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A computer-based method for the accurate analysis of the trilobate spouts found in the cathedral of Amiternum

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Abstract. The traditional manual method of analysis of ceramic finds involves expert operators in long and routine activities whose results depend on their subjectivity, specialization, and professional experience. This implies that the analysis of sherds is carried out using few data affected by high uncertainty. These limitations are even more clear with fragments with small axially symmetric portions whose elements of the investigation are not axially symmetric, such as handles, spouts, decorations. In this way both the axis of symmetry of the original object and the reference planes and/or axes of the characteristic dimensions of the elements are identified with such approximations as to compromise subsequent analyses and comparisons. To overcome these limitations, in this paper a new computer-based procedure is proposed. As a case study, the analysis fragments of jugs/bowls with trilobed spouts found in the site of Amiternum, coming from 12th-13th century contexts are considered; their analysis is fundamental to analyze the site where they were found since there is no archival documentation about their use.

1. Introduction

The analysis and classification of archaeological finds, such as pottery, providing a clear indicator of their use, are a reliable tool for interpreting the context of retrieval [1]. To this end, the shape, size, decoration, color, and material are analyzed by an experienced operator. Some of them, such as decoration and color, are studied by visual analysis, while the characterization of shape and size is based on the graphic representation of the results: the attribution to specific ceramic types is made through visual comparison with known classifications. Since ancient ceramics are typically found in fragments, these operations are more complex to perform [2]. The traditional archaeological method for sherd investigation follows the following steps: orientation, diameter estimation, profile extraction, sherd drawing, and additional measurements [3]. Like all manual operations, the results obtained depend on the subjectivity, specialization, and professional experience of the operator: the traditional method is poorly repeatable and reproducible and the size comparison between the fragments is performed with high uncertainty. In addition, the traditional method involves experienced operators in time-consuming routine activities [4]. These limitations are even more evident in the case of fragments with small axisymmetric portions whose elements of the investigation are not axisymmetric, such as handles, spouts, decorations, etc. This determines for the operator great difficulties both in the individuation of the symmetry axis of the original object and of the reference plans and/or axes to determine the characteristic dimensions of the non-axially symmetrical elements on which to base the comparisons.



In order to overcome these limitations, this paper proposes the development of a computer-based method for the analysis of the characteristic shape and dimensions of specific non-axially symmetrical ceramic artifacts; the 39 ceramic artifacts consisting of mugs/bowls with trilobed spouts, found in surface stratigraphies at the Amiternum site from 12th-13th century contexts, are considered as a case study. The mechanical actions consequent to the agricultural works have disseminated in the area of the cathedral finds coming from the neighboring areas, wherein all probability the presumed settlement was located. An aim analysis of these fragments is fundamental in order to analyze the site of discovery since there is no archival documentation about its frequentation. Moreover, the information generated by the method will provide an innovative tool to clarify, for example, the reasons for such an anomalous diffusion of this ceramic class in a relatively restricted territory, or to expand the data on production centers and areas of diffusion.

The method represents the first attempt, to the knowledge of the authors, to measure the characteristic features of ceramic spouts. The performance of the method, tested by processing the 39 above mentioned ceramic spouts, has been analyzed. The analysis of the results permitted the identification of critical aspects for further improvement.

2. Proposed method

Figure 1 summarizes the key steps of the proposed computer-based method (in the following referred to as CBM). CBM requires as input a discrete manifold model of the object to be analyzed (figure 1a). A fundamental preliminary step is the evaluation of the axis of symmetry. For this purpose, the axially symmetric area of the internal wall is segmented, by identifying the widest portion of the sherd's surface having the mean curvature positive (figure 1b); the sherd external surface is not considered for the presence of the spout. The axis of symmetry of the sherd is evaluated by applying the method proposed by Halir [5] to this recognized area; the geometric model is roto-translated so that the axis α coincides with the z -axis of the Global Reference System (figure 1c). The user selects the part of the external wall of the sherd where the spout is located (figure 1d). The axially symmetric part (in the following referred to as \wp_{AX}) and the non-axially symmetric part (in the following referred to as \wp_{NAX}) are then analyzed by different specifically designed tool.

