



Book of Abstract

MORPH 2019 Sendai

A conference on the Archaeological Application of Morphometrics

13-15 September 2019

at Tohoku Forum of Creativity, Tohoku University, Sendai

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## General Program

13 September

AM: Registration (no lunch meal provided)

PM (13:00~16:30)

Workshop #01 *Introduction to Geometric Morphometrics in Archaeology*

by Christian Steven Hoggard (Southampton University)

evening: Icebreaker

14 September

AM (9:00~12:00)

Workshop #02 *Reproducibility and Transparency in Archaeological Science using R*  
and Related Tools by Ben Marwick (The University of Washington)

lunch

PM: Plenary Session *Recent Progress of Morphometrics in Archaeology and Anthropology*

Evening: Conference Dinner

15 September

AM and PM: Oral and Poster Presentations

16 September

Guide Tour to Tomizawa Site Museum (in Sendai City) \*optional

## Workshop #01

# Introduction to Geometric Morphometrics in Archaeology

Christian Steven Hoggard

This workshop is designed to provide an introduction into the application and potential of geometric morphometric (GMM) methodologies for archaeologists, researchers and enthusiasts. The workshop first introduces participants to the mathematical underpinnings of statistical shape and form, before detailing the fundamentals of geometric morphometrics, emphasising its statistical power and convergence in comparison to traditional morphometrics.

Through two practicals, one landmark-based and one outline-based, this workshop details the complete workflow from data acquisition to subsequent analysis and interpretation. While a high degree of technical knowledge is necessary, an incredible amount of analytical possibility can be harnessed through the adoption of two- and three-dimensional GMM methodologies.

**Software:** All data input, manipulation and analyses will be performed in the R Environment through geomorph and Momocs. Please ensure R/RStudio and all files are downloaded onto your computer/laptop before or at the beginning of the workshop. Run the Setup.R file in R/RStudio to ensure all packages are downloaded. Other digitisation methods including tpsDig2 (<https://life.bio.sunysb.edu/morph/soft-dataacq.html>) and GUImorph (<https://github.com/GUImorph/GUImorph>) will also be showcased.

### **Practical One** (Landmark Analysis: Generalised Procrustes Analysis)

Using a sample cranial dataset this practical will explore some of the features used through geomorph, including digitisation, the GPA procedure, and the analysis of Procrustes coordinates.

### **Practical Two** (Outline Analysis: Elliptic Fourier Analysis)

This is a modified R script from The Application of Elliptic Fourier Analysis in Understanding Biface Shape and Symmetry Through the British Acheulean in the Journal of Palaeolithic Archaeology (<https://doi.org/10.1007/s41982-019-00024-6>). Three files are required for this practical: 1) the script (practical\_two.r), 2) the outline data created in the TpsSuite (practical\_two.tps), and 3) the metadata in .csv format (practical\_two.csv).

For any queries please contact [C.S.Hoggard@soton.ac.uk](mailto:C.S.Hoggard@soton.ac.uk)

### **Suggested Reading**

- Adams, D.C. and Otárola-Castillo, E. (2013). Geomorph: an r package for the collection and analysis of geometric morphometric shape data. *Methods of Ecology and Evolution* 4, 393-399.
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- Bookstein, F.L. (1991). *Morphometric Tools for Landmark Data: Geometry and Biology*. New York: Cambridge University Press.
- Kovarovic, K., Aiello, L. C., Cardini, A. and Lockwood, C. A. (2011). Discriminant function analyses in archaeology: Are classification rates too good to be true? *Journal of Archaeological Science*, 38(11), 3006–3018.
- MacLeod, N. (1999). Generalizing and extending the Eigenshape method of shape space visualization and analysis. *Paleobiology*, 25 (1), 107–138.
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- Yoshioka, Y. (2004). Analysis of petal shape variation of *Primula sieboldii* by elliptic fourier descriptors and principal component analysis. *Annals of Botany*, 94(5), 657–664.
- Zelditch, M.L., Swiderski D.L., Sheets H.D. and Fink, W.L. (2004). *Geometric morphometrics for biologists: a primer*. San Diego (CA): Elsevier Academic Press.

Workshop #02

Reproducibility and Transparency in Archaeological Science  
using R and Related Tools

Ben Marwick

Plenary Session

## Recent Progress of Morphometrics in Archaeology and Anthropology

14 September at Tohoku Forum of Creativity 3<sup>rd</sup> floor

13:20~14:10

1. Typology and morphometrics: How we see and interact with things  
by Naoko Matsumoto (Okayama University)

14:10~15:00

2. What Shape can tell us about Homo erectus' Mind  
by Cory Marie Stade (Southampton University)

(15:00~15:20 *Coffee Break*)

15:20~16:10

3. Integration and modularity of the primate pelvic girdle  
by Katrien G. Janin (The University of Cambridge)

16:10~17:00

4. Inferring the anatomy of the Neanderthal brain using geometric morphometrics  
by Naomichi Ogiwara (The University of Tokyo)

## 1. Typology and morphometrics: How we see and interact with things

Naoko Matsumoto

In both English and Japanese, and probably also in many other languages, 'to see' means "to know, understand and think". How we see things is closely related to how we think. In this talk, I first propose this point referring to a specific nature of typological study of pottery in Japan, and then discuss its implications for our endeavor to elucidate the cognitive characteristics of people in the past.

Typology as the classification of objects for constructing a spatio-temporal framework as a basis for archaeological researches was established in the 19th century and has been practiced widely in the world. While its chronological significance has faded since the development of radiocarbon dating, typological study has remained at the core of education and research in Japanese archaeology to date. The strong tradition of typological analysis is coupled with the skill of drawing which has been considered as one of the most essential archaeological abilities. The standardized method of archaeological drawing of pottery is useful as it represents many important features which we cannot recognize on photographs, but at the same time, it restricts the way we see the objects and how to think about them. By learning how to draw pottery with your body and mind, you also learn how to think about the objects. This practice may be related to the fixation of the main stream paradigm in Japanese archaeology. Small number of statistical or mathematical analysis of the shape of pottery have been practiced for decades in Japan, but they have been mostly regarded as unorthodox.

