

CULTURAL INTERACTION AND EXCHANGE, EXPRESSED THROUGH THE GEOMETRY OF INTER-LOCKING KEY PATTERNS

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Abstract

This paper identifies various key-type patterns which although from apparently remotely different geographical/cultural and historical sources are similar structurally. A well-established means of analysing reoccurring designs by reference to their constituent structural (or underlying) geometry is acknowledged and relevant explanatory literature identified. A representative analysis of a small number of key patterns is presented. The nature of diffusion theory and alternative perspectives which may explain cultural change (expressed through the alternative analysis explored and discussed) and the similarity between various interlocking key patterns is discussed in light of evidence for a process of 'diffusion' rather than of independent evolution.

1. Introduction

Figure 1 shows a decorative wooden door of the Great Mosque (or Masjid) of Córdoba (Spain) made in the Andalus for modern day Spain so that it was known as the Masjid al-Sharif (the most pure of the Islamic world of the early medieval period). Typical Moors historical architectural features are depicted. These were created around 837 CE in the context of this paper the distinctive geometric structure within the three arches is of particular note. Meanwhile Figure 2 shows a photograph of an original brickwork on a wall of a small gate house (or, and, rather, entrance) the Malindi Museum of Kenya in Kenya. The architectural brick work depicted is in imitation of a design regarded by modern-day Koreans as 'traditional' to Korea although there is some (small) acknowledgement among Koreans that the design is also found in traditional Chinese and Japanese architecture. At the Malindi Museum the design is believed to have been an early Islamic dynasty (1392 – 1510 CE) or maybe before. Figure 3 shows a section of the topographical field in the Topkapı Palace Museum in Istanbul (the central historical city) to the Ottoman world in the (early) 16th century. While it can be seen that the two local designs contain various recognisable solutions in their basic form, in each case, the geometric (which history, interestingly, has a less similar, strikingly by the design identified in Figures 1 and 2, this is particularly true of the design in Figure 3).



Figure 1. Interior wall of Great Mosque at Cordoba (photograph M. A. Hazen)



Figure 2. Wall of gate house at entrance to National Museum of Korea, Seoul (photograph M. A. Hazen)



Figure 3. Detail of wall from Tipsoke Palace, Seoul (upper design is arched lower design is). Source: Tipsoke Palace Museum Website

Although the three locations are distant geographically, it is readily apparent that the designs depicted are structurally similar. This similarity suggests knowledge of relevant geometry. The designs from the three sources are known as *key (or knot) designs*, a class of designs which shows remarkable universality. The aim of this paper is to demonstrate further this universality and in particular to address the question: Why do these designs from geographically distant locations have such remarkably similar structural features?

2. The Space Between East-of-East and West-of-West

The use of key-type designs can be detected in various ancient cultures. Jablan referred to evidence for their very early use in Paleolithic times (from Mezin in the Ukraine) and also gave examples from late Shang dynasty China, Celtic Europe, fourth-to-first millennium BCE Western Siberia, as well as ancient Mexico and Neolithic Yugoslavia [1]. An interesting article by Davidson noted the use of an "interlocking key design" in aboriginal Australian decorative art, and observed further the prominence of such designs in "Greece, China and Peru" as well as in the "Bronze Age deposits in Celebes" (Indonesia) [2]. In addition to the areas mentioned above the use of key-type designs has also been prevalent to varying degrees in Egyptian tomb painting,

various Islamic contexts (including Moorish, Turkish and Persian), as well as Anglo-Saxon, traditional Korean, Japanese, West African, Peruvian and Indonesian forms of decoration. Probably the most prolific early form is the sub-class known as Greek key patterns, in widespread use during the Geometric Period (around 8th century BCE). These included border patterns with arrangements of zigzags, triangles, frets or swastika shapes. Subsequently the use of such designs could be detected in the Roman and Byzantine works as well as in Italian renaissance times. What is readily apparent is the ubiquitous nature of the class of designs. Various examples of key-type border patterns are given in Figure 4.



