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# ANALYSIS OF PATTERN STRUCTURE BY GEOMETRIC SYMMETRIES

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## INTRODUCTION

While a large literature exists on the technologies different peoples use to manufacture woven fabrics (cf. Emery 1966), little attention has been given to developing equally systematic ways to study the patterns produced. This paper outlines one approach to pattern analysis which utilizes mathematical symmetries to describe the way design parts are arranged in a pattern. The advantages of this method are discussed and examples of a number of problems that such an analysis of pattern structure can address are described.

## SYMMETRY ANALYSIS:

Symmetry analysis is a mathematically based description of the structure of a pattern. It specifies the geometries which organize, that is, repeat, the parts in a pattern. Only patterns whose design elements repeat regularly can be described by this geometry. For the purposes of textile pattern analysis, I am considering that textiles are flat--in mathematical terms they are two-dimensional planar surfaces. (Textural elaborations should not affect this classification scheme, unless one considers that these render the piece a three-dimensional object, in which case the three-dimensional symmetries should be used for the classification.)

There are four symmetry motions that move the parts of a design onto themselves and produce the repetition of the parts in the pattern. Geometers call these motions distance-preserving motions because the distance between any two parts is always the same. These motions are translation (a shift by a given distance along a line) (Figure 1a), rotation about a point in the plane (Figure 1b), mirror reflection across a line in a plane (Figure 1c) and glide reflection (translation followed by mirror reflection) (Figure 1d).

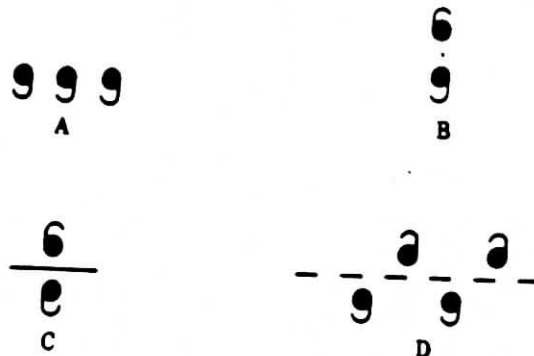


Figure 1

For patterns in the plane, there are three axial arrangements around and/or along which the parts of a pattern are repeated. Finite designs are generated by the repetition of parts around a central point axis (Figure 2a). A swastika, for example, has four extensions rotating from a central point. Because finite designs are generated only by mirror reflections through the central point axis or rotations around that axis (there are no translations or glide reflections), an infinite number of reflections or rotations can occur and thus an infinite number of different patterns can be generated.

One-dimensional patterns are generated by the repetition of their parts along a line axis in one direction (Figure 2b). All four motions can be used to generate these patterns; the greatest combination of these motions produces seven different classes.

Two-dimensional patterns are generated by the repetition of their parts in two or more directions (Figure 2c). All four motions can be used to generate these patterns. Because they translate in two directions, there are a possibility of 17 pattern classes.

