AUTOMATIC DATA LOGGING FOR RESISTANCE SURVEYING AND SUBSEQUENT DATA-PROCESSING

M.A. Kelly and J.G.B. Haigh†

School of Archaeological Sciences, University of Bradford, Bradford, West Yorkshire. BD7 1DP

1. Introduction

Although resistance surveying can offer archaeologists a very economical source of field data, there are problems that may restrict its use. Manual recording is slow and liable to error. Interpretation of the results on site is difficult. Long data preparation times are needed for final computer analysis. Attempts have been made to overcome some of these problems by using automatic logging systems in the field (Scollar and Krückeberg, 1966: Becker, 1978: Freeman, 1981: Sowerbutts and Mason, forthcoming). All these systems have the disadvantage of being somewhat cumbersome and expensive. The first part of this paper describes an alternative; a compact and inexpensive field logging system based on a portable microcomputer.

Once data has been logged it must be interpreted. This is done by first processing the data into a suitable form for display. A common representation is a contour plot, but proprietary contouring packages (NAG, 1981: Noland, 1979) do not produce satisfactory results (Haigh and Kelly, in preparation). The second part of this paper describes an alternative contouring package based on mathematical splines (de Boor, 1978). The package has been especially designed to interface to the field logging system.

2. Field logging hardware

The field logging system consists of a Bradphys Earth Resistance Meter (Aspinall and Walker, 1975) interfaced through an eight-channel analogue-to-digital convertor to an Epson HX-20 portable computer. The resistance meter is connected to a two-probe configuration of electrodes (Aspinall and Lynam, 1970) which is the standard probe arrangement used at Bradford (Figure 1).

The Epson HX-20 is an A4 sized portable computer. Its features include an LCD screen, integral printer, micro- cassette drive, RS-232C port, and a full sized keyboard. A rechargeable battery powers its CMOS twin 6303 processors and 16k RAM.

The A-D convertor has eight channels each of eight bits. The convertor is connected to the Epson via the system bus. The channels are memory mapped with a sensitivity of 20 mv per bit and conversion times of 1 ms or less.

† also attached to the School of Mathematical Sciences.

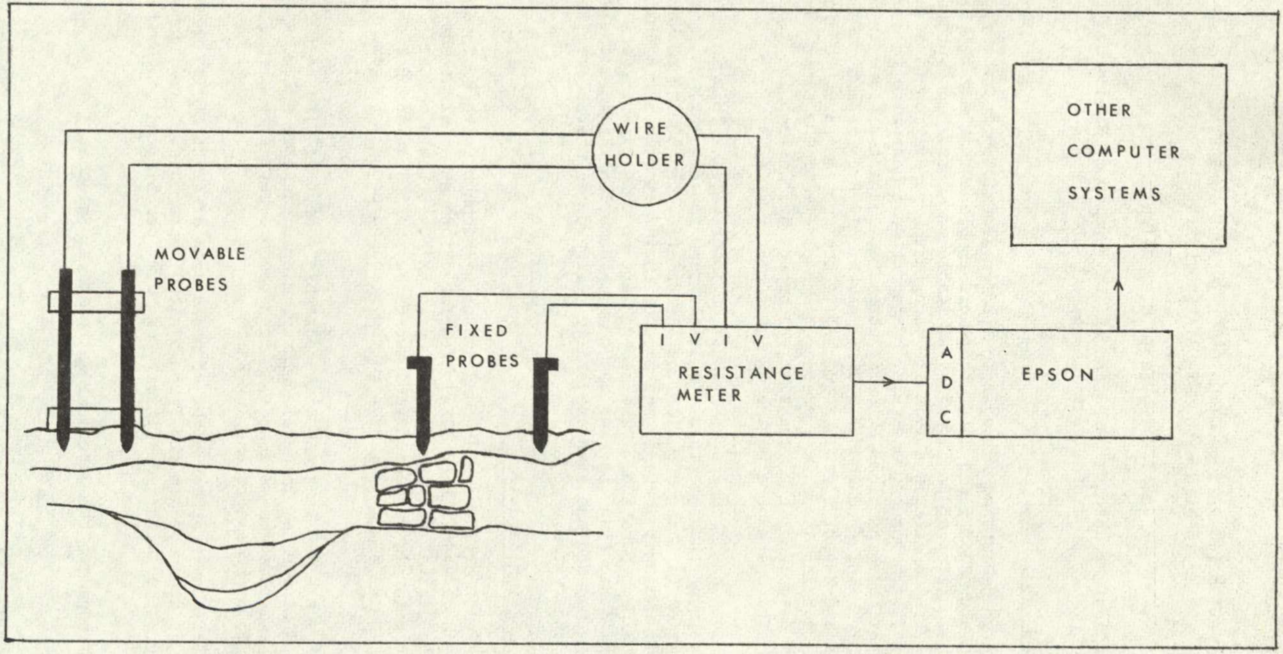

Figure 1. Field logging system

The Bradphys Earth Resistance meter is designed to detect shallow archaeological features. It uses four ground electrodes, two to pass an electric current through the ground, and the other two to measure earth resistance. Resistances from 0 to 1000 ohms may be measured. The meter has been slightly modified to connect it to the A-D convertor.

