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Computerbased Analysis of Symmetrical Properties of Weavings

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Different methods can be used for analysis and classification of weavings. A structural approach using the symmetrical properties can provide some new aspects for studying material culture. Based on geometric principles developed by crystallographers, this method has been recently adapted for the humanities by Washburn and Crowe. This paper describes an approach where rules for the design classes are implemented in a PROLOG program and special topographic operators have been developed for describing compound objects. As a database, a combination of PROLOG and SQL has been used. The method has been tested on different samples of weavings. The creation of expert systems for taxonomy reasons is discussed.

コンピュータによる織り柄の対称性解析

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織り物の柄の解析と分類にはいくつかの方法がある。対称性を考慮した構造的手法は物質文化の研究に新たな視点を提供する。Washburn　と　Croweは、結晶学者によって開発された幾何学的方法を基礎にして、この手法を人文科学の分野に導入した。本論文ではPROLOGによって記述されたデザインの規則と、複合図形を記述するオペレータについて述べている。データベースにはPROLOG　と　SQL を使った。この方法によっていくつかの織り物を解析した。また分類を行なうエキスパートシステムについても触れている。

1. Introduction

Material anthropology is that part of anthropology where the emphasis lays on material culture. Special analysis techniques should be developed to make the analysis of artifacts more effective and intersubjective. In the era of information technology these methods should be adequate for computer applications. This paper discusses an approach to the analysis of weavings (textiles) mainly based on symmetrical properties. In anthropology we have to deal with the emic/etic-problem. If we use the etic (culture free, universal) method of symmetry analysis we have to ask ourselves if there is an emic (culture dependent)-equivalent, which carries some meaning for the specific culture which is studied (see Washburn and Crowe 1988:19). An example, how geometrical, symmetrical properties of textiles could be seen as expression of the structural organization of the society can be found in the study by Adams (1973) about Eastern Sumba (For an example of an Eastern Sumba ikat see Figure 1). The study of symmetry based on geometric properties is not new, but just recently rediscovered and adapted for anthropology by Washburn and Crowe (1988).

2. Basic Principles

For more detailed information I would recommend the study of "Symmetry of Cultures" by Washburn and Crowe, where many examples can be found. A more mathematical and group theoretical approach can be found in Grünbaum and Shepard (1987) and Wieting (1982). In common thinking, symmetry usually means bilateral symmetry, but other categories of symmetry in the plane exist: "The symmetries of the plane, then, describe the geometry of repetition of all repeated decorative patterns studied by anthropologists, art historians, craftsmen, or designers. Various combinations of symmetries, herein called *motion classes*, are present in all regularly repeated designs." (Washburn and Crowe 1988:15). As it can mathematically be proven there are only four rigid motions of the plane: translation, mirror reflection, glide reflection and rotation. With this rigid motions different designs (or patterns) can be constructed. For this purpose some definitions are necessary: One-dimensional patterns admit translation in only one direction, two-dimensional patterns in at least two and finite designs don't admit translations, but only reflections and/or rotations (See Washburn and Crowe, p. 52-55). It is often unclear if an annulus should be considered as a circular band or a finite design. In this case I would suggest the following criterion: It is a circular band, if the outer radius of the annulus is equal or less than twice the inner radius, otherwise the annulus is classified as a finite design. The criterion for a two-color pattern (or design) is that "there is some rigid motion of the plane, which interchanges the colors everywhere". Rigid motions are called "consistent with color", if they reverse colors everywhere or if they preserve colors everywhere (Washburn and Crowe, p. 64). Often additional colors can be found, but have to be considered as background only. According to theory of crystallography, the following different patterns can be found: 7 one-color one-dimensional patterns, 17 one-color two-dimensional patterns, 17 two-color one-dimensional patterns, 64 two-color two-dimensional patterns, and a theoretically infinite number of finite designs. The 23 three-color two-dimensional patterns can be found in Grünbaum and Shepard (1987), the 96 four-color two-dimensional patterns in Wieting (1982). Fortunately, however, the are extremely rare in ethnographic praxis.