\wp_{AX} is segmented in the typical surfaces considered by the archeologists by using the automatic method proposed in [4]; the dimensional features of the obtained mean profile are recognized by the method presented in [6] (figure 1 e).

\wp_{NAX} (figure 1f) is analyzed by a specifically designed method. First, the bilateral symmetry plane is evaluated according to [7], so that the left and right parts of the spout are easily identifiable. The user selects the two areas ($\wp_{\wp_{NAX}}^r$ and $\wp_{\wp_{NAX}}^l$) where, presumably, the manufacturer has applied pressure to shape them appropriately (figure 1g). The concave zones of each of the two areas are approximated by a ruled paraboloid ($\Gamma\{\wp_{\wp_{NAX}}^r\}$ and $\Gamma\{\wp_{\wp_{NAX}}^l\}$), resulting in the evaluation of the two evolutes ($\mathbb{C}\{\wp_{\wp_{NAX}}^r\}$ and $\mathbb{C}\{\wp_{\wp_{NAX}}^l\}$) and the plane of symmetry ($\Pi\{\wp_{\wp_{NAX}}^r\}$ and $\Pi\{\wp_{\wp_{NAX}}^l\}$) (figure 1h). Finally, the $\mathbb{C}\{\wp_{\wp_{NAX}}^r\}$ is aligned to the z -axis of the Global reference system (figure 1i).

Based on the features recognition here proposed, the following dimensional ones are considered characterizing each spout:

- Diameter of *rim*: Φ_{rim} ;
- Radius of $\Gamma\{\wp_{\wp_{NAX}}^r\}$: r_{Γ^r} ;
- Radius $\Gamma\{\wp_{\wp_{NAX}}^l\}$: r_{Γ^l} ;
- Angle between $\mathbb{C}\{\wp_{\wp_{NAX}}^r\}$ and $\mathbb{C}\{\wp_{\wp_{NAX}}^l\}$: $\alpha_{\mathbb{C}}$;
- Angle between $\Pi\{\wp_{\wp_{NAX}}^r\}$ and $\Pi\{\wp_{\wp_{NAX}}^l\}$: α_{Π} .