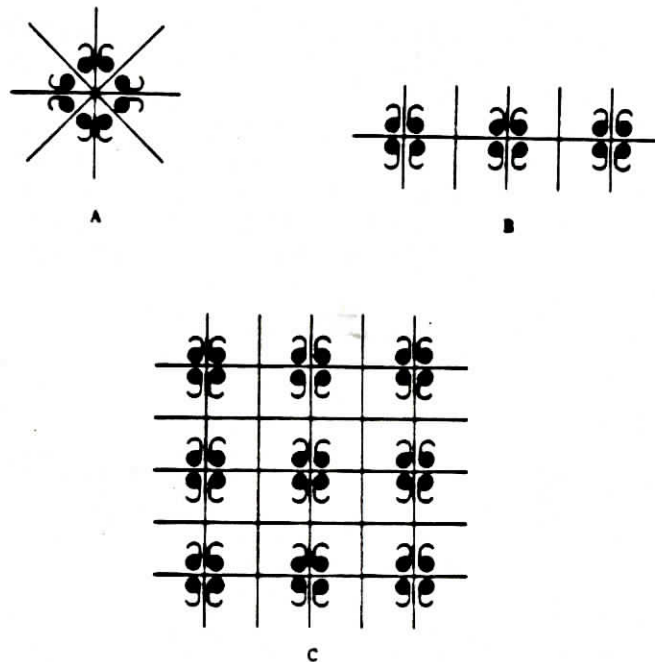


Figure 2

One-dimensional patterns are often called bands or friezes and are typically found along the borders of cloth. Two-dimensional patterns are also called overall patterns and are typically found decorating the central portions of textiles. Be advised, however, that these characteristic locations for these pattern categories do have exceptions. Many bands, that is, narrow spaces demarcated by upper and



lower banding lines, are found to contain two-dimensional patterns, and conversely, broad expanses of fabric are often decorated with rows of one-dimensional band patterns. The location on the textile is not necessarily an indicator of the symmetry class of the pattern placed in that area. Only a detailed study of the symmetries present in each pattern will lead to the correct classification.

The classification process is aided by the use of flowcharts which lead the user through a series of yes/no questions concerning the presence of the four motions to the correct symmetry assignment. The flowchart for the seven one-dimensional patterns is found in Figure 3 and for the 17 two-dimensional patterns in Figure 4.

These flowcharts, however, pertain only to one color patterns. If the user is analyzing patterns whose parts alternate two colors consistently (black-white, black-white, black-white) then they should consult the flowcharts for the classes of patterns which result from those combinations of motions and colors. For the one-dimensional patterns, there are 17 classes of two-color symmetries and for the two-dimensional patterns there are 46 classes of two-color symmetries.

Each symmetry class is described by a distinctive nomenclature which is a code for the presence or absence of the four basic symmetry motions. The nomenclatures for the one and two color symmetries and their flowcharts are described in detail in Washburn and Crowe (1988). For patterns with more complex color alternations, there are no flowcharts, but discussions of their motion classes are referenced in Washburn and Crowe (1988).