Figure 4. Examples of Key-type Border Patterns
Source: L. F. Gagliardi, *Pattern Design*, Dover Publications, New York (1999) p.58

3. Diffusion Versus Evolution

Structurally-similar designs depicted in different environments and created at different points in time may result from two causes: a process of diffusion or exchange, which allows an idea or invention to be transferred from one geographical location to another or, alternatively, a process of independent discovery and evolution. The authors' position is generally that a vast range of design components (e.g. a motif of a particular type or a composition involving a particular structural geometry) result, to large degree, from a process of cultural diffusion. Cultural diffusion is the process by which cultural traits, belief systems, musical styles, cooking procedures and ingredients, material objects, ideas, artistic styles, inventions, innovations or patterns of behaviour are spread from one social or geographical context to another. Such a process is integral to globalisation, a term coined in modern times to refer to the increased inter-connectivity between countries, societies and cultures, expressed primarily through trade and facilitated through developments in technology and communication. There are many examples of similar forms of decoration existing in different cultural or historical domains, attributable to a common identifiable source and thus resultant from a process of diffusion. However it may be the case that certain basic motifs and patterns (e.g. spots, stripes and checks) are examples of classes of designs developed largely on an independent basis across many cultures, time zones and geographical locations, thus suggesting a process of independent evolution rather than diffusion.

Among the leading theoretical contributors to the development of diffusion theory and its associated concepts and perspectives were: Franz Boas (1858-1942) a pioneering anthropological field worker and theorist; Leo Frobenius (1873-1938), the originator of the concept of cultural circles; Fitz Graebner (1877-1934), a leading

diffusion theorist; A. C. Haddon (1855-1940), a Cambridge zoologist and anthropologist, who produced an important book entitled *"A Short History of Anthropology"*; Thor Heyerdahl, a twentieth century Norwegian adventurer; A. L. Kroeber (1876-1960) a student of Franz Boas; Friedrich Ratzel (1844-1904) who contributed significantly to nineteenth century theories of migration and diffusion; W. H. R. Rivers (1864-1922) was a strong supporter of diffusion perspectives and spoke strongly against evolutionist explanations (3-10). Diffusion theory therefore has its origins in the discipline of anthropology. In modern times, diffusion concepts have been used in the areas of archaeology, cultural geography, business studies and marketing. The work of Rogers and Shoemaker (1971) is of particular importance in introducing diffusion concepts to researchers from a wide range of disciplines in modern times (11).

Trade has been a major stimulus for cultural diffusion. There was much trade between nations for many centuries before the commonly-accepted "Year One". In theory there was access between Europe (say Britain or Spain) in the west and Korea or Japan in the east. By the end of the first century BCE, there was substantial international trade, involving the Roman Empire (in the east of the Mediterranean), the Parthian Empire (Iranian Plateau), the Kushan Empire (current day Pakistan, north India and part of Afghanistan), a confederation of Central Asian nomads and the Han Dynasty (China). Various routes developed and terms such as "Amber Route", "Spice Route", and "Incense Route" as well as "Silk Road" (or "Silk Route") have been used in relatively modern times to refer to geographically separate trade networks, often used during different time periods. The term "Silk Road" was first used by the German scholar Ferdinand von Richthofen to refer to the network of trade routes stretching from China (Chang'an, or today's Xi'an) to the eastern Mediterranean, extending over 5,000 miles (8,000 km), with branches into South and South-east Asia. Silk and other woven goods were indeed transported, but so also were spices, porcelains, religious relics, precious stones, metals, jewellery and other precious items. Parallel with this, artistic methods, motifs and symbols, styles of music, religion, languages and literature, philosophies and political ideologies were transmitted from one region to others.