The recent explosive development of computer-aided technologies to record, measure and analyze not only shapes, but also the movement of the body and the working of the brain, seems to bring a breakthrough in archaeological thinking. If we can reconstruct how the ancient people saw with a new morphometric analysis, we may be able to discuss how their mind and object interacted through their body. I will elaborate the discussion with an example of Jomon pottery and the subsequent Yayoi pottery.



## 2. What Shape can tell us about Homo erectus' Mind

Cory Marie Stade

As archaeological morphometricians we are invariably interested in the form artefacts take, and how they change over time and across space. The end goal of our study is to better understand the behaviour of the makers and users of these artefacts. Cognitive archaeology is the study that connects these interpreted behaviours to the workings of the mind. In this way, we can build a bridge from artefact form and shape, to behaviour, to what ancient minds were like. I will explore different works that connect shape to cognition, including two case studies of my own research. In the first, shape is connected to mind through how copying fidelity affects levels of standardisation at the assemblage level. In a lithic knapping experiment, different simulated social learning methods, which use increasing levels of cognitive sophistication, are shown to produce decreasing levels of morphological variability in a geometric morphometric analysis of 2D outline shape. The conclusion is that very low level of morphological variability in a sophisticated technology may only be possible by a community with sophisticated copying mechanisms. Copying is cognitively complex, and requires the copier to think about the thoughts of others – called ‘theory of mind’. Theory of mind, in turn, relies on language for its development. The makers of idiosyncratic tools therefore may have also been language users. In the second case study, with Dr John McNabb, we take a new look at the shape of Acheulean artefacts from Olduvai Gorge, Tanzania. Resourcefully collected from archived trace outlines, hundreds more handaxes from this site have been made available for our analysis. Both outline shape and symmetry are combined in an innovative metric, and examined at different localities at Olduvai. Even when dealing with artefacts over such a range of time, we find a general similarity in both median values and the range of values over different localities and timeframes. Certain shapes do not appear more symmetrical than others, which would be expected if certain sites or groups of artefacts were producing handaxes which had more intentional shaping to them. Has this metric captured a general lack of differentiation in intentional shaping? Does stability in shape represent stangnancy, or complex cultural transmission? With these two studies, this presentation will emphasise the far-reaching implications morphometric studies have for not only human behaviour, but for understanding the mental worlds of our ancestors.

### 3. Integration and modularity of the primate pelvic girdle

Katrien G. Janin

Integration and modularity are connected concepts that have become a central framework within evolutionary biology, providing a unifying theory of organismal structured patterns and variation to those patterns that can be applied at multiple hierarchical levels. The concepts are similar to those used in systems theory and network analysis, conceptualizing biological organisms as a system of parts working together through a series of networks with the interrelated parts having varying degrees of interconnectedness among them.

Precise definitions of integration and modularity are surprisingly elusive. At its broadest definition, morphological integration refers to the level of cohesion, the tendency for parts to be interlinked and consequently shape changes in a coordinated manner. A morphological module is a unit (e.g. morphological trait, anatomical element, etc.) that displays high levels of internal integration but between such modules low levels of integration exist, enabling them to operate relatively independent from each other. Modularity refers to the relative degrees of integration within the model system. Integration and modularity together configure the structured pattern that governs shape.

Why is it important to study the structured patterns? A strongly integrated pattern constrains adaptation and restricts evolutionary options as traits must evolve together, whilst a more modular organisation tends to facilitate evolutionary divergence since selection can act relatively independently on each module. Gaining an understanding of the structured pattern and being able to recognise divergence in those patterns are key to gaining insights of the evolutionary processes at work.

My research centres around the pelvis structure of humans and of our closest relatives, the non-human primates. The pelvis represents an interesting model system for the study of modularity and integration since primates display greater diversity in pelvis morphologies compared to other mammal groups. What enabled them to do so, and how changes to the structured pattern may have facilitated human bipedalism are the focus of my investigation.

The presentation consists of three main parts: firstly, I will explain the core concepts of integration and modularity; and secondly how I applied these concepts using GMM to investigate the structured pattern within the primate pelvic girdle. I shall close the presentation by highlighting how these evolutionary biological concepts equally may serve archaeologists researching artefact changes through time.

#### 4. Inferring the anatomy of the Neanderthal brain using geometric morphometrics

Naomichi Ogihara

The causes of the replacement of Neanderthals by anatomically modern humans remain key questions in paleoanthropology. One hypothesis that possibly explains the disappearance of Neanderthals and expansion of *Homo sapiens* is the differences in the cognitive or neural function between the two populations resulting from anatomical differences of the brain. To infer possible morphological differences in brain anatomy between the two species, we attempted to virtually reconstruct the brains of Neanderthals and early *Homo sapiens* using geometric morphometrics. Computed tomography scan data of Neanderthals and early *Homo sapiens* were obtained and 3D ecto- and endocranial surface models were virtually reconstructed using anatomical and sliding semi-landmarks defined on the surfaces. Then we reconstructed the brain morphology of each fossil cranium using a spatial deformation function. Specifically, the 3D structure of the average human brain and endocast were obtained by MRI scans from living humans, and the 3D structure of the fossil brain was reconstructed by deforming the human brain using the deformation function from the human endocast to each fossil endocast. The volume of each brain region was also estimated using the neuroanatomical labels for the brain locations. The virtually reconstructed fossil brains revealed that early *Homo sapiens* had relatively larger cerebellar hemispheres but a smaller occipital regions in the cerebrum than Neanderthals. Such a neuroanatomical difference in the brain may have caused important differences in cognitive and social abilities between the two species and might have contributed to the replacement process.

