THE COMPUTER ANALYSIS OF POTTERY SHAPES WITH APPLICATION TO BELL BEAKER POTTERY

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Abstract

The paper describes the use of the PLUTARCH System since 1969 in the analysis of pottery shapes using two distinct methods (the "sliced" and "mosaic" methods). Each pot is automatically allocated a classification code which describes its general shape, and the volume of the pot is calculated. The statistics may be used in clustering procedures which produce dendrograms, skyline plots and scalograms with group size indications and minimum spanning trees. The procedure is illustrated by preliminary results from an analysis of Bell Beaker pottery from Central Germany.

The Problem of Pottery Classification

Pottery has been studied in a systematic manner for almost twenty years. Insufficient space is available here to give a comprehensive coverage of previous work, but a brief summary follows.

The first worker to consider the systematic geometric description of pottery shapes was Shepard (1957); the procedure proposed considered corner points (carinations), inflection points and orifice diameters. Unfortunately the system as proposed did not provide a continuous transition between types in all cases.

Ericson and Stickel (1973) have more recently proposed a geometric classification system based on simple solid shapes such as sphere, cylinder and cone. A pottery shape was described in terms of conjunctions of these solids plus radius, thickness, height, etc. If complex forms are described using the scheme, systems of brackets become necessary and it seems unlikely that such a complex nomenclature will find acceptance among archaeologists. Gardin et al (1962) have coded pottery forms on punched cards but not for computer use. Poulsen (1972) developed Gardin's system, commenting that the detailed observations proposed by Gardin were too time-consuming. Instead a series of codes for rim types, wall thickness and decoration were suggested. Clarke (1962, 1970) classified British Beaker pottery using various ratios of dimensions (e.g. rim diamter/waist diameter) and codes for decorative motifs, position of decoration, paste and firing. Perhaps the biggest curse which plagues the archaeologist in the classification of pottery forms is the proliferation of terms used. An attempt is made below to group similar forms:

plate/platter/pancheon/charger
dish/saucer
bowl/basin/porringer
cup/goblet
mug/tankard/tyg/"beaker"
chamber pot/possetpot/pipkin
jug/pitcher/ewer/flagon
jar/albavello/galley pot/olla/vase

but the only really objective way to describe a profile is as a numerical code which embodies the form of the pot. Kim (1969), Gaines (1970) and Hardy-Smith (1974) have all strongly recommended the standardisation of pottery terms.

Orton (1970, 1971, 1973) has described pottery forms in a statistical manner, working on a collection of pottery from a kiln site in Highgate Wood, London. Wagner (1971) has used coded descriptions of pottery for analysis of sites at Tell-Hesi and in Canada.

2) Methods of pottery classification in the PLUTARCH System

The PlUTARCH System has been described by Wilcock (1974). This paper will confine itself to a brief description of the pottery profile statistics capability.

The profile of the pot is first digitised and input from what may be a fairly crude diagram produced by drawing round a pin template previously pressed against the pot. The inner and outer profiles are rotated by the computer, so that the centre line is truly vertical, then smoothed and scaled to standard height. The profile code and the colume of the pot are determined from the outer and inner profiles respectively, and the pot is displayed in conventional left-hand section and right-hand elevation. If accepted by the archaeologist, the name of the pot, the scale factor, profile code and volume are recorded, and are later available with other pots for various statistical analyses.

Two main types of profile code are available: the 'sliced' and 'mosaic' methods, each of which expresses the form of the pot. The main difference between these codes is that the sliced method only records the outer profile from the footring to the rim, while the mosaic method records the whole outer profile from the centre of the base to the rim. Figure 1 shows the sliced method where an arbitrary number of horizontal "slices" of equal thickness are taken, and the radii of the intersections of the slices are expressed as percentages of the height of the pot. The profile code is thus expressed as a calculated string of percentages.

