Applying Anthropological Shape Analysis Techniques to Archaeological Research: Overcoming Problems and Exploring Possibilities

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Introduction

• The last two decades have seen geometric morphometrics (GMM) revolutionise anthropological studies of morphological variation. GMM techniques have statistical power and ready visualisation, allowing understanding and interpretation of causes of morphological variation but archaeology has only recently begun to use these techniques despite sharing materials and many other methods with bioanthropology.

• Here we discuss the possibilities and problems of applying GMM to archaeological data, using a number of recent case studies from the AnthArch morphometrics group at Durham University. The studies cross the boundaries of these disciplines and illustrate research questions in palaeopathology, migration studies, and zooarchaeology. E.g. Can GMM help us quantify disease processes? Can they aid interpretation of human migration and social change on large and local scales? What can animal remains tell us about the human past and domestication processes?

• We also highlight limitations to their application in archaeological contexts, and questions which are not readily answerable even with these advanced methods.

Methods

• Landmarks were collected directly from crania using a 3D Microscribe G2 digitizer (3D landmarking and stored standardised photograph using PHOTOSHOP) (2D landmarking. Surface scans were collected using a non-contact Konica 222 Minolta Digitizer (p=100) and warped in the PRIMER software.

• Exocentric approximations (QIA) were performed to remove site and orientation of the landmarks and principal components analysis (PCA) to explore patterns of shape variation in the sample. Shape variation was illustrated by warping the mean landmark configuration to particular positions in the shape space as relevant to the questions being asked of the data, and further illustrated using Thin Plate Splines where necessary.

• Morphological outliers in Example 2 were identified by calculating the Euclidean distance of each individual from the sample mean followed by a chi-squared statistic for each individual using a degrees of freedom where r is the number of landmarks multiplied by the number of dimensions. Statistical significance was set as p<0.05. A second iteration of this test was performed where the individual being looked at was not included in the mean (i.e. the assumption was made that each individual was an outlier).

• In order to identify short distance migration from similar geological areas a different proxy for population affinity is needed.

Example 1: Zooarchaeology

Identifying wild from domestic animal remains (Owen et al. in press)

Aim: To investigate whether GMM analyses of cranial shape can be used to provide better resolution between wild and domestic pigs (Sus scrofa).

Background: The process of domestication increases the variety of phenotypes expressed in members of the same species. Zooarchaeologists have attempted to study the geographic and temporal origins of initial animal domestication during the early Holocene.

Traditional osteometric and Historic approaches have been used to explore changes in morphology and body size over time, but this approach provides poor resolution.

Methods: GMM techniques were applied to 3D landmarks from the crania of 42 domestic modern pig (Sus scrofa) and 10 wild domestic first generation hybrid pigs and 55 wild adult boar.

Further analyses were carried out on morphologically discrete portions of the crania to stimulate the fragmented nature of archaeological mammal remains.

Results:

• It is possible to discriminate different domestic breeds on the basis of cranial morphology.

• Discrimination between wild and domestic pigs is highly significant.

• Significant discrimination is found using both cranial and visceral, the backbone, the angle of the mandible, the size of the canine, the nasal and the zygomatic.

Advantages of GMM:

• GMM allows us to identify subtle morphological characteristic distinguishing domesticated and wild members of the same species.

• Three shape differences provide a valuable insight into the implications of domestication and associated selection pressures have on animal morphology.

• The ability to accurately identify domesticated animals aids interpretation of human bioarchaeology.

Problems with working with archaeological material:

Archaeological skeletal remains are often fragmentary and this create problems when using morphometric techniques, especially on animals used for human consumption. This study illustrated that domesticated pigs can be identified based on both full cranial and individual portions of cranial bones.

Example 2: Palaeopathology

Identifying possible relationships between vertebral morphology and Schmorl's nodes (Plomp et al 2012)

Aim: To use 3D landmark data on the superior surface of the lower vertebrae, T12, L1, to identify morphological variation related to the presence of Schmorl's nodes (Plomp et al 2012).

Background: Schmorl's nodes are lesions on the superior or inferior surface of the vertebral body caused by a herniation of the nucleus pulposus of the intervertebral disc.

• Although they are a common ailment in both modern and archaeological vertebral samples, their aetiology remains unclear.

Methods:

• Schmorl's nodes were identified on cranial scans and illustrated using the EVAN toolbox.

• Statistical analysis was performed using 3D geometric morphometrics (GMM) and its application to zooarchaeology.

• Significant discrimination is possible between vertebral morphology and Schmorl's nodes (Plomp et al 2012).

Results:

• There are differences between the cases of Schmorl's nodes.

• Main differences are concentrated in the posterior elements, with a particular emphasis on the lower thoracic (T11, T12) and T13 individuals.

• The posterior elements of the sample show the most extreme shape variation in the sample and illustrate morphological associations with the presence and severity of the lesions.

Advantages of GMM:

• GMM techniques were able to identify subtle morphological differences associated with Schmorl's nodes, which may suggest vertebral morphology is one possible aetiological factor in their development.

• Quantitative data is less subjective than macroscopic description.

Problems with working with archaeological material:

• Many remains can be lost due to damage and preservation issues on archaeological sites. Use of the landmarking system can be used to map out the shape variation and then verify results on larger samples.

• Short of a consensus of the intervertebral disc.

Example 3: Population history

Identifying migrant individuals in prehistoric cemetery samples

Aim: To assess whether 3D geometric morphometric analysis of cranial landmarks can be used to identify migrant individuals from different, but closely related, parent populations.

Background: Migration is often a significant process in shaping human society. The introduction of migrant groups can significantly alter cultural change. Usually research on archaeological mobility is undertaken using strontium isotope analysis. RTI is often only effective when migrants have origins in areas with different underlying geology.

Methods:

• 3D landmarks were taken from archaeoanat'cal crania from the site of Run Nen Wat, Northeast Thailand (figure 1).

• Results of geometric morphometric analysis compared to isotopic results to assess similarities differences in information gained.

Figure 2 shows PC1 and 2 (accounting for 37% total variance), with isotopic outliers marked as shaded symbols.

• No true outliers were identified as morphologically different to the local individuals, indicating their origins in a generally similar population.

Figure 3 highlights individuals shown by two forms of chi-squared testing to be morphologically outliers (red and blue symbol).

The individuals identified as morphological outliers include:

1. All those displaying 3D upward motion (17) and 2D (16)

2. Two of the one adult animal in the collection were also a carbon isotope outlier.

These unusual characteristics are considered further evidence for external origins.

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• Significant discrimination is possible between vertebral morphology and Schmorl's nodes (Plomp et al 2012).

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• Subtle, biologically significant patterns can be detected.

Conclusion

• The great resolution and statistical power of GMM allows for re-examination of older archaeological questions, often lending new clarity to issues that were near to impossible to resolve using traditional means (such as the domestication study presented here).

• Despite this, preservation of archaeological remains is going to be a great challenge in this field, although it may be possible to work around preservation issues by using reduced dataset or multiple analyses such as in two of the studies presented here.

• Certain skeletal studies, such as those of many diseases in the past, may never be fully explored, even with GMM (and we would suggest, any other shape analysis technique), due to the lack of predictable directionality of the disease process. Thus GMM analyses are not applicable to all studies of skeletal remains.

• Thus the results of these studies indicate that GMM methods have the potential to increase our understanding of the past in terms of aetiology of disease, and morphological affiliations of both humans and their domesticates. There are limitations to their application in archaeological contexts, and questions which are not readily answerable even with these advanced methods, but there is a great deal to be gained by adopting anthropological GMM approaches more widely in archaeological contexts.