It is important to recognise that the Silk Route was a network rather than a single road and it is doubtful if many traders travelled the full distance, but instead exchanged goods at various locations between east and west. Key points along the routes from Chang'an (regarded as the first or last staging post in China) were Lanzhou, the Gansu Corridor (between the Tibetan and Mongolian Plateaus), the Taklamakan Desert, Dunhuang, several alternatives which ultimately joined in Kashgar, the Pamir mountains, alternatives into Central Asia or southwards into Pakistan, India or Afghanistan, the Iranian Plateau, Black Sea, Marmara Sea, through the Balkans to Venice or across the Black Sea to Georgia and then to Constantinople (current-day Istanbul). From here, sea and land routes led to North Africa and parts of western Europe including the Iberian peninsula (Spain and Portugal). Notable travellers associated with parts of the Silk Route include Alexander the Great, Xuan Zang (sometime appears as Hsuan Tang), Marco Polo, Ibn Battuta, Aurel Stein and Sven Hedin. Religions associated in some way with the Silk Route include Buddhism, Islam, Manichaeism and Nestorian Christianity. Important periods, empires or dynasties, from the viewpoint of developments in the decorative arts as well as trade between nations, include: The Parthian period, the Sassanian period, the Kushan Empire, Han Dynasty China, Tang Dynasty China, the Mongol Empire and the Timurid period, as well as: Saffavid Persia, Mughal India and Ottoman Turkey. There are numerous examples of artistic styles diffusing across the silk route and often connections between one culture or region and another can be found readily. Examples include Gandhara and Hellenistic sculpture or Persian silver and Tang porcelain. It seems that diffusion is dependent on either a

portable object being transferred from one zone to another, or for certain knowledge, ideas, skills or principles being transferred from one individual or group to another by word of mouth or through demonstration.

It seems also that knowledge and skills relating to mathematics (particularly geometry associated with building construction) also transferred from one culture to another. Precisely how this knowledge was transferred is not entirely clear. If in written form, then literacy and linguistic skills in dealing with the language of the culture of origin would be required, though illustrations of geometric shapes/figures or arrangements may have been self explanatory from illustrations alone. A further possibility is that artisans migrated and settled in distant locations bring with them relevant knowledge and skills.

It is largely accepted that the ancient Greek geometers (such as Euclid and Archimedes) drew heavily on the knowledge of the ancient Egyptians (possibly through visits to north Africa). Subsequently, various Islamic mathematicians (e.g. al-Khwarizmi) developed this accumulated knowledge further and also added insights from lands as far away as India. Such knowledge was then applied across several scientific and engineering areas as well as in the realms of architecture and decorative design (especially tiling designs). It seems that Euclid's *Elements* (the classic treatise which formed the basis of all geometry taught worldwide until relatively recently) was safeguarded through its translation initially from Greek into Arabic and, a few centuries later, from Arabic into Latin (for transmission into much of Europe during early Renaissance times) [12]. So in this case it seems that a process of diffusion is followed up by independent development and then subsequent further diffusion.

A process of independent evolution is occasionally argued as an explanation for cultural development. For example, some early anthropologists argued that all cultures are best considered lying at some point along a line of evolution with some positioned ahead of others, and that all cultures will ultimately (and independently) discover the necessary accoutrements of "civilisation" such as, for example, the wheel, fire, writing and counting, the spinning of fibres, the weaving of threads, pottery and metal smelting. While this "evolutionist" view has lost popularity, and it is largely contrary to the perspective taken in this paper, it is not dismissed totally from the discussion and some recognition is given to the possibility that certain basic geometric knowledge and constructions may well have diffused from one geographic zone to another and were then applied independently to achieve certain universal forms of decoration such as key-type designs.

As noted by Leblond, when observing the characteristics of very ancient Palaeolithic and Neolithic forms of the design class, all resultant designs seemed to result from the systematic manipulation of only a few basic units which he referred to as "prototypes" [13]. This calls to mind the principal of modularity in design whereby a few basic units or modules are capable of being arranged and re-arranged to produce a wide range of alternatives within a collection of designs; although different, each design within the collection will have characteristics which place it clearly in the same class as its relatives. This is the case with key-type designs.