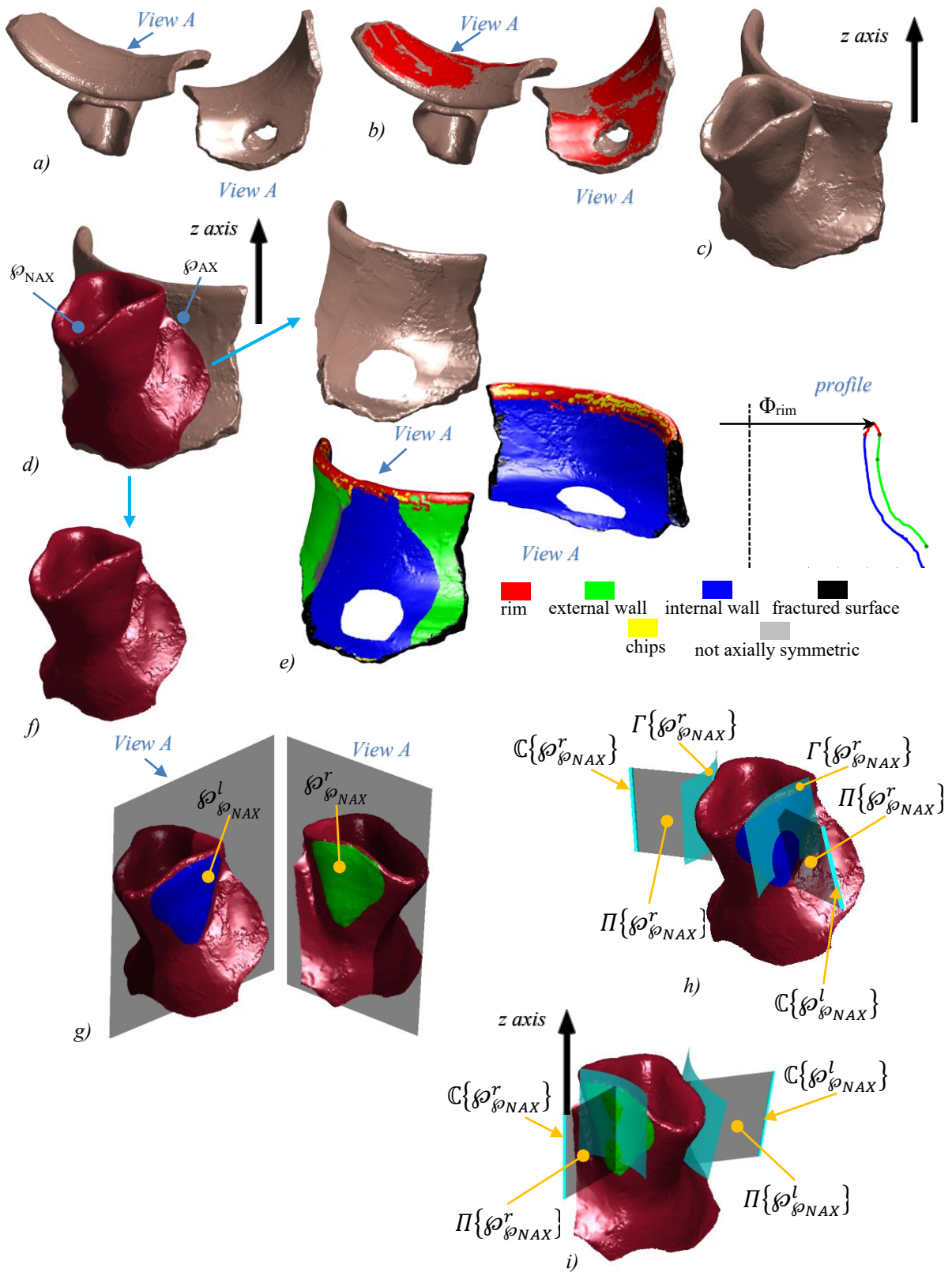


Figure 1. Key steps of the proposed method.

3. Results

The proposed cbm was implemented in original software, coded in MATLAB. In order to characterize the accuracy of the presented computer-based method (CBM), specific experimentation was carried out. Since any measurement uncertainties in the dimensional features result from the contribution of both intra-tester repeatability and inter-tester reproducibility, in this paper, these two components of measurement error are analyzed. In particular, the phase of the procedure that requires the intervention of the skilled user (figure 1): the selection of the two areas ($\wp_{\wp_{NAX}}^r$ and $\wp_{\wp_{NAX}}^l$) where, presumably, the manufacturer has applied pressure to shape them appropriately. The testers are 12 students in the fifth year of their engineering course, trained appropriately. All the testers have been blinded to the results of the measurements. The spout to be analyzed has been chosen randomly selected by the set of 39 available. Testers were required to select the two above-mentioned patches starting from the \wp_{NAX} (figure 1f) by using the same commercial software with tools for manually segmentation of features. In order to evaluate the intra-tester repeatability (TRA), the 12 testers performed 50 selections of every patch. For each couple of patches ($\wp_{\wp_{NAX}}^r$ and $\wp_{\wp_{NAX}}^l$), by using the proposed method, the radii (r_{Γ^r} , r_{Γ^l}) and angles (α_C , α_{Π}) are estimated; the obtained dimensional features were tested for normality using the Kolmogorov–Smirnov test. The intra-tester repeatability is evaluated as the standard deviation of the performed measures: table 1 reports the results. The inevitable variability due to manual selection has a greater influence on the evaluation of the radii of the two paraboloids; this is shown by the significant differences between the minimum and maximum values of the observed TRA.

Table 1. The intra-tester repeatability evaluation.

