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

Una Strand Viðarsdóttir[1] , Kimberly Plomp[1,2], Charlotte King[1], Joseph Owen[3]

1) Evolutionary Anthropology Research Group, Department of Anthropology, Durham University, Dawson Building, South Road, Durham DH1 3LE 2) Department of Archaeology, Durham University, Dawson Building, South Road, Durham DH1 3LE 3) Department of Archaeology, University of Aberdeen, St Mary's Building, Elphinstone Road, Aberdeen AB24 3UF

Durham University

University of Aberdeen

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 Anth/Arch 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 3-D Microscribe G2 digitiser (3D landmarks) and from standardised photographs usingTPSdig© (2D landmarks). Surface scans were collected using a non-contact Konica 229 Minolta Digitiser (v-910) and warped in the EVAN toolbox.

•Generalised procrustes analysis (GPA) was performed to remove size 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.

•Histograms in Example 1 show results of a linear discriminant analysis with leave-one-out cross-validation computed between the cranial subsets of wild (grey) and domestic (red) pigs, with frequency on the y-axis and the discriminant function score on the x-axis. Differences between the extreme ends of the discriminant function are visualised using wireframes.

•Morphological outliers in Example 3 were identified by calculating the Euclidian distance of each individual from the sample mean followed by a chi-squared statistic for each individual using *n* degrees of freedom (where *n* is the number of landmarks multiplied by the number of dimensions). Statistical significance was set as $p = 0.01$. 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 a priori that each individual was an outlier).

Example 1: Zooarchaeology

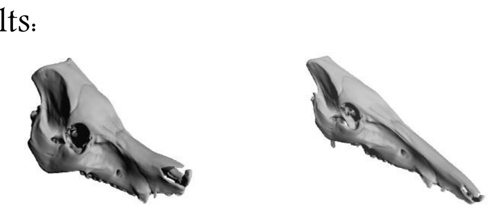
Identifying wild from domestic animal remains (Owen *et al.*, in press) .

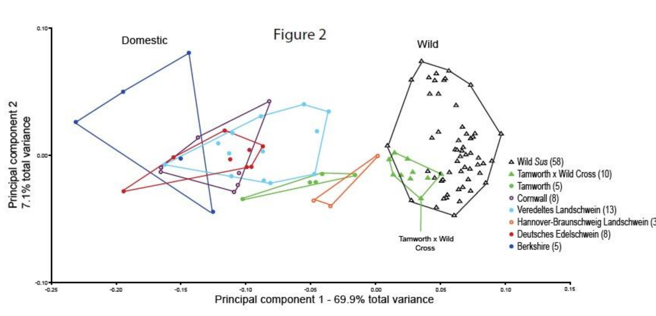
Aim:
To investigate whether GMM analyses of cranial shape can be used to provide better resolution between wild and domestic pigs (*Sus scrofa*).

Background:
- The process of domestication increases the variety of phenotypes expressed in animals.
- Zooarchaeologists have attempted to study the geographic and temporal origins of initial animal domestication during the early Holocene.
- Traditional osteological and biometric approaches have been used to explore changes in morphology and body size over time, but this approach provides poor resolution.

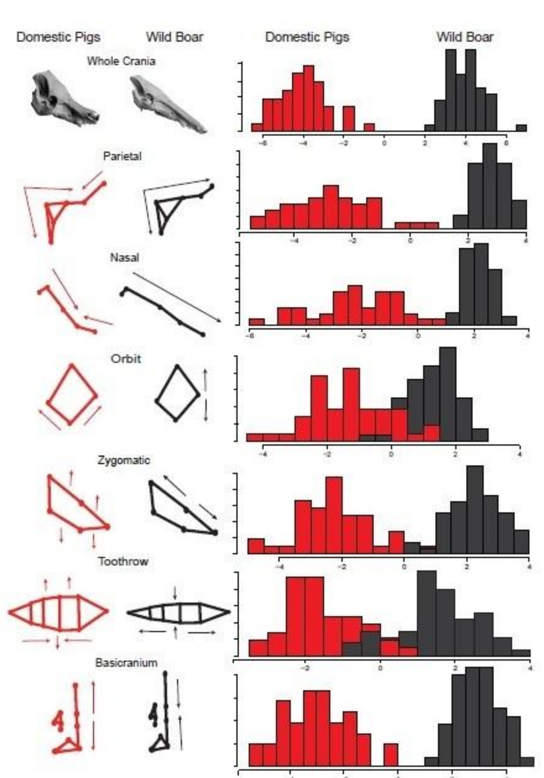
Methods:
- GMM techniques were applied to 3D landmarks from the crania of 42 modern domestic pigs (6 breeds), 10 wild-domestic first generation hybrid pigs, and 55 wild adult boar.
- Further analyses were carried out on morphologically discrete portions of the crania to simulate the fragmented nature of archaeological mammal remains.

