https://doi.org/10.5817/CZ.MUNI.P210-8822-2017-10

MORPHOMETRICS OF (ESPECIALLY CERAMIC) CELTIC ARTEFACTS – NEW METHODS OF ACQUISITION, SYSTEMATIZATION AND VALORIZATION OF THE PAST

Josef Wilczek

Abstract:
The work of archaeologists is generally based on the classification of archaeological artefacts. Amongst all observable intrinsic descriptors (material, decoration, fabrication mode/chaine operatoire, etc.), the shape is often considered as the most important feature, giving clues to study chronological, social, religious or cultural aspects of ancient populations. Although ceramic classifications are well elaborated nowadays, they are sometimes considered as being subjective, ambiguous and hard to implement. The main goal of the project is therefore to bridge the gap between archaeology and recent developments in mathematics, statistics and 2D/3D imagery, in order to (semi-)automatize the process of ceramic classification and attribution. We hope that the project will bring a normative and standardized solution, allowing to overcome the linguistic, temporal and spatial limitations. We hope that this solution will be possible to be easily generalized and adopted to study other kinds of archaeological artefacts (axes, brooches, swords, etc.).

Keywords:
ceramics, classification, La Tène, Iron Age, morphometrics

Résumé :
Etude morphométrique des mobiliers (et surtout de la céramique) celtique – les nouvelles méthodes d'acquisition, de systématisation et de valorisation du passée
Le travail des archéologues est basé sur la classification des artefacts archéologiques. Parmi tous les descripteurs intrinsèques des mobiliers (matière, décoration, chaine opératoire, etc.), la forme est souvent considérée comme l'aspect le plus important, donnant des indices pour étudier des problématiques chronologiques, sociales, religieuses ou culturelles des populations anciennes. Même si les classifications des céramiques sont aujourd'hui bien élaborées, elles sont parfois considérées comme subjectives, ambigües et difficiles à implémenter. Le but majeur du projet est donc de créer un pont entre l'archéologie et les développements récents en mathématiques, statistiques et imagerie 2D/3D afin de semi-automatiser le processus de classifications et d'attributions des objets céramiques. Nous espérons que le projet apportera une solution normative et standardisée, permettant de dépasser les limitations linguistiques, temporelles et spatiales. Nous espérons également que cette solution sera généralisée et adoptée pour étudier d'autres objets archéologiques (haches, fibules, épées, etc.).

Mots-clés :
céramique, classification, La Tène, âge du Fer, morphométrie géométrique

Introduction

For my doctoral research, I have chosen to study several aspects of Hrazany – one of the most important archaeological sites in Central Europe. The site was occupied between the 2nd and 1st centuries BC by the Celts, who built an *oppidum* – fortified structure – which is considered to be the political, economic and religious centre of the territory. The huge amount of archaeological artefacts unearthed by L. Jansová during several excavation campaigns (1951-1963) gave rise to three monographs and several other articles concerning various related topics (*e.g.* Horáková-Jansová 1952; Jansová 1959, 1960; 1986; 1988; 1992). Nevertheless, Second Iron Age research has largely developed since that time and new questions and approaches as well as new methods of responding to them have appeared.

The excavations by L. Jansová have brought to light a huge quantity of artefacts. Nevertheless, the comprehension of more complex phenomena (exchanges, strategies of production organization) associated with Celtic society cannot be studied from a corpus collected at only a single site. For these reasons, the corpus studied was augmented by objects from other zones in Central Europe (Central Bohemia, Moravia and Silesia), as well as from other European regions (Burgundy and the *oppida* of Manching in Germany and Bibracte in France). The particular focus of the present project will be laid on the study of ceramics.

The choice of ceramics is quite evident: it is the most abundant material found by archaeological excavations – it is almost omnipresent. As ceramics first emerged in Prehistory, they bear not only information about chronology, technical and stylistic evolution, but also information about human relations. Contrary to precious artefacts intended for elites, ceramics are used and touched by all social strata. They reflect not only the cultural entities to whom they belong but also more intimate features – their personal preferences. By quantifying their intrinsic characteristics (form, decoration, technology of fabrication) and by observation of their spatial distribution, we, as archaeologists, are capable of modelling the socio-economic dynamics of ancient populations (Orton *et al.* 1992).

Despite their informative qualities, ceramics suffer from strong post-depositional degradation caused by climate, soil acidity, *etc.* We are estimating that almost 95 % of all ceramic objects have disappeared over time and, from that highly-reduced quantity, only 10 to 20 % of fragments possess information about the original form. At the same time, traditional typological techniques used for the treatment of residual information suffer from recurrent problems: they are subjective, often ambiguous and take too long to

be implemented, while their adaptation to another spatial or temporal window is rather delicate (*e.g.* Hodson *et al.* 1966).