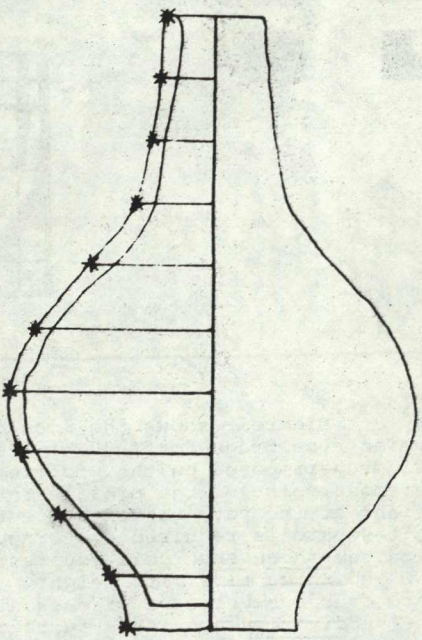

Figure 1

Illustration of the readings taken along the profile of a pot during the operation of the sliced method

Figure 2.

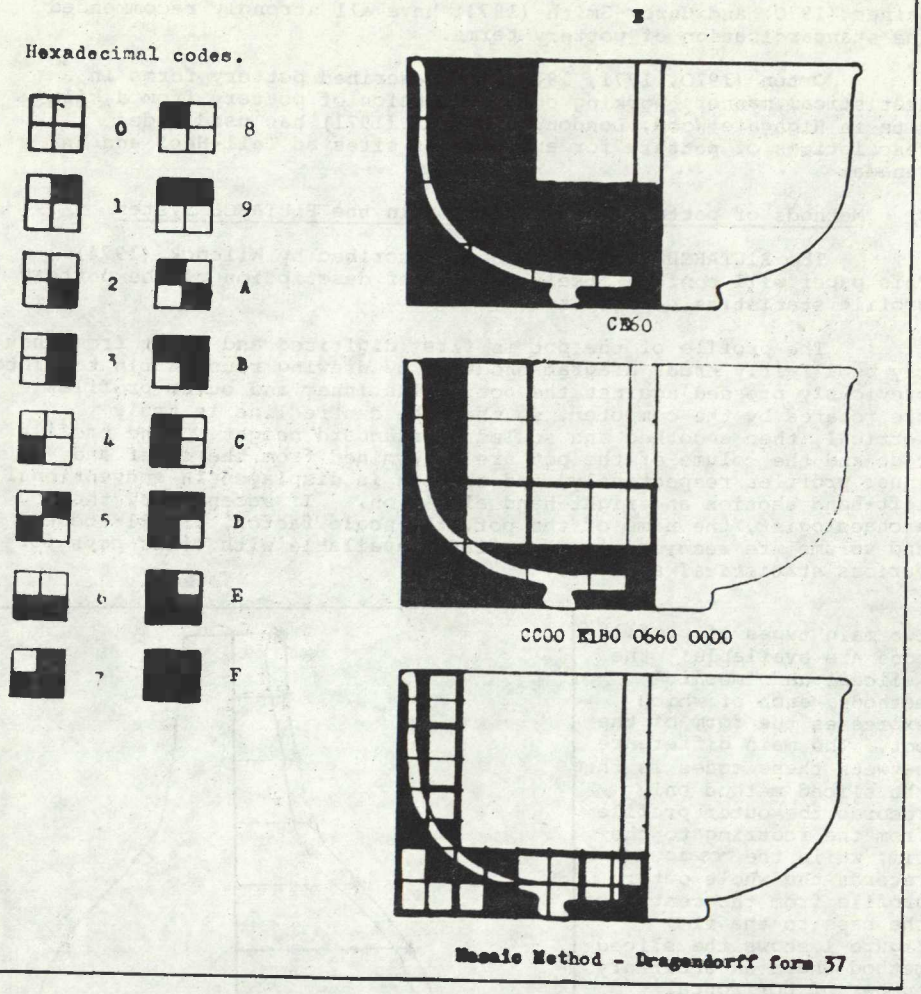

Figure 2 shows the mosaic method, taking as an example the Samian type Dragendorff 37. The method is based on a rectangular grid superimposed on the profile and extended to the right from the leftmost point of the profile in unit squares of side equal to the height of the pot, until the centre line is overlapped. Only one unit square is required for Drag. 37, but Drag. 18, for example, requires three such unit squares, since its maximum radius is between two and three times its height. The unit squares are subdivided into four sub-units of side equal to half the height of the pot, and the subdivision continues further until sufficient resolution is obtained. At each stage the presence or absence of the outer profile in each current sub-unit is recorded in a binary fashion, and the binary string may be expressed for mnemonic purposes as a hexadecimal number, as illustrated on the left of Figure 2. Thus at the first level of resolution Drag. 37 may be described as a "Type E" pot, at the second level as a "Type C560" pot and at the third level as a

"Type CCOO E lBO 0660 OOOO" pot.