It appears that many designs in antiquity were planned and worked out using squared paper. It should be recognised that certain methods of working, for example, using squared paper (as was the case with the Topkapı Palace scroll designs) may encourage resultant similarities in designs produced. However such similarities would only be apparent in the simplest of cases. Also, as indicated in Figure 5, starting from a simple balanced black-and-white diamond-shaped grid, numerous alternatives (recognisable within the same class) are indeed possible (although only a few are shown here). Figure 6 give a further impression of the wide-ranging possibilities readily evident from developments using a simple square-grid structure.

double tails of 13 squares overlapping at the top and bottom of the "T". When placed at 90-degree-rotational intervals a four-part unit results. When the unit is repeated in two independent directions across the plane the final design develops. Two further examples of interlocking key patterns are shown in Figures 9 and 10.



Figure 7: *Identical key design. A. H. Christie, Patterns Design: An Introduction to the Study of Formal Design, Dover Publications, New York (1960), Christie p.81*



Figure 8: *Stripes of possible construction. Drawn by A. Humphrey*



Figure 9: *Example of interlocking key-type pattern. Source: A. Fenn, Abstract Design and How to Create It, Dover Publications, New York (1990) p.128.*



Figure 10: *Example of interlocking key-type pattern. A. Fenn, Abstract Design and How to Create It, Dover Publications, New York (1990) p.128.*

5. Towards a System of Classification and Analysis

Probably the most influential nineteenth-century study of pattern was Owen Jones' *The Grammar of Ornament* (1856), which focused on the cultural and historical aspects of patterned ornament [15]. Although this work was not concerned with the geometrical characteristics of pattern structure, it was an early attempt to categorise patterns in terms of their cultural and historical origins. A large proportion of the design literature of the late-nineteenth and early-twentieth centuries focused on pattern construction. The fundamental geometric principles underlying the construction of regular repeating patterns was indeed understood by many observers; relevant literature in this category has been identified by Hann and Thomson [16]. A small number of publications are of particular interest as they suggest perspectives similar to those used at a later date in more mathematically-focused work. Meyer, for example, grouped designs according to spatial characteristics

into enclosed spaces, ribbon-like bands, or unlimited flat patterns, corresponding to motifs, border patterns and all-over patterns respectively [17]. Meyer also recognised that there was a "... certain division, a subsidiary construction or a network, anticipating the principle of lattices underlying the structure of all-over patterns [18]. Stevenson and Suddards, in their appraisal of the geometry of jacquard-woven patterns, illustrated constructions based on rectangular, rhombic, hexagonal and square lattices [19]. Similarly, Day (1903) emphasised the geometrical construction of patterns, illustrating all-over patterns based on square, parallelogram, rhombic and hexagonal type lattices [20]. Christie's **Pattern Design**, first published in 1910, made a formal classification of patterns according to the motifs appearing within them, rather than by reference to time periods or culture [21]. This work is of significance as it represents an early stage in the categorisation of patterns in terms of their geometric properties. The works of Walker and Padwick (1977), Schattschneider (1978, 1986) and Stevens (1984) made the consideration of pattern symmetry accessible to a non-mathematical audience [22-25]. In 1980, Crowe presented a flow-chart to aid the recognition of the seventeen symmetry classes of all-over patterns [26]. This was developed further in collaboration with Washburn in 1986 [27]. Grünbaum and Shephard (1987) charted much of what is known currently about the geometry of both regular tilings and patterns; in fact their work is the obvious landmark to date in the mathematical investigation of the subject [28]. Washburn and Crowe (1988) published an impressive work dealing with the theory and practice of pattern analysis and, in particular, with the use of symmetry concepts as an aid to the classification of designs from different cultural settings and historical periods [29]. This has proved to be a classic reference for anthropologists, archaeologists, art historians, mathematicians and designers. A series of papers produced by Harm presents a comprehensive review of theoretical developments during the latter part of the twentieth century [30-32]. It is now therefore well established that regularly-repeating patterns can be classified readily by reference to their underlying geometric or symmetry characteristics. In brief, a group of four geometric actions known as symmetry operations combine to form seven possible classes of border patterns and seventeen possible classes of all-over patterns. It is of course the case that variations in line, texture, colour and scale, can yield infinite possibilities (aesthetically) within each class. Symmetry is an underlying feature, which is read subliminally or unconsciously, and believed to have deep cultural significance.