Results:





- It is possible to discriminate different domestic breeds on the basis of cranial morphology.
- 1st generation hybrid (wild x domestic) pig morphology more closely resembles wild pigs than domestic, suggesting that wild morphology is dominant over recessive domestic morphology.



- Discrimination between wild and domestic pigs is highly significant.
- Significant discrimination is found using both whole crania, and subsets of the parietal, the basicranium, the angle of the nasal and the zygomatic.

Advantages of GMM:
- GMM was able to identify subtle morphological characteristics distinguishing domesticated and wild members of the same species.
- These shape differences provide a valuable insight into the implications domestication and associated selection pressures have on animal morphology.
- The ability to accurately identify domesticated animals aids interpretation of human history, migration and trade routes.

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 crania and individual portions of cranial bones.

Acknowledgements
Co-authors of the paper not included on the authorship of this poster are K. Dobney, G.Larson, A. Evin, P Rowley-Conwy, and T Cucchi.. We thank the many institutions and individuals that provided sample material and access to collections . This research was funded by a NERC grant NE/F003382/1.

J Owen, K Dobney, A Evin, T Cucchi, G Larson and **U Strand Vidarsdottir** (in press): Quantifying cranial shape differences between wild boar and domestic pigs (Sus scrofa) using 3D geometric morphometrics, and its application to zooarchaeology *Journal of Archaeological Science*

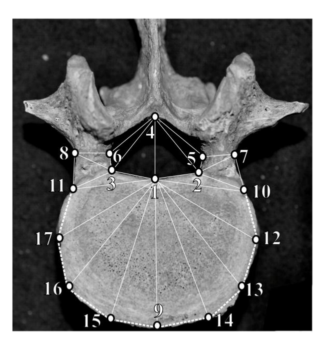
Example 2: Palaeopathology

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

Aim:
To use 2D landmark data on the superior surface of the lower vertebrae, T12-L4, to identify morphological variation related to the presence of Schmorl's nodes (Plomp et al. 2012).

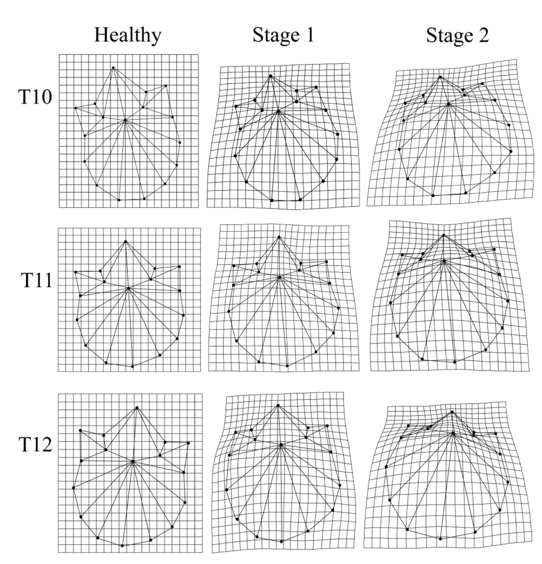
Background:
- Schmorl's nodes are lesions on the superior or inferior surface of the vertebral body caused by a herniation of the nucleus pulposus of the intervertebral disc.
- Although they are a common ailment in both modern and archaeological times, their aetiology remains unclear.