## Oral and Poster Presentations

15 September at Tohoku Forum of Creativity 3<sup>rd</sup> floor

### Time table

No.	Time	Title	Author
	9:00	<i>Opening address</i>	
1	9:10~ 9:35	Estimating Missing Landmarks in GMM	Hist <i>et al.</i>
2	9:35~10:00	Canonical Variate Analysis	Hist <i>et al.</i>
3	10:00~10:25	Lithic Illustrations in Morphometric Analyses	Hoggard <i>et al.</i>
	10:25~11:00	<i>Coffee break</i>	
4	11:00~11:25	Morphometric and Experimentative approaches for Strategic Diversity	Kumagai
5	11:25~11:50	EUP lithic technology in NE Paleo-Honshu Is.	Noguchi <i>et al.</i>
	11:50~12:00	Discussion	
	12:00~13:00	<i>Lunch</i>	
	13:00~14:00	<b>Poster core time</b>	
6	14:00~14:25	Understanding technology through shape	Pederson and Riede
7	14:25~15:00	Shaping the terminal Pleistocene bifaces	Noguchi <i>et al.</i>
	15:00~15:30	<i>Coffee break</i>	
8	15:30~15:55	Relationship between Ancient Shell and Stone Adze	Yamagiwa and Tamura
9	15:55~16:20	Beyond Relative-Chronologies	Loftus
10	16:20~16:45	Investigating social change during cultural contact period	Wang and Marwick
	16:45~16:50	Discussion	
	16:50~17:00	Closing remarks	

### Poster presentation

No.	Title	Author
1	The Genetic Architecture of Facial Traits among West African	Olowo
2	Geometric Morphometrics of human fetal brain development	Yamaguchi <i>et al.</i>
3	Morphological similarity of pottery	Tateuchi
4	3D surface morphology of hammer stones	Noguchi <i>et al.</i>
5	Morphology of Middle Yayoi Pottery in northern Kyushu	Hirakawa <i>et al.</i>
6	EFA on the Ongagawa Yayoi Pottery	Tamura <i>et al.</i>
7	Quantifying the morphological trend of key-hole shaped Kofun	Tamura <i>et al.</i>
8	Quantifying morphological variation of Bronze and Iron arrowheads	Tamura <i>et al.</i>

## Oral Presentations

### 1. Estimating Missing Landmarks in GMM

Cara S. Hirst, Annabelle L. Lockey and Carolyn Rando

In archaeological research one of the greatest issues is the preservation of material, especially for human skeletal remains. Various natural taphonomic processes can act upon remains, as well as human induced ones, such as excavation damage or even some mortuary practices that can impact sample size. Geometric Morphometrics (GMM) requires the consistent placement of homologous landmarks on the entire sample, as such even a small amount taphonomic damage can result in exclusion from a GMM study, making GMM studies more susceptible to preservation limitations. Methods are available to estimate missing landmarks which can reduce the impact of poor preservation, however the accuracy of these methods are influenced by several variables such as the landmarks utilised, size and relevance of a reference sample, specimen and skeletal elements, number of landmarks missing, and the location of missing landmarks. It is therefore necessary to determine the most suitable estimation method and identify the error introduced on a case by case basis rather than relying on previously published methods. This paper details a method for determining the most suitable estimation method in GMM studies which can be applied to different samples and research methodologies.

The proposed method is illustrated in a case study. A sample of 606 modern human archaeological mandibles were analysed to determine the most suitable method for estimating missing landmarks. The first stage of analysis involved documenting the preservation and estimation requirements of the sample. This included understanding the proportion of incomplete individuals in the sample, the number of landmarks missing for each individual, which landmarks were most frequently missing and the mean number of landmarks missing. Four estimation methods were then used to estimate missing landmarks in R using the packages Geomorph (TPS and Multivariate regression method) and Morpho (TPS and Mirroring across an empirical midplane). This study investigated how the accuracy of these methods varied between specimens, landmarks and the number of missing landmarks and determines that the most suitable method to be utilised in this case. As no method produced a suitably low level of error when estimating landmarks from a hemi-mandible (50% of missing landmarks) it was determined in this case that only individuals with fewer than 9 missing landmarks would be included and landmarks would be estimated using Mirroring across an empirical midplane in Morpho which produced <2mm of error for each landmark making this method comparable to the intra-observer error.

## 2. Canonical Variate Analysis: In the shadow of Principal Component Analysis

Cara S. Hirst and Carolyn Rando

Principal Component Analysis (PCA) is generally considered the standard statistical analysis in geometric morphometrics (GMM), particularly in 3D landmark based geometric morphometric studies. Conversely, Canonical Variate Analysis (CVA) is relatively underused in GMM research. PCA produces Principal Components, which in the case of GMM studies reflect the total shape variation, while CVA analysis focusses on group differences in shape variation. Despite the fact that many anthropological and archaeological GMM studies focus on investigating shape differences between groups such as sex estimation, age, time periods, species or populations PCA is still more frequently employed compared to CVA.

The aim of this paper is to encourage researchers to consider including CVA when applicable to their research. The benefits of CVA are discussed, outlining previously published research which demonstrates the analytical value of CVA. This issue is further explored in two case studies. The first case study demonstrates at the value of CVA in a landmark based 3D GMM study of mandible morphology. 777 mandibles were 3D scanned and 46 landmarks were placed. Originally in keeping with the majority of previously published literature PCA was conducted. It was found that even the first two PC's represented a relatively small proportion of the total shape variation in the sample and showed no discernible pattern or separation between the groups. Subsequently CVA was conducted which revealed significant differences between the six time periods analysed, illustrating that mandible morphology became increasingly gracile over time with significant differences occurring three times in British history.

