Investigating social change during cultural contact period using geometric morphometry of pottery shapes from Iron Age northeast Taiwan

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10 October, 2019

Text of abstract

# Introduction

Ceramic production can reflect prehistoric socioeconomic patterns since it relates to not only economic base for households but also societies as a whole when specialized production was organized. Identifying the specialization in ceramic production will help to understand how complex societies form and further explore the underlying mechanism. One way to examine ceramic specialization is to identify whether ceramics present standardization in production, which 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 that enable us to interpret social organization or social relations such as type of production, and the presence of elite control (Arnold, 2000, p. 334; Costin, 1991; Stark, 1995).

Several variables have been proposed to measure ceramic standardization, including metric, compositional, and technological attributes (Blackman et al., 1993; Costin, 1991; Hirshman et al., 2010; Rice, 1991; Tite, 1999). 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 to identify changes in pottery production at Kiwulan (1400-1900 AD), a large multi-component archaeological site in northeast Taiwan. We apply 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.

Culture contact between indigenous people and colonizer with imperial power usually leads to profound changes in local indigenous societies. We explore the culture changes in indigenous societies in northeast Taiwan that experienced foreign contacts with the Europeans and Chinese since 17th century by examining the local pottery production. We observed pottery production in northeast Taiwan in the late Iron Age period and historical period (1400-1900 AD) presenting a high consistency in form and shape compared to other pottery found from other regions on this island that hints the emergence of pottery specialization. We asked the questions: Did foreign contact have an impact on indigenous pottery production in Northeast Taiwan that can be detected in the shape of the vessels? Did the pottery production become more standardized and homogeneous in shape after foreign contact? Did the contact with European cause more homogeneous shape than Chinese contact period because of large scale exchange network?

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. These results are important to understand the influence of culture contact on local indigenous societies and answer the anthropological question that concerns the the mechanisms for social changes. 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.

# Geometric Morphometric approach: shape analysis for pottery specialization

Geometric morphometry methods (GMM) has been widely applied recently in archaeology to study the morphological variability and similarity of archaeological materials to address the questions of anthropological interests. Different from taking linear measurements of objects as variables, geometric morphometrics methods use geometric coordinates of morphological structures as variables to specify the shapes (Adams et al., 2004; Lawing and Polly, 2010). According to different focuses, there are two common methods used to capture and analyze the shapes of objects, landmark analysis and outline analysis (Adams et al., 2004). Landmark analysis

* related to the issue of specialization

# Hypotheses and expectations

The goal for locally made pottery data collection is to explore whether pottery production could reflect the social change, from more corporate modes to more network modes after European contact. The level of craft specialization usually relates to the presence of elite control. In this case, if competitions for prestige and European resources among individuals gradually lead to change in social organization, then the production of pottery will show more homogeneous features after European contact due to the craft specialization. The standardization of metric attributes for pottery will be used to measure the craft specialization.

# Materials and methods

## Archaeological pottery from Kiwulan

Ceramics data analysed in this paper come from the Upper Culture Layer of Kiwulan, northeast Taiwan. Those ceramics dated from AD 1400 to AD 1900, which covers 500 years from the late Iron Age to the historical period by the European presence in the 17th century. Kiwulan is situated on a hill near a riverside at the northern margin of Yilan, which is characterized by a triangular alluvial plain facing eastwards the Pacific and mountains on three other sides. The Upper Culture Layer experienced frequent foreign contacts including the European colonial presence in the 17th century and great waves of Chinese immigrants since 19th century. The excavation revealed abundant artifacts in which potsherds are the dominate materials throughout the site. Imported ceramics from mainland China, stonewares, and ornament elements such as beads were usually found in the Upper Culture Layer that indicates the prosperous international trading activities in the 17th century during the European presence in Taiwan. In addition to artifacts, features were also found, such as burials, middens, and postholes with in-situ posts that explains Kiwulan was a large settlement site.