3. Computer-implemented Method

For easier classification, Washburn and Crowe developed some flowcharts, which I transformed into a simple PROLOG program which uses backward chaining (Marcellus 1989) to reach a result. It classifies 93 different designs (24 one-dimensional and 63 two-dimensional patterns, 6 rules for finite designs), each described by a single rule. This program shows an apt dialog where the user is only asked about such informations which the program needs and does not already have. The dialogs will differ in form and length according to the different rules. Since it is asking the right questions at the right time the program will appear as to be something like intelligent. One example follows below:

```
Is it a finite design (only reflection and/or rotation)? n
Is there only one dimension (else two)? n
What is the smallest rotation consistent with color:
(none,60,90,120,180)? 180
Is there a reflection consistent with color? y
Is there a half-turn which reverses colors? n
Are there reflections, consistent with color, in two directions? y
Are all rotations centers on reflection axes? n
Is there a reflection which reverses colors? n
design: cmm (zoomomooo)
```

The result-expression in brackets, which consist of 9 characters, I used internally in the program, because the original crystallographic notation is not very suitable for string comparison. Since there are often some ambiguities and irregularities the pattern can be classified in a different way. For this reasons a certainty factor (between 0.00 and 1.00) gives information about it, depending on how certain the researcher is in classifying a special area of a weaving (or the whole). Is there more than one possibility then each possibility is stored as a variant. For the description of the spatial operators I used 3 characters. These operators fall into two classes: part-whole-relations(P,W) and part-part-relations(P2,P1).

As a first attempt I introduced the following operators:

ctr(P,W)	P is central in W
hom(P,W)	P is horizontally in the middle of W
hnm(P,W)	P is horizontally near the middle of W
vem(P,W)	P is vertically in the middle of W
vnm(P,W)	P is vertically near the middle of W
vag(P,W)	P is vertically arranged in W
hag(P,W)	P is horizontally arranged in W
weo(P2,P1)	P2 is west of P1
eao(P2,P1)	P2 is east of P1
noo(P2,P1)	P2 is north of P1
soo(P2,P1)	P2 is south of P1
cic(P2,P1)	P2 circumscribes P1

This is as far as I have experimented with the most important ones. Other ones f. e. describe the diagonal arrangements. If there are any examples, where the existing set of operators are insufficient, further ones can be created. Additional information can be added in a special field:

r ... this part is reflected
a ... when a part is repeted, the repetition is alternating (one or more other parts between)

t ... when a part is repeted, it is transposed along the longitudinal axis
m ... this part is the main part of the weaving (largest area)
b ... some details which have their own structure are classified as background
c ... "color transformation": a structured small part is interpreted as if it has a single color

Since almost all of the weavings are compound figures, the symmetrical analysis can be made at different hierarchical levels. Usually the overall figure is inspected first and it's symmetry class determined. However, this is often done for completeness and not with regard to the importance. The symmetry of the overall weaving is often a finite design only and the parts with higher symmetry are usually around the center (spatial operators "ctr", "hom", "vem", "hnm" or "vnm"). There are no standard rules of speaking of higher or lower symmetries of pattern, but I would propose that a two-dimensional pattern has higher symmetry than a one-dimensional one and patterns which admit more rigid motions of the plane have higher symmetry than ones which admit fewer rigid motions.

For subdivision into smaller parts I would propose the following rule: Larger parts with a specific symmetry are subdivided into smaller ones, only if the symmetry of at least one of the smaller parts is higher and if the smaller parts are easily separable, which means, that an imaginary straight line (or circle) can be drawn between these parts in such a way that there are no interlacing details.

For describing the form of the different parts of a weaving I used some linguistic variables according to the fuzzy set theory (see Zimmermann 1988), which rests on the vague nature of how humans perceive the world. The exact length and width of a specific part of a textile are not recognized and therefore not necessary for making folk taxonomies and typologies. Since the perception of the world is often vague and fuzzy, one might suggest that methods which can deal very well with this fuzziness might be adequate in the field of anthropological research. As an ethnologist one has not only the computer implementation in mind but the data collection during fieldwork as well. An ethnographer cannot always measure the observed properties and in such a case linguistic variables could fill the gap. Instead of the crisp membership in traditional set theory, fuzzy set theory uses a membership-function which uses the continuous interval between 0 and 1. For the description of different rectangles, the following linguistic variables have been created:

1. square	sqr	6. broad stripe	bst
2. square-like rectangle	slr	7. medium broad stripe	mst
3. slighty elongated rectangle	ser	8. small stripe	sst
4. medium elongated rectangle	mer	9. straight line	lin
5. strongly elongated rectangle	str		

An additional character gives information about the orientation, for example "h" (horizontal) or "v" (vertical). In many cases, only different rectangles are used for subdivision, but similar linguistic variabels can be used in the case of circles, frames and annulus. The same method might also be useful in coding colors during fieldwork.