The second case study explored previously published research of a 2D landmark based GMM study of modern human cranial and mandible variation between Medieval (n= 86) and Post-Medieval (n= 100) British assemblages. Originally this research only presented results from PCA which showed little difference between the time periods, despite linear calliper measurements demonstrating significant differences between time periods. These results conflict with published literature which argue for the relative superiority of landmark GMM methods over linear measurements. These data were re-examined and CVA was conducted. Results from the CVA show significant differences between the Medieval and Post-Medieval assemblages which are consistent with the results from the 3D GMM discussed above. Furthermore, results demonstrated significant morphological differences between the early and late Medieval assemblages which had not previously been reported from PCA or linear measurements.

### 3. Evaluating the Suitability of Lithic Illustrations in Morphometric Analyses

Christian Steven Hoggard, Thomas Birch, Cory Marie Stade, Katrien Janin and Felix Riede

Illustrations of lithic artefacts are an abundant source of morphological and technological information for those interested in our human past. As a typical part of archaeological reports and publications, lithic drawings are - or have to be – trusted as faithful reproduction of the selected artefacts. Despite the considerable epistemic work lithic illustrations are expected to do, usually little information is available regarding the illustrator's technical skill; thus, it remains unknown whether illustrations of differing technical skill in drawing lithics are comparable or produce images of equal analytical potential to other media, e.g. photographs. The issue of lithic illustration accuracy is brought to the fore by the recent emergence of geometric morphometric approaches as innovative and powerful ways of describing and analysing complex shapes, as lithic illustrations provide one of the key sources for such analyses. Motivated by these issues, we present an experiment investigating the degree of error observed in illustrations of differing technical illustrative skill.

Analyses suggest that lithic illustrations produced by individuals with a variety of experience in drawing lithics create, in the majority of instances, equally faithful representations (in outline shape) of chipped stone artefacts. With error observed in a small number of instances, archaeologists are still urged to be critical of an illustration's source prior to lineal and geometric morphometric methodologies. However, despite this, archaeologists can be confident in their exactitude and we remain strong advocates in favour of lithic illustrations as a readily available legacy resource for morphometric analyses.

#### 4. Morphometric and Experimentative approaches for Strategic Diversity of Higashiyama Blade Industry

Ryosuke Kumagai

Higashiyama blade industry characterizes the North-Eastern part of Japan in the late Upper Paleolithic (28,000cal BP~). These blades were concentratedly produced at certain production sites nearby lithic resources, and transported into several functional sites to be used for various activities. This strategy shows their high mobility, high ability of resource prediction and planning, but its details are still not unveiled.

The aim of this study is to understand strategic diversity of Higashiyama blade industry. Functional studies of stone tools could play important role in the research of human strategic behaviors. In addition, morphometric and experimentative approaches will be useful to reveal the relationship between functions and morphological information of stone tools as results of human strategic behaviors which may differ by each situation.

First, I compared plane figures of excavated blades and knife blades from 3 sites in Yamagata Prefecture mainly using Elliptic Fourier descriptor. Subjects were divided into some groups by their excavated sites and useware traces like as meat-cut polishes and impact fractures, etc.

Second, I arranged a thrusting experimentation of stone-tipped wooden spears. Higashiyama type knife blade has been considered that the tools were used as spearheads based on their breakage patterns. The 20 replicas were hafted to wooden foreshafts using animal glue mixed with red iron oxide for cementing. A half of the replicas were connected with relatively light weight wooden shafts (400g) and others were attached with heavy shafts (600g). 3D measurements of replicas were taken before the experiments in order to analyze the effects of twist and curve to frequencies and sizes of impact fractures.

It is clear that the relationship between functions and morphological information of stone tools are not consistent in each site. It seems to be strongly affected by the situation or kind of activities in the site. Experimentative approach shows that shapes and sizes of spearheads have an effect to their own breakage patterns by impact. These results show us a part of the complex and developed human strategic behaviors, but also show new criteria for reach them in future researches.

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## 5. Geometric morphometrics and techno-morphology of the EUP lithic technology in NE Paleo-Honshu Island

Atsushi Noguchi, Yusuke Sato, Rei Watanabe and Kazuhiko Kanda

The Early Upper Palaeolithic in the mainland (Paleo-Honshu Island) of Japanese Archipelago is generally described as the component of 'blade-mode' and 'flake-mode' of technology as well as heavy duty tools such as pebble tools and axe-shaped tools. It is considered that blade-mode is curated to produce elongated-convergent flake which modified to 'base-retouched tool', while 'flake-mode' is under expedient operation. Also, the simple linear evolutionary idea that the EUP 'blade-mode' and 'base-retouched tool' developed into 'advanced' blade technology and backed tools is widely accepted. In this regard, EUP 'blade-mode' is evaluated as the basement of Upper Palaeolithic technology in the Japanese Archipelago.

On the contrary, the authors have different idea as follows:

- 1) The EUP lithic technology is totally different from 'advanced' blade technology in the later period both in its concept and technological method;
- 2) Both 'blade-mode' and 'flake-mode' are based on similar technological method with less core modification through its reduction sequence;
- 3) Therefore, shape of debitage is unstable, depend on the condition of core which modified by previous flaking performances.

These technological characters are recognized on refitted material and examined by reconstructive experiments.