Confronted with similar problems, biologists and palaeontologists (following the works by mathematicians and statisticians) have developed methods of analysing forms, generally named "geometric morphometrics" (*e.g.* Bookstein 1997; Kuhl and Giardine 1982; Lestrel 1989; Zelditch *et al.* 2004). These methods are based on the study of open (Discrete Cosine Transform – DCT, b-splines, Orthogonal polynomials) or closed outlines (*e.g.* Elliptic Fourier Analysis – EFA, Wavelet analysis) or on observation of differences in constellations of so-called "homologous points" (Procrustes Analysis, Thin-Plate Spline, *etc.*). These techniques allow treatment of huge amounts of data. Morphometric approaches are objective, fast and reproducible, and largely generalized, to be used to treat a large variety of objects. They offer graphical tools allowing condensation of complex information into a two- or three-dimensional space. For example, it is possible to graphically represent a large corpus of ceramics in only one diagram – *e.g.* a morphospace (Fig. 1) - in which structuration of individuals into groups may be directly observed. Contrary to discrete traditional typologies, the morphospace is continuous by its nature and therefore allows vast application of statistical methods, including validations – thus means which are not available with traditional approaches.

Fortunately, these methods have recently been applied in archaeology, but in spite of good will, the creation of an efficient technological transfer between mathematics and archaeology is not always a simple task - due to "isolation" between interlocutors – in terms of differences in nomenclature, goals, methods, knowledge or even mental representation of concepts (the problem of the so-called "Third culture" - Brockman 1995).

1. Research objectives

At the first stage, it is therefore necessary to bridge the gap between recent developments in mathematics, statistics, 2D/3D imagery, 3D printing *etc.*, and archaeology (and more especially in the field of material culture).

The first goal is to propose a new procedure allowing attribution of a fragment to the complete form, based on the probabilistic approach. It is sure that the quality of output will depend largely on fragment quality. Nevertheless, the multiplication of individuals treated in this way will largely augment the spectra of known types of vases. More techniques, recently developed in Computer Vision and robotics, seem suitable to fulfil this task – as for example the Iterative Closest Point algorithm (ICP) - an algorithm which is unexploited in archaeology, but which is used in numerous domains requiring the 3D reconstruction of objects from several partial views.

Once this method, along with morphometrics and statistics, can be applied to the corpus studied (*e.g.* ceramics from Second Iron Age):

- The density of probability maps reflecting fragment attributions to different types will be obtained, and therefore for the first time, the information contained in fragments, until now ignored by archaeologists, will be exploited.
- Once the complete vase is reconstructed from fragment(s), its 3D impression will be possible, in the domain of museums and numerical archaeology. From this point of view, archaeological objects will not be only observable in display cabinets, but may be touched and manipulated by the general public. Virtual representation of objects *via* virtual reality (Oculus Rift, Samsung Gear VR) also is envisaged.
- The automatized typology/classification of ceramics will be achieved by applying probabilistic tools in the open-source software program R (http://www.r-project.org/), which is nowadays widely used in the academic environment.
- A new typology based on the form of objects will be created. Once established it will be possible to trace form changes through time.
- The know-how of ceramic producers will be possible to retrace.
- All existing forms of vases as well as those potentially existent (mathematically calculated) will be visualized, allowing better understanding of ancient ceramic productions.

The second objective of the project is dedicated to the study of the spatial management of the Celtic period in Central Europe. Once types of objects are defined by statistics and morphometrics, the tools of Geographic Information Systems (GIS), will serve to reconstruct schemes by which archaeological objects circulated from their producers to their consumers. These methods will render more visibly the material and cultural exchanges between ancient populations.

Using GIS will serve to delimitate zones of producers' economical impact, to trace more precisely passages and ancient commercial roads, to define relations between rural and urban space, or at a more intimate scale between « neighbours » occupying the same sites.

Merging results from all these methods, the objectives of the project are: (*i*) definition of ceramic productions for each period of the Second Iron Age; (*ii*) identification of their origins and geographical limitations of their distribution; in order to (*iii*) identify social and economic interactions and dynamics between cultural groups; and to (*iv*) define zones of their influences.

These aspects, observed at different scales – either "microscopic" (sites, micro-regions) or "macroscopic" (region, country) – will contribute to better understanding of the territorial organization, technological and stylistic evolution of production as well as socio-economic implications.

