Steps Towards the Analysis of Geometric Decorative Motifs Using Shape-matching Techniques

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Abstract

The classification of geometric decorative motifs has tended to emphasise the geometric by comparing the decoration to mathematically perfect constructions. Focussing on spirals as exemplars, this paper proposes that additional information may be gleaned from historic decoration on the assumption that such decoration often does not conform exactly to mathematically correct constructions. Shape-matching analysis methods combined with the analysis of stylistic variables are put forward as a means of comparing cultures; in particular, of looking for evidence of cultural diffusion and studying the manner and rate of evolution of geometric motifs.

Introduction

Spiral decoration is geographically widespread and long-established with the earliest known occurrence dating back to the Palaeolithic period [1: 10]. Formal geometric approximation techniques for spirals possibly date back to Theodorus in the fifth century BCE [2] and Vitruvius' manual of the first century CE presented geometric constructions for spirals to be used in architectural decoration. Consideration of decorative spirals as a tool for studying cultural diffusion dates back to the late-nineteenth century; cultural contact routes across Europe have been proposed on the basis of similarities in spiral decoration [3: 141-2]. These early comparison systems did not tend to employ formal typologies, instead working from subjective identification of the co-occurrence of similar motifs to infer links. That these proposed links have sometimes been shown by improved dating techniques, to be false [4], supports the case for more precise and formalised typologies as a basis for cultural comparison.

Classification of decoration using geometric constructs

The possibility of comparing decorative schema using geometric motifs was suggested by established methods of cross-cultural comparisons which identify differences between cultural groups in the presence and frequency of occurrence of types of symmetry transformation [5]. Motifs with an underlying form which closely approximates to a geometrically definable construct may be evaluated according to a constant set of geometric properties. These properties offer the potential for a generic comparison method, applicable across a range of cultures, to be developed.

Existing anthropological classification systems analysing a single geometric motif have tended to emphasise the mathematical basis of the motif and assign classes based on resemblance to perfect mathematical constructs [6, 7]. These type groups are applied on the tacit assumption that the producer aspired to create a regular construct – for spirals, a curve in which the radius is a continuous monotonic function of the angle [8: 357]. In some cases as, for example, with Gil *et al.*'s analysis of Islamic tilings [9], the assumption of a geometric basis to the designs can be readily supported so there is good reason to look for an underlying ideal structure in geometric terms. Decorative spirals, however, often differ sufficiently from mathematical ones to prevent secure identification of them as a defined mathematical type [10]. The sine wave plots of Figure 1 show considerable deviation of architectural spirals from mathematical forms even when the superficial similarity appears strong. This degree of variation is likely to be present in other geometric motifs, if more than one construction method is available, and renders classes based on the pure mathematical constructs inappropriate to the decorative motifs of many cultures.