For further examination of technological character, the authors apply geometric morphometric analysis on 'base-retouched tool' and elongated-convergent flakes as expected products. If the production of elongated-convergent flake is curated as considered, the shape must be less variable. Or if retouches observed on 'base-retouched tool' are for curating shape of the tool, differences of shape from elongated-convergent flake must be correlated to retouched part. These hypotheses are examined among archaeological samples from excavated sites in Akita Prefecture, northeastern Honshu Island. The result is opposite from expectation. Shape of elongated-convergent flake is variable. And variation of shape recognized on 'base-retouched tool' is not correlated to retouched parts. These suggest that shape of both 'base-retouched tool' and elongated-convergent flake is not curated as considered and retouches on 'base-retouched tool' is not for maintaining uniform shape of tool.

This observation gives us the interpretation that the EUP lithic technology is less controlled for curation of shape of both debitage and tools. Such technological concept and method are far different from the IUP blade technology in North Asia and beyond. This leads us to re-examine the Japanese EUP lithic technology in relation with East and Southeast Asian perspective.

6. Understanding technology through shape  
- a mixed-method approach to examining the impact of individuals in the Upper  
Palaeolithic Hamburgian culture

Jesper Borre Pedersem and Felix Riede

The pioneer colonisation of northern-central Europe and southern Scandinavia is associated with the Hamburgian culture (~14,700-14,000 cal BP) and understood as an enduring process spanning almost a millennium with continuity to subsequent cultural traditions. The Hamburgian is traditionally divided into an earlier and more eastern 'classic' and a later and more north-western 'Havelte' phase. However, these two phases diverge only in their diagnostic projectile point forms rather than in any other aspects of their lithic repertoire or their economy. They furthermore overlap chronologically and spatially, making them somewhat awkward to handle archaeologically. The Hamburgian technological tradition consists of quite unique knapping behaviours and contrary to the traditional interpretation, does not seem to be connected with those of the subsequent Federmessergruppen. Additionally, the archaeological record reflect the Havelte occupation of southern Scandinavia as brief and ephemeral. Preliminary 2D GMM studies of the diagnostic projectile points from these sites suggest that this occupation may only reflect the presence of few individuals closely related temporally and socially and that its seemingly abrupt end may reflect a local extinction. This project therefore examines an entirely novel explanation for both the transition between 'classic' to 'Havelte' and the latter's sudden and complete disappearance. The aim is to develop a mixed-method approach where GMM and traditional technological lithic analyses are combined in order to identify individual signatures more clearly. Combining these different artefact data may give a meaningful understanding of the technological and morphological variability inherent in the Hamburgian and shed light on this earliest colonisation.

## 7. Shaping the terminal Pleistocene bifaces in the Japanese Archipelago : between reduction strategy and isocrestic style

Atsushi Noguchi, Shin Yokoyama, Fumito Chiba and Masao Kosuge

Following the spread of micro-blade technology over the area, bifacial laurel leaf point becomes dominant of lithic assemblage in the terminal Pleistocene Japanese Archipelago. It is parallel with the emergence of earliest pottery therefore the period is archaeologically described as the Incipient Jomon as well. The character of laurel leaf point in this period its morpho- technological uniformity and sequential changes in shape. Mass production in source sites and long-distance transportation of supports and products is another key feature of lithic technology in this period.

In the earliest stage of this period of the central Honshu Island, both 'Mikoshiha' and 'Yokokura' type of laurel leaf points are widely distributed. Shape of these points are very similar. Mass production sites are located nearby sources of obsidian, glassy andesite or rhyolite (so-called Gero stone as well). Reduction of biface form is recognized through long-distance transportation into basin or plain area far from sources in mountain.

For examining similarity on shape through the reduction sequence, the authors apply geometric morphometric analysis on samples from 2 source sites of glassy andesite (Happu- san and Shimomouchi) and the terminal site in remote area (Yokokura). The result shows that the range of shape variability in the terminal site is narrower than source sites and it is well-correlated to reduction of size from source to remote area. This suggest that the reduction strategy with maintaining shape of tool is obviously adopted in the period, just before the spread of semi-sedentary settlement system of Jomon. The emergence of isocrestic style of lithic tool is related to socio-economic context at the terminal Pleistocene as same as other changes.

## 8. Relationship between Ancient Shell and Stone Adze Artifacts in the Southern Ryukyu Islands: A Morphological Analysis Using Elliptic Fourier Analysis

Kaishi Yamagiwa and Kohei Tamura

In the Southern Ryukyu Islands which southwestern end of Japan archipelago, a prehistoric pottery culture was appeared at least 4,800 BP, but this potsherd usage had lost by 2,800 BP, no-pottery prehistoric culture named “the Aceramic phase (Mudoki-ki)” had developed until 900 BP. The Aceramic phase was also characterized by “Giant clam (*Tridacna*/*Hippopus*) shell adzes”, some previous studies regarded this adze as an evidence of migration from the southward regions because similar shell adzes were found in the southern Philippines.

On the other hand, the artifacts of Aceramic phase contained not only shell adze but also stone adze, each adze showed different regional distribution in the Southern Ryukyu Islands, which regional variation was considered as result of different cultural migrations or material usage adapting for each geological island environment like a coral island lacking stone material in previous studies. Therefore, the commonality or differences between shell adze and stone adze is attracting considerable attention. However, a comparative study of these adzes did not prosper, especially morphological comparative analysis was few because quantifying their form was difficult.

In this study, we conducted a morphological analysis of ancient shell adzes and stone adzes in Southern Ryukyu Islands using Elliptic Fourier Analysis. Our method was successful in quantifying their morphological variation, and our comparative analysis showed that their formal commonality was high. Our result suggested that shell adze and stone adze in the Aceramic phase had same function and Production process, which assisted that the ancient people in the Southern Ryukyu Islands used shell adze or stone adze for each island environment.

