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# An Integrated Information System for Archaeological Evidence

*This paper reports on an ongoing programme to provide a tailor-made database facility including linkage to stratigraphic analysis and automated procedures for the visualisation of principle classes of artefacts.*

## 1 Introduction

The Xaghra Brochtorff Circle site in Malta was excavated for seven seasons (1987-1994) resulting in the recovery of many artifacts including thousands of human bones (Evans 1971; Malone 1986; Malone *et al.* 1988; Stoddart *et al.* 1993). The archaeologists now face the daunting task of characterising, quantifying and analysing these finds. A system is under development at the University of Bristol to computerise this procedure, and provide an integrated framework for visualising and analysing the multitude of archaeological evidence from this important site.

The foundation for the system is a detailed database of the information. Constructed on top of this database is an interface to allow archaeologists to use established tools such as a Harris Matrix package, as well as new facilities which have been developed to enable the location of the bones and artifacts to be viewed in a three-dimensional volume. The Harris Matrix program establishes the relationship between different contexts in an archaeological site as a two-dimensional hierarchy (Harris 1989). As there are more than 1500 contexts within the Brochtorff Circle, such a computerised hierarchy is essential to gain an easy understanding of the contexts. The three-dimensional volume visualisation of the bones may be used to determine spatial relationships between the contents of a spit, distinctive bones from an area, or the orientation of the bones within the site.

## 2 The System

Data gathered at a site currently is recorded on paper forms. (The growing availability of inexpensive portable computers could enable this data to be directly entered into the computer.) To minimise errors, the data entry interface resembles the paper version as closely as possible. The individual records have a unique identifier, so once entered, they can be selected, amended or deleted. Some records

which in previous years had already been entered into an alternative database format can be added to the system using the file conversion interface so the database is complete. The Harris Matrix Analysis Program and the Graphical Display of Bones use these stored records.

### 2.1 USER INTERFACE

The User Interface is a series of windows. Movement between the windows is either by pressing the highlighted key, clicking on the button using the mouse or by moving to the choice using the Tab key and pressing Return. Figure 1 shows the screen used for capturing all the necessary information concerning the bone finds.

The design of the data entry screens was based on the paper forms filled in at the site to aid the transfer of the data. The form is split into four parts, each containing its own fields. When data entry for a field is completed, pressing tab moves the cursor to the next field. The final field in each window is a button allowing the user to move to the next part of the form. The order of tab movement is based on the number identification used on the paper forms. Creating a new form or exiting from the data entry screens will save the data to a file. Individual forms can be retrieved by typing in the context number, the unique identifier for each form. This also serves as an error detector so that no form can have the same context number.

There are four entities in the database: Common, Stratigraphic, Interpretation and Small Finds. The Context Number field is the primary key of the Common entity and the foreign key for all the other entities, so that the four parts of the one form can be retrieved together. The system provides, via the Stratigraphic entity, an automated interface between the database and a widely available Harris matrix program.

### 2.2 HARRIS MATRIX ANALYSIS

A Harris Matrix Diagram is a simple way in which relationships between stratigraphic sections can be viewed on a single diagram, as shown in figure 2. It describes the stratigraphic sequence of the site as found during excavation, no matter how complex the individual sequences may be and helps to clarify the relative chronology. The Bonn Harris Matrix Analysis Program

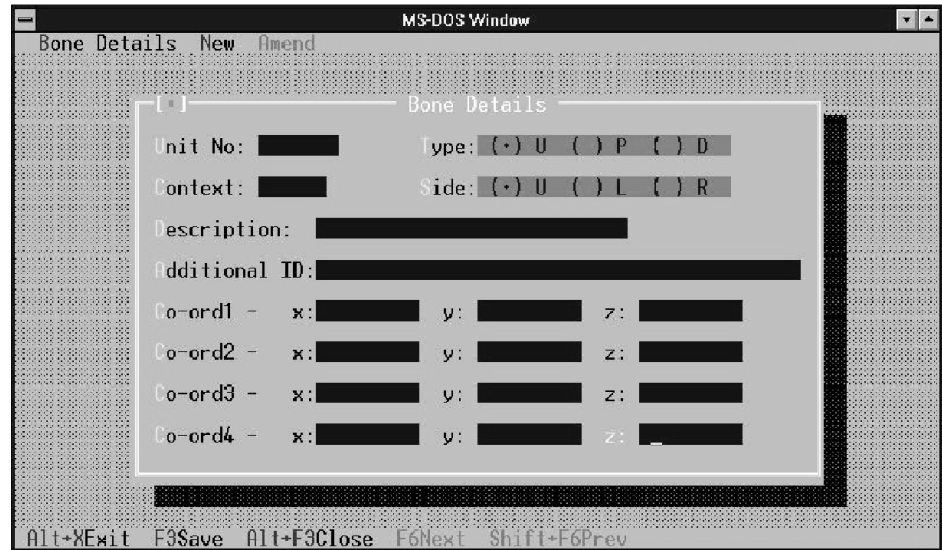


Figure 1. Bone information capture screen.

provides a computer-aided method of stratigraphic analysis (Harris 1989).

