Computer Post-Hole Analysis   Stephen Cogbill
with reference to the British Bronze Age   Cambridge

This paper will describe some work on the analysis of post-
hole distributions and the directions this has suggested for
future research. At least part of its value lies in the stimu-
lus it provides for more rigorous thought on such distributions.
The paper will discuss the background to the analysis, the tech-
niques used and its possible implications.

The problem arose out of the interpretation of a Middle Bronze
Age site in Wiltshire, suggested to me by Richard Bradley. The
excavation of a Deverel-Rimbury settlement at Thorny Down, Winter-
bourne Gunner took place between 1936-1939 under the direction of
J.F.S.Stone. Post-depositional erosion of the site resulted in the
structural evidence for its occupation being limited to the post-
hole distribution recorded in Stone (1941). Despite the meticulous
recording of these features, no attempt was made to plot artifact
distributions in the hope of correlating one form of evidence with
the other. The interpretation of the structures, therefore, remains
somewhat arbitrary. As Stone himself remarks of 'House III' "..It
cannot be said that this group of post-holes represents a very def-
inite structure......although its unitary character is self-evident."
(ibid. p120). Examination of the site plan does little to confirm
this. In each instance Stone makes the assumption that the struct-
ures are circular. For none of his putative houses are the exact
post-holes being referred to defined.
In the light of such ambiguity it is hardly suprising that alt-
ernative interpretations have been proposed. Piggott (1965, p153)
favoured sub-rectangular structures, although as he later admitted
this is scarcely more convincing. As Chris Musson points out (1971),
whether one interprets rectangular or circular houses is largely a
matter of personal preference. To be at all sure about the validity
of such patterns one needs to know much more about the depth, shape
and filling of each post-hole, or have some clear evidence (such
as a preserved floor level) to show where the external wall lay.
At Thorny Down there is no evidence on post-hole filling or floor
levels. The resulting ambiguity led to its inclusion at an Instit-
ute of Contemporary Arts exhibition in London. There, two rival int-
erpretations were juxtaposed as an example of the way in which our
hypotheses can structure our perception of the data. This theme was
subsequently published in Gregory and Gombrich (1973).
The inability of the human eye to recognise spatial patterns ab-
ove a certain level of complexity has been noted by geographers
(Harvey, 1969), but insufficiently studied. The greater the compl-
exity, the greater the ambiguity in interpretation, but too much
complexity can saturate the 'channel capacity' of the brain and st-
imulate a negative response. For psychological reasons outlined by
Gregory (1970) there is a tendency to fixate on one form of patter-
ning to the exclusion of others, as expectation structures percep-
tion. Even assuming our ability to overcome such 'blinkering' and
to evolve alternative interpretations, there remains the problem of
deciding which explains the data most successfully. There are two
reasons for adopting a more rigorous and quantified approach to the
search for patterning : 1) to generate a greater number of alterna-
tive hypotheses (patterns) ; and 2) to decide between alternatives
on a more than intuitive basis.
Despite the growing body of knowledge on machine pattern recog-
nition, or even more specifically on recognising geometric shapes,

none of this relates to the identification of geometric shapes in point distributions. From theoretical work (and common sense !) it is clear that ..."one cannot attempt to 'do' pattern recognition by allowing for every possible combination of elements and then using statistical techniques to work out the constraints since, even in what appear to be simple cases, the possible number of class partitioning is far too great." (Newman, 1972 p293).

It was therefore decided to choose a 'target shape' and evolve a search procedure for that shape. For ease of definition the circle is the most obvious choice : it can be unambiguously defined by just three variables - the co-ordinates of its centre and its radius. To fix a rectangle in 2-D space one needs to know its length and width, the co-ordinates of a given point, as well as its orientation. The problems this choice of shape raises for interpretation will be discussed subsequently.

It might be argued that since the inferred round houses at Thorny Down might prove ellipsoidal, oval or pear-shaped, the circle is an unrealistic choice of target shape. There are structural reasons, however, for believing round-houses to be more rather than less circular. A ring of post-holes can be interpreted in a number of ways. The five basic types of structure which might have been used in the Bronze Age/Iron Age have been outlined by Musson (1971). These are termed the 'wigwam', centre-post, tie-beam, mass-wall and ring-beam systems. In the ring-beam structure, the radial forces exerted by the rafters are converted into circumferential stresses passing around horizontal beams which are in tension and supported upon internal posts. The diameter of the ring-beam post circle may be substantially smaller than the often non-surviving external wall. Since the building can only be as strong as the the weakest segment of the tie-beam, there are structural benefits to be gained from the equal spacing of posts : each tie-beam will be in equal tension. This type of building is likely to have rotational symmetry and the ring-posts approach the configuration of a true circle. In the other types of construction the accuracy of the circle is less critical to their stability, but still desirable. The circle therefore seems a justifiable initial choice of target shape.

Given the complexity of the Thorny Down post-hole distribution, and a range of possible building diameters, it was clear that the search would have to be performed by computer. The machine used was Reading University Computer Centre's ICL 1904s and the programming language FORTRAN IV.