## 9. Beyond Relative-Chronologies

### : Towards a Model of Pottery Morphometric Analysis in Prehistoric Societies

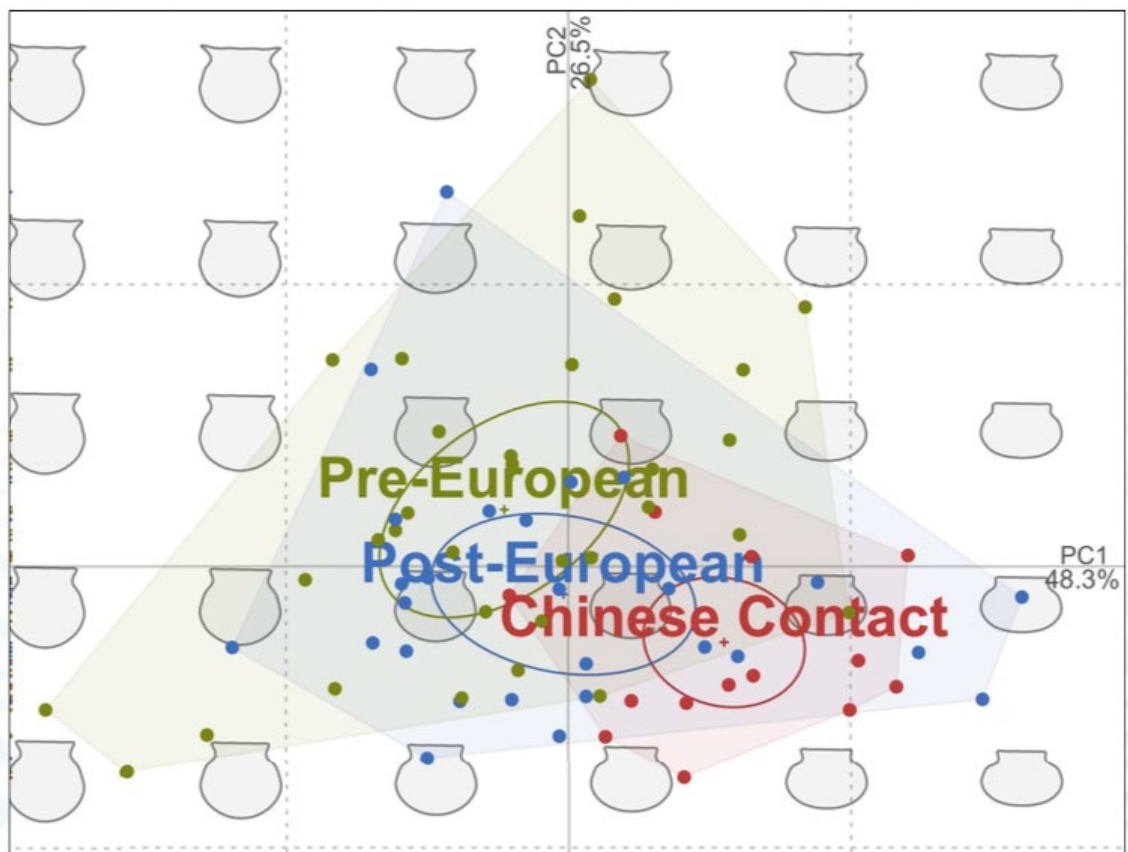
James Loftus

Despite the staggering theoretical and methodological advancements made in the field of archaeology in the past century alone, the matter of overcoming gaps in sample availability is one that consistently plagues even the most rigorous of methodological and theoretical projects. Coupled with this is the nature of prehistoric-archaeology itself, the subjects of study being those peoples that have already long left this plane of existence, leaving only bits and pieces of their material culture to interpret. Ethnoarchaeology has consistently sought to overcome many of the challenges of sample availability and access to living subjects often through the use of detailed anthropological and statistical analysis of contemporary societies creating a given material cultural object, and by doing so, overcome many of the previous challenges of wide-scale typologies based in attribute analysis. However, ethnoarchaeology has yet to fulfill the latter half of its name by reflecting on how these methods may be utilized in a firmly archaeological environment. Through the application of rigorous morphometric statistical analysis onto a strictly prehistoric pottery case study, this study seeks to create a multi-step analytical model to not only test the statistical validity of previously untested pottery typochronologies, but also to inform the ways in which morphometric clustering of vessel types may be used in conjunction with the great theoretical advancements made in the field of ethnoarchaeology. The chosen case study focuses on the early Yayoi period in the northern region of Kyushu Island, Japan. This important transitional period saw several significant upheavals in societal structures, subsistence practices, and the creation of multi-leveled material cultures attributed to large waves of migration from the Korean peninsula into the Japanese archipelago. The ways in which these new cultural aspects were dispersed is a continuous point of contention among many contemporary Yayoi period scholars. Looking at the clean-cut pottery typochronologies of contemporary literature on this important hunter-gatherer to subsistence agriculture transitional period may lead one to believe that the indigenous material culture, especially pottery, was completely uprooted and replaced by the “technologically superior” migrant culture. However, this project, through the use of multivariate morphological statistical pottery analysis shows that this initial period of interaction between the indigenous Jomon and the incoming migrants was instead characterized by multiple intervals of experimentation in pottery production methods and vastly different social learning environments derived from divergences in technological choices.

