An Interactive Computer Graphic Technique for Identifying Occupation Surfaces in Deep Archaeological Sites

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A computer graphic technique, 3DPLOT, is presented. Its purpose is to identify occupational horizons in deep sites that have no visible stratification. The program treats the locations of subsurface artifacts in three-dimensional space as if they were in a clear matrix, rotating and tilting to any desired viewing angle. The benefits of this method are explained, and an example is presented.

Introduction

The search for occupation surfaces, in order to be able to detect patterning and define activity areas in single horizons, and to examine temporal change from one horizon to another, is a common research strategy for archaeologists. Occupation surfaces, however, are often elusive, defined only by artifact distributions in three dimensions within a soil matrix that cannot be differentiated during excavation by color, texture, or other obvious changes. Here we present a method to discover such occupation surfaces after excavation with a visual inspection of computer-generated points in space, examined interactively on a screen.

If an occupational surface is defined as having depth as well as extent (in other words, both vertical and horizontal dimensions), and consisting of a scatter of human-manufactured debris (artifacts, debitage, bone waste, etc.) on approximately the same plane surface, it is possible to reconstruct such a surface after excavation by plotting the locations of these items in three-dimensional space, providing that three-dimensional location data were collected during excavation. Our program is designed to aid in this reconstruction.

Various attempts that have been made to solve the problem of a lack of visible stratigraphy include excavation in thin artificial layers, statistical analyses to find clustering, and other computer graphic programs. The difficulty with excavating in 10 cm layers (or layers of any other arbitrary depth) is that they may not correspond to the thickness of the actual living floors, thus perhaps dividing a real living surface into two or more analytical units. This problem is compounded if the occupational surface slopes, for then a single floor may be sliced into several different 10 cm units. If the occupational horizons are close together or the slope is great, several real floors can become mixed together, making interesting but entirely artificial patterns. This will be illustrated below with an example.

Statistical programs can be no better than the underlying data, and therefore may suffer from the same problems, creating specious patterning. The understanding of spatial relationships in archaeology does not extend to three-dimensional patterning. Clarke’s Spatial Archaeology (1977) only considers surface distributions. In a recent review of computer graphics, no figure of three-dimensional plots of artifacts within a soil matrix is given, although two, BACKPLOT and BLOCK, are mentioned (Arnold 1982). Martin Wobst (1979) was the first to attempt a computer solution to the problem of sloping living surfaces within undifferentiated soil matrices. His approach included a program (BACKPLOT) which plots each point in space so that it can be viewed from any side. To use the program, one must record each artifact with its coordinates in three-dimensional space as the excavation progresses. Later this information is transferred to a computer and printed out with a view from any desired direction. Several such views may be generated on a line printer, rotating the matrix to allow visual inspection of the distribution of the data from any side. The output is two-dimensional, but it allows views E–W, N–S, or any rotation in between, so that with a series of views the best
understanding of the distribution pattern is obtained. The output, at least in the published example, is difficult to read. BLOCK creates stereoscopic views, but the stereoscope necessary for viewing the three-dimensional effect is an added detriment to easy analysis (McNett 1979).

Program Characteristics

Our program, 3DPLLOT, has four major characteristics that will be discussed in turn. First, it is three-dimensional in power. Second, it reproduces subsurface distributions. Third, the program is interactive, and finally, the effective use of the program depends on human pattern recognition rather than on statistics. Some examples using ideal distributions will be presented, followed by a discussion of an actual use of the program in an excavated site.

Three-dimensional computer graphic techniques have not received the attention they deserve in archaeology. While analysis of two-dimensional patterns is better developed (Hodder and Orton 1976), three-dimensional patterning is rarely considered. Arnold (1979:6) provides a number of examples of three-dimensional effects in computer graphics, but basically it is surface contours that he describes. He justifies the three-dimensional techniques by their ability to “bring the surfaces to life” and by the “easily understandable proportions of a perspective drawing.” In other words, human pattern-recognition is enhanced. The use of subsurface, rather than surface three-dimensional graphics, has concentrated on displays of magnetometer readings and other remote-sensing devices. Three-dimensional subsurface plotting of artifacts is a rare application, as discussed above.

Pattern recognition is accomplished intuitively and not statistically in this technique. As Arnold (1982:179) has said, “If a picture is worth a thousand words, then a computer-generated graphic is worth 10,000 statistical tables.” While we would not deny the validity of the use of statistics for this purpose (e.g., Hietala and Stevens 1977), there are patterns that may be best detected with the human eye and brain. Kintigh and Ammerman (1982:34) argue eloquently in favor of this point, while presenting yet another statistical procedure. They describe their technique as a “computer assisted heuristic approach.” Another way to state this point is that “we have an innate visual ability to scan and organize information as clusters and patterns” (Csuri 1977:53, quoted in Arnold 1982:187). Our method simply allows one to “eyeball” the distribution of artifacts on various planes, presenting endless views interactively. The user may confirm the apparent association of artifacts on a plane by various independent means such as the presence of conjoinable pieces or the distribution of flakes from cores of unusual colors or other traits. It is expectable that some vertical movement will have taken place within a site, so a vertical dimension must be programmed in, as mentioned above.

