6

Multi-Response permutation procedures

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6.1 Introduction

This paper concerns the application of a program called 'multiple response permutation procedures' (MRPP) to archaeological data retrieved from the multi-phase site of Winnall Down, Hampshire. I am conducting a spatial analysis of the artifacts from this site for a PhD in the Department of Archaeology at the University of Southampton (Rodgers in prep). Some preliminary results from the analysis of the ceramic database are presented here.

Winnall Down is a multi-phase site just outside Winchester, now destroyed by the M3 and its interchanges. Excavation took place in 1976–77 under the auspices of the M3 Archaeological Rescue Committee, and was subsequently published in 1985 (Fasham 1985). Excavation revealed evidence from the Neolithic to Medieval periods, but my research is confined to phases 3 and 4 (the early and middle Iron Ages respectively) which are the richest phases in artifactual terms.

The original impetus to my work was the notable absence (prior to work at Winklebury (Fisher 1985) and Danebury (Cunliffe 1984)) of any attempt to analyse large assemblages of artifacts at an intra-site level within Iron Age studies. Paradoxically, it is Palaeolithic intra-site analyses which have shown how behaviourally-meaningful comments can be made from close examination of artifact covariation. Later prehistoric analyses have tended to be bogged down in typological and dating debates, with scant attention paid to potential of the archaeological record to yield patterns of social and/or behavioural significance. The root cause of this dichotomy in archaeological investigations stems from the nature of the archaeological record and the behaviour that produced it. Sites in earlier prehistory are characterised by short durations of occupation and low energy inputs into such facilities as houses. No active refuse disposal had to be practised; if debris from activities became a problem it was easier to move to a new location. Hence, *in situ* finds in discrete activity 'packages' are recoverable from the Palaeolithic. Later prehistoric sites are characterised by sedentary communities making more intensive use of settlement space. Debris from activities becomes a problem, and active strategies of disposal become necessary. It has been assumed by archaeologists that these active strategies increased entropy in assemblages, blurring any behaviourally significant patterning. Indeed, simple visual examination of artifact distributions would appear to confirm such a view. I hope this paper will show that these views are unfounded, and that with the aid appropriate computer-based techniques archaeologists can recover data from secondary and even tertiary deposits.

This paper therefore has three objectives:

1. to publicise the availability of the MRPP program;

2. to display the advantages this program has in the process of archaeological investigation; and
3. to present some preliminary results from my own research and show how latent patterning can be identified amongst apparent disorder.

6.2 Methodology of spatial analysis

In a general sense, human societies are a spatial phenomenon; they occupy regions of the earth's surface. Societies, however, do more than exist in space, but take on a specific spatial form in two ways:

1. they arrange people in space in that they locate them in relation to each other, with a greater or lesser degree of aggregation and separation;
2. they arrange space itself by means of buildings, boundaries, paths etc. so that the physical milieu of a society takes on a definite form (Hillier & Hanson 1984, pp. 26–27).

In a broad context, a settlement provides a framework of spaces and boundaries for the location of activities performed in the community. The 'site structure' (which is the relationship between buildings, activity areas and storage spaces) has obvious functional characteristics which are dominated by requirements such as structural stability, manpower supplies etc. Ultimately, the objective of my research will be to consider the social form of the group inhabiting Winnall Down.

Clarke's (Clarke 1972) seminal analysis of the Glastonbury settlement has been taken as the yardstick against which all other attempts at intra-site analyses in the Iron Age have been measured; not surprisingly this led to a malaise, since we could never hope to match the 'Pompeii' preservation conditions at this wetland site. Techniques and methodologies have to be evolved and geared to the average type of site encountered, not aberrant examples of exceptional preservation. It is the failure to come to terms with the nature of the archaeological data available to us and the evolution of appropriate methodologies that provided the initial niche into which my research fitted; the realisation that Iron Age subsoil feature sites might not be producing an amorphous 'mash' of finds led to the formulation of a simple model to account for regularity. This model weighted factors such as activity frequency and the duration of the activity to determine whether space utilisation was extensive or intensive within the site. Other factors, such as facility requirements for activity performance were also included to establish the type of site maintenance performed. The interplay of these factors ultimately determines the type of archaeological deposit (which may be homogeneous or heterogeneous) activity in which by-products end up.

