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Original article

Efficient classification of Iberian ceramics using simplified curves

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ABSTRACT

We present a new method for comparing and classifying wheel-made pottery vessels, based on the simplification of the external contour of their profiles. We use the Douglas-Peucker algorithm to obtain a polyline that preserves the coarse features of the profile shape. A characteristic vector is derived from each polyline, allowing us to compare profiles by measuring the distance between the corresponding vectors. We have tested our technique with a profile database of Iberian pottery vessels from the upper valley of the Guadalquivir River (Spain). Results show that our approach not only achieves better results than most of the state-of-the-art methods used nowadays, but is also more efficient and generates more compact characteristic vectors.

1. Introduction and related work

Ceramics study and analysis constitutes one of the most frequent activities of the archaeological work [1], mainly consisting of classifying ceramic vessels gathered in interventions, in order to select those that can best contribute to the deduction of chronology, forms and functions. Until the early 1990s, the primary medium for sharing and representing archaeological excavation data was freehand drawing. This made it extremely difficult for the user to analyze and compare artifacts in a quantitative manner.

In order to better study the material, a number of typologies have been proposed based on different criteria. Since the selection of these criteria depends on each individual researcher, they hardly contribute to homogenizing the analysis of pottery shapes. It is therefore interesting for the archaeologist to have coherent, non-subjective classification criteria. In recent years, it has become crucial to provide automated tools in order for researchers to interact with large archaeological datasets [2].

We have a set of 1133 ceramic vessels, coming from 16 different archaeological sites located in the eastern area of Andalusia [3–5], specifically form the provinces of Jaén, Granada and Córdoba, and belonging to the Iberian period (6th Century B.C.–1st Century A.C.). This amount of data made our team look for non-subjective criteria that could be integrated into a computer application, thus simplifying the work of the researcher.

This paper presents a new method for comparing and classifying wheel-made pottery vessels, based on the external contour of their profiles, and represents an interesting alternative to our previous Mathematical Morphology-based technique, presented in [6]. Using our approach, we can provide a tool for the archaeologist that will help him to find in a profile database the most similar classes for a given shape, thus facilitating the classification of newly found material. Profiles are defined as the vessel's cross-section in the direction of the rotational symmetry axis (see Fig. 1), and represented by a simple black and white bitmap. Taking this information as input, we derive a *characteristic vector* that captures the morphological features of each vessel, allowing us to compare two profiles by computing the Euclidean Distance between their corresponding vectors.

In previous works [6,7], we proposed a Mathematical Morphology-based profile classification method. In that case, the characteristic vector corresponding to a profile was obtained by sampling the curves derived from the application of four well-known morphological operators (erosion, dilation, opening and closing), with structuring elements of different orientations and sizes. Although the results were clearly better than the ones obtained by other, state-of-the-art methods, the computational requirements were very high, and the resulting characteristic vectors too long. For these reasons, we have developed a new, more efficient approach, which we will call *Simplified Curve*, capable of providing comparable classification rates at a lower computational cost, and with more compact characteristic vectors. We make use

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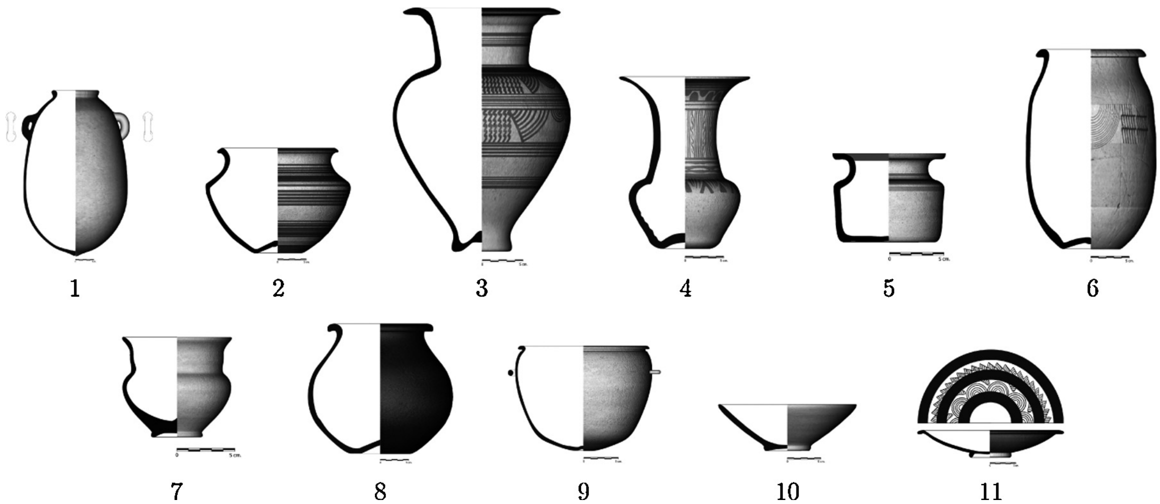

