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A proposal of ceramic typology based on the image comparison of the profile

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Abstract

Ceramics are one of the most documented materials in the archaeological interventions. The documentation and the analysis of the pottery shapes allow the knowledge of the chronology and the functionality of the settlement where they have been found. The achievement of a typology of ceramic materials is made attending on different aspects (function, context, morphometry …).
In this contribution a methodology of analysis of archaeological ceramic is showed. This methodology is based on the technique of nonrigid deformable analysis applied to the drawing of the profile and is aimed at the construction of a ceramic typology. This work is included on the CATA project (Archaeological Wheel Pottery of Andalusia in its acronyms in Spanish). The main objective of the project is the achievement of a reference collection accessible by Internet.The above-mentioned reference collection consists of a sample of 1,390 complete shapes corresponding to different chronological periods; from the seventh century B.C. until the fiftteenth century A.D., documented in the region of Andalusia. Also fragments of ceramic shapes have been compared with complete vessels to be associated to certain shapes.
The morphometric analysis allows on one hand the evolution of the ceramic shapes across the different historical periods and the creation of typologic groups based on the similarity of the shape.
On the other hand, the computerization of the archaeological ceramic data across Internet allows a uniform and standard ceramic analysis.

***Key words**: Archaeological ceramic typology, morphometric analysis, deformable models*

1 Introduction

Ceramics forms are one of the most documented in the archaeological interventions, and therefore are the most voluminous, allowing greater information that contributes to the reconstruction of the historical sequence of a place (Orton, Tyers, Vince, 1993). The study and analysis of the ceramics constitutes one of the most frequent activities of archaeological work, which consists habitually of classifying the thousands of ceramic fragments gathered in the interventions and selecting those that contribute to deduce forms, functions and chronology.

The ceramic materials usually appear in fragmented state. In fact, except for the case of a sudden desertion of a place, with good conditions of conservation throughout the time or closed sets like graves, it is normal to find a great amount of ceramic fragments.

The study of archaeological ceramics means giving continuity to an archaeological investigation that has tried diverse classification approaches since the very origins of the discipline, and none of them can be considered valid.

The different criteria used in the elaboration of typologies do not contribute to homogenize the analysis of the pottery shapes, since the election of criteria depends on each researcher. The most used criteria have been the morphometrics, functional, statistical, technological and contextual. Taking this division into account, the criteria used in this research is morphometrics because, within this scope, methods and techniques of analysis coming from graphical computer science can be applied and can be useful for classifying pottery shapes according to degrees of similarity.

In this chapter a deformable-contour based, computational method of comparison of profiles is discussed. This method allows the automatic classifiaction of pottery shapes based on morphometrics criteria. This methodology of comparison has been practised on a sample of drawings of complete ceramic vessels and fragments, allowing not only grouping similar shapes but also assigning pottery fragments of the base or the rim to complete forms.

The present contribution has been structured as it follows: definition and evolution of the concept of *type* in the classification of ceramics, description of the area of study and the analyzed data, methodology of analysis and the conclusions.

2 The concept of *type*

The increasing number of excavations since the 19th century and the need to establish typologies related to stratigraphical chronologies helped to the establishment of descriptions, typological sequences and determination of *fossil-guides*.

The multiplicity and diversity of criteria regarding the ceramic classification have produced, since the second half of the 20th century, *typological* discussion, put forward by authors such as Adams or Orton (Adams, 1988:44 - 42 Orton *et alii*, 1993:21 - 26).

Generally the objectives of a classification are the arrangement and cataloguing of the material, the relative dating of the archaeological contexts and the establishment of parallelisms with materials documented in other zones (Shepard, 1956). The accomplishment of a typology is an empirical practice, oriented to facilitate the interpretation, but isolated and without theoretical expositions in which to
sustain itself.

At the end of the 1960's an important advance of the General Theory of Archaeology was achieved with the publication of the work of D.L. Clarke *Analytical Archaeology*. From this moment on, the use of mathematical methods applied to Archaeology commences with the purpose of being able to make the data more objective. One of the added concepts in this book is the concept of *type*, which is considered as *the element that is related to a more or less ample group through a series of common attributes. An exact place and a chronological context differentiate it from other types* (Clarke, 1984).