Since PROLOG provides a relational database automatically, the searches and analysis can be made directly inside PROLOG, however, some PROLOG-Versions provide an interface to SQL (Structured Query Language), which might be more convenient for this purpose. Images can be called from PROLOG as selfdisplaying files via DOS-access. When I am pointing out some results, I would like to emphasize, that this could only be viewed as some tendencies, since the number of inspected samples is not large enough and not randomly taken. For example, the main part of an Iban ikat (Borneo, Figure 2) shows typically a pm11-pattern, which means one-dimensionality and only one symmetry (vertical mirror reflection). Inspecting some designs of the T'boli in Mindanao, Philippines (Casal, 1978:149-151) brought the following results: They are typical two-dimensional patterns. "Klung" (shield, Figure 4), "sawo" (python's skin, Figure 3), "bangala" (man within the security of his house), "g'mayaw" (mythical bird) show a cmm-pattern. "Tofi" (frog) is a pm-pattern, but if you overlook slight asymmetries inside the hexagon, it can also be described as a cmm-pattern. "Nipa" shows a typical pm-pattern.

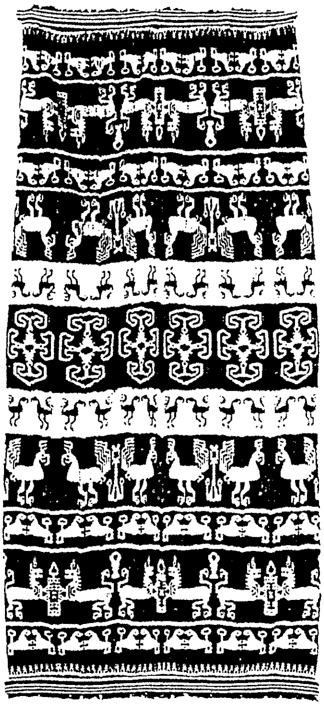

Fig.1
(O'Neill 1979:25)

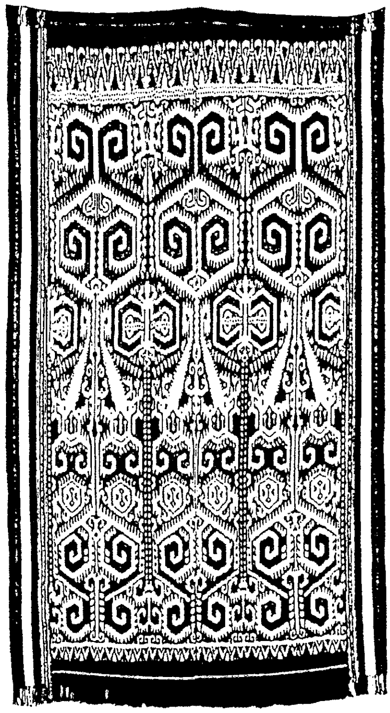

Fig.2
(Ong 1986:41)

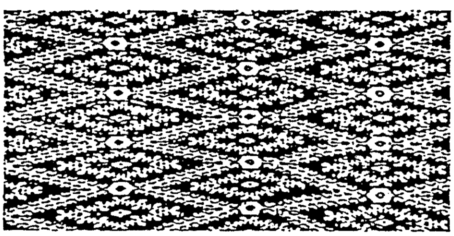

Fig.3

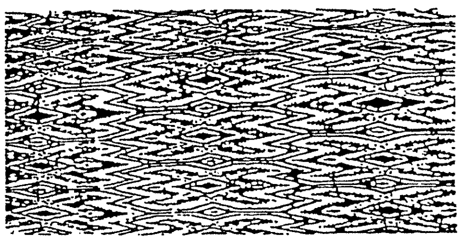

Fig.4

At this stage of analysis new questions arise and one would like to look for some explanations of these differences. Heine-Geldern mentioned that the Dong-Son style had influenced the whole Indonesian archipel, but the late Chou style succeeded only on some islands especially in Borneo (Wagner 1972:32), whereas the "... T'böli have remained completely unexposed" (Casal 1978:169). The Dong-Son style is characterized by its very symmetrical and highly geometrical construction, whereas the late Chou style does not so much emphasize symmetry (Wagner 1978:32). On the other hand the pm11-patterns of the Ibans only show a vertical reflection and is one-dimensional, the cmm-patterns of the T'boli show the following characteristics:

- two-dimensional, 180° rotations
- horizontal + vertical mirror reflections
- glide reflections, which are not mirror reflections
- twofold center (some rotation centers are not on reflection axes)

Since the cmm-pattern has "higher" symmetry as the pm11-pattern, the theory of Heine-Geldern is in agreement with the observed properties of the symmetry patterns. However some exceptions to the rule can almost always be found. If some samples vary from the mainstream then this is a good opportunity to ask new questions about the socio-cultural background of the weaver.

