Computer Applications in Archaeological Pottery: A Review and New Perspectives

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Abstract

During the past few years, many publications about computer applications in the field of drawing, classification and analysis of archaeological pottery have been presented at various congresses by various researchers. This paper will review and analyze the most relevant works published so far. It focuses on computer applications oriented towards the graphical visualization and analysis of data relevant to archaeological pottery. The intention is to order and systematize these data and to review those publications that are most relevant to computerized systems of archaeological pottery.

This review and analysis will introduce the methodology used in the CATA project (Archaeological Wheel-made Pottery of Andalusia), the procedures used in the CATA project for the representation, archiving, analysis and retrieval of data concerning pottery vessels and their fragments. The main aim of the CATA project is to provide a scientific tool for the analysis of pottery finds in eastern Andalusia. These findings will be introduced into a database with documentational and graphical capabilities for visualizing pottery fragments and vessels. The objective is to create a general tool that can be applied to any kind of ceramic material found in any geographical location.

Keywords

Archaeological pottery, Review, Methodology

1. Introduction

Pottery finds tend to be the most abundant type of archaeological materials. The study of these materials is a key element in understanding the level of sociological development of a specific culture and is often useful in determining the functional uses of the areas in which they were found.

The classification of pottery finds must first be described according to the traditional method of drawings. The procedures currently used give rise to the need for new methods of documentation, classification and analysis of archaeological pottery finds.

This paper will deal with the methods that different publications have introduced for automated representation, reconstruction, classification and archiving of archaeological pottery.

2. Drawing and representation of pottery shapes

Archaeological understanding of pottery has largely been based on the graphical representation of finds. This representation has allowed the possibility of obtaining data and logical results as a previous step towards a more concrete knowledge in any field which concerns archaeological studies.

The basis of archaeological drawing is based on the extraction of a complete profile from a collection of shapes or the extraction of this same profile from complete vessels. The profile permits the reconstruction of complete pots by rotating this profile 360º.

Traditionally a template is used to graphically describe the profile and caliper is used to measure the thickness of various points in the profile. The angular orientation of the profile is calculated manually.

Concerning the work centered on the rotational evaluation of pottery profile fragments, the following efforts should be noted: Halir and Flusser (1997) proposed a method where by 2.5D representation of a pot can be reconstructed based on the symmetric nature of manufacturing pottery created by a potter's wheel. A fundamental prerequisite is the correct orientation of the shapes before a volumetric representation can be generated. A method for an estimation of a sherd's profile is proposed.

In recent years, Willis *et al.* (2003) have further developed the analysis of pottery profiles to create an algebraic model capable of generating a 3D surface area representation of pottery vessel shapes.

The principal aim of other approaches is to generate a 3D model of vessels from shapes. They describe a novel, robust and computationally efficient approach for finding the geometric structure of an axially symmetric pot from a small fragment of it (Cao and Mumford 2002).

Finally, Melero *et al.* (2003) discuss the use of genetic algorithms to determine the correct axial angle of an orientation of a shape in order to extract a vessel profile. This system uses the current archaeological methodology of registering profile parameters (shape orientation, diametric measurement, profile generation, graphic representation of fragments and other additional measurements). The use of genetic algorithms permits the addition of flexible data which adapt to the imperfections caused by the digitization of pottery.

Recently, new software called Profile Analysis Tool (PAT) has been developed to assist the graphical drawing of pottery (Lettner *et al.* 2006). This system permits the extraction of a profile and shapes based on a 3D model. In general terms, the system does the following: it creates a 3D matrix surface area, orients the fragment or vessel, generates the profile, and semi-automatically estimates profile with measurements. This system is very efficient in alleviating all the manual steps necessary before a pottery artefact can be introduced in a computerized system.

3. Vessel reconstruction and classification

3.1. Reconstruction

Other investigations are focused on the reconstruction of pottery vessels based on shapes. The techniques used to synthetically generate the complete vessel are based on algebraic models and applied algorithms.

One of the methods used is a jigsaw-puzzle approach based on fracture line coupling (Kampel and Sablatnig 2004). A similar approach is used to orient fracture lines using a Bayesian approximation of fracture line coupling, orienting the shapes relative to the profile's rotational axis (Cooper *et al.* 2002). Fourier series are also used for shape analysis in the case of closed forms (Gero and Mazzullo 1984).

Another method uses a two-step approach to solve the puzzle. First, an algorithm is used to match sherd coupling points in a 2D space similar to the proposal of Leitao and Stolfi (2002; 2004). Second, this 2D model is transformed into a 3D projection using synthetic virtual geometric learning processes in order to match fracture line borders (Kong and Kimia 2001).

3.2. Classification

Durham, Lewis and Shennan (Durham *et al.* 1995) have proposed a two-phase fragment classification system. First, the derived pottery image is analyzed and then static grouping techniques are used to create classes of images known as image clusters. This method permits the classification of pottery by geometric form similarity.