Therefore, in the establishment of a typology is necessary to know clearly the concept of *type*, since its meaning varies in the space and in the time. Every type has to show two basic properties: identity and meaning. In addition, a type is defined in relation to a specific classification that partially indicates the rules by which that is formulated. Furthermore, a typology is a system and not only a collection of types, it must be coherent as a system.

Therefore, according to these postulates, in the elaboration of a typology the types are defined first, and then subtypes or variants are established. The differences between types are marked by the presence or absence of the most significant atributes.

This concept of type and its supposed implications were the basis of the difusionism that dominated the prehistoric archaeology of the 1950's and the 1960's.

From the seventies these concepts are reviewed, generating a wide discussion. The discussions is considered from the problems derived of the meaning that was attributed to the functional identity of a vessel, since that characteristic frequently began to be used for the identification of the archaeological contexts. The situation arrived at a point in which the chronology, the functionality of the establishments or the cultural identification was even established on the basis of the percentage of different vessels entered in the site. As Shennan indicates, the quantitative information is an essential part of the archaeological work, in this sense the use of the computers is a useful tool for the data processing (Shennan,1992).

The methodological development of the Archaeology during the last thirty years has allowed the incorporation of quantification techniques in the archaeological studies. For this reason, against the logic of the method, the critics argued that the used criteria were intuitive and subjective, since was the researcher that established the most significant characteristics; reason why the type is defined only represented an imaginary ideal.

In recent years, archaelogist have rejected basing ceramics classification on a single feature, because taking conclusions from a single element leads to an erroneous classification, since the presence of determined material can be due to many different factors. It is obvious that in many occasions the classification or the types established with the interpretation of the context is being confused. Contextual archaeology includes diverse scales and space, hierarchic and ecological dimensions. This approach can be applied to simple or complex societies (Butzer, 2007).Therefore the context in which an artefact is found has special interest for the later analysis of the site.

3 Area of study and documentation of the material

The selected ceramic material for the morphometric analysis comes from different archaeological settlements located in the andalusian provinces from Jaén, Granada and Cordoba (see fig. 1)

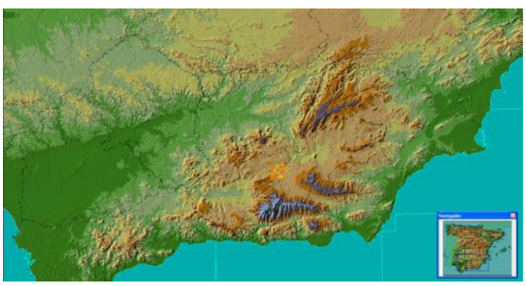


Figure 1. Studied area

The combination of different archaeological sites, with different chronologies makes the accomplishment of a diachronic and synchronous study possible, allowing to contrast materials of different archaeological sites with different chronologies.

The sample for the analysis has been made of 1,390 complete forms whose chronology goes from the seventh century B.C. until the fifteenth century A.D., belonging to sixteen archaeological settlements in Andalusia.

The sample of the reference collection is formed by drawings of complete vessels, understanding as such drawings of complete profiles or fragment drawings had enough form information that is possible to reconstruct the complete section of the vessel.

The drawings of the complete vessels come mainly from publications. The documentation available has been compiled to homogenize the graphical and documentary information, which is not standardized and it does not follow canons at the time of his study and publication.

The computerization of the archaeological registry allows to homogenize the data that are introduced and to make agile the process of obtaining of results, reason why allows a standardization of the used methodology to compare results.

Figure 2. a) Digitalized drawing from a publication; b) Previous image vectorization; c) Vessel's profile

The representation of the drawing has normally been realized the representation of the profile usually imagines in left half of the drawing along with the internal decoration, whereas the other half is reserved for the outer representation of the vessel.

Once compiled all the publications in which they appear drawings of ceramic vessels it carries out a task of digitalization of these drawings to homogenize the visual reconnaissance of all the drawings and to vectorize , and therefore to even compress the space of each image for its later computer processing (see fig. 2).

The digitalization process consists of scanning and vectorizing each one of the compiled ceramic forms.

4 Profile comparison method

4.1 Deformable Models

In order to estimate the similarity between two profiles, a comparison technique based on non-rigid deformation analysis will be used.

First of all, a measure to evaluate the *effort* or *deformation energy* needed to apply to a given contour in order to adapt it to another is defined.

The deformable model given by Nastar (1994) and Nastar and Ayache (1996) is used, which is described briefly below.