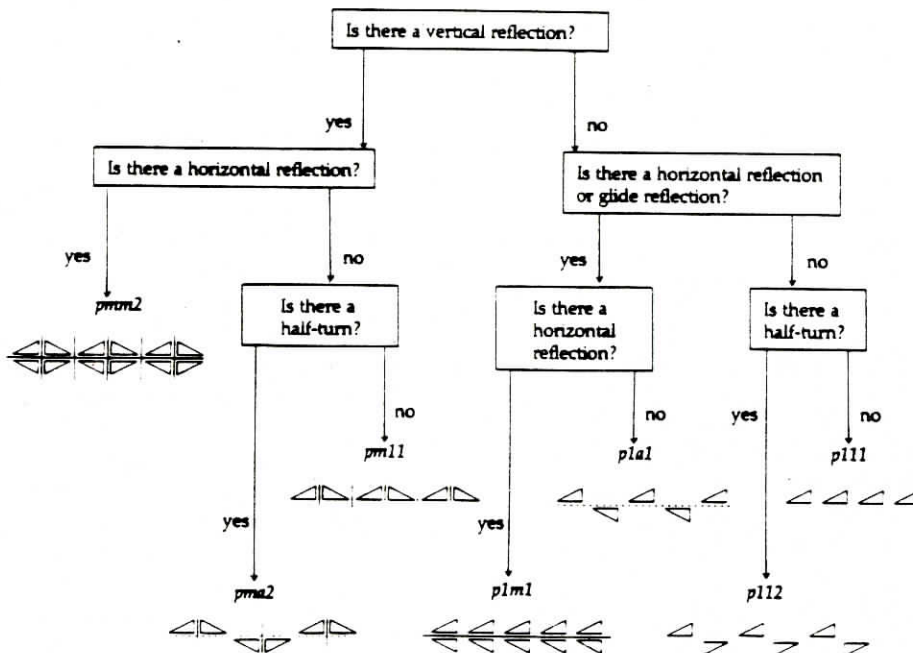


Figure 3

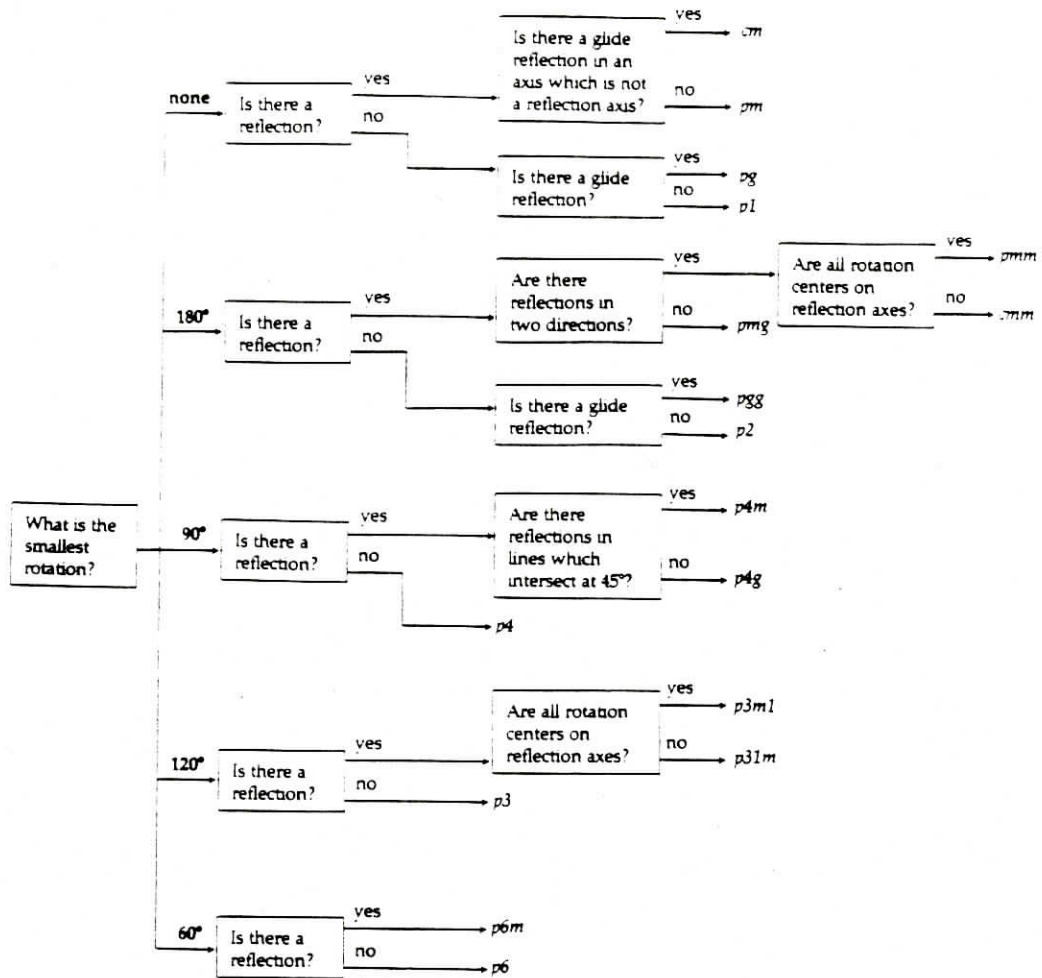


Figure 4

#### ANALYTICAL ADVANTAGES OF SYMMETRY ANALYSES:

Symmetry analysis offers both methodological and interpretative advantages.

First, description of a style by the structure of patterns which typify it is systematic and objective. Although the method can only be applied to patterns that are regularly repeated, thus excluding some decorative treatments that are random in their distribution, and although the method addresses only the structure of the pattern, not its particular motif shapes, textures or other aspects, the systematic nature of a classification by geometric motions argues for its adoption on those patterns for which it is appropriate.

Furthermore, because pattern structures defined by symmetry are so precisely delimited, comparative studies over space and time are facilitated. The mathematical basis ensures that different investigators analyzing the same data base will arrive at the same answers, or, that one investigator analyzing a number of similar data bases will be



able to consistently describe the patterns. In contrast, descriptions of a style by the design elements which compose it tend to be idiosyncratic for that object type only.