6.3 Data from Winnall Down

Winnall Down is typical of many Iron Age sites in central southern Britain. It is a chalkland site from which the topsoil has been mechanically stripped; the 'site' therefore consists of the features which have been cut into the chalk, such as pits and ditches. For artifacts to be recovered they had to become incorporated in one of these features by a variety of processes. Recent work at Little Butser by Peter Reynolds (pers. comm.) would suggest that the topsoil itself contains a considerable number of artifacts. If there was such a deposit at Winnall Down the data has been lost forever. The varying size and depth of the subsoil features, and their relationship to human activity areas will determine the kind of assemblage and size classes eventually recovered. As we have assemblages recovered from locations remote from the activity areas which produced them, we will not be able to recreate specific events that occurred in the past; the archaeological data I have utilised lend themselves to the identification of processes and activities which occurred over a longer time scale than the day-to-day organisation of activities and had a different set of constraints operating on them for this reason.

We must begin with two basic premises:

1. that activities within the settlement were spatially segregated and deposited artifacts in distinct areas (at least in some cases); and

2. that artifacts will tend to be deposited in features closer to their origin than in other features on the site.

The primary site archive for the site was one of the first in Britain to computerise all primary records (only the computerisation of the Gussage All Saints records preceded it): indeed, this was one of the factors which encouraged me to select Winnall Down in first place. There appeared to be the potential for the rapid investigation of the 27,000 individual records. However, problems were encountered in outputting the data, due in part to their sheer quantity, but also to the peculiar structure of the data (Rodgers 1987). For instance, the record length was a maximum of some 2668 characters and each block on the tape consisted of five such records. In addition to these problems, the data were input in a highly convoluted way (some of the original coding sheets have gone missing, making certain parts of the archive indecipherable). However, most of the obstacles were successfully tackled, and I obtained the ceramic data for phases 3 and 4 from the archive.

The pottery from the site was sorted into fabric groups on the basis of visible inclusions and then counted and weighted. Phase 3 yielded some 2384 sherds of pottery, Phase 4 producing 4297. Phase 3 had some 21 fabrics associated with it, Phase 4 being associated with a more restricted range (10 in all, 41% being fabric 3 alone). Data now included on my ceramic database includes the context number, co-ordinates, depth, description, weight and the type of feature the sherd came from for every sherd recovered from Phases 3 and 4 at the settlement. These seven fields of information give me some 46,767 individual pieces of data for the site. The analysis of this extensive data matrix is still being conducted, but I now have several preliminary analyses using the MRPP program, and eight specific examples follow.

6.4 The MRPP program

MRPP is a spatial analysis program designed to detect locational differences among artifact classes within intra-site space; it will detect a significant 'partitioning' in artifact distributions.[1]

The signifance of the program for the analysis of data from sites like Winnall Down is that it can tolerate data from non-contiguous site structures (that is, in this case, the subsoil features). Written in FORTRAN77, it calculates the test statistic and probability value for the multi-response permutation procedures (as described in Berry *et al.* 1984). The original program supplied by Dr. Kenneth Berry had a batch-oriented user interface and data input procedure (this was implemented on the now defunct ICL 2976 by Douglas Burnett in the Department

[1]A listing of MRPP can be obtained from Dr. Kenneth Berry, Department of Sociology, Colorado State University, Fort Collins, CO 80523.

of Archaeology). However, Sebastian Rahtz of the Department of Electronics and Computer Science has implemented a more user-friendly interactive interface, and the new version, called MRPPX, can be acquired on a floppy disk or by electronic mail.[2]

The analyst can select the number of dimensions in which the analysis is to take place (which may be one, two or three) and also the type of space the calculations are made in; although most analyses will take place in Euclidian space (v = 1), they could be calculated in squared distance space (v = 2). Originally the program needed to know the number of artifact classes and the number of artifacts in each class; MRPPX no longer requires these additional inputs, but instead searches through the data file co-ordinates until reaching an asterisk (*), taking this as the end of one artifact class and the beginning of another. My analysis has used four digit co-ordinates, since these were present in the computerised record, but other sizes of co-ordinate can be used, as long as the values are separated by a single space.