The similarity between pots is calculated in the case of the sliced method by a form of inverse Euclidian distance where the differences between corresponding percentages are summed, and in the case of the mosaic method by binary correspondence between profiles. In the analysis of European Bell Beakers below the sliced method of profile code unmodified by scale or volume has been used.

3) Application to Bell Beaker Pottery from Central Germany.

The problem of pottery classification is not as simple as it might seem, because pottery has two main spheres of variation: shape and decoration. The conventionally recognis types used in establishing chronologies are generally combinations of these, and it is necessary to ask whether we are justified in combining them in this way. The decoration of a vessel will be related to social-symbolic, religious, aesthetic, and fashion considerations, although even here function may be important (cf. van der Leeuw, in press). A vessel's shape will first of all be determined by its function, but it will also relate to a variety of factors, including the type and moisture content of the clay, variations in the technique of manufacture, and the vessel size. There is thus no a priori reason why shape should covary with decoration. This is not to deny that particular shape types can be especially appropriate for particular modes of decoration, as Clarke (1970) has shown for the British Beakers. It does mean that it is very important to treat shape and decoration separately and to explore the degree of covariation between the two. A corollary of this argument is that while variation in decoration can often be regarded as relating to variation in human interaction, this is not necessarily the case with shape. A situation in which they might be expected to covary especially closely is when there are specialist potters. Since a particular shape and form of decoration are combined in a given vessel, it is the variation between vessels which matters. If a large number of pots is being made and distributed by a (semi-) specialist, technical reasons for shape variation are likely to be at a minimum and decoration to vary within fairly narrow limits. Thus there will be an invariant relationship between the two, both of which are likely to be more or less constant over an unknown number of pots. The problem about recognising this is that only a minute sample of the vessels will remain.

The above discussion has largely been in terms of the space dimension, but the problem of covariation through time is similar. Both shape and decoration will change with time; whether such change in either shape, decoration, or both, will be directional is a matter for investigation rather than assumption.

With all this in mind, it is now necessary to turn to the concrete problems of the Bell Beaker culture. The area of the present study has been Central Europe, which has one of the densest concentrations of Bell Beaker material, and to which little attention has been paid by British archaeologists. The vessels on which this paper is based come from one part of the area - the Saale valley, in what is now the German Democratic Republic. This is the first part of an analysis which will eventually cover the Bell Beakers from Czechoslovakia, Hungary and Bavaria as well. The aim of the study is to make suggestions about the sort of human behaviour which produced the variations in shape and decoration visible in the data, and will therefore be relevant to a more general understanding of the Bell Beaker 'culture'. The first stage is to reduce the material to some sort of order, in this case grouping together those pots most similar to one another. We have already seen that this should be done separately for different criteria, lest we emerge with a confused and meaningless picture. The method chosen for the

analysis described here is ideal since only shape is considered, and these shape groupings can then be compared with those produced on the basis of decoration; moreover, by including undecorated vessels of the same type, it is possible to discover whether the ornamented pots form a subset of the total range of shape variation.

Results

Ninety vessels were used in the analysis, all classified as Bell Beakers although some perhaps are on the fringe of such a definition. Nineteen groups were produced initially, of which four consisted of single individuals (Figure 3). Before discussing the archaeological significance of these clusters, it is necessary to make some comments on the method and the validity of the groups it produces.

First of all, the method used - weighted pair-group clustering using average links - produced some large and heterogeneous groups (e.g. group FG 9, which contains fifteen vessels, three of which are illustrated in Figure 4); within the cluster there are smaller groups of vessels which are very similar to one another, but the group as a whole, at the level at which it appears in the dendrogram, is not very meaningful. One implication of this is that we must be careful of the whole idea of average-similarity when applied to vessel shape, since the agglomeration into groups depends on the idea of an average profile. This is meaningful at a level when the vessels are still very similar to one another, but as soon as any heterogeneity is introduced into the shapes concerned, such a synthetic profile bears little resemblance to reality. For this reason only the initial low level groups are suitable for consideration, and it is only these with which will be considered below.