Second, the analysis of pattern structure, rather than individual pattern elements, bases the description of style on a feature of patterns--the organization of the design as a whole--which artisans articulate as being significant during their conceptualization of the patterns. In contrast, 20th century Western analysts often select features as significant merely because they are easily observed and documented.

Third, stylistic descriptions based on single features facilitate the study of the meaning, distribution, and correlation of each feature as well as the discovery of new insights and patterns of behavior that were not observable using traditional approaches. In symmetry analysis the only feature studied is pattern structure, and the only aspect of that structure analyzed is its planar geometry. In contrast most styles are defined by constellations of features. Since each feature may be associated with a different behavior and have a different meaning, an analysis which examines them in combination may mask a behavior pattern produced by any one feature. While one may validly argue that the well known styles defined for many historical periods, such as the Baroque style, accurately reflect a particular behavior pattern, I argue that a more detailed analysis by separate features may uncover hitherto unknown aspects of the style because of the masking effects of combined feature analysis.

However, while I have been arguing that study by one feature is preferable to the study of many features together, I must also argue that not all features studied by themselves will yield meaningful results. For example, because artisans think about their designs in terms of a whole, rather than separate elements, the description of design by their elements may not yield any meaningful patterns of behavior.

In order to demonstrate this point I describe a study which illustrates how analysis by design structure rather than design elements can uncover important new patterns of behavior and insights about cultural activities. Because pattern analysis by symmetry can describe the many different ways the **same** design element can be structured, it can potentially separate the pattern production activities of different cultural groups. In contrast, a simple tally of the presence or absence of design elements will obscure the presence of these distinctive and potentially mutually exclusive ways of element structuring that may be indicative of certain cultural activities.

For example, researchers have described all ceramic designs with pendant triangles from Early Neolithic sites in Greece as "flame patterns". A plot of the distribution of flame patterns reveals that they were distributed throughout all sites occupied during this period. In contrast, if the use of flame patterns are plotted by the symmetries which arrange them, distinct distributions of each structure are found which can be related to environmental and cultural



factors.

During the Early Neolithic, the distributions of each different way of structuring the "flames" are found to be almost mutually exclusive. Groups living in the isolated mountain and narrow river valleys of central Greece are each characterized by a different way of structuring the "flames." However, in the northern Thassalian Plain, a flatter area more conducive to travel and trade, there were overlapping zones of the use of different flame pattern structures. By the Late Neolithic, however, the widespread trade networks throughout the Aegean appear to have promoted one site as some kind of "bulking" center, represented archaeologically by the presence of all the different ceramic design structures, while sites in the immediate area are "producers" of different wares, each represented archaeologically by shards with only one design structure (Washburn 1983). Thus, symmetry analysis can be an efficient and effective way to discover new patterns of activity as well as to discover some of the factors which may be responsible for the kinds and distributions of these activities.

#### APPLICATIONS OF SYMMETRY ANALYSIS:

The following section describes some of the cultural practices which appear to be sensitive to pattern structure and which can be studied by symmetry analysis. I have cited examples from my research; many other examples may be found in Washburn and Crowe (1988).

One of the most interesting discoveries of symmetry analysis has been that cultural groups tend to prefer to structure their designs very consistently. Usually, only one or two symmetries characterize the structure of most of a group's designs. While other researchers have shown that art forms have structure, symmetry analysis has demonstrated that the geometry of the structure is consistent throughout an art form of a specific group. For archaeological data bases, the finding that structural consistency is a hallmark of a group's design system may enable the researcher to define the presence of a cultural entity where other evidence for this characterization is minimal or inconclusive.

Given this structural consistency, interesting problems involve the discovery of the behaviors and events related to this preference as well as the activities which perturb this structural system.

For example, an ethnographic case study of design preferences on northern California Indian baskets revealed that these peoples deliberately used structure to preserve their ethnicity by using different symmetries to decorate baskets made for their own use versus those made for sale to non-Indians (Washburn 1986a).