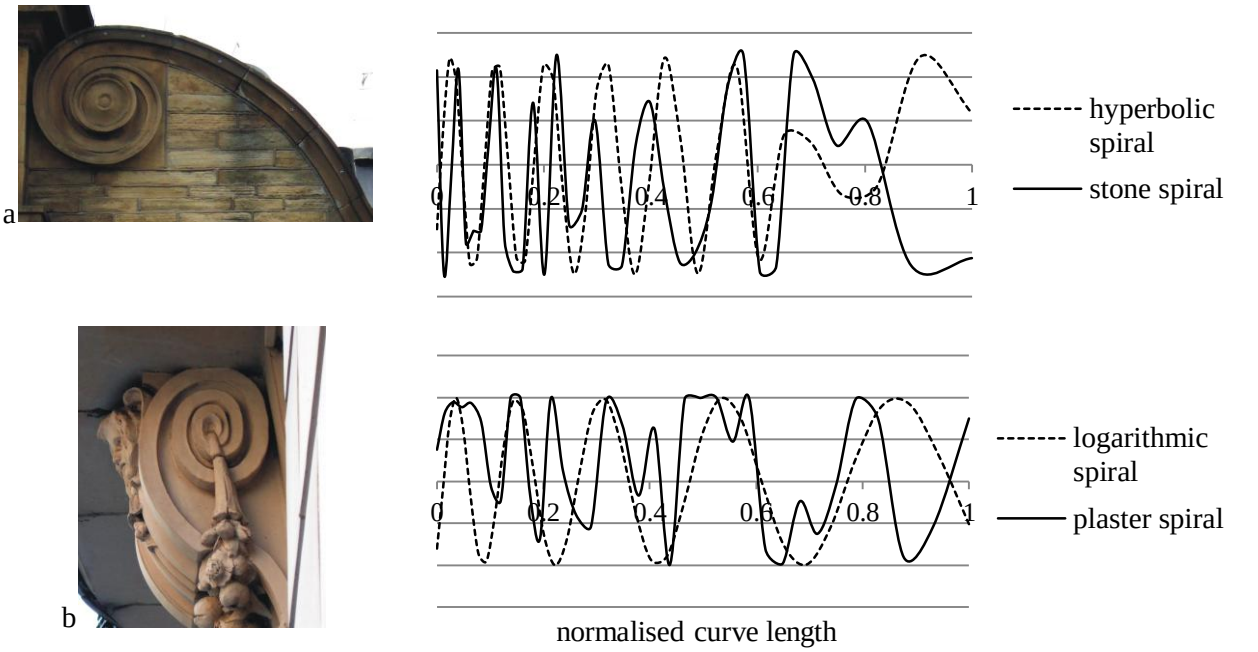

Figure 1 *Tangent angle sine plot comparing an architectural stone spiral (a) with a true hyperbolic spiral and a plasterwork spiral (outermost 630°) (b) with a true logarithmic spiral. (photographs: A.Humphrey)*

In application to the analysis of decoration, it is worth noting that consideration of a motif in its real, rather than ideal, form offers the potential to characterise the construction method employed and to gain an indication of the mathematical knowledge or craft techniques employed within the culture (Figure 2).

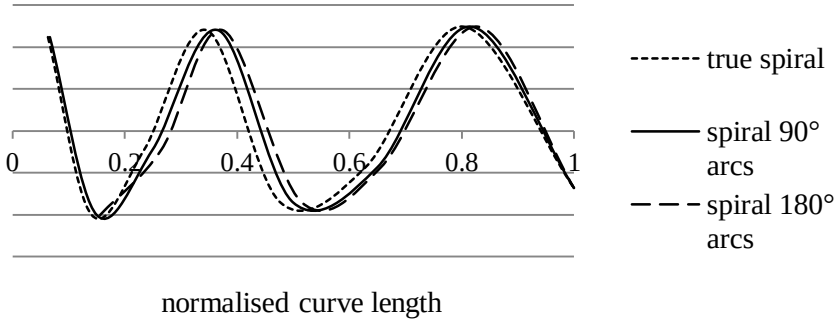

Figure 2 *Characteristic tangent angle sine plot of a true Archimedes' spiral compared to the signatures of common decorative approximation methods using 90° and 180° circular arcs*

A final drawback in the classification of decorative spiral motifs with reference to mathematical spirals is the isolation it imposes on them when it is clear from reference to extant decoration that spiral motifs may form a continuum with geometrically unrelated forms (Figure 3).

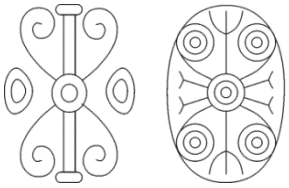

Figure 3 *Aesthetically related motifs on scarabs involving different geometric constructs (both acc. no. EG6007, Wellcome Collection, Oriental Museum, Durham University)*

Shape-matching in cultural comparisons

Shape-matching techniques emphasise the measurement of similarity between forms over absolute description. This approach has been applied as a means of reconstructing cultural heritage [11] and as a basis for indices of historical decorative designs [12, 13] but seems less common in anthropology as a means of cultural comparison. Shape-matching avoids many of the problems found in motif classification systems based on direct comparison with geometric constructs by allowing type classes to be constructed with reference to other motifs within the sample. Furthermore, encoding the motif shape allows detailed comparison of short sections and wavelet transformation of the encoded data permits examination at varying resolutions [14]. Both these points are of potential value in identifying the small distortions of form which can indicate construction method. Shape-matching can also be used to extend comparison beyond a single type of geometric motif to the measurement of relatedness between aesthetically similar motifs as with the spirals and the concentric-circle 'false spirals' on the scarabs (Figure 3).

Shape-matching provides particular benefits for cultural comparison in offering a means of identifying gradual change in style and assessing the timescale over which these changes occurred. Such graduated change can be seen in Maori pendant forms which originated as functional fishhooks converted into pendants but were subsequently produced primarily as pendants in forms which show increasing abstraction from the original inspiration (Figure 4).