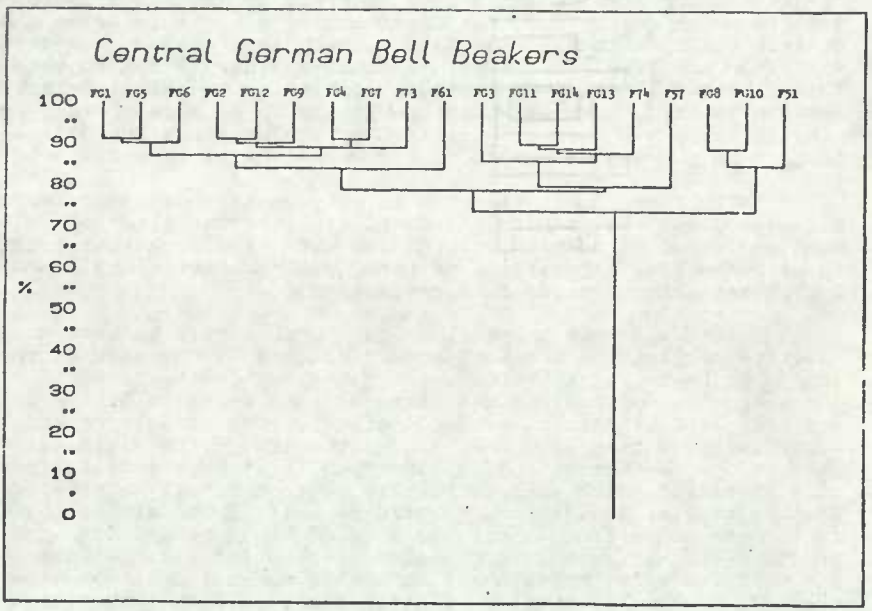

Figure 3. Dendrogram produced by Average-link cluster analysis of the similarities between Central German Bell Beakers, based on shape alone.

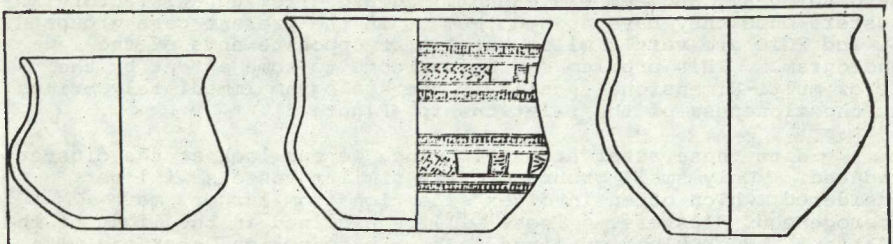

Figure 4

Three extreme forms of vessels from group FG9, showing the variety of shapes within this one cluster.

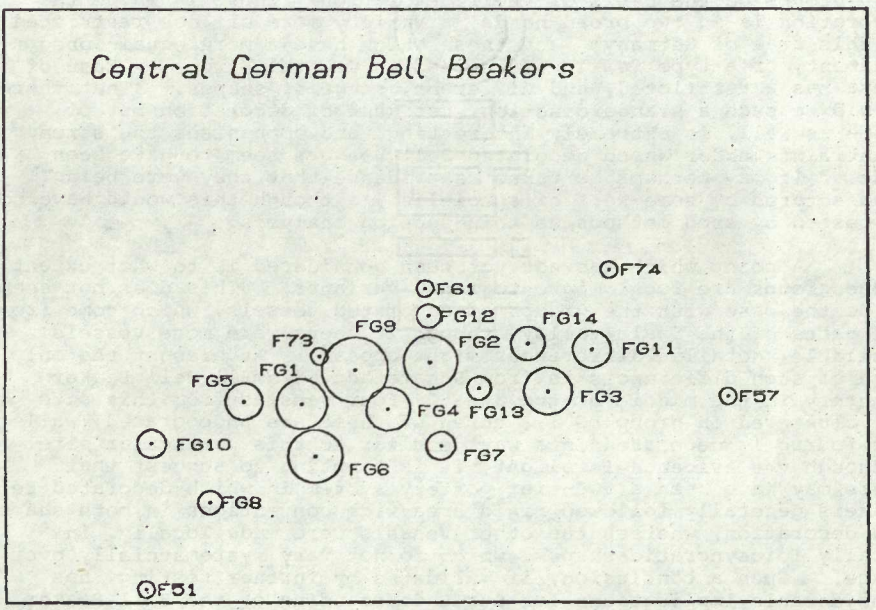

Figure 5

Scalogram showing relationships between the clusters of Central German Bell Beakers.

