# A CLUSTER ANALYSIS OF WEAPON HEADS.

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Little effort has been made to develop a typology for weapon heads. This is strange, as they are amongst the most common artifacts to be discovered. Warfare is a favourite pastime for homo sapiens and its traces are to be found in the remains relating to every age in history. Though the weapon shafts may totally disintegrate their heads usually survive in varying states of preservation. This paper outlines the development of a procedure using clustering techniques, to identify a typology for iron weapon heads. It is a summary of work carried out at the University of Birmingham Computer Centre, as part of an M.Sc. in Computer Science.

## Computer-assisted Classification:

It is well known that archaeologists, when asked to classify the same set of items, will each produce a different typology (ref. 1, study of La Tene fibulai). Like archaeologists, computers, when analyzing the same body of data using different numerical techniques will come up with several answers. Which one, if any, is correct? It is necessary to determine the significance of the various results. Patricia Galloway (ref.3) in her cluster analysis of bone combs, was faced with this problem. Although a number of the computer's classifications could be rejected on a theoretical or analytical basis, in the end a subjective choice was necessary. She also found that the methods tested had great difficulty in coping with incomplete data. Incomplete combs were found to be more similar to each other and proved difficult to integrate into clusters containing complete combs.

Perhaps a more objective computerized typology might result from a model analysis. This involves the classification of a known set of data which should produce known results. If the results are achieved then the methods employed might stand a better chance of being objective and accurate for other samples. This study commenced with a known set of simulated data containing complete and incomplete items. A number of clustering methods were applied to the data and the results were compared with the expected results.

## Artifact Description.

The recording of finds for study, publication and information exchange, necessitates the development of methods for artifact description. They must accurately describe all the features of the artifacts. Usually each site will have its own methods of describing particular types of artifact. The measurements and codes chosen are those which seem most convenient and suitable to the local group. However, considerable benefits would accrue if a number of study groups could agree upon standardized descriptions. This would greatly facilitate the interchange of information and increase the overall level of understanding. From a computer point of view it would present the possibility of setting up artifact data bases and ease numerical analysis.

Standard description methods must be succinct and easy to use. A cumbersome system will not gain wide acceptance. Great care must be taken to ensure that duplication and redundancy are kept to a minimum in such systems. Since objects are rarely found in perfect condition, the methods must cope easily with incomplete items.

Phil Barker (Ref.2) has outlined a possible method for describing iron weapon heads. This method has been used in the current study. 13 attributes are recorded including a number of dimensions which define the shape and a set of indicators giving the cross section and the condition of the head. If a feature such as a lead weight were absent in the manufacture of a weapon type, it is recorded as zero. If a feature were missing, through damage, then a blank is recorded for the measurement.

The Data.

For the model analysis a known set of data was supplied. Descriptions of 50 iron weapon heads, of various types, were created. An ideal design for each weapon type was first of all generated. Then decimal dice were used to introduce the following types of error: 1 manufacturing errors (greater with native weapons than Roman), 2 wear and sharpening, 3 corrosion and damage in the ground, 4 archaeologists estimation errors (through rounding and use of preferred numbers). The types chosen included various Roman and native weapons, all of a similar period, and a modern Masai lion spear.

The CLUSTAN Package.

The CLUSTEN 1A Package, as implemented on the University of Birmingham ICL 1906A, was used to carry out the cluster analyses. 9 transformations are provided by the package, of which the 8 hierarchical methods were used. The system is designed to produce classifications directly from the input of raw data. On the surface, it appears to have a considerable amount of flexibility, providing standardization of raw data and 38 similarity coefficients. However, on closer examination, the package proved inadequate for the current study in four areas.

1. The 38 similarity coefficients are very poorly documented. The descriptions given range from being very brief to nonexistent for certain coefficients. This makes their use rather difficult, if not dangerous. I was unable to discover if my chosen coefficient, the Gowers coefficient, was available and the facilities for user defined coefficients were very inadequate.

2. My attributes were of two types: continuous variables and unordered multistate variables. The package only permits analyses to be performed on variables of one type at a time. To convert all the attributes into one type would introduce some possibly misleading discontinuities.

3. The input module could make no distinction between missing and absent values.

4. No provision is made for the weighting of attributes.

I decided to generate the similarity matrix externally and to input it to the package which could then carry out the various cluster analyses.