## 10. Investigating social change during cultural contact period using geometric morphometry of artifact shapes from Iron Age Northeast Taiwan

Liyang Wang and Ben Marwick

Culture contact between indigenous people and colonizer with imperial power usually leads to profound changes in local indigenous societies. This research seeks to answer the question: did contact with the Europeans and Chinese communities cause social changes in the Taiwanese indigenous community at Kiwulan, a large multi-component Iron Age site (1400-1900 AD) in northeast Taiwan? One approach to explore the impact is studying the changes in artifacts or assemblages by examining typological and linear measurements, that helps to identify any craft specialization present in indigenous societies caused by culture contacts. Based on the assumption that the specialized mass production will lead to uniformity of the product due to increased skills, routinization, and lower diversity of producers, we may be able to determine the type of production, and the presence of elite control, from artifact analysis. However, traditional typological and linear measurements are limited because they can be insensitive to subtle variations resulting from changes in craft specialization. Taking a new approach to the measurement of craft specialization, we studied shape and standardization of locally made pottery and foreign stone beads to identify changes in pottery production and consumption of stone beads at Kiwulan. Using the R programming language, we apply reproducible geometric morphometric methods to study artifact shapes to investigate if there are any changes resulting from foreign contact of European and Chinese that might indicate social changes in the indigenous society. We find differences in shape and shape standardization of pottery that indicate changes in pottery production resulting from foreign contact, suggesting increasing craft specialization and changes in local social organization at Kiwulan. Also, the higher diversity of stone bead shapes during the European contact period indicates increased social inequality and differentiations between different social groups. These results are important to understand the mechanism of social change and the agency of local indigenous people not as passive receptors of imperial powers, but as actively incorporating foreign goods into their culture. In addition, our case study, which includes an openly available research compendium of R code suitable for use with any other assemblage, will help to expand the use of shape-based quantitative methods to questions about craft specialization and standardization in prehistoric technologies.



## Poster Presentations

### 1. The Genetic Architecture of Facial Traits among West African Population - A Comparative Study of Facial Morphological Variation among the Hausa, Igbo and Yoruba Peoples of Nigeria

Abiodun Y. OLOWO

Craniofacial genetic research has not just focused on identifying the causes of craniofacial anomalies but has also helped to detail the genetic basis of normal-range facial variation both within and between populations across diverse geographical groups. However, majority of facial genetics research has been carried out using Asian and European-derived persons, and many populations, such as West Africans, remain understudied making our understanding of the genetic architecture of facial traits incomplete. Very few existing studies on skeletal and anthropometric comparison of Nigerian ethnic groups have supported the hypothesis that varying facial traits exist between the groups. However, the genetic basis of this variation remains unclear.

In this study, we seek to test the hypothesis that facial variation among African populations is greater than expected under a neutral model of evolution (AIM1). Using three major ethnic groups in Nigeria (Hausa, Igbo and Yoruba) and modern 3D facial morphometrics method, we quantify facial traits among each group and query (describe) patterns of inter-group facial morphological variation (AIM 2). By analyzing genomic and facial data using multivariate model including both genetic and non-genetic factors, we test whether previously associated facial genes will replicate in these samples (AIM 3) or whether different loci are involved in facial variation among these West African populations (AIM 4).

In addition to describing the genetic architecture of facial variation among these people, the results may corroborate and expand existing genome data for West Africa. The patterns of facial variation may also enhance forensic profiling, ancestry mapping and DNA-Facial construction models.



## 2. Geometric Morphometrics of human fetal brain development

Yutaka Yamaguchi, Motoki Katsube, Hiroko Hashimoto, Chigako Uwabe, Hirohiko Imai, Akira Yamamoto, Tetsuya Takakuwa, Kaori Togashi and Shigehito Yamada

Several fetal skeletons were excavated in some ruins; however, the analysis of these sample is not yet advanced enough. One of the reasons for this is that developmental mechanism of human fetus mostly remains unsolved. The aim of this study was to analyze the morphological changes of developing human brains using three-dimensional (3D) models reconstructed from formalin-fixed embryo and fetus specimens. At the Congenital Anomaly Research Center, Kyoto University Graduate School of Medicine, over 45,000 human embryo and fetus specimens are stored as the Kyoto Collection. Human fetal specimens of between 7 and 24 weeks gestational age with normal external appearance were selected for inclusion in this study. Data were obtained using 2.34-Tesla (T), 3-T, and 7-T magnetic resonance imaging (MRI). First, 3D models segmented into a maximum of six regions were reconstructed, and the rate of increase for each region was measured. Next, the direction of brain expansion was analyzed using geometric morphometrics, a statistical shape analysis based on landmark coordinates. The 3D models of fetal whole brains were reconstructed semi-automatically with anisotropic diffusion filtering and machine learning; 21 landmarks were registered on these models. The direction of growth was calculated using the landmark coordinates and generalized procrustes analysis, principal component analysis, and multivariate regression. The major pattern of morphological change was significant expansion of the posterior part of the cerebral hemisphere. In addition, statistical shape models showing changes according to fetal growth were created. These morphological analyses of human fetus will offer new insight into various fields; Medicine, Embryology, Anthropology, and Archeology. This study was authorized by the Ethics Committee of the Graduate School of Medicine and Faculty of Medicine, Kyoto University (R0316, R0347).

### 3. Morphological similarity of pottery between Kyoto and northeastern part of Japan

Kai Tateuchi

9th and 10th centuries in Japan were characterized by the dynamic reformation of political connection between the capital (Kyoto) and provincial areas. The degree of political and cultural interaction between areas has been routinely measured by the morphological similarity of pottery. In Japan, previous studies have argued that the pottery which was manufactured morphologically in imitation of Chinese ceramics appeared in Kyoto between 9th to 10th centuries, suggesting Chinese cultural influence on Japan. In addition, pottery in provincial areas in Japan has been considered to be manufactured by imitating the pottery of Kyoto because morphological changes of pottery in Kyoto were followed by the provincial areas. Therefore, the pottery has been studied to understand the connection between Kyoto and provincial areas. However, the morphological change has not been empirically examined. A possible reason is the lack of methods to capture it. Although the roundness of the pottery could be an important feature in the morphological change, the traditional morphological analysis used only three measurements (the lengths of the rim and bottom and the height of pottery). As a result, previous studies have had methodological difficulties to describe the detailed morphological changes and visualize them. Instead, by using the elliptic Fourier analysis (EFA), the present study compared pottery of Kyoto and the northeastern part of Japan to investigate the process of morphological changes and the relationship between Kyoto and the northeastern part of Japan.