This model was first used for analysing the non-rigid motion of structures in temporal sequences of 2D and 3D biomedical images. The mechanical formulation of the problem consists in assuming that the contour is made up of a set of points (or nodes) with mass, joined together by springs. These elastic springs provide a *polygonal approach* of the contour and are supposedly identical, without mass, with stiffness k and length l_0. These springs modelize the *surface elasticity* of the object.

4.2 Similarity Measure Between Complete Vessels

For the comparison of the complete profiles, being that we already know the number of points of the simple, a reference prototype is used. Each profile can be classified in relation to it's *deformation spectrum* to the prototype. This way, similarity between two profiles can be computed as the Euclidean distance between their associated deformation spectra (see equation 1).

$$d(D_1, D_2) = \frac{1}{p}\sqrt{\sum_{i=1}^{p}\left(\tilde{u}_i(D_1) - \tilde{u}_i(D_2)\right)^2} \qquad \textbf{(1)}$$

Equation 1: Euclidean distance

The prototype *C* (Figure 3) is the circumference centred in (0.5, 0.5) and that passes through the point (0, 0) subsampled uniformly in *N* points. All the profiles should be scaled in relationship to the prototype. This makes our *measure of deformation* invariant to scale.

First the profile *P* is aligned over the profile to calculate the spectrum. The lowest point of the axis of rotation is aligned with the point (0, 0). Next, *P* is scaled uniformly so that its highest point corresponds with the edge of the piece that belongs to the circumference *C*.

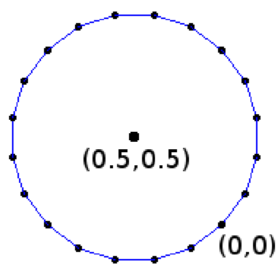


Figure 3: Circumference used as prototype

Different techniques are designed to establish the correspondence between the points (nodes) of the profile and the points of the prototype. The best results have been achieved when the profile is divided in exterior and interior halves that connect the origin with the edge of the piece. Both curves have been subsampled uniformly in $N/2$ points (see figs. 4 and 5).

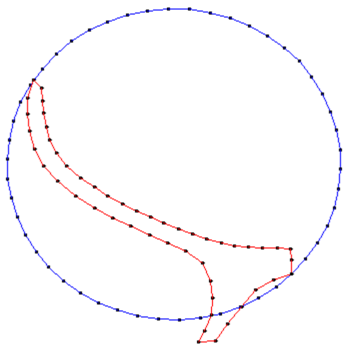


Figure 4: Subsampled profiles and prototype

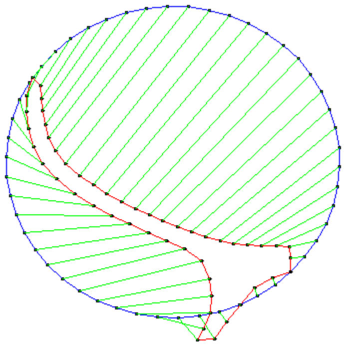


Figure 5: Correspondence between profile and prototype nodes

4.3 Similarity between Fragments and complete Profiles

The comparison of fragments with complete profiles can not be done with a prototype. This is because we do not know the number of nodes of the piece that correspond to the fragment points. Thus a different method must be used.

In the first place, three significant points are designated on any profile, called *anchor points* (see fig. 6). These anchor points are the edge, the lowest point that is in contact with the axis, and the base point most distant with the axis.

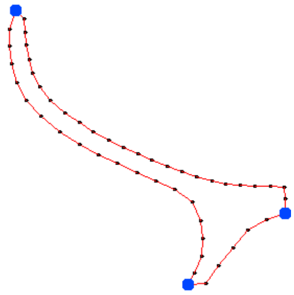


Figure 6: Anchor points

To be able to compare a fragment, it's necessary that it contains at least one of the three anchor points, as well as knowing the scale ratio between the associated fragment image and the complete profile. The whole process is as follows:

- Adjust the profile to a known or standard scale. The fragment should be scaled proportionally in relation to the scale of the profile.
- Measure the length of the contours of the fragment, to each side of each anchor point contained in the fragment.
- Take out the portion of the profile contours that correspond to the same lengths measured in the fragment, in relation to the anchor points.
- Subsample both contours in N points, with each side of each anchor point uniformly distributed and so that each point that corresponds with and anchor point is in the same relative position.
- Calculate the spectrum of deformation for open chains.
- Calculate the similarity between them (see equation 1).