	TRA _{mean}	TRA _{min}	TRA _{max}
r_{Γ^r}	5.53	1.25	8.35
r_{Γ^l}	9.06	5.69	14.01
α_C	3.02	2.77	3.38
α_{Π}	1.72	1.04	2.63

In order to evaluate the inter-tester reproducibility, each of the 12 testers performed three selections of the patches: each value of the corresponding dimensional features is calculated as the mean of the three measures obtained by the proposed method. The inter-tester reproducibility (TER) was evaluated as the standard deviation of the 12 measures performed, for each dimensional feature, by the manual segmentation of each tester: table 2 reports inter-tester reproducibility for each dimensional feature and the percentage value regarding the mean value. The reported values highlight the poor reproducibility of the protocols proposed for the manual method, especially in the calculation of the radii of the paraboloid that approximate the areas where, presumably, the manufacturer has applied pressure to shape the spouts appropriately.

Table 2. The inter-tester reproducibility evaluation.

	TER	TER/mean[%]
r_{Γ^r}	16.77	31.3
r_{Γ^l}	11.31	35.2
α_C	2.53	19.6
α_{Π}	1.54	5.29

In order to give an initial valuation of the proposed method, the obtainable quantitative assessment was compared with the qualitative assessment of an archaeologist. In particular, the archaeologist who is part of our research group was asked to choose, among the 39 finds available (figure 2 a), the two that in his opinion were the most similar: the archaeologist identified the two finds shown in figure 2b. Each

of the two finds was subjected to analysis using the method presented here. Figure 2c shows the map of the distances between the two discrete models, aligning their recognized non-axisymmetrical part: the maximum distance on the areas where, presumably, the manufacturer has applied pressure, is up to 3mm.

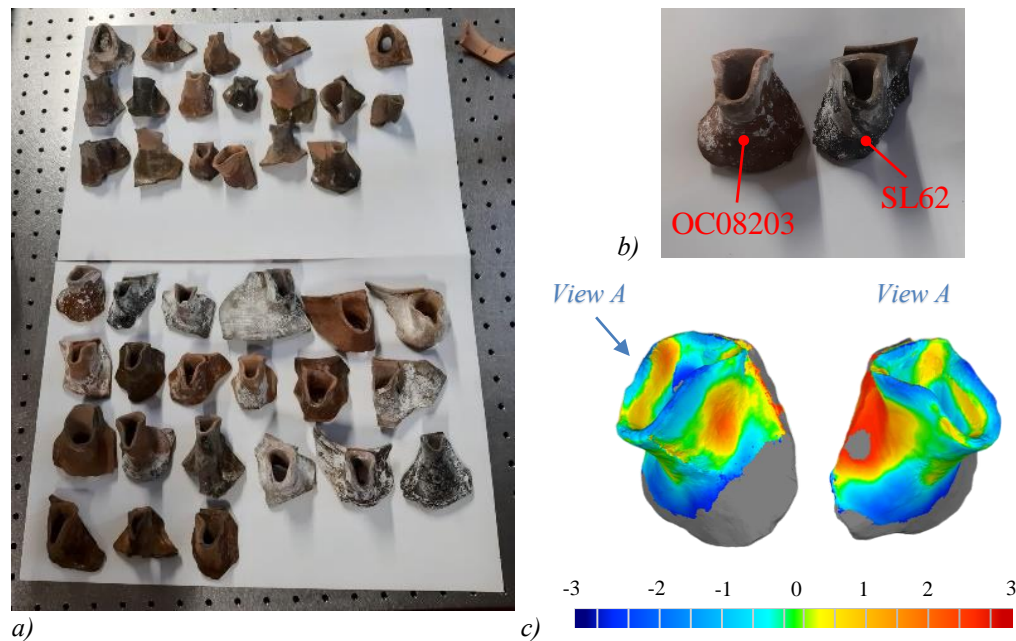


Figure 2. The 39 test cases here considered.