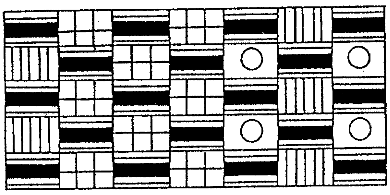

Fig.5

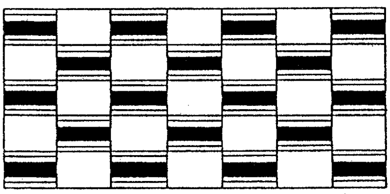

Fig.6

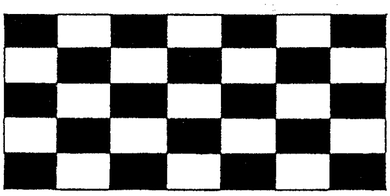

Fig.7

Kente-clothes of West Africa (Eguchi 1987) usually have on both ends a part, where the structure is different from the structure of the main part. Different small rectangles cover the whole or at least part of the textile. These rectangles can be classified as "basic units" with their own symmetrical properties. In this case instead of a spatial operator the designation "bas" is used. This basic units can still be classified without any emic knowledge. Similar additional informations can be added in the case of ikat weavings about the motifs (special animals, etc.), but since these are commonly stylized one has to know something about the emic categories, the local knowledge and classification. A stylized example is shown (Figures 5, 6, 7). In Figure 5 one can see different basic units, but the one with the solid bar in the middle appears more often than the others (It shows for itself a d2-pattern, that means it is a finite design with reflection and 180° rotation).

If we consider all the others as background then we can find an underlying one-color pmm-symmetry (Figure 6). But there is another way to look at this pattern: One can consider the structure inside the small rectangle as an uniform color and then the pattern will have a two-color c'mm-symmetry (rectangular checkerboard, Figure 7). In this case, two different versions are stored, each labeled with a subjectively chosen certainty factor. After several textiles have been studied one might arrive at a different level of knowledge according to the hermeneutic spiral. I would suggest, that afterwards the sample is inspected again and the certainty factors changed if necessary. An additional question arises when on some textiles the "dominant" basic units are uniformly in structure but exhibit partly different colors, which have to be equated in order to build the whole structure. For example, it can be found that yellow and orange are equated. In such a case the ethnologist has to inquire additional information about basic color terms, etc.

After several examples of weavings of a specific ethnic group have been analyzed and some distinguishing features are discovered, one can think about making a synthesis, creating a taxonomy. For this reason expert systems can be constructed. Expert systems contain the best available knowledge human experts posses in a particular field of knowledge. This knowledge is extracted by a knowledge engineer and is implemented in a computer program. It might be interesting to point out, that the work of a knowledge engineer resembles the work of an ethnographer on fieldwork (For other applications of expert systems in anthropology see also Wilson 1992). In the field of material anthropology the human experts are curators in the museums or local informants in the field. But experts in a special field are rare and it might be useful to have a computer-implemented expert system which could give advice for taxanomic reasons (type diagnosis). As an example, below is a listing of the production rule for an ikat weaving of East Sumba (Figure 1), which uses only etic information, i.e. anyone without any specific knowledge about the ethnic group, which produced this weaving should be able to classify it. At first, a formulation in common language is given and afterwards the transcription into the Prolog syntax is shown:

```
IF  the main part shows a pmm2-symmetry
    AND it's form is a rectangle in horizontal position where the
        degree of membership to the medium elongated rectangle is
        greater than 0.60 OR the degree of membership to the
        slightly elongated rectangle is greater than 0.40
    AND north of the main part are at least 3 rectangles in
        horizontal position, which are reflected at the main part
    AND these rectangles show a pm11-symmetry
THEN this is probably a weaving of East Sumba.
```

Notice, that in this example, the word "where" and "which" function also as a logical AND. Now let us see, how the implementation in Prolog looks. A comma has the meaning of a logical AND , a semicolon the meaning of a logical OR and ":-" means IF.

```
weaving(east_sumba,0.90):-
      sym(P,pmm2), main_part(P),
      (memb(P,merh) > 0.60; memb(P,serh) > 0.40),
      noo(Q), sym(Q,pm11), refl(Q), noo(R), sym(R,pm11), refl(R),
      noo(S), sym(S,pm11), refl(S).
```

Informations about colors can be added if necessary for finer discriminations. For color-description I used the Japan Standard Color of Paint which is based on the HVC-System. However, for fieldwork I would suggest the additional application of a color naming system, which is based on English phrases.

4. Conclusions and Prospects

As it was shown the analysis of symmetrical properties can provide some new insights into the study of weavings. Computer-implemented methods are useful to handle a lot of items, for efficient information retrieval and to create expert systems for taxonomies. Future improvements should be made in establishing internationally accepted standard notations for higher-colored patterns and color descriptions. To my knowledge the methods of automatic pattern recognition are not yet developed to the point where they are fully applicable, but developments in the future could change this situation. Finally, a more comprehensive database should be built, where additional informations about other classification methods, weaving technic, local terms, socio-cultural datas, etc. are included.

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