The result suggests that, in the Gohonmatsu pottery production site, which was close to the provincial center of Mutsu (the northeastern part of Japan), pottery shape became similar to that of Kyoto in the late 9th century. However, such assimilation was not clearly observed in other pottery production sites. The result of the EFA revealed that the morphological change occurred in a limited area, indicating a stronger cultural and/or political relationship between the provincial center and Kyoto.

#### 4. 3D surface morphology of hammer stones

: examination of potential parameters and visualization methods

Atsushi Noguchi, Fumito Chiba, Shin Yokoyama and Yusuke Sato

Stone made hammers for production of chipped lithic tools are the one of longest enduring tool in the history of human evolution, and would be extended to other animals which developed tool-using behavior such as *Sapajus libidinosus* in South America. Hammer stone is absolutely expedient and casual tool. Its raw material is just pebble selected from river bed. It is used with less intensive modification. Only use-wear can identify human-used tools from many other natural pebbles. But it is difficult to distinguish intensive use-wear from occasional percussion marks by natural agency. Quantification of variation and deviation of surface morphology has the potential to yield indicators to identify area and magnitude of intensive use of hammer stone. In this paper, we present the preliminary result of 3D measurement and morphological examination with surface roughness. It shows effectiveness to distinguish used part from natural surface in comparison with natural pebbles and experimentally used ones. However, deviation between different material (ex. sandstone and andesite) is too large to establish standard among archaeological material. Further controlled experience for building archives is necessary while other statistic morphological approach or visualization should be testing.

## 5. A Morphological Analysis of the Simple Pottery Form of the Middle Yayoi Period in Northern Kyushu, Japan

Hiromi Hirakawa, Satoru Nakazono, and Maki Tarora

Studies on Yayoi pottery often ignore vessels that have a simple form without noticeable characteristics, treating them as subordinate to typical vessels such as pots and jars. We previously tried to apply elliptic Fourier analysis to small cylindrical bowl stands having a simple form that were unearthed in northern Kyushu, which were representative samples of the middle Yayoi period (Hirakawa and Nakazono 2019). In this study, we analysed larger samples and compared the results with those of a more ‘classical’ typological analysis and those of a principal component analysis based on the ‘traditional’ distance-based method. As a result, we once again confirmed the effectiveness of the quantitative method in the analysis of the simple pottery form and successfully detected useful morphological elements that went unnoticed when using conventional methods. The application of geometric morphometrics is useful in understanding morphological variation, for treating vessel forms that tend to be ignored on par with typical vessel forms, and for recognising the biases of researchers as they analyse pottery forms.

## 6. Elliptic Fourier analysis of the Ongagawa pottery in prehistoric Japan

Kohei Tamura, Hisashi Nakao, Yuji Yamaguchi and Naoko Matsumoto

The Jomon-Yayoi transition is a remarkable event in which the Jomon people, who mainly engaged in hunting-and-gathering, adopted rice farming (and/or replaced by migrants), leading to various socio-cultural changes. It has been considered that the Yayoi cultural complex was established in the northern Kyushu region under cultural influence from the Korean peninsula and then diffused to other parts of the Japanese archipelago. The Ongagawa-style pottery has been considered as an important indicator of the diffusion of the Yayoi cultural complex. Previous studies have thus analyzed morphological similarity and difference of the pottery among regions to reconstruct the diffusion process. While the majority of these studies have relied on typological approaches, due to morphological homogeneity of the pottery, a quantitative method could allow us a more detailed comparison. In the present study, we used the elliptic Fourier analysis to quantify regional variation in morphological similarity and difference of the pottery. Under the assumption of the concept of “descent with modification” in evolution, our results are consistent with the above-mentioned spreading process: pottery in the Korean peninsula and the northern Kyushu is more similar than that in the Korean peninsula and the further eastern part of the Japanese archipelago.

## 7. Quantifying the morphological trend of keyhole-shaped mounds of the Kofun period in Japan

Kohei Tamura and Takehiko Matsugi

The Kofun period is characterized by Kofuns or tombs of ancient political leaders. In particular, keyhole-shaped mounds has been of central importance. The mounds with distinctive shapes appeared in the 3rd century and widely distributed in Japan. Because of their morphological homogeneity, enormous size, and wide distribution, the process of political centralization and state formation in Japan has been a central research focus in this period. To this end, the morphological similarity of keyhole-shaped mounds has been used as a proxy to measure political connectivity between regions. However, previous studies used a typological approach based on a few two-dimensional measurements. In the present study, by using three-dimensional data on the shapes of keyhole-shaped mounds and landmark-based morphometrics, we quantify morphological variation in keyhole-shaped mounds. We found a temporal trend in shapes of the mounds from various regions, indicating the presence of a broad communication network. We also compared our results and the previous typology. Our results suggest that different types can include different levels of morphological variation.

## 8. Quantifying morphological variation of bronze and iron arrowheads of the Kofun period in Japan

Kohei Tamura, Hisashi Nakao, Kanta Takada, Tatsuya Hashimoto and Takehiko Matsugi

The Kofun period, or the period of state formation in Japan, is characterized by kofuns, or tombs of political leaders. Among a wide variety of grave goods, bronze and iron arrowheads have been considered to be of particular importance as prestige goods. Further, based on their morphological homogeneity, several studies have suggested the existence of a centralized distribution system. While these arguments have been based on typological approaches, a quantitative method can play a complementary role in comparing morphological variation within and between regions and phases. In the present study, by using the elliptic Fourier analysis, we quantify morphological variation in bronze and iron arrowheads. We found temporal variation in bronze arrowheads and geographical variation in iron arrowheads. Based on the results, we discuss the distribution system.