Construction of the similarity Matrix.

A number of similarity coefficients have been used with archaeological data. Several were considered for the current problem. Since most of the attributes were continuous variables, various distance coefficients were first of all considered. However, they proved unable to cope with incomplete data and the introduction of possible errors through discontinuities in the conversion of unordered multistate attributes seemed an unnecessary risk.

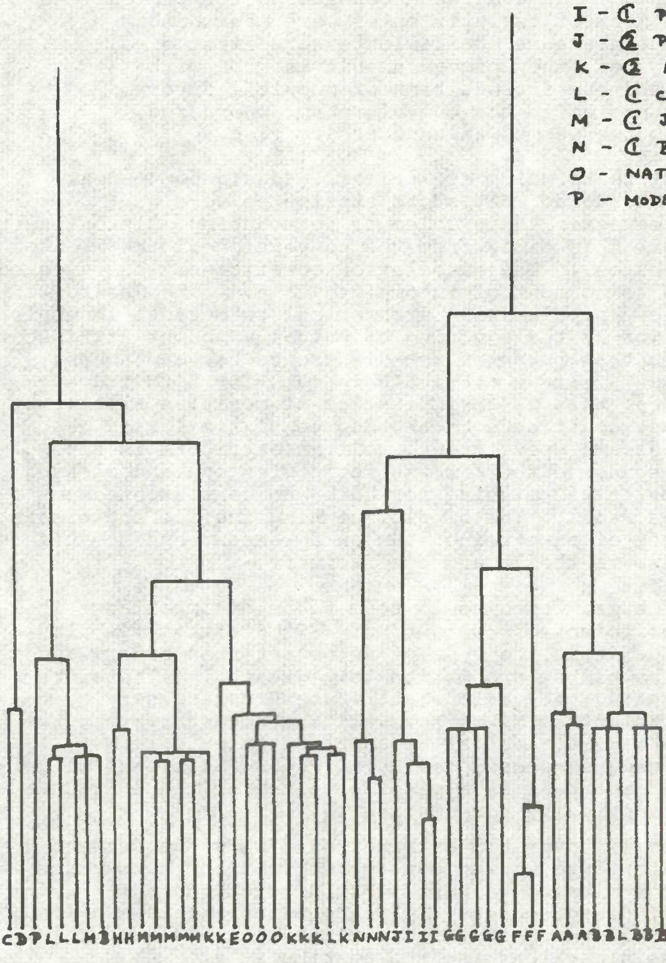
Three coefficients which are primarily designed to deal with binary and unordered multistate attributes were next considered. Once again the problem of introducing discontinuity errors arose, but, this time, from the conversion of the continuous attributes. The association coefficient was rejected because it takes no account of incomplete data. The Jacard coefficient is very popular with archaeologists because incomplete data is catered for by the ignoring of mutually absent attributes. However, no account is taken of the difference between absent and missing values. If an attribute is zero for both items because of absence, this is an indication of positive similarity, but this would not contribute to the degree of similarity as measured by the Jacard coefficient. If an attribute is zero for both items because either it was absent for one and missing for the other, or it was missing for both, no conclusion about similarity can be made. The simple matching coefficient treats the mutual absence of an attribute as an agreement and so suffers the same criticism as the Jacard coefficient.

A further feater, which would seem to be of importance in a similarity coefficient, is weighting. Some attributes play a greater part in defining the type of an object than others and their influence should be proportionately greater. Therefore a method of weighting the various attributes is necessary. The Gowers coefficient seems to have all the necessary features. It can cope with a mixture of all possible attribute types. Incomplete data can be catered for by using an additional weight of zero if one of the pair is a missing value for the attribute under consideration. The formulation is:

Sg = sum(w*s)/sum(w) over all attributes. w is the current weight for the attribute, being set to zero, if the comparison is invalid through missing values. For discrete data s = 1 for matches and 0 for disagreements. For continuous data s = 1 − dx/r where dx is the difference in value for the attribute and r is the range of possible values for the attribute.

An additional bonus with this coefficient is that the need to standardize raw data is obviated, as each value difference is taken as a proportion of the range of an attribute. Thus, all that is necessary, is an initial pass of the data to calculate actual ranges.

