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

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Abstract:
The work of archaeologists is generally based on the classification of archaeological artefacts. Amongst all observable intrinsic descriptors (material, decoration, fabrication mode/chain of operation, 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-)automate 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

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 Bibraclte 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 ef-
ficient technological transfer between mathematics and archae-
ology 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 con-
cepts (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 at-
tribution 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 multipli-
cation 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 al-
gorithm (ICP) - an algorithm which is unexploited in archaeol-
ogy, but which is used in numerous domains requiring the 3D
reconstruction of objects from several partial views.

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

- 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 rep-
resentation 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 now-
adays widely used in the academic environment.
- A new typology based on the form of objects will be cre-
ated. 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 ex-
istent (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 archaeologi-
cal objects circulated from their producers to their consumers.
These methods will render more visibly the material and cul-
tural exchanges between ancient populations.

Using GIS will serve to delimitate zones of producers’ eco-
nomical 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 » oc-
cupying 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 ori-
gins and geographical limitations of their distribution; in order
to (iii) identify social and economic interactions and dynam-
ics between cultural groups; and to (iv) define zones of their
influences.

These aspects, observed at different scales – either “micro-
scopic” (sites, micro-regions) or “macroscopic” (region, coun-
try) – will contribute to better understanding of the territorial
organization, technological and stylistic evolution of produc-
tion 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 en-
tered in the database. At this moment, the database contains in-
formation 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).
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.

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References


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