2. First results

The project started in September 2013. The methodological part already carried out may be briefly summarized:

1) For the studied zone and period, no archaeological database containing information about ceramics existed. At the first stage, almost all well-published sites from the zone were entered in the database. At this moment, the database contains information of *circa* 1,500 accurately geo-localized sites, 2,500 structures (graves, houses, pits, ditches, trenches) and 36,000 archaeological objects (including 27,000 ceramic entries with 10,000 individuals – *e.g.* rims – which are morphometrically exploitable).

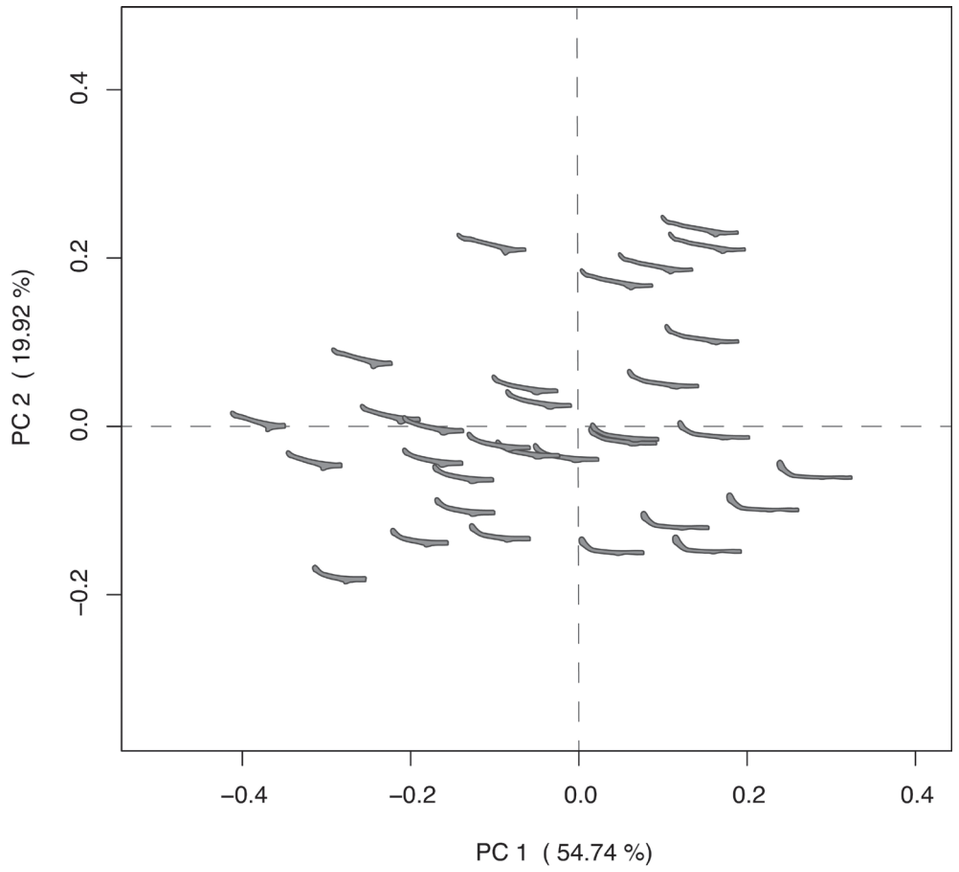

Figure 1: Projection of 32 ceramic plates from the Bibracte *oppidum* (Burgundy, France) in a PC2 vs PC1 morphospace. The morphospace is given by a PCA performed on the first 20 harmonics obtained by Elliptic Fourier Analysis (EFA) performed on the profile outlines (J. Wilczek).

2) The chronological sequence based on seriation of archaeological structures containing well-dated artefacts (brooches, jewellery, belts) was established.

3) Before the beginning of the analyses, it was necessary to make sure that the choice of methods, which at that time were only rarely applied in archaeology, were appropriate to the studied goals. For that reason, two morphometric methods (EFA, DCT) were applied to the corpus of 154 complete vases from the contemporary *oppidum* Bibracte (Burgundy). The approaches served: (*i*) to identify the most appropriate method of visualization and morphometric standardization of vases, (*ii*) to test whatever morphometrics match two traditional classifications of ceramics, and (*iii*) to show their pros and cons. Results showed that all morphometric approaches are reliable and coherent with traditional typologies. Nevertheless, it was demonstrated that morphometric methods yielded results which are not achievable by classical typologies (see Wilczek *et al*. 2014 and above for more details).