A - (4) SPICULUM (3)
B - (4) VERUTUM (6)
C - (4) TRIANGULAR KONTOS (1)
D - (4) LEAF-BLADE KONTOS (1)
E - (4) BARBED JAVELIN (1).
F - (4) MARTIO-BARBULUS (3).
G - (1) SCYTHIAN ARROW HEAD (6)
H - (1) THRACIAN ARROW HEAD (2)
I - (1) PILUM (3)
J - (2) PILUM (1).
K - (2) LANCEA (6)
L - (1) CRUDE WRAPPED JAVELIN([illegible]
M - (1) JAVELIN (6).
N - (1) BALLISTA BOLT (3).
O - NATIVE HUNTING SPEARS (3).
P - MODERN MASAI LION SPEAR (1).




DENDROGRAM FOR WARDS METHOD

A suite of two programs were written to convert the raw data describing the set of weapon heads into a similarity matrix using the Gowers coefficient. The lower triangle of the similarity matrix was then output ready for input to the CLUSTAN package.

Weighting.

Two types of weighting are provided in the programs which generate the similarity matrix. Type 1 permits the relative weighting of attributes according to their relative importance. It was used to produce the analyses weighted by cross section. Type 2 provides an additional weighting for each comparison of two items which is dependent upon their condition. The additional weighting is applied to five attributes which describe the parts of a weapon head which are most likely to suffer damage and is a negative value which increases as the condition of both items gets worse. Weight type 2 was used to produce the analyses weighted by condition.

Unweighted Results.

Eight unweighted cluster analyses were produced and the results seem to indicate a surprisingly consistent and accurate typology. No significance level appears to be especially meaningful but most items seem to cluster very rapidly. Most of the different types of weapon form their own, distinct, clusters, before fusing into larger groups and Ward's error sum of squares method (shown in the reproduced dendrogram) is the most successful. There is only one, relatively minor, point, at which the classification fails. One lancea, which is in very bad condition, is grouped with the Thracean arrowheads prior to joining a large group containing the other lanceae. Similar results are produced by four other methods, furthest neighbour, average linkage, Lance Williams and Mcquitty's method but they fail to cope with the Scythian arrowheads. All but one of the Scythian arrowheads form into two distinct clusters before they join the Martio barbuli, never forming a separate cluster of their own. The remaining Scythian arrowhead, which is again in very bad condition, joins this larger group much later on in the clustering.

The Gowers and centroid methods generate good classifications but with more anomolies than the previously discussed methods. The only failure is the nearest neighbour method which suffers greatly from chaining and produces no significant results.

Results of Weighting by Cross Section.

Weight type 1 was used to give the cross section attribute a weight of 5,, leaving all the other attributes at a weight of 1. Thus one third of the similarity coefficient was dependent upon cross section. The resulting classifications are, interestingly enough, very similar to those produced with no weighting at all. The main differences are that one of the ballista bolts is completely separated from the other two and the Scythian arrowheads cluster very easily (strangely enough using the rogue arrowhead, which the unweighted analyses found so difficult, as a key). The problem lancea remains a problem. The same five methods prove to be the most successful, with average linkage perhaps producing the best results this time.

Results of Weighting by Condition.

The final eight analyses were carried out using weight type 2, in order to try and minimize any anomolies which might arise through items which were in very poor condition. However, again there are very few differences in the overall classification from the other two sets. The "crude" wrapped javelins are no longer classified with the major lancea group, but are transferred to the verutum group. The Scythian arrowheads are easily clustered, but the lancea in very bad condition is still unclassifiable. The ballista bolts are again separated. The same five methods prove to be the most successful.

Conclusions.

The majority of the clustering techniques were successful in bringing together the various weapons into their classes prior to fusing them into larger, hierarchical groups. The weighting methods had little effect upon the results. The model analysis, at this stage, appears to be surprisingly successful. Expected results have been generated from the known data and the best procedure seems to be Ward's method unweighted. The next step is to apply the technique to some real weapon heads. Plans are in hand to test it on some Saxon spearhead data and also perhaps on some genuine Roman weapons.

Phil Barker's exact method for describing iron weapon points has proved to be very robust and capable of defining weapon shapes. Perhaps it would be a good candidate as a standard description and as a foundation for a weapon head database.

References.

Doran and Hodson, Mathematics and Computers in Archaeology. Edinburgh University Press.

P. Galloway, Computer Applications in Archaeology 1976. p41-47.

P. Barker, Computer Applications in Archaeology 1975. p3-8.