Finally, Table 3 summarises the obtained data (mean, minimum and maximum values for each measure): the values reported are the result of 5 different segmentations performed by an expert operator. This processing verifies the results shown in figure 3c: there is no simultaneous overlapping of the variability ranges of the 4 parameters.

Table 3. Results obtained for the two test cases.

	SL62			OC08203		
	Value _{mean}	Value _{min}	Value _{max}	Value _{mean}	Value _{min}	Value _{max}
r_{Γ^r}	1,95	1,12	2,81	2,65	2,17	3,58
r_{Γ^l}	9,78	3,78	18,45	8,02	5,25	11,87
α_C	8,64	5,21	12,42	14,89	13,08	25,71
α_{Π}	19,36	17,08	21,69	27,43	25,71	30,32

4. Conclusions

In this paper an original computer-based method for the analysis of the characteristic shape and dimensions of specific non-axially symmetrical ceramic artifacts is proposed. The 39 ceramic artifacts consisting of mugs/bowls with trilobed spouts, found in surface stratigraphies at the Amiternum site from 12th-13th century contexts, are the cases study. The proposed method, starting from a discrete model of the fragment to be analyzed, evaluates the radii of the two paraboloids that approximate the deformed side areas of the spout, the angle between their evolutes, and between their symmetry planes.

In the first experimentation, the repeatability and reproducibility of the phase of the procedure where the operator's intervention is fundamental were evaluated: the selection of the two deformed areas where,

presumably, the manufacturer has applied pressure to shape them appropriately. As expected, this phase causes an inevitable variability for the whole method because of the manual selection; in particular, the evaluation of the two paraboloid radii seems to be more sensitive to the users' selection.

By a second experimentation, the obtainable quantitative assessment by the proposed method was compared with the qualitative assessment of an archaeologist: by analysing two spouts considered similar non-negligible differences were verified in the values of the 4 parameters here considered.

Based on the results obtained by these preliminary experimentations, some improvements have to be required. The most critical aspect to be improved is certainly the need to find an automatic procedure for the segmentation of the two deformed areas. Given the complexity inherent in such selection, the authors are exploring the possibility of using artificial intelligence or statistical shape methods.

Only in this way will the method become robust and reliable in the analysis of these fragments, making repeatable and reproducible information available that will allow an objective comparison between them. This will allow archaeologists to make hypotheses on the site of finding that does not have any documentation of archive about its frequentation. Moreover, the information generated by the method may provide new information to clarify, for example, the reasons for such an anomalous diffusion of this ceramic class in a relatively restricted territory, or to expand the data on production centers and areas of diffusion.

References

- [1] C. Orton, M. Hughes, M. Pottery in Archaeology: The Potential of Pottery as Archaeological Evidence (2013).
- [2] C. Hörr, D. Brunner, and G. Brunnett. "Feature extraction on axially symmetric pottery for hierarchical classification." *Computer-Aided Design and Applications* 4.1-4 (2007): 375-384.
- [3] C. Orton, M. Hughes, M. Hughes. *Pottery in archaeology*. Cambridge University Press, (2013).
- [4] Di Angelo L, Di Stefano P, Guardiani E., Pane C., "Automatic shape feature recognition for ceramic finds", *Journal on Computing and Cultural Heritage (JOCCH)*, 2020, 13 (3), 1-21.
- [5] R. Halir , An automatic estimation of the axis of rotation of fragments of archaeological pottery: a multi-step model-based approach, in: *Proc. of the 7th International conference in Central Europe on computer graphics, Visualization and Interactive Digital Media (WSCG99)*, 1999.
- [6] Di Angelo L., Di Stefano P. and Pane C., " An automatic method for pottery fragments analysis." *Measurement: Journal of the International Measurement Confederation* 128, 2018, pp. 138-148.
- [7] Di Angelo L., Di Stefano P., "A computational Method for Bilateral Symmetry Recognition in Asymmetrically Scanned Human Faces". *Computer-Aided Design and Applications*, vol. 11 (3), 2014, p. 275-283.