## metric measurements

In this study, we examine 291 pots recovered from Kiwulan site. The layer from 1 to 6 could be divided into 3 time periods. Layer 5 and 6 represent pre-contact period, layer 4 represents contact period, and layer1, 2, and 3 represent post-contact period. The amount of pots for each layer shows below. Although most pots are not complete, the thickness from rim, neck, to body can be measured. I have also measured the diameter of rim, neck, and body. For those pots that are incomplete, the diameter is measured by its curvature. Since the height is incomplete for most pots, this preliminary analysis focuses more on the possible change in thickness and diameter of pot for different parts, and their ratio over time.

## Outline analysis approach

The scanned pottery drawings for reconstructed pots that mostly covers from rim to bottom were acquired from Bureau of Cultural Affairs in Yilan. All drawing presents two-dimensional view of the section of a vessel with indications of metric measurements. The scanned drawings were imported into the Inkscape software for outlines tracing to remove some information such as marks, lines, and numbers on the original file. Each traced half cross-section image was duplicated, flipped, and then joined with another one to create a 2D closed outline that can be processed later in the R software (www.rproject.org, Core-Team, 2015). Geometric morphometric analyses were conducted using the functions included in the Momocs, a R package intended to quantify the shape and compare its variation, especially for outline analysis (Bonhomme et al., 2014). The digitised outlines were converted into a list of successsive x-y pixel coordinates for elliptic Fourier analysis (EFA), which assesses morphological differences among pottery shapes from three occupation contexts. EFA is a powerful method to extract geometric information where closed outlines are considered as periodic functions and decomposed into a series of trigonometric functions referred as harmonic coefficients (Bonhomme et al., 2014; Claude, 2008). The number of harmonics determines the quality of the geometry that more harmonics can capture the shapes more precisely (Bonhomme et al., 2013). Here we used 13 harmonics to describe pottery shapes. The harmonic coefficients generated by EFA were analysed by principal component analysis (PCA) to illustrate the diversity of the shape data and identify the major patterns of variation through dimensionality reduction. The principal components (PCs) scores were analysed with a multivariate analysis of variance (MANOVA) to test for significant effects of the groups of occupation context on shape variances. Finally, we computed a significance test to assess the equality of coefficients of variation (CVs) among multiple groups of PCs to understand the differences in shape standardisation among context groups. The R package cvequality (Version 0.2.0; Marwick and Krishnamoorthy 2019) in the CRAN repository was used to conduct the significance test for CVs.

# Results

Elliptic Fourier analysis (EFA): Thin-plate splines compares the average shapes of vessels from each period to visualize the outline deformations required to pass from an extreme of one morphospace to the other. The results of PCA show that the first three PCs explain 86% of shape variation. PC1 relates to height of vessel, PC2 relates to width of neck and mouth, and PC3 relates to width and flare of neck. The PCA biplot of vessel shape shows grouping by each occupation phase. MANOVA shows significant differences in shape between Pre-European and Post-European (p = 0.02) and Pre-European and Chinese contact shapes (p < 0.01). The distributions of the first three PCs for each vessel suggest variations in shape standardization by period. PC1 shows more variation in the pre-Euro period compared to the Chinese period. Standardization appears strong in the pre-Euro period but weak in the Chinese period. P-values for a modified signed-likelihood ratio test of equality of CVs of PC1 & PC2 show significant differences in standardization of vessel shape across some periods, especially between Chinese contact with either pre-European or post-European.

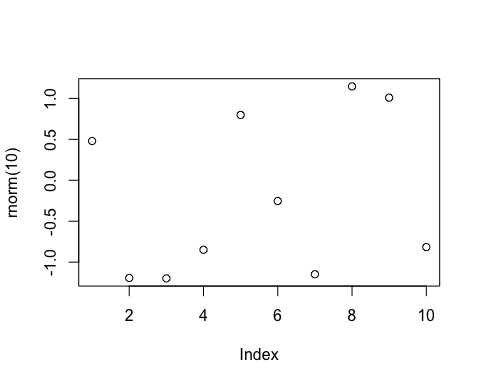


Figure 1: A plot of random numbers

Figure 1 shows how we can have a caption and cross-reference for a plot

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# Discussion

# Conclusion

# Acknowledgements

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### Colophon

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