Methods:
- Schmorl's nodes were recorded based on depth and size. Smaller, shallower lesions were categorized as Stage 1 and deeper, larger lesions were categorized as Stage 2 (based on Knusel et al. 1997).



- 2D landmarks were digitised on the superior surface of 322 vertebrae from the lower thoracic spine (T10-T12) of 132 individuals (Medieval/Post-Medieval English).
- GMM methods were used to identify shape variation in the sample and illustrate morphologies associated with the presence and severity of the lesions.

Results:



- There are morphological differences between healthy vertebrae and those with Schmorl's nodes. Severe lesions (Stage 2) show the more extensive shape differences from healthy vertebrae.
- Main shape differences are concentrated in the posterior elements, with a posterior translation of the vertebral margin into the neural canal and a relative shortening of the pedicles.

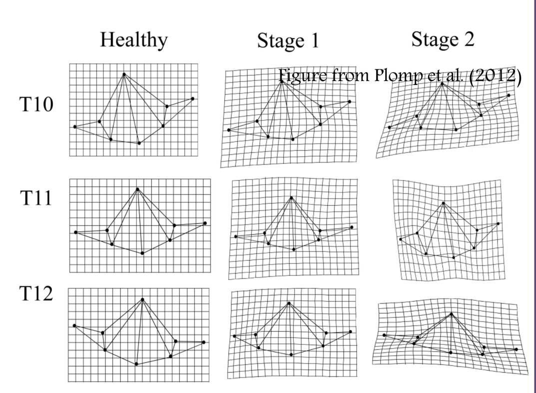


Figure from Plomp et al. (2012)

- Vertebral bodies are often damaged in archaeological situations. A subset of the landmark configuration (the 8 landmarks of the posterior elements) can be used to verify results with an increased sample size.
- The shape differences identified in the 8 landmark set are the same as in the 17 landmark set.

Figure from Plomp et al. (2012)

Advantages of GMM:
- GMM techniques were able to identify subtle morphological characteristics associated with Schmorl's nodes, which may suggest vertebral morphology is one possible aetiological factor in their development.
- Quantified data is less subjective than macroscopic description.

Problems with working with archaeological material:
Many landmarks can be lost due to damage and preservation issues on archaeological bone. The use of multiple landmark sets can be used to investigate shape variation and to verify results on larger samples.

Acknowledgements
Special thanks to co-author Prof. Charlotte Roberts Thanks to the Museum of London and Durham University for access to the skeletal remains analysed in this study. This research was funded by Durham University and the Canadian Centennial Scholarship fund.

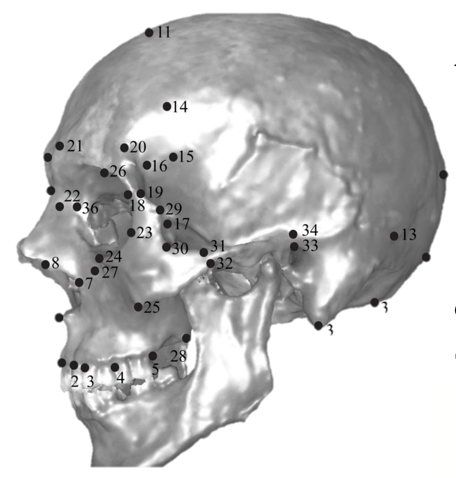
KA Plomp, CA Roberts, U Strand Vidarsdottir (2012): Vertebral Morphology Influences the Formation of Schmorl´s Nodes in the Lower Thoracic Vertebrae. *American Journal of Physical Anthropology* 149:572-582

Example 3: Population history

Identifying migrant individuals in prehistoric cemetery samples.