5 Experimental results

The output of the comparison scheme has been tested against a given set of 121 expert-made classifiaction taken from the database. As the information about fragments hasn't been allowed, the results shown here only refer to complete profiles.

Each expert, given a test profile *T*, has marked as *relevant* a variable size subset of the database profiles. Next, the similarity measure has been computed, using 200 nodes per contour, for *T* and the rest of the profiles in the database, and ordered increasingly the results. It has been computed two different classification performance estimators, applied to the first *N* profiles returned by our algorithm, given *T*:

Precision:

$$P = 100 \cdot \frac{R_N}{N}$$

Recall:

$$R = 100 \cdot \frac{R_N}{N_T}$$

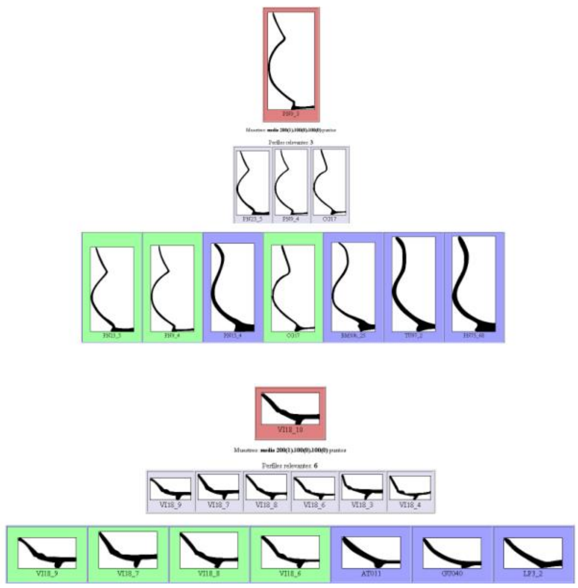
Being N_T the total number of relevant profiles related to *T*, and R_N he number of relevant profiles present in the first *N* returned profiles. Both measures range from 0 (worse) to 100 (best). For each example profile, it's computed the maximum obtained precision *Pmax*, the *N* value that gives such precision (*NPmax*), and the minimum value of *N* that gives *R* = 100, (*NRmax*). The average values obtained are: *Pmax* = 46.67%, *NPmax* = 25, and *NRmax* = 121.

Table 1 represents the accumulated percentile values for *Pmax*, *NPmax*, and *NRmax*. For example, the column labeled 50% means that for one half of the profiles present in the database, a query with *N* = 7 returns at least a 45.5% of *relevant* profiles, and a query with *N* = 28 provides all of the *relevant* ones. Figures 8 and 9 show some classification examples.

It must be noted that the classification performed by the experts does not only attend to geometrical cues, but also to semantic ones, therefore the algorithm can return profiles that are geometrically similar to the query one, but unrelated from the expert point of view.

Percentile	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
P_{max}	100.0%	75.0%	60.0%	50.0%	45.5%	33.3%	25.0%	16.7%	4.8%	0.2%
N_{Pmax}	1	3	4	5	7	9	12	17	29	568
N_{Rmax}	1	4	9	14	28	44	126	233	410	874

Table 1: Accumulated percentile values for *Pmax*, *NPmax*, and *NRmax*



Figures 7 and 8. First row: Query image. Second row: relevant profiles. Third row: Classifications results. (Relevant profiles marked in green)

6 Conclusions

Archaeology is a comparative discipline: archaeologist spends much of their time making comparisons between artefacts, between assemblages, between sites and even between regions. Such comparisons may be made in different ways for different purposes; for example, assemblages may be compared for chronological purposes (e.g. seriation), for spatial purposes (e.g. distributional studies), or for the study of function or status. None of these activities is possible unless comparable"objects" (in the widest sense) are given the same names wherever they occur. If different terminologies are used in different places, then a means of translating between them must be made available (Orton, 2004). This generates anarchic situations like the different nomenclature used for the same shape of a vessel.

The methodology exposed constitutes a multidisciplinary approach for the anarchic situation concerning to the elaboration of a ceramic typology due to:

- The homogenization of the drawing.
- Uniformity of the methodology used.

Also, with the results exposed it is possible to say that in the majority of the cases the classification made for an archaeologist and the results obtained with this methodology coincide.

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