Secondly, a word is in order about dendrograms as a method of presentation. These can be very misleading in that groups which are in fact very similar can end up at completely opposite ends of the dendrogram, and members cannot 'migrate' from unsatisfactory clusters once they have joined them. In the present case groups FG1 and FG10 are very similar but lie at opposite ends of the dendrogram. This problem can be overcome to some extent by the use of multi-dimensional scaling; the scalogram immediately brings out the closeness of the relationship (Figure 5).

With these reservations in mind, we can look at the clusters produced. Only small groups of very similar vessels will be considered, which often involves selection from larger, more heterogeneous clusters. These will be examined in the light of the questions and problems outlined in the introduction, starting with the problem of covariation between shape and decoration as this is probably the most important.

In the first place, decorated vessels are by no means randomly scattered across the various shape clusters - some clusters include virtually all decorated Beakers (e.g. group FG 11, 4 pots out of 5), others have very few (e.g. group FG 3, 1 pot out of 8). In fact, among the undecorated vessels there is a variety of shapes which both includes and extends beyond the repertory of the decorated Beakers, most of which fall into quite a small number of well-defined classes. This suggests that shape and decoration are related, and there is further confirmation when we look at the groupings apparent within the decorated Bell Beakers. These may be divided into two main groups on the basis of their decoration: those in which the decoration is in two broad bands, a variety more or less restricted to this area of Germany; and those which have a more equal-zoned ornament, of a type fairly widespread in Central Europe. Each of these has a restricted, and different, range of shapes. That there should be such a standardisation, not just of decoration but of shape as well, is extremely interesting, and emphasises the strong constraints under which decorated Bell Beakers seem to have been made. It may perhaps be taken as evidence that they were being manufactured by some sort of specialist, although this would have to be tested by such methods as thin-section analysis.

A point which has not yet been considered is to what extent these groups are local micro-regional variants. This does not seem to be the case with the groups of decorated vessels, which come from all parts of the Saale valley, though if there were more vessels available, detailed differences might appear. At present the only sign of such differences is from Schafstädt, a small Bell Beaker cemetery in the middle of the area. Four vessels from this site are clustered in group FG 1; three of these are undecorated, while the fourth is decorated in a way peculiar to this particular site. Although the evidence is slight, it is tempting to suggest that there may have been a two-tier pottery system in which decorated Bell Beakers generally followed rigid area-wide conventions in both shape and decoration, whereas the other vessels were made locally, in locally idiosyncratic shapes, which do not vary systematcially over space. Such a conclusion, if validated by further testing, has considerable implications for our understanding of the Bell Beaker 'culture' and its significance; moreover, it fits in with results obtained from work on other aspects of the culture, particularly the burial (Shennan, in press).

But this is not the place to get involved in these more general problems, and I would just like to conclude by emphasising the inductive role which such computer techniques as cluster analysis can play in developing hypotheses by bringing some sort of order to large quantities of complex archaeological data.

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RELATED PUBLICATIONS

Proceedings of last year's conference are published as Computer Applications in Archaeology 1974, while the 1973 conference was published as Science and Archaeology 9. These are available from the conference organiser (address on p.1). The cost of the 1974 proceedings is £1 sterling and the cost of the 1973 proceedings is 75p sterling. This includes postage within Great Britain and surface mail outside but an extra charge is made for air mail (e.g. in March 1975, 60p for air mail to U.S.A. and 40p air mail to Europe).

Longer versions of some papers in this year's proceedings are published in Science and Archaeology 15 and in the 1974 proceedings are published in Science and Archaeology 11. Both are available from George St. Press, Stafford.