While certain basket forms, such as basket tea cups and saucers, were clearly made for white buyers, other baskets, also made for the non-Indian, are differentiated from baskets for Indian use only by subtle differences in the feature of design structure. That is, since whites wanted to buy

"traditional" baskets, the Indians were required to use the traditional design elements and basket forms to satisfy white demand. However, the Indians were able to differentiate Indian and for sale baskets by the way the elements were structured. Traditional structures (pma2, pl12) were reserved for Indian-use baskets while other symmetries were used to structure elements on baskets made for sale.

Similarly, differences in symmetry preferences for raffia designs differentiate patterns produced by different tribes in the Bakuba kingdom. The attributes of structural symmetry in conjunction with contrast in color, texture and line are the features which hallmark the Bakuba style (Washburn, in press).

Once the consistent structural symmetry of a group has been defined, its use can often explain the presence of a number of apparent aberrations. For example, the presence of an unusual design element shape—a metal suspender clip-on northern California Indian basket hats can more easily be understood if one sees that the foreign shape has been easily incorporated because it can be arranged in a one-dimensional design on the hat within one of the two traditional symmetries. In Figure 5, I have illustrated how this shape can be arranged in three possible band symmetries. However, despite these possibilities, only the pma2 arrangement was used by the Yurok in their basket designs.

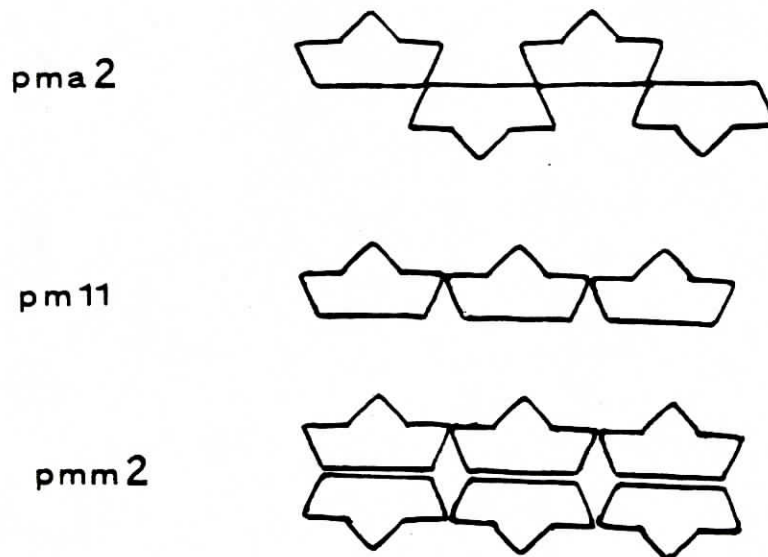


Figure 5

Similarities and differences in pattern symmetry also appear to be accurate measures of the distribution and spread of design ideas through space and time. For example, with the aid of the multivariate statistical tool of multidimensional scaling, similarities and differences in ceramic design symmetries were shown to be good measures of the relative distances between Anasazi sites in the American



Southwest. A multidimensional scaling of Anasazi pottery designs from a series of sites on Wetherill Mesa, Mesa Verde National Park, revealed that changes in design symmetries, but not changes in pottery types, paralleled the decreasing age of the sites along the mesa as measured by dendrochronology (Washburn and Matson 1985).

Changes in symmetry structures may indicate the onset of specific historical events. The arrival of the Inca in the Ica valley and their subsequent departure was recorded in change from then reversion to the traditional Ica Valley ceramic pattern structures (Washburn ms.). The beginnings of trade in the Aegean Sea is recorded in the dramatic increase in different patterns and their structures in the ceramic sequence at the site of Knossos on Crete (Washburn 1983).