If, after computation, the skewness value of the sampling distribution is greater than -0.001, the program computes the probability value from the normal distribution. MRPPX outputs seven values, each calculated by subroutines of the program, these being:

1. The test statistic;
2. the distance adjuster;
3. the observed delta;
4. the expected delta;
5. the variance of delta;
6. the skewness of delta; and
7. the probability value

If there is any separation of the artifact classes within intra-site space and classes are tending towards tight clustering and separation then the average distance between artifacts will be small. The average distance values are simply the average pairwise associations of all artifacts in each particular class. In such a circumstance the observed delta will also be small (when compared with other delta values). If the probability value is also small there is evidence for a locational difference in the distribution of artifacts. However, a small probability value may arise from essentially two types of locational difference: separation and/or concentration. The average distance values in such cases provide the means of differentiating the varying distributions.

1. *Separation.* A locational difference can be attributed to separation of artifact classes when the probability value is small and all the average distance values are similar in magnitude and less than the expected delta value. In other words, all the artifact classes are clustered to about the same degree and the difference is the result of artifact classes being separated in site space.

[2]The source of MRPPX can be obtained on an IBM PC floppy disk from Sebastian Rahtz, Department of Electronics and Computer Science, University of Southampton, Highfield, Southampton SO2 5NH. Alternatively, it can be sent by electronic mail to JANET/BITNET/EARN sites; mail requests to: spqr@uk.ac.soton.cm or cmi011@uk.ac.soton.ibm.

2. *Concentration.* A locational difference can be attributed to concentration when the probability value is small, the average distance values differ in magnitude, and one or more of the values is greater than the expected delta value. In other words, the degree of clustering is large relative to their separation in site space.

3. *Separation and Concentration.* In the event that the small probability value results from a combination of separation and concentration within the artifact classes an examination of the plotted data will indicate the nature of the difference.

6.5 Results

Some preliminary results have been obtained from the application of MRPPX to the Winnall Down fabric data conducted on a IBM 3090 mainframe and an RM Nimbus microcomputer (the latter machine was slow and could only handle the smaller datasets).

The basic hypothesis about pottery distributions is that ceramic vessel types (as reflected in fabric groupings) will denote different types of activity, status and/or wealth differences within the settlement. For instance, fineware pottery should be unevenly distributed across the site (Barrett 1978), whilst coarsewares will tend to be more evenly distributed (presumably because they fulfilled a wider range of storage/functional tasks within the settlement). My analyses to date have centred on this 'fine' versus 'coarse' division; only some 9% of Phase 3 sherds have been attributed to definite forms, whilst 76% of sherds attributable to Phase 4 are so-called saucepan pots. Using the fabric groupings instead of the pot forms means that all the data can be utilised, and in any case, the specific forms are unimportant when the major consideration is the broad patterning of ceramic groups. The analyses below compare fabric groups on a site-wide basis.

Eight analyses were conducted on the data, all comparing finewares with coarsewares. Varying numbers of fabrics were included, the best results to date coming from the comparison of a single finewares and single coarsewares.

Test 1 compared fineware fabrics 14, 15 and 16 with coarseware fabrics 20, 25 and 29, some 565 sherds in all (Table 6.1). The skewness of the sampling distribution was less than -0.001, and so the program did not compute a probability value for the test. In other words, the program was unable to detect any evidence for any patterning in the data.

Test 2 compared fineware fabrics 14, 15 and 16 with coarseware fabrics 17, 19, 64, 38, 39 and 73, some 412 sherds in all (Table 6.2). The probability value was calculated to be 0.434. Taking the standard significance test value of 0.05 (or less) as statistically significant, we must conclude that the program failed to detect any significant pattering in the data (there was a 43% chance in this instance that the patterning observed was due simply to chance).