The Harris Matrix Program provides a file converter called Harconv. This converts an ASCII file for use by the Harris Matrix program. On choosing this option, the program generates the ASCII file, passes it to Harconv and runs the Harris Matrix program. On start up the Harris Matrix program asks the user for the data set to be used. By entering the name of the file created from file conversion the user will be able to carry out analysis on the data.

### 3 Visualising the Bones

A substantial number of human bones have been recovered from the site in Malta. There is thus an enormous amount of data that needs to be incorporated within the system. The bone visualisation facilities within the system can be split into three main areas: recording the information about each bone, obtaining analysis details from the user and displaying the results graphically.

There is an individual record within the database for a single bone, identified by a unique bone number. This number is assigned by the archaeologist during data preparation. The details recorded for each bone include:

- Four sets of  $(x, y, z)$  coordinates to specify the three dimensional location of the bone with respect to a reference point; and,
- the bone type, side, proximal/distal, additional identification, context, age and method used, sex and method used, measurements, pathology, conservation, related units and any remarks.

In setting up the database the archaeologist is required to enter such details for every bone recovered from the site. Hence a data entry screen with all such fields is presented to the user to enable each bone record to be created. Additional options to assist this process are display, amend and delete. The creation of the full database of bones is expected to be carried out prior to any analysis, as incomplete data may affect the results produced, which in turn could lead to an incorrect assessment of such results. This will, however, be a lengthy process due to the large amount of data.

#### 3.1 OBTAINING ANALYSIS DETAILS

The main body of the system consists of a series of pull-down menus that the user is able to manipulate to enter all the details required for the analysis. The options available for entering data are:

- rotation: enter degree and axis
- scaling: enter 'factor' and 'focus'
- sectioning: enter axis and coordinate value to define partitioning line
- grid squares: indicate whether to add or remove
- bone details: enter new bone type
- bone details: enter bounding coordinates  $(x_1, y_1, z_1)$  and  $(x_2, y_2, z_2)$  for a particular area

These latter two forms of data entry result in the search for and retrieval of all matching bones from the bones database. The first of the two finds all bones of the specified type, setting up a new temporary data structure in

main memory recording bone unit number and the four sets of coordinates for each match. The latter sets up a similar structure for all bones recovered from the specified area. The user is able to enter a maximum of ten types to be used in the analysis at any one time, but only one area can be specified. In addition to entering such data, the user is also able to display and delete bone types, and display the full records (i.e. all relevant details stored in the database of bones) of those bones which satisfy the specifications entered.

A final option offered is to display the site, either the whole site with the bone types specified, or the specified area of the site with all bones recovered from that area. The results of these options are outlined in the following section.

### 3.2 DISPLAYING THE RESULTS

The three-dimensional visualisation facility of the system uses computer graphics techniques to manipulate the large database of bone finds. The initial display on screen depends on the choices made by the user as outlined in the previous section. Whatever the choice, however, the user is presented with a representation of either the whole or part of the site, containing all relevant bones. At present, the 'whole' site is not actually the whole of the site in Malta, but a specific area of it, namely that enclosed within 98E to 102E, 108N to 114N, and 135.4 m up to 137 m vertically. Thus the representation of the whole site on screen is a cuboid with dimensions  $4 \times 6 \times 1.6$  m. Similarly, when only part of the site is displayed, a cuboid of the relevant dimensions is constructed on screen. Such cuboids are labelled with the relevant world coordinates in order to aid analysis and avoid confusion.

The bones within the representation of the whole site are the 4 sets of coordinates from the bones database linked by coloured lines, where each colour represents a different type. A key is displayed on screen to relate these colours to the actual type descriptions. When a particular area is displayed, the bones are again the 4 sets of coordinates linked by lines, but this time no colours are used as there are likely to be too many types displayed on screen to enable a colour coding scheme to be used effectively. Hence, if an area is chosen from which many bones have been recovered, the display is simply a mass of lines on the screen. The only way this display can be improved is to introduce a more sophisticated method of graphical display, such as scanning the bones in or producing a set of accurate illustrations for all possible bones. Then the display would consist of detailed representations of all bones recovered from an area, each of which could be identified by the archaeologist from the shape alone, with perhaps an accompanying list to detail all bones displayed.

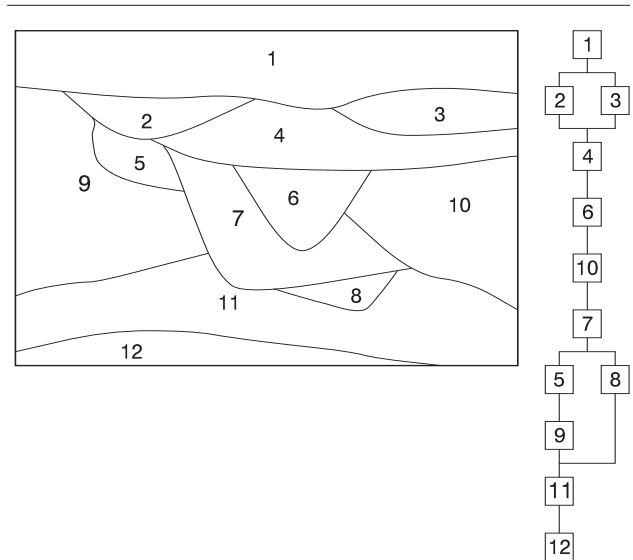


Figure 2. Sample Harris Matrix Analysis.