These examples suggest ways in which the systematic study of the feature of pattern structure can reveal insights about the relation of design to certain cultural activities. I have compared this approach to traditional studies of the presence and distribution of single elements or of styles which are defined by their co-occurring constellations of attributes. Studies of design elements do not appreciate the fact that artisans think of their designs in terms of the way the elements are arranged into the whole, not simply of the presence or absence of the elements. Studies of styles falter since, because each feature is related to a different activity, study of their distributions as a conglomerate will not clearly reveal the activities with which each is most closely associated. For example, even a sophisticated statistical routine could not arrange the ceramic types from a series of Wetherill Mesa sites in correct temporal sequence (Washburn and Matson 1985), nor did a design element study of "flame" patterns reveal how settlements were strongly influenced by geography during the Early Neolithic in Greece (Washburn 1983).

Finally, while symmetry analysis is appropriate for the study of all plane patterns, whether on textiles, tile, ceramics, baskets, or any other flat surface, I should like to elaborate on the relationship of pattern structure to the technologies which produced the patterns since this is a particularly appropriate consideration for the analysis of patterns on woven textiles.

First, although the structure of designs on ceramics, for example, is not affected by the different technologies used to produce the vessels, the different techniques used in textile weaving may indeed have an effect on the pattern. That is, the pattern structure itself may be controlled and limited by the technology. An excellent example comes from my studies of the patterns on southern Lao woman's skirts (Washburn and Petitto, ms.).

Lao women weave their tubular skirts on large floor looms using four weaving techniques: djok, mi, kahn, and mok. Analysis of the patterns produced reveals a distinct preference for pattern symmetries with horizontal reflection. Band patterns are usually structured by the plm1 or pmm2



symmetries, while the two-dimensional patterns are structured by the dmm or pmm symmetries. This consistency is not simply a result of cultural ideas about appropriate design; it is also dictated by the mechanical set up of the pattern sticks in the heddle.

It should be emphasized here that if this structural preference were solely controlled by the loom technology, then only those techniques which controlled the design structure would produce designs with those symmetries. However, although only the djok produced patterns are controlled by the pattern sticks which favor this symmetry, all textiles, regardless of the loom technology used to produce them, seem to carry patterns structured by these symmetries. Thus, both technology and cultural preference are factors in the observable pattern structure.

In the djok technique, each row of the pattern is marked by a pattern stick interwoven in the threads in the vertical heddle. Each stick records the sequence of threads to be raised and lowered when the sheds are opened for the addition of a weft thread. When a line of weaving is complete the pattern stick is moved from above the warp to below the warp. The most efficient use of these pattern sticks dictates that the design has horizontal symmetry, such that only one half the design need be marked by sticks; the other half can be produced by reversing the sequence of the sticks. For example, to produce a diamond shape, only enough sticks to mark the rows in the lower half of the diamond are placed in the heddle above the warp; are used; and then are brought down and stored below the warp. The upper half of the diamond is then formed by bringing them back sequentially from below the warp to above the warp. While any shaped element can be produced using this technique (and there are a number now being produced for Western consumption that depict elephants and other figurative elements which do not have horizontal symmetry), the greatest proportion of traditional Lao designs are characterized by horizontal symmetry.

Second, there are yet to be studied relationships between technology and pattern and between pattern and color as exemplified in the complex interlacing of pattern structure and color in pre-Columbian Peruvian textiles (Washburn 1986b). These problems reinforce the need to study systematically the manifestation of each feature carefully.

#### SUMMARY:

In this brief paper I have outlined the analysis of patterns by geometric symmetries and have discussed the advantages that such descriptions of the geometry of the feature of structure can afford. While I have emphasized its advantages over design element analyses and stylistic studies which consider conglomerates of features, it should be emphasized that each approach uncovers different information about different aspects of the data. No method of analysis can answer all questions. Thus, I would recommend that symmetry analysis be applied in conjunction with other types



of analyses, each chosen for its ability to shed insights on different aspects of the particular problem under investigation. I would urge that as we develop such detailed analyses of particular features, whether it be of the symmetry of pattern structure or the chemistry of the dyes used in the yarns, that we collaborate, each contributing our particular expertises and perspectives toward the greater understanding of our material.

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