Test 3 compared fineware fabrics 14, 15 and 16 with coarseware fabrics 3, 4, 8, 9, 11, 22 and 33, some 1220 sherds in all (Table 6.3). The skewness of the sampling distribution was less than -0.001, so the probability value was not calculated and the test failed.

Test 4 compared finewares 14, 15 and 16 with coarsewares 5, 27, 67 and 141, some 498 sherds in all (Table 6.4). The probability value was again 0.434, which is not a statistically significant result.

The failure of these large assemblages, comparing multiple numbers of fabrics, to yield any significant spatial patterning could potentially be explained by the blurring of any significant relationships amongst the data by a background 'noise' of irrelevent fabrics. For this reason I conducted four further analyses, each comparing a single fineware with a single coarseware.

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Input consists of: 565 data points
In: 2 dimension(s)
There were 6 group(s)
Sizes: 55 60 108 25 285 31

Group  Size  Average distance
  1     55     0.4346E+03
  2     60     0.4341E+03
  3    108     0.5629E+03
  4     25     0.2802E+03
  5    286     0.1500E+03
  6     31     0.2901E+03

The test statistic = −0.8785E+02
The distance adjuster = 0.1000E+01
The observed delta = 0.3164E+03
The expected delta = 0.4037E+03
The variance of delta = 0.9878E+00
The skewness of delta = 0.0000E+00

The probability of a T this extreme or more extreme = 0.0000E+00
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Table 6.1: Results for test 1

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Input consists of: 412 data points
In: 2 dimension(s)
There were 9 group(s)
Sizes: 55 60 108 32 112 25 10 9 1

Group  Size  Average distance
  1     55     0.4346E+03
  2     60     0.4341E+03
  3    108     0.5629E+03
  4     32     0.1101E+03
  5    112     0.1274E+03
  6     25     0.1836E+03
  7     10     0.3026E+03
  8      9     0.0000E+00
  9      1     0.0000E+00

The test statistic = −0.1841E-35
The distance adjuster = 0.1000E+01
The observed delta = 0.3304E+03
The expected delta = 0.4308E+03
The variance of delta = 0.2973E+76
The skewness of delta = −0.1000E+01

The probability of a T this extreme or more extreme = 0.4335E+00
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Table 6.2: Results for test 2

Input consists of: 1220 data points
In: 2 dimension(s)
There were 10 group(s)
Sizes: 55 60 108 141 279 193 17 67 170 130 12

Group	Size	Average distance
1	55	0.4346E+03
2	60	0.4341E+03
3	108	0.5629E+03
4	141	0.4912E+03
5	279	0.4026E+03
6	193	0.3905E+03
7	17	0.4452E+03
8	67	0.3717E+03
9	170	0.4404E+03
10	130	0.2194E+03

The test statistic = −0.2714E+03
The distance adjuster = 0.1000E+01
The observed delta = 0.8051E+02
The expected delta = 0.4367E+03
The variance of delta = −0.1722E+01
The skewness of delta = 0.7078E+01

The probability of a T this extreme or more extreme = 0.0000E+00

Table 6.3: Results for test 3

Input consists of: 498 data points
In: 2 dimension(s)
There were 7 group(s)
Sizes: 55 60 108 101 120 1 53

Group	Size	Average distance
1	55	0.4346E+03
2	60	0.4341E+03
3	108	0.5629E+03
4	101	0.2040E+03
5	120	0.4608E+03
6	1	0.0000E+00
7	53	0.3520E+03

The test statistic = −0.8238E-36
The distance adjuster = 0.1000E+01
The observed delta = 0.4135E+03
The expected delta = 0.4502E+03
The variance of delta = 0.1990E+76
The skewness of delta = −0.1000E+01

The probability of a T this extreme or more extreme = 0.4335E+00

Table 6.4: Results for test 4

Input consists of: 87 data points
In: 2 dimension(s)
There were 2 group(s)
Sizes: 55 32

Group	Size	Average distance
1	55	0.4346E+03
2	32	0.1100E+03

The test statistic = −0.1712E+02
The distance adjuster = 0.1000E+01
The observed delta = 0.3152E+03
The expected delta = 0.3650E+03
The variance of delta = 0.8462E+01
The skewness of delta = −0.2251E+01