Figure 4 *A Maori fishhook developed into an early pendant form (centre) and further abstracted in a contemporary example (right) (drawings: A.Humphrey)*

Stylistic elements of decorative motifs such as path width, irregularity of curvature and orientation are liable to be lost in the consideration of motifs purely as geometric constructs. This is problematic in studies of decoration as these aspects may be as significant in choosing type classes as the underlying geometric construction; Phillipps provides an example of this in his characterisation of spirals in Maori woodcarving [15]. An additional significant aspect of the analysis of decorative motifs is the recording of groupings and linkages between individual motifs. By combining principal components of the geometric shape coding with quantitative measurements of style variables and the relationships between motifs, both geometric data and aesthetic variables can be combined in the same classification system. Cluster analysis can then be applied to these data to identify type groupings of motifs within and between cultures. From these, individual variables which show significant patterns of change between cultures or over a period of time may be identified.

Summary

The value of employing geometric concepts in cultural comparison to provide a basis for the objective comparison of like with like is well established. It is proposed that such an approach may be extended from the identification of the framework underlying decoration to the comparison of individual motifs which are susceptible to geometric description. It is however suggested that in application to motifs, in contrast to layout, the extension of geometric definitions to the creation of decorative classes is liable to create types which do not truly reflect decorative groupings present in the culture and which lose relevant

aesthetic information. Shape-matching offers a more flexible alternative means of classification which derives the classes from the data itself in the manner of qualitative typologies without losing the broad applicability of geometry-based classification systems.

References

[1] Haarmann, H. and J.Marler. *Introducing the Mythological Crescent: Ancient Beliefs and Imagery Connecting Eurasia with Anatolia.* Wiesbaden: Harrassowitz, 2008.

[2] Gautschi, W. The Spiral of Theodorus, Numerical Analysis, and Special Functions. *Journal of Computational and Applied Mathematics.* **235**, pp.1042-1052, 2010.

[3] Haddon, A.C. *Evolution in Art.* London: Walter Scott, 1895.

[4] O'Sullivan, M. Approaches to Passage Tomb Art. *The Journal of the Royal Society of Antiquaries of Ireland.* **116**, pp.68-83, 1986.

[5] Washburn, D.K. and D.W. Crowe. *Symmetries of Culture: Theory and Practise of Plane Pattern Analysis.* Seattle: University of Washington Press, 1988.

[6] Zhushchikhovskaya, I and O. Danilova. Spiral Patterns on the Neolithic Pottery of East Asia and the Far East. *Documenta Praehistorica.* **XXXV**, pp.215-226, 2008.

[7] Takaki, R. and N.Ueda. Analysis of Spiral Curves in Traditional Cultures. *Forma.* **22**, pp.133-139, 2007.

[8] Dixon, R. Green Spirals. In *Spiral Symmetry*, I. Hargittai ed. World Scientific Publishing, London, pp.353-368, 1992 (rpt 2000).

[9] Gil, F.A., J.M.Gomis and M.Pérez. Reconstruction Techniques for Image Analysis of Ancient Islamic Mosaics. *The International Journal of Virtual Reality*. **8**(5), pp.5-12, 2009.

[10] Andrey, D. and M. Galli. Geometric Methods of the 1500s for Laying Out the Ionic Volute. *Nexus Network Journal*. **6**(2), pp 31-48, 2004.

[11] Al Ajlouni, R. The Use of Digital Pattern Recognition Techniques for Virtual Reconstruction of Eroded and Visually Complicated Archaeological Geometric Patterns. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* **XXXVII**(B5), pp.193-198, 2008.

[12] Djibril, M. O. and R. O. H. Thami. Islamic Geometrical Patterns Indexing and Classification Using Discrete Symmetry Groups. *ACM Journal on Computing and Cultural Heritage.* **1**(2), Article 10, 2008.

[13] Ullrich, T., V. Settgast and D. W. Fellner. Semantic Fitting and Reconstruction. *ACM Journal on Computing and Cultural Heritage.* **1**(2), pp.69-84, 2008.

[14] Sifuzzaman, M., M. R. Islam and M. Z. Ali. Application of Wavelet Transform and its Advantages Compared to Fourier Transform. *Journal of Physical Sciences.* **13**, pp.121-134, 2009.

[15] Phillipps, W. J. Maori Spirals. *The Journal of the Polynesian Society.* **57**(1), pp.30-40, 1948.