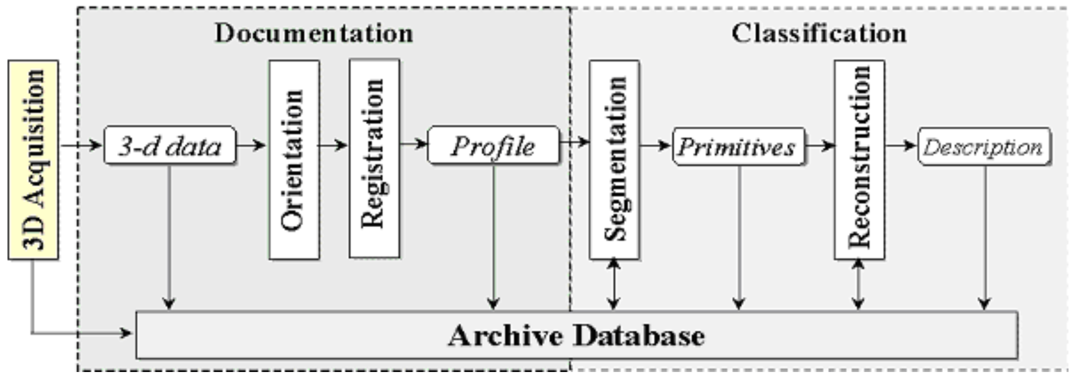


Figure 2: automated archive process

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 it possible to publish both the profile of the sherd and a virtual reconstruction of the whole vessel. Another major advantage will be to publish by means of virtual images the assemblages characteristic for each specific archaeological layer. This will be of tremendous help to other excavators or museums for dating their (imported) sherds. To sum up, following sub-goals can be identified for the automated archivation of pottery:

1. Automatic orientation
   - Determination of the axis of rotation
   - Registration
   - Profile generation
2. Automatic profile-segmentation
   - Determination of shape characteristics
   - Determination of description
   - Curvature-based segmentation
   - Generation of primitives
   - Generation of a description (archive database)
3. Automatic reconstruction
   - Automatic classification
   - Reconstruction of missing parts of profile
   - Reconstruction of vessel
   - Search for already archived fragments of the same vessel

The acquisition method for estimating the 3d-shape of a sherd is shape from structured light [PT96], which is based on active triangulation. The projector projects stripe patterns onto the surface of the objects. In order to distinguish between stripes they are binary coded. The camera grabs gray level images of the distorted light patterns at different times. With the help of the code and the known orientation parameters of the acquisition system, the 3d-information of the observed scene point can be computed [KKS96]. This is done by using the triangulation principle. The image obtained is a 2D array of depth values and is called a range image. For recording on the excavation site a portable 3D sensor (Eyetronic ShapeCam [1]) was used.

3 Results

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 [14]. Figure 3 shows a registered fragment and its estimated rotational axis. The fragment is oriented along the axis.

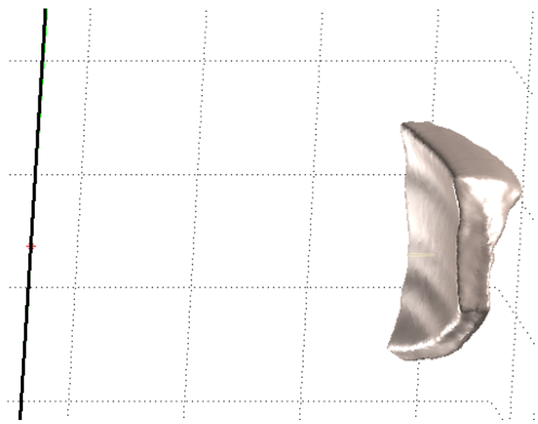


Figure 3: 3d Model of a fragment and its axis of rotation

We use the oriented sherd for the estimation of the longest profile line, which is supposed to be longest elongation along the surface of the sherd parallel to the rotational axis. With the parameters of a plane E that intersects the fragment in the direction of the rotational axis the profile line can be estimated. See Figure 4 for computed profiles.