Fig. 1. Example vessels of each of the eleven classes, showing on the left its corresponding profile.

of the Douglas-Peucker algorithm [8], which has been widely used for contour simplification in image analysis applications, and has been applied successfully in various shape recognition tasks [9–11]. This method allows us to obtain a compact and still meaningful representation of the profile contours.

Over the years, many systems have been proposed to classify vessels from the shape of their profiles [12]. Nautiyal et al. [13] propose a parametric representation method, mainly focused on visualization and archiving purposes, but lacking an appropriate numerical comparison method. Other approaches are more oriented towards reconstruction from ceramic fragments, and the measurement of volumetric features, such as height, width, diameter or volume [14], giving less importance to the comparison of shapes.

With respect to the automatic comparison between profiles, we can also find several methods in the literature. Shennan and Wilcock [15] proposed the *Sliced* method for deriving automatically a typology for Bell Beaker pottery, measuring the horizontal displacements needed to align two given shapes, previously divided into *slices*, but their results were comparable to the ones obtained by Principal Component Analysis over the height/width ratios of each shape. In [16], the authors propose a classification system which, along with the *Sliced* method, calculated a similarity measure based on the overlap maximization between two profiles, although it is not well suited for vessels, because of the elongated shapes of their corresponding profiles. More recent works [17] rely on well-known local features, such as Shape Context descriptors [18], to characterize profile shapes, along with a multivariate analysis to compare and group profiles corresponding to similar vessels, although the resulting clusters do not match very well with existing typologies. Other approaches [19,20] use a continuous, sub-pixel approximation of the profile shape, and represent it by computing its radius, tangent and curvature along the contour. Similarity is then computed using a weighted Euclidean Distance that can be modulated to focus on certain parts of the shape. The main drawback that we found with this approach is the need to obtain the curve approximation itself, which must be a continuous function of the arc length, starting from a discrete source, i.e. a binary image.

This paper is organized as follows: Section 2 gives a brief description of our profile database. Section 3 shows in detail how the profiles are characterized and classified. Sections 4 and 5 present our experimental results and conclusions of our work.

2. Profile database

We have a database of 1133 vessel profiles, corresponding to Iberian pottery, found in different archaeological sites belonging to the upper valley of the Guadalquivir River (Spain). Our classification is based on morphological criteria supervised by an expert, taking into account the presence or absence of certain parts (lip, neck, body, base and handles), and the ratios between their corresponding sizes. We have a total of 11 classes (Fig. 1) with different number of elements (Table 1), nine corresponding to *closed forms*, and two corresponding to *open forms* [7]:

1. Shapes with oval body, prevailing over other parts of the vessel.
2. Shapes with body in form of *conic bifrustum*. The joints of the different body parts are discontinuous.
3. Shapes with developed, short neck with divergent walls, and globular body.
4. Shapes with developed, divergent walls neck, and globular body. This shape is also named *chardon vessel*.
5. Shapes with cylinder body. Also known as *kalathos*.
6. Elongated shapes.
7. Profiles in form of *S*.
8. Shapes with globular body. The joints of the different body parts are continuous.
9. Shapes with globular body and a largely developed rim.
10. Shapes with semi-spherical body.
11. Shapes with semi-spherical body and reversed rim.

3. Profile classification

In order to be able to compare two given profiles, we will first apply a pre-processing stage where we will simplify the external contour of each profile with a polyline, and then compute the corresponding characteristic vectors based on this.

Table 1
Number of elements of each class in our database.

Class	1	2	3	4	5	6	7	8	9	10	11
No. of samples	30	47	75	10	56	52	50	293	22	373	125