It was unfortunately not possible to trace J.F.S.Stone's original site notes in Salisbury Museum. The published plan (Stone, 1946, plate I), although only 29cms by 23cms, represents the most accurate record. Neither was it possible to gain access to a digital graph reader at this stage. Instead, a photographic enlargement of the plan was made at approximately 1:50 scale, an arbitrary grid superimposed and the co-ordinates read off manually. The centres of 322 post- or stake-holes were recorded along with their diameters to the nearest 2.5cms and depths. The data was punched onto cards and a short program written to place it in more manageable form. This scales the co-ordinates into metres and sorts them into increasing order of X to save time in subsequent handling.

The search procedure evolved over a number of months experimentation. It is based on a metric grid covering the whole site, whose size is calculated to allow for circles with centres outside the maximum and minimum values of X and Y. The search passes over all the grid moving up each column and along each row from left to

right in metre increments. At Thorny Down with a maximum grid size of 42 by 36 metres, this amounts to over 1500 such steps. At each of these points a imaginary annulus is drawn with a pre-selected radius and width. The latter was set to 1 metre for convenience. The first objective is to try and draw a circle through (or as close as possible to) all those post-holes within the annulus. Provided there is a minimum number of such points (the number can be varied in proportion to the radius) these will be fitted using the procedure outlined by Angell and Barber (1976). This relies upon minimising the sum of the fourth power of the tangential distance and deriving three simultaneous equations in three unknowns. These are then soluble by the matrix method. The values of the constants in the equations of the fitted circles are calculable by summation for the selected points.

A measure is needed to discriminate the good fits from the indifferent ones. The distance of any given point from the fitted circle results from substituting its co-ordinates back into equation of the circle and dividing by twice the radius. This information can then be used in two ways. Points lying greater than a given distance from the circle are eliminated and the fitting procedure repeated. This has the effect of eliminating those points that deviate highly enough from the true circle to distort its centre. The second fit may include some points which were eliminated by the first fit and, if this is so, a third application of the procedure is attempted. This re-iterative fitting is designed to 'home in' on the best solution.

Another approach to the goodness of fit is the average distance of all the points to the fitted circle. I am now replacing this 'average measure' by a modified Chi-Squared statistic, to test the hypothesis that the points lie on a given circle againast the null hypothesis that they do not. It is then possible to reject the circle if the resulting value exceeds the Chi-squared value at the 5% level.

Having completed the search procedure for one specific size of circle, the size of the annulus is increased and the process repeated. The program was run on a range of diameter sizes between 4 - 12 metres. This range was selected after a rapid study of known house-plans. The results of the program were output to file for subsequent plotting. The program proved successful in that it fitted circles to satisfy the criteria of having at least 6 to 10 post-holes (depending on diameter size) lying within 30cms and with a maximum average distance of 15cms. What was totally unexpected was the vast amount of patterning. In the 5m to 6m radius band alone over 80 circles were fitted. Statistical analysis of the results is still being undertaken, since there is a significantly greater amount of patterning than was produced when the search was applied to some simulated random data of equal density. This is perhaps not surprising, since an analysis of the nearest neighbour statistic shows that the Thorny Down distribution is non-random.

The amount of identifiable patterning is clearly a problem. While it is possible to say that a particular configuration is unlikely to be the result of random patterning, it is also true that, even for a high level of significance, one is able to detect more circles than a Bronze Age site is ever likely to have sustained even allowing for multiphase occupation.

For a site with a high density of structural evidence such as Thorny Down it is clear that the circle as so far defined is rather too simple a choice of target shape. There are two alter-

natives : one is to adopt an heuristic approach and allow the patterning expressed by the program suggest new criteria. The expected regularity of Iron Age sites immmediately suggests post-hole spacing as a next step. On Bronze Age sites, having lesser regularity, this approach might well lead to rather directionless exploration of the variability in post-hole spacing, depth and diameter.

The other is a more inductive approach, involving the examintion of reasonably well-attested Bronze Age structures and the inference of hypothetical limits within which they seem likely to have been built.

There are problems associated with trying to define a more specific target shape. One frequently made assumption is that the width and depth of a post-hole are a direct function of the size of post they supported. Depth is clearly affected by post-depos-itional erosion of the site and the diameter will be greatly aff-ected by the amount of post-packing used in construction. A second problem relates to the re-interpretation of reports. All site plans are interpretative and to some extent reflect the expectations of the excavators. A good site is report is perhaps not one that is definitive but one that is capable of subsequent re-assessment. This is clearly not always the case.

Since most of the Bronze Age sites for which there is struct-ural evidence are on similar geology, the preservational 'noise' is kept to a minimum. Aswell as this control between sites, an analysis of depth data alone for Thorny Down suggests that there is little within-site bias. Some consistency of depth and width can therefore be expected within the same structure and between structural elements (such as door posts) of differing structures. There is a good case for trying to characterise this variability more explicitly. For the site of Itford Hill, there is recorded evidence on post-hole depths and diameters, and plans for 14 huts. This evidence is now being recorded using a D-MAC Digitiser in order to quantify the variability in post-hole depth/diameter and spacing.

New definitions of target shape will take account of the cons-istency in the south-east orientation of doorways ; the greater depth of the door-posts ; and the trapezoidal form of the porch. The north-west sectors of the huts appear to retain a greater am-ount of circularity and for this the existing program is easily modified.

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