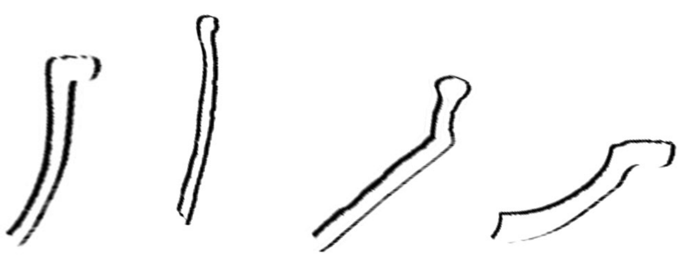
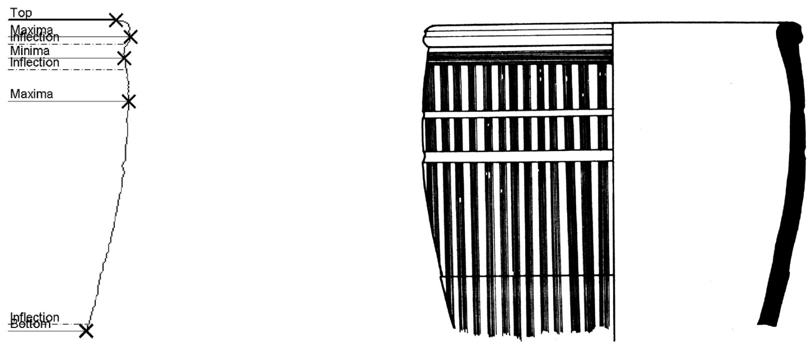


Figure 4: Profiles of different fragments.

Following the manual strategy of the archaeologists, the profile should first be segmented into its parts, the so-called *primitives*, automatically. Our approach is a hierarchical segmentation of the profile into rim, wall, and base by creating segmentation rules based on expert knowledge of the archaeologists and the curvature of the profile [10, 12]. The segments of the curve are divided by so called segmentation points. Our formalized approach uses mathematical curves to find the extremal and inflection points necessary to classify the original fragment. It is based on cubic B-Splines. Figure 5 left half shows one example of an automatically segmented pot with the characteristic points detected and the appropriate manual segmentation on the left of Figure 5.



(a) (b)

Figure 5: (a) detected classified pot with characteristic points for primitive classification and (b) manual drawing.

A profile computed and the axis of rotation are shown in Figure 6. It was rotated 360 degrees around the axis of rotation in order to construct the vessel in 3D. Next the resulting 3D point cloud was triangulated and the acquired texture was mapped onto the triangulated mesh. Figure 6 shows the reconstructed pot.

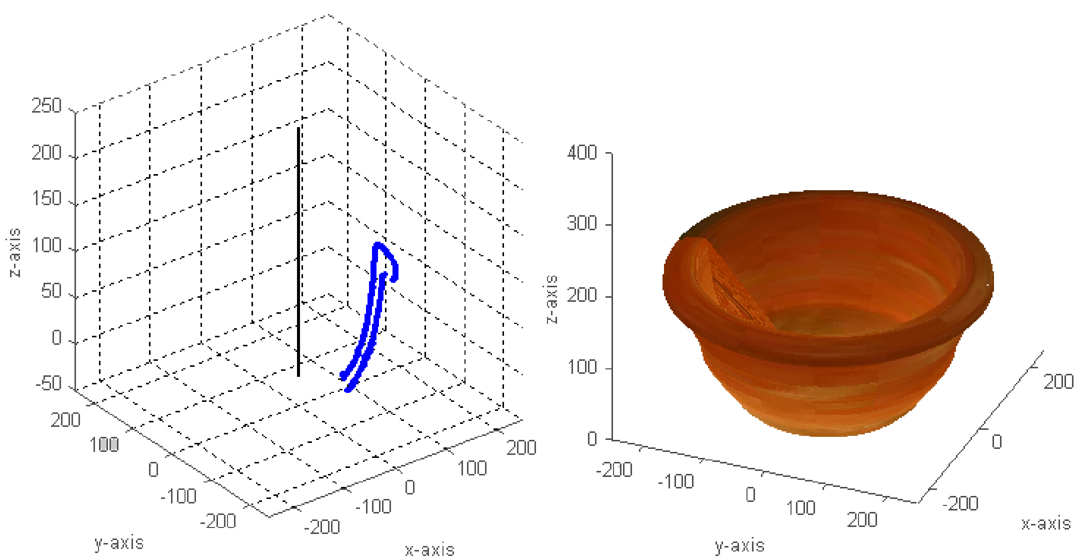


Figure 6: 3D profile section and 3D reconstruction out of the profile section

4 Conclusion and Outlook

We have proposed a prototype system for the automatic archivation of archaeological fragments. The work was performed in the framework of the documentation of ceramic fragments. The methods proposed have been tested on synthetic and real data with reasonably good results. The ceramic documentation and reconstruction system described is currently under further development to be integrated in the virtual excavation reconstruction project MURALE. 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 from singular vessels finally.

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