Smilansky, Karasik, Gilboa and Sharon (Smilansky *et al.* 2004) have proposed a computerized typological system in order to identify prototype vessels. This permits the observation of correlations amongst different pottery profiles.

Maiza and Gaildrat (2005) propose the use of an automated methodology to establish the relationship of a sherd to a known pottery vessel model. To see the similarity between two pottery shapes, a genetic algorithm is applied. Once the vessel image is generated and reconstructed, the generated image is compared to other known images, which enables the categorization and association of the vessel to a region or a given society.

One of the latest developments in the previously mentioned lines of investigation is the classification of pottery shapes using a combination of textures and colours (Bishop *et al.* 2005). This procedure uses 5 vessels with a maximum similarity as a comparison point for the new vessel being compared. The precision of this method is 99% for entire pottery pieces and 70% for partial shapes.

4. Information storage and internet oriented query systems

During the 70s an increased effort was made to find an adequate system to store and retrieve archaeological data. Most of these efforts centred on computerized systems as applied to archaeological data. During this decade the most relevant work was Lengyel's (1975), which dealt with the storage and retrieval of archaeological data. During the mid 80s, the first ideas on computerizing pottery profiles were being developed by Hall and Laflin (1984). The main effort was focused on allowing the 3D modelling of pottery vessels and the storage of the data composing these models in a compact and accessible way.

Further developments in this area of investigation were achieved by using the curvature of shapes and pottery vessels as a classification system for facilitating internet oriented investigation. At the beginning of the 90s, Lewis and Goodson (1990) developed the Graphically Oriented Archaeological Database (GOAD project). The information base of this initiative included the storage of texts, graphics and images. This system focused mainly on the capabilities of storage, retrieval and global availability of archaeological information. Part of the importance of this project was that it was one of the first to use Hugh transformations as a tool to couple and combine pottery forms.

In the mid-90s, Durham, Lewis and Shennan (Durham *et al.* 1994) continued the above line of investigation with an artefact classification system called *Smart*. The system stores and uses information concerning textures as a comparison a method amongst vessels and shapes. Some of the results of this study are reduced query search time, the use of fixed scale and orientation, and the extension of the system to permit the coupling of objects based on visual and textural similarities.

Sablatnig and Menard (1997) use a pottery classification system based on the attributes of the profile's curvature and the division of the profile into base, rim and body. Also included in the categorization are additives found in the clay, colour, decoration and other treatments. This form of analysis has two main objectives: the reconstruction of the original vessel and a logical association of non-associated shapes to types of "well-known" pottery vessels stored in a database of known characteristics. The advantage of this approach is the reconstruction of entire vessels from few given shapes and using partial information (rim, base). A shape can then be associated with a known type of pottery.

The role of information system data interchange protocols over the internet should also be mentioned in this section. Extensible Mark up Language (XML) is playing a key role in facilitating the flow of data.

Schurmans *et al* (2001) propose the extraction of the geometric 2D and 3D characteristics of a pottery vessel for the classification of artefact forms and the subsequent study of uniformity and standardization of these forms. These forms are introduced into an extensible numeric library which references the previously mentioned geometries. This library is then made available via the internet to researchers for study purposes. This technology allows the diffusion of both data and images using an XML schema. The external curvature of vessel profiles is used as reference index for data retrieval purposes.

Liu *et al.* (2005) also use geometric information derived from the curvature of vessel profiles to analyze pottery shapes. The information gained from this analysis is then made available in an XML format through the internet for consulting and storage purposes.

5. Conclusions and future steps

As a common denominator in each of the steps concerning the study of archaeological pottery, it should be noted that 3D modelling of fragments and vessels constitutes a fundamental shift towards an objective and favourable systemization of pottery classification systems.

The above-mentioned investigations demonstrate that in the field of archaeological investigation of pottery the collaboration between archaeologists and computer scientists permits the development of useful applications for the drawing, classification, storage and management of archaeological data. However, there is still a need for the further development of information systems specifically targeted at using the full range of applied computation mathematics in archaeological pottery analysis.

The use of computational pottery systems accessible via the internet favours the unification and standardization of different methodologies. This is the reason why standardized data interchange formats should be used and enforced for internet knowledge base transactions.

The CATA project (Archaeological Wheel-made Pottery of Andalusia) is developing a methodology for the classification of pottery based on qualitative, quantitative, contextual and conservation metrics as a tool for the better understanding of information provided by archaeological findings, and as a data interchange instrument. This system will incorporate some of the previously elaborated approaches to the analysis of archaeological pottery. In this sense some algorithms for image comparison are being investigated. The purpose of the project is to create an integrated system which takes into consideration the widest possible number of variables, such as text, numeric, graphic (2D-3D) and geometric data, applicable to the analysis of archaeological pottery.

The orientation of the system will be open and easy to use for anyone who wishes to investigate archaeological pottery from Andalusia using the internet.

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