Our technique is based upon the same concepts as BACKPLOT with points plotted in space so that they can be viewed from any side, but 3DPLLOT includes tilt as well as rotation. Additionally, the output can be viewed interactively on a screen, so that nearly infinite views of the distribution are possible. The data file records each item with its precise location in three-dimensional space. Another program draws boundaries to the space and locates each item with a symbol. Views from any angle are possible. Although the plots on the screen are necessarily two-dimensional, the lines delimiting the edges of the excavation unit give a three-dimensional perspective effect, aided further by 10-cm ticks along the north-south west edge of the unit. The ability to change the viewing angle by tilt (elevation) and rotation (azimuth) in any combination of degrees is a major aid to three-dimensional comprehension. A dot matrix or thermal printer can make an exact hard copy of any output on the screen, or the view may be replicated (using a variety of colors if desired) on a plotter. Examples follow as an aid to comprehension.

An Example With Random Points

To demonstrate the possibilities of the program, we generated a set of imaginary data, each composed of 100 points, dispersed randomly within layers. The three layers are parallel and have slopes of 20 degrees from the horizontal in the direction of maximum slope, each is 10 cm in thickness, and the layers are separated by “empty” space (i.e., volumes that do not contain any points representing cultural debris). Viewed from a direction almost at right angles to these slopes (elevation 5°, azimuth 5°), a clear separation of these horizons can be seen (Fig. 1). When the same set of points is rotated to 85 degrees, still at a 5 degree tilt, the pattern is totally obscured (Fig. 2). Observed from above, the randomness of the data points within the layer can be clearly perceived, and no pattern is visible (Fig. 3). So far, we have merely demonstrated what Wobst (1979:fig. 2) has already shown. Further dangers lurk, however, for the archaeologist probing for patterns. A 10-cm slice through these data illustrates a possible misinterpretation of an artificial horizontal layer. Patterning appears that is real enough, but it does not comprise three “activity areas,” as it might appear to the unwary, but rather the three different occupation horizons that the arbitrary level has intercepted (Fig. 4). From another view, a continuous living floor seems to emerge (Fig. 5). Even seen from above, as the “plan” view for this “living floor,” patterns appear which are the combination
Figure 1. Three hypothetical occupational horizons, each with 100 randomly-generated data points representing the placement of artifacts. The wire-framed box represents an excavation unit $2 \times 2 \times 2$ m. Each layer is 10 cm thick, with a slope of 20°. The rotation and tilt are slight: azimuth 5°, elevation 5°.

Figure 2. The same set of data points as in Figure 1, rotated 80° (azimuth 85°, elevation 5°). The pattern is now obscured.

Figure 3. The same set of data points as in Figure 1, seen from above in plan view (azimuth 0°, elevation 90°). The randomness of the data points can be appreciated.

Figure 4. A 10-cm-thick horizontal slice through the same data set as Figure 1 (azimuth 5°, elevation 5°). Three clusters appear, which might be interpreted as activity areas if the underlying patterning were not known.
Figure 5. The same 10-cm-thick horizontal slice as Figure 4, rotated to the same view as Figure 2 (azimuth 85°, elevation 5°). A continuous "living floor" seems to emerge.

Figure 6. The same 10-cm-thick horizontal slice as Figure 5, seen in plan view from above (azimuth 0°, elevation 90°). Linear patterns and clusters can be perceived.

Figure 7. Grid square D-9, from the Crescent Site, with each artifact located in three-dimensional space (azimuth 275°, elevation 5°). The ground slope is depicted in the upper line. Ticks along the NW corner are at 10 cm intervals. In this site, the prehistoric surfaces have nearly the same slope as the present surface. At least two levels can be distinguished, with greater density of material in the lower level.

Figure 8. Bone pieces in grid square D-9, the Crescent Site, with locations known to within a 50 × 50 × 10 cm space (azimuth 310°, elevation 3°). Specific points within each space were assigned with a random number generator. Four separate layers can be perceived.
of the random data and the intersection of the three floors (Fig. 6). In fact, they look suspiciously like the "linear site distribution" illustrated by Kintigh and Ammerman (1982:fig. 1c). If the appropriate view of the floors is found, spurious interpretations can be avoided. The problem of selecting the appropriate view is not a simple one. Clearly, one must not stop with the first apparent pattern, but continue to look until all reasonable tilts and rotations have been observed. When a "best" interpretation of the visual data has been decided upon, it should then be tested with independent data, the nature of which will depend upon the specific site.