3. Field logging software

Field data is collected in sets of 400 readings which form 20 × 20 square grids. Each set or grid is separately identified as a data file.

The software to run the logging system is written in BASIC and incorporates eight routines which are selected by pressing the appropriate function key on the Epson.

Data files are stored internally in a RAM file. Two functions SAVE and LOAD allow whole data files to be transferred to and from the microcassette drive. To accomplish this each cassette contains a catalogue of file names and tape positions. Two functions SET CATALOGUE and LIST CATALOGUE, allow this catalogue to be initially set and the contents of a data cassette listed.

In LOGGING mode the software expects readings to be taken in a set pattern. To ensure accuracy audible and visual validations of the resistance readings and current survey position are given. If mistakes are made readings can easily be back-tracked and retaken.

Once logged and saved data files can be displayed in the field using the DISPLAY function. This can produce descriptive statistics and dot density or interval code displays; all copied onto the integral dot-matrix printer. A HARDCOPY facility allows the raw data file to be printed out.

When the survey is completed, the logged data files may be rapidly transferred to other computer systems using the TRANSFER function via the RS-232C interface.

4. Field logging use

In practice the system is very simple to use. The computer and meter remain stationary with one operator while a second operator moves the probes. A new cassette is initialised, if needed, before logging begins. By using the automatic logging system at least 10 minutes may be saved in survey time on each grid. A futher 15-20 minutes will be saved per grid as data preparation is no longer needed. Once a grid has been logged it is saved automatically on the microcassette drive and the catalogue updated. A single microcassette can store at least 20 grids. Processing of the grids may take place after logging and storage, but it is usually more convenient to process a whole days work in the evening. Figure 2 shows a dot density display and interpretation of a test survey at the site of a Roman road at Ogden, near Halifax, West Yorkshire. The system has been used on several surveys and has proved to be reliable, fast and efficient. One survey of 25 grid squares at West Heslerton, North Yorkshire, was completed within two winter days.

5. Contouring technique

As most of the standard contouring packages have proved to be deficient in some respect (Haigh and Kelly, in preparation) a contouring algorithm based on bilinear splines is presented. A spline in the context of contouring is a local function chosen to fit an individual grid cell and match contiguous splines at its boundaries. A bilinear spline is defined as the function:

$$g(x, y) = a + bx + cy + dxy ;$$

which can be fitted precisely at the four nodes of the grid cell.

The contouring algorithm proceeds as follows. Given a matrix of data values and a list of contour heights, each individual contour is traced through the entire grid (Sutcliffe, 1980). Using simple linear interpolation the grid cells through which a contour will pass are determined and stored in a table. This table is then used to trace an individual contour through the grid from cell to cell. Within a grid cell a contour will have an entry and exit point. The form of the contour between these two points will be rectangular hyperbola. Although a bilinear spline is continuous in itself its derivatives are not. Therefore cusps may occur when a contour crosses a grid line. McLain (1974) overcomes this problem by using bicubic splines, which are continuous up to their second derivatives and give very smooth contours; but the technique is expensive in computer time and complicated. Bilinear splines offer a good compromise, being simpler to implement yet providing better results than conventional linear and curve contouring packages.

To plot the rectangular hyperbolae within grid cells the following algorithm is used. For a curved contour:

$$g(x, y) = c$$

where c is a constant, a starting point $P_0(x_0, y_0)$ is given which is known to be on the contour. Calculate the two derivatives:

$$u_0 = \frac{\partial g}{\partial x}(x_0, y_0)$$

$$v_0 = \frac{\partial g}{\partial y}(x_0, y_0)$$

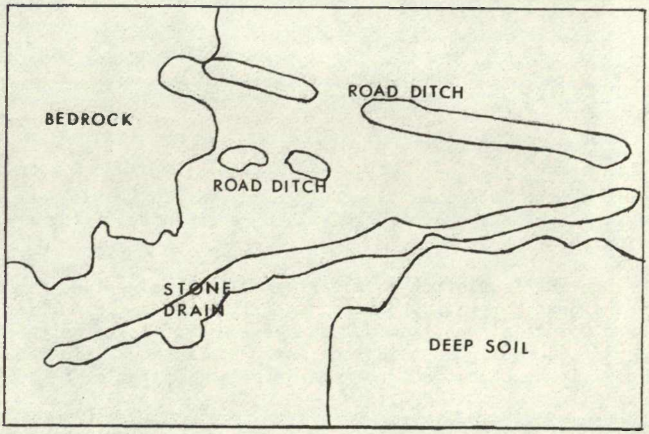

Figure 2. Dot density display (250-700 ohms) and interpretation of a survey area (40m × 60m) at Ogden, near Halifax, West Yorkshire

the normal to the contour is in the direction of the gradient vector (u_0, v_0) and the tangent is in the direction of the vector $(v_0, -u_0)$. To move an estimated distance h along the contour, first calculate the point $P_1(x_1, y_1)$ on the tangent at P_0, where:

$$x_1 = x_0 + \frac{v_0 h}{\sqrt{u_0^2 + v_0^2}}$$

$$y_1 = y_0 - \frac{u_0 h}{\sqrt{u_0^2 + v_0^2}}$$

(it may be necessary to reverse the signs of the two increments to ensure that the contour is traversed in the correct direction). To get back on to the original contour from the tangent at P_0, one applies incremental corrections along the normal at P_1:

$$\delta x = u_1 k$$

$$\delta y = v_1 k$$

where

$$u_1 = \frac{\partial g}{\partial x}(x_1, y_1)$$

$$v_1 = \frac{\partial g}{\partial y}(x_1, y_1)$$

$$k = \frac{c - g(x_1, y_1)}{u_1^2 + v_1^2}$$

The point $P_2(x_1 + \delta x, y_1 + \delta y)$ should then lie close to the required contour, so that the line segment P_0P_2 may be plotted as part of that contour. The whole operation may then be repeated, using P_2 as the new starting point.

A contour is plotted as a series of successive line segments, until the next point is predicted to fill outside the current grid cell. The next point is then recalculated as the exit point on the appropriate side, simultaneously becoming the entry to the next grid square; the grid cell is then removed from the intersection table.

6. Contouring implementation

The contouring algorithm has been implemented as a package written in Fortran 77 for a C.D.C. Cyber 170/720 mainframe and as a program written in Fortran 66 for a R.M.L. 380Z-D microcomputer. Both systems interface to the Epson HX-20 field logging system to allow the transfer

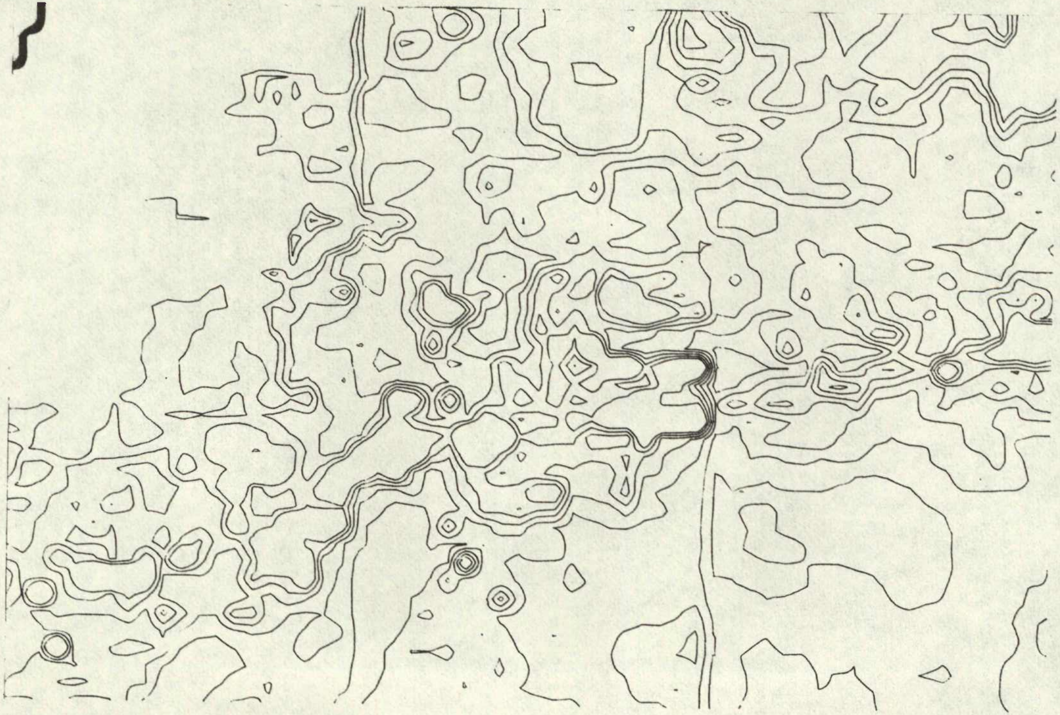

Figure 3. Contour plot (250 - 700 ohms) of a survey area (40m × 60m) at Ogden, near Halifax, West Yorkshire.

of data files. The programs are designed to allow the contouring of very large amounts of data without virtual storage. Scratch files are created from all data files, and are augmented to contain edge values from neighbouring grids, so as to allow the contouring of individual data files without risk of edge mismatch. Thus immediate access storage is reduced to one data file. Both computer systems provide facilities to produce high quality hardcopy of the resulting contour plots. Figure 3 shows a contour plot (unlabelled for clarity) of the survey illustrated in Figure 2.

7. Conclusions

The field logging system based on the Epson HX-20 has proved to be both reliable and accurate in the field. The system has significantly increased the speed of surveying and allowed primary interpretation of the results to be carried out on site. By transferring data to larger computer systems more sophisticated processing can be carried out. Contouring using bilinear splines gives a good clean representation of the data allowing detailed interpretation. In conjunction with the logging system it provides a very powerful geophysical survey system.

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