One of the problems encountered in producing even such simple graphical displays on the screen was the representation of a three-dimensional image in a two dimensional environment. Perspective projection was used in the solution of this problem, as this converts world coordinates into screen points in such a way as to enable the user to perceive depth in a two-dimensional image, namely by displaying distant lines as shorter than lines of the same length that are closer. Perspective projection is achieved by firstly choosing a view reference point (VRP) which is the point from which the site is viewed, and the distance ( $d$ ) of the object plane away from the viewpoint. These were determined during the design stage of the project to produce images that would represent those seen from an observer located centrally, standing a couple of metres away from the site. Then, for each of the world coordinates (both of the site and the bones) the screen point is calculated by the following algorithm:

- translate the point so the VRP becomes the origin (i.e. subtract VRP from world coordinate);
- set two-dimensional coordinate  $x$  to world coordinate  $x$  multiplied by  $d$  and divided by world coordinate  $z$ ;
- set two-dimensional coordinate  $y$  to world coordinate  $y$  multiplied by  $d$  and divided by world coordinate  $z$ ;
- reposition and scale to produce image of required size in required area on screen.

Hidden surfaces also had to be considered in the display of the site and bones: those on the site are displayed as dotted lines on the screen, to prevent any confusion; the bones are sorted before display into order of depth, from those

furthest away to those closest, thus any that are hidden will not be seen unless the site is rotated.

In addition to the initial display of the site and bones on screen, facilities to rotate, scale and section the site are available to the user. These use the data entered by the user as in the previous section, and enable the user to view any section of the site from any angle, to any degree of magnification.

The rotation facility enables the user to rotate the site (and all bone types displayed within it) about any axis (x, y or z) by the required degree (1 - 359). The standard rotation equations below were incorporated into the system to produce the rotation effect:

About the x-axis ( $\theta$  degrees):

$$\begin{aligned}x' &= x \\y' &= y\cos(\theta) - z\sin(\theta) \\z' &= y\sin(\theta) + z\cos(\theta)\end{aligned}$$

About the y-axis ( $\theta$  degrees):

$$\begin{aligned}x' &= x\cos(\theta) + z\sin(\theta) \\y' &= y \\z' &= z\cos(\theta) - x\sin(\theta)\end{aligned}$$

About the z-axis ( $\theta$  degrees):

$$\begin{aligned}x' &= x\cos(\theta) - y\sin(\theta) \\y' &= x\sin(\theta) + y\cos(\theta) \\z' &= z\end{aligned}$$

The centre of the site was chosen as the most logical coordinate to fix as the point about which to rotate the site. When carrying out the rotation, it is necessary to rotate the world coordinates of the site (including bone types) to produce new world coordinates, which are then converted to points on the screen by perspective projection and scaling.

The scaling facility enables the user to 'zoom in' to the site representation at a particular point to the required magnification. These two pieces of information, referred to as the 'focus' and the 'factor' respectively, are specified by the user as required. The effect is achieved in implementation by:

1. taking the focus to be the origin, thus translating all world coordinates appropriately;
2. scaling all the coordinates by the factor;
3. translating all coordinates so that focus returns to its original position; and finally,
4. converting the world coordinates to screen points as outlined earlier.

A 'zoom out' facility is also provided to the user to reverse any enlargement of the display. This is achieved in implementation by the same procedure as 'zoom in' but with the focus being replaced by its reciprocal.

Finally, the sectioning facility enables the user to divide the site into two separate cuboids by specifying a line to act as the partition (i.e.  $x = a$ ,  $y = b$ , or  $z = c$ ). Both cuboids are displayed on the screen at the same time, with each occupying half the area used to display the full site. The rotation and scaling facilities are applicable to both representations, though the user is required to specify which cuboid. This is achieved by using the same procedures as outlined earlier, but with two different sets of world coordinates. Clipping is also required for any bones that may cross the boundary line used to partition the site.

#### 4 Future Developments

The system developed so far has proved to be a useful prototype for analysing bone finds from Malta. There are several areas of the system that will be developed in the future to enhance the existing facilities. For example, the visualisation of the site could include some of the natural and cultural features, such as the surrounding rock, and the central stone bowl discovered at the site. These features would aid the archaeologists, as they would be able to incorporate them within their analysis of the site. The graphics display of the bones could also be improved to provide a more detailed and accurate illustration of bones recovered. The Archaeology Department would also like to see some statistical displays as part of the system – e.g. all femurs, skulls, etc. found within a certain area plotted on a histogram.

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