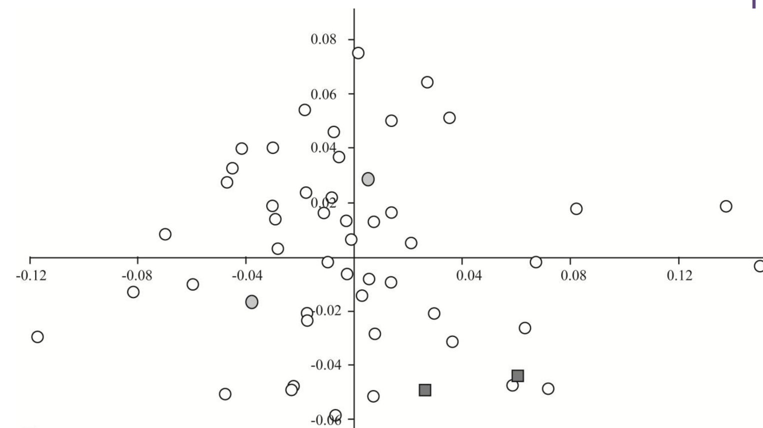
Aim:
To assess whether 3D geometric morphometric analysis of archaeological crania can be used to highlight individuals from different, but closely related, parent populations.

Background:
- Migration is often a significant process in shaping human society. The introduction of migrant groups can seriously affect cultural evolution. Usually research on archaeological mobility is undertaken using strontium isotope analysis BUT this is only effective when migrants have their origins in areas with different underlying geology.
- In order to identify short distance migration from similar geological areas a different proxy for population affinity is needed.

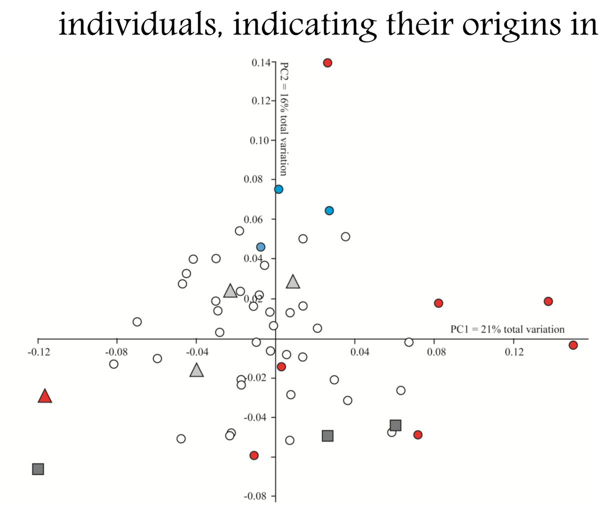


Methods:
- 3D landmarks were taken from archaeological crania from the site of Ban Non Wat, Northeast Thailand (figure 1).
- Results of geometric morphometric analysis compared to isotopic results to assess similarities/ differences in information gleaned.

Results:
- Figure 2 shows PCs 1 and 2 (accounting for 37% total variace), with isotopic outliers marked as shaded symbols.



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



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

The individuals identified as morphological outliers include:
1) All those displaying 6th cusped molars (B17 and B246)
2) One of the two adult jar burials at the site (B28, also a carbon isotope outlier).

These unusual characteristics are considered further evidence for external origins.

Advantages of GMM:
Advantages of GMM in this context include:
- The non-invasive and non-destructive nature of analysis
- Speed and low-cost of analysis cf. isotopic studies.
- Subtle, biologically significant patterns can be detected.

Problems with working with archaeological material:
The fragmentary nature of some archaeological samples means that landmarks must be chosen with care.
In order to identify short-distance migration/pinpoint origins, morphological variation in the possible parent populations must be fully characterised.

Acknowledgements
Co-investigator s not included on the authorship of this poster are RA Bentley, N Tayles, G Nowell and CG Macpherson. Thanks go to Prof. Charles Higham, Dr Rachanie Thosarat , Earthwatch and the people of Ban Non Wat for access to the collection. This work was made possible through an AHRC UK grant: AH/F009275/1

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 fields of shape study, 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 affinities 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.

Natural Environment Research Council
The Leverhulme Trust
Arts & Humanities Research Council
Canadian Centennial Scholarship Fund