It is now accepted widely (indeed established) that when a representative group of patterns from a given historical or cultural context, is analysed by reference to symmetry characteristics and classified accordingly, a non-random distribution of symmetry classes results. Also, different cultural settings and historical periods exhibit their own unique symmetry preferences. It is therefore well established that symmetry classification is a culturally-sensitive tool. Indeed symmetry classification could be useful as a means of pinpointing cultural adherence, continuity and change (possibly as a result of diffusion). Subject to the availability of representative (and chronological) collections of data, symmetry classification could be used to evidence the point in the past when cultural diffusion actually took place.

6. A Preliminary Analysis

It is not the intention of this paper to report on a wide ranging empirical survey but rather to suggest a methodology which could be of value in determining whether or not cultural diffusion took place. In other words, accepting that different cultures express their own unique symmetry preferences and also that symmetry preferences will vary as a result of cultural change, it may be worth analysing representative selections of key-type

patterns from different cultures, in order to determine the degree of similarity and thus the degree to which such cultures may have come into contact with each other and initiated a process of diffusion. Research with this focus is in the early stages and this paper reports on preliminary findings only. An examination has been made of small numbers of key-type all-over patterns from the three locations, including the interlocking key designs identified in Figures 1, 2 and 3. A predominance of four-fold rotational symmetry can be reported. Also of great importance is the fact that the interlocking key-type all-over patterns identified in Figures 1, 2 and 3 are of exactly the same symmetry class (class p4gm). It is worth reporting further that this particular symmetry class is probably the most complicated, in terms of constituent symmetries, of the seventeen possible all-over pattern classes. In view of this it is difficult to resist the proposal that the relevant cultures came into some degree of direct contact, involving person to person interaction, rather than either indirect and more remote contact, and involving several stages of interaction across time and from zone to zone between the three geographical locations.

7. Conclusion

The geometrical intricacy of the inter-locking key-type patterns from Spain, Iran and Korea present a challenge in terms of analysis and, in particular, in accounting for their close structural similarity. Symmetry classification is a clear and objective means for confirming this similarity, rather than relying on subjective comparison only. Although the three inter-locking key-type designs presented in Figures 1, 2 and 3 have minor structural differences (not obvious immediately to all observers), they are identical in terms of their underlying symmetry. Key-type designs are exceedingly universal, and early indications in this investigation suggest the use of various types of the design class within most continents at some time over the past three millennium. The survey of the evidence suggests to the authors that independent invention and discovery in isolation may have initiated certain rudimentary key-type designs built from cross-type line configuration (thus accounting for the wide spread use of the design). However the sophistication (in the geometric sense) of the interlocking key patterns and their close structural similarities suggests a process of independent discovery in one centre and further development in the wake of diffusion, possibly in several directions and involving several different cultures. In the context of the interlocking key patterns shown in Figures 1, 2 and 3, it is believed by the authors that regular trade and frequent interactions were instrumental in design development. It is worth noting that it has been observed that during the 7th and 8th centuries CE, the Silk Road connected Korea with Arabia, and in 845 CE an Arab trader proclaimed that:

"Beyond China is a land where gold abounds and which is named Silla [an ancient name for Korea]. The Muslims who have gone there have been charmed by the country and tend to settle there and abandon all idea of leaving" [33].

It is interesting to note that around the same time, Arabic influence (particularly from Syria) was exercised to the west in al-Andalus. However while significant numbers of key-type patterns have been found in non-Arabic regions (including Turkey and Iran), the design class is not readily evident in the bulk of Arabic countries. So the evidence collected to date (surprisingly) does not support an Arabic source. Substantial further research is required however in order to confirm whether or not this is the case. It is necessary to determine more precisely the chronology and extent of the interaction between east and west, and also to suggest a chronology of key-type pattern development. There does however appear to be sufficient evidence to suggest a process of



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