4) To prove that the strength of morphometrics is neither limited only to ceramics, nor chronologically limited, the analysis of Bronze Age flanged axes was performed. The goal of the study (Wilczek *et al*. 2015) was to propose the new flanged-axe classification based on the combination of morphometrics (EFA) and statistics (SOM, Model-based Clustering and Discrimination analysis). This new classification, validated geo-statistically (Multinomial Scan Statistics) and by spatial distribution (Kernel density) revealed complex relations between several flanged-axe productions. It is worthy of mention that the classification obtained by these methods is fully automatic, *i.e.* "on its own" and allows individuals of unknown membership to be classified (*e.g.* newly found artefacts).

Conclusion

The main goal of the project is to adapt and develop morphometric methods to study archaeological ceramics. From a methodological point of view, we hope that it will bring a normative and standardized solution, which will overcome the linguistic, temporal and spatial limitations, already evoked in archaeological literature. The approach can easily be generalized and adopted for other kinds of artefacts, to study the level of production standardization and the evolution of shape over space and time, and to provide information about material and cultural exchanges. Applied to a corpus of several thousand Central European ceramic vases dated to the Second Iron

Age, we hope that this project will considerably contribute to better understanding of archaeological sites and interaction mechanisms between Celtic populations.

Acknowledgements

I am very thankful to Carmela Chateau for her English corrections.

References

Bookstein 1997 : BOOKSTEIN (F. L.). – Landmark methods for forms without landmarks: morphometrics of group differences in outline shape. *Medical Image Analysis*, 1, 3, 1997, p. 225-243.

Brockman 1995 : BRONCKMAN (J.). – *The Third Culture: Beyond the Scientific Revolution*. New York : Touchstone, 1995.

Hodson *et al.* 1966 : HODSON (F. R.), SHEATH (P. H. A.), DORAN (J. E.). – Some experiments in the numerical analysis of archaeological data. *Biometrika*, 53, 3-4, 1966, p. 311-324.

Horáková-Jansová 1952 : HORÁKOVÁ-JANSOVÁ (L.). – Keltské *oppidum* u Hrazan na Vltavě. *Archeologické rozhledy*, 4, 1952, p. 102-106.

Jansová 1959 : JANSOVÁ (L.). – Studně na laténských oppidech I. *Památky archeologické*, 50, 1959, p. 557-578.

Jansová 1960 : JANSOVÁ (L.). – Studně na laténských oppidech II. *Památky archeologické*, 51, 1960, p. 136-160.

Jansová 1965 : JANSOVÁ (L.). – *Hrazany - keltské oppidum ve středních Čechách*. Praha : Nakladatelství Československé Akademie věd, 1965.

Jansová 1986 : JANSOVÁ (L.). – *Hrazany. Das keltische Oppidum in Böhmen. Band I. Die Befestigung und die anliegende Siedlungsbebauung*. Praha : Archeologický ústav ČSAV, 1986.

Jansová 1988 : JANSOVÁ (L.). – *Hrazany. Das keltische Oppidum in Böhmen. Band II. Die Gehöfte in der mittleren Senkung*. Praha : Archeologický ústav ČSAV, 1988.

Jansová 1992 : JANSOVÁ (L.). – *Hrazany. Das keltische Oppidum in Böhmen. Band III. Die Besiedlung der Abhänge der Červenka*. Praha : Archeologický ústav ČSAV, 1992.

Kuhl, Giardina 1982 : KUHL (K. P.), GIARDINA (G. R.). – Elliptic Fourier features of a closed contour. *Computer Graphics and Image Processing*, 18, 1892, p. 236-258.

Lestrel 1989 : LESTREL (P. E.). – Method for Analyzing Complex Two-Dimensional Forms: Elliptical Fourier Functions. *American Journal of Human Biology*, 1, 1989, p. 149-164.

Orton *et al.* 1992 : ORTON (C.), TYERS (P.), VINCE (A. G.). – *Pottery in Archaeology*. Cambridge : Cambridge University Press, 1992.

Wilczek *et al.* 2014 : WILCZEK (J.), MONNA (F.), BARRAL (P.), BURLET (L.), CHATEAU (C.), NAVARRO (N.). – Morphometrics of Second Iron Age ceramics - strengths, weaknesses, and comparison with traditional typology. *Journal of Archaeological Science*, 50, 2014, p. 39-50.

Josef WILCZEK - PhD student (cotutelle program)
Thesis supervisors: Natalie VENCLOVÀ and Fabrice MONNA
Affiliation: Université de Bourgogne Franche-Comté,
UMR 6298 ARTEHIS / ÚAM FF MU Brno
Email: *josef.wilczek@hotmail.com*