The probability of a T this extreme or more extreme = 0.3304E-10

Table 6.5: Results for test 5

Test 5 compared fineware fabric 14 with coarseware fabric 17, some 87 sherds in all (Table 6.5). The probability value was calculated to 3.30×10^{-11}, a highly statistically significant result. As outlined above, a small probability value may result from the separation and/or concentration of the artifacts. This test revealed evidence for the concentration of the fabric types since the average distance values differ and that of fabric 14 (4.34×10^{-2}) was higher than the expected delta (3.65×10^{-2}).

Test 6 compared fineware fabric 14 with coarseware fabric 9, some 122 sherds in all (Table 6.6). The probability value was calculated to 2.13×10^{-2}, a statistically significant result. The average distance values were broadly comparable, but again that of fabric 14 was higher than the expected delta (4.07×10^{2}). We may conclude that the patterning in the data is one of concentration of fabric types, that is, the degree of clustering of the artifacts is great relative to their separation in site space.

Test 7 compared fineware fabric 14 with coarseware fabric 27, some 175 sherds in all (Table 6.7). The probability value was calculated to 8.12×10^{-3}, again a statistically significant result. The average distance values were in this case reasonably similar (4.35×10^{2} and 4.61×10^{2} for fabrics 14 and 27 respectively); neither of these values was higher than the expected delta (4.62×10^{2}). On the basis of these values, we can say that both artifact classes were clustered to about the same degree and the difference is the result of artifact clusters being separated in site space.

Test 8 compared fineware fabric 14 with coarseware fabric 20, some 80 sherds in all (Table 6.8). The probability value was calculated to 7.96×10^{2}, a statistically significant result. The average distance values differed in magnitude and that of fabric 14 was once again higher than the expected delta (4.14×10^{2}). The program therefore detected evidence for concentration of these two fabric types.

These smaller analyses show conclusively that we can, given appropriate techniques and methodologies, produce new kinds of patterning from archaeological data which, in visual terms at least, are in a state of apparent disorder. The program is presented here as nothing more than a heuristic device with which to make initial investigations of data; the program does

Input consists of: 122 data points
In: 2 dimension(s)
There were 2 group(s)
Sizes: 55 67

Group	Size	Average distance
1	55	0.4346E+03
2	67	0.3717E+03

The test statistic = −0.2756E+01
The distance adjuster = 0.1000E+01
The observed delta = 0.4001E+03
The expected delta = 0.4061E+03
The variance of delta = 0.4800E+01
The skewness of delta = −0.1699E+01

The probability of a T this extreme or more extreme = .2133E-01

Table 6.6: Results for test 6

Input consists of: 175 data points
In: 2 dimension(s)
There were 2 group(s)
Sizes: 55 120

Group	Size	Average distance
1	55	0.4346E+03
2	120	0.4608E+03

The test statistic = −0.4757E+01
The distance adjuster = 0.1000E+01
The observed delta = 0.4525E+03
The expected delta = 0.4618E+03
The variance of delta = 0.3780E+01
The skewness of delta = −0.1089E+02

The probability of a T this extreme or more extreme = 0.8115E-02

Table 6.7: Results for test 7

Input consists of: 80 data points		
In: 2 dimension(s)		
There were 2 group(s)		
Sizes: 55 25		
Group	**Size**	**Average distance**
1	55	0.4346E+03
2	25	0.2802E+03
The test statistic = −0.7472E+01		
The distance adjuster = 0.1000E+01		
The observed delta = 0.3863E+03		
The expected delta = 0.4135E+03		
The variance of delta = 0.1319E+02		
The skewness of delta = −0.3006E+01		
The probability of a T this extreme or more extreme = 0.7957E-03		

Table 6.8: Results for test 8

have the potential, however, of facilitating not only the rapid investigation of datasets, but also revealing socially and behaviourally relevant data from archaeological assemblages. To achieve this, however, modelling must precede the formulation of testable hypotheses.

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