An Example Using Real Data

In an actual example of use in the field, the occupational horizons do not perform quite as satisfactorily as in the demonstration, but patterns do emerge. The program was used at the Crescent Site, 5JF148, a deep site with no visible stratigraphy in the earth. The site lies in front of a rock shelter in the Colorado Front Range near Denver. It was excavated by the Colorado Archaeological Society under the direction of the third author, supervised by the senior author. For various practical reasons, the site was sampled on a 2-m grid. Because of the homogeneous nature of the soil, all units were excavated in 10-cm levels. All culturally modified materials found in situ were measured and recorded in their exact locations, measured from the NW corner of each grid square. Features were also measured in and recorded. Each 2-m-square excavation unit was further subdivided into 16 squares, 50 cm on each side. Any microdebitage or bone missed by the trowelers and collected in the screens could thus be located within an area 50 \( \times \) 50 \( \times \) 10 cm. All material so collected was counted and weighed. These two different collection strategies necessitated two different programs for the graphic presentation. The first used precisely-located, culturally-modified stone or bone in the three-dimensional space to be represented as points with letter designations for different classes of items (Fig. 7). The second program used a random number generator to locate each of the pieces of bone or stone flake within the known 50 \( \times \) 50 \( \times \) 10 cm boundaries (Fig. 8). Randomization allows an equal and independent chance to each point in space, which may distort the actual unknown distribution of locations but should aid in the visual apprehension of floors. Both classes of data used together show that there are at least four occupational horizons in Grid Square D-9, and that prehistorically these occupational horizons had more horizontal integrity, with the graphics indicating the breakdown of the prehistoric surfaces near the modern slope.

Other classes of data also indicate four occupation surfaces.

The Computer Program

The program 3DPlot was written in BASIC for a Hewlett-Packard Model 9845 microcomputer. The program could be adapted to other computers, but the use of a microcomputer with a graphic display or a terminal with a graphics-capable CRT is integral to their use. The various artifact/ecofact classes can be plotted separately or in combination, utilizing letter symbol codes.

The first subroutine creates a data file that includes the length, width, and depth of each sampling unit, the three-dimensional coordinates of all artifacts/ecofacts found within, and a letter symbol for each class.

The next subroutine reads the data files and calculates the coordinates of each artifact with respect to the center of each sampling unit. The user selects a viewing direction with the azimuth of the viewer situation relative to the center of the unit and elevation above or below the horizontal plane. A wire-framed outline of the unit is projected with the location of each identifiable artifact/ecofact on a plane passing through the center of the unit and normal to the viewing direction. The artifacts/ecofacts are assigned and plotted by letter symbol. Using the midpoint of the unit as the reference for all other points avoids the possibility of vertical or horizontal exaggeration. The computer tabulates the coordinates of the unit and supplies the midpoint from which all artifact/ecofact measurements are taken. The projection displays solid lines at the edges of the space for three-dimensional rotation and perspective guides. Ticking at 10-cm intervals along the NW vertical boundary further aids in visualizing the space. The three-dimensional perspective projection begins 0° (due north) of the unit midpoint and is moved clockwise to establish rotation, while the elevation plane 0° begins at the same level as the midpoint and increases as the observer moves up to view the data from above.

The other subroutines utilize the 50 \( \times \) 50 cm secondary grids for each level in each unit to establish bone and flake counts randomly generated by 10 cm levels and continues this for all levels and secondary grids in each excavation unit. The random generation program described here takes the counts of crushed, unidentifiable bone from each 50 \( \times \) 50 cm secondary grid in each level and generates a random location within the level.

A series of specific additional programs will slice the data on the horizontal or vertical plane utilizing any increment desired. These programs can also be adapted for viewing two separate examples of the same projection utilizing a stereoscope.
Summary

We have presented a method for discovering patterning in artifact and ecofact distribution in real space within sites, which may reasonably be interpreted as occupational horizons. A series of computer-generated graphics provides a three-dimensional perception of their locations through rotation and tilt of the array of points until a pattern appears. This avoids mistaking patterning caused by sloping occupational horizons for activity areas within one horizontal level. 3D PLOT is an additional tool for interpreting archaeological distributions.

The computer programs described here were developed specifically for use with the Crescent Site data set and for our Hewlett-Packard computer. The essential features of these programs, however, can easily be adapted to other data sets and to other computers with graphics capabilities. An annotated listing of the programs is available upon request.

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