A MICROCOMPUTER SYSTEM FOR PRACTICAL PHOTOGRAMMETRY

M. P. Chamberlain &
J. G. B. Haigh

School of Archaeological Sciences
University of Bradford

INTRODUCTION

The conversion of oblique aerial photographs to true map projections is of crucial importance for the production of archaeological surveys and other archaeological planning purposes. There are three well known graphical methods to achieve rectification of such photographs: the Paper Strip and Mobius Network methods (Scollar, 1975) and a modern variation on the Mobius Network (Palmer, 1976). The three methods, based on principles of projective transformation, can all be taken to a fairly high level of accuracy if they are worked carefully. However, all three are slow and cumbersome, and lack versatility.

The rectification may also be carried out mathematically, using photogrammetric methods described by Hallert (Hallert, 1960). The process, involving mathematical transformation of a large number of points, is ideally suited to the use of computer methods. Dr. Scollar (Scollar, 1975) has published an account of one such computer system in use in Germany. Upon examination of Scollar's methods, it was felt that his system was too detailed for convenient use: the process demands that at least three control points be precisely located in height as well as in ground coordinates; the focal length of the camera should also be available, and the use of polyester contact prints is suggested, in order to reduce distortion. Such factors require considerable research into each individual photograph, and would be too slow to be very effective in an attempt to convert the immense backlog of archaeological aerial photographs existing in Britain at present.

A more suitable method for this particular task was described by Palmer (1977). This requires four reference points, but in two dimensions only, plus two Ordnance Survey points to provide orientation (these two points are of course not necessary to perform the transformation). This information is obviously all readily available on a large scale map of the relevant area. The equations described in this method were also used as a basis for the interactive system developed at Bradford University. The system has been fully described in an earlier paper by Haigh (1980); this description will be given from the user's point of view. It is based on a Research Machines 380-Z Microcomputer, linked to a Hiplot Digitizer Pad and a Hiplot Incremental Plotter. The four control points are digitized from both the map and the photograph and used to solve eight simultaneous equations and thus find eight coefficients for the photogrammetric transformation. When the coefficients have been calculated, it is possible to input information as a series of points from the digitizer pad. This information is stored on disk file, converted to the 'true' coordinates, and plotted out. A second program allows for replotting of the stored data with any alterations necessary.

The system is designed to be used by archaeologists with little or no computing experience, and therefore is highly interactive. Various prompts are displayed by VDU, telling the user what to input at each stage of the program, and asking for various optional factors. When replotting, it is possible to alter the scale of the plot, or the origin from which the plotter works. Thus the user may plot two photographs together, which are not immediately compatible in scale or position. A further option is available to alter the reference points to produce a better fit, and the user may plot certain sections of the file only, dividing the file by inserting captions during the digitization of the photograph.

THE DUNNINGTON PHOTOGRAPHS

As a test for the system it was decided to rectify a series of cropmarks contained in fields south of Dunnington, in North Yorkshire. The photographs used were from the collection of Mr. Derrick Riley of Sheffield University. The cropmarks stretched over several fields, and as far as could be determined from the photographs and OS maps, the area was very level.

As a preliminary, the relevant section of an OS map was digitized and stored on file. This was replotted at a scale factor of 2.5, producing a plot at 1:4000 scale - the largest scale capable of accommodating the cropmark area on the A4 size paper used. This replotted map was used as the base map of the exercise.

When the photographs were digitized and replotted, it was found that coincidence with the base map was not sufficiently close for planning purposes - the accuracy was up to 10 metres off (Figure 1). It was felt that this may have been caused by inaccurate control point placement: what appears as a single line on a map will be a hedge or a drain on a photograph, possessing a measurable breadth as well as length. Thus it is not always possible to determine where a field corner ought to be. Other factors may affect placement: the moving of cultivation boundaries from year to year, or even inaccuracies on the original map.

In order to correct the placement of the photograph plots, trials were made at replotting them with slight alterations to the control points. These proved to be successful, giving a picture which, though still a poor fit at the edges, was accurate with respect to the base map in the region of the cropmarks. When several photographs were plotted on top of each other, it was still possible to distinguish outlines seen on single plots(Figure 2). The plots had an accuracy of between one and two metres; it was felt that this was sufficient for most planning purposes.

A subsequent expedition to Dunnington revealed that the area was extremely flat, and well suited to coplanar transformations. One small hump was noted at the northern edge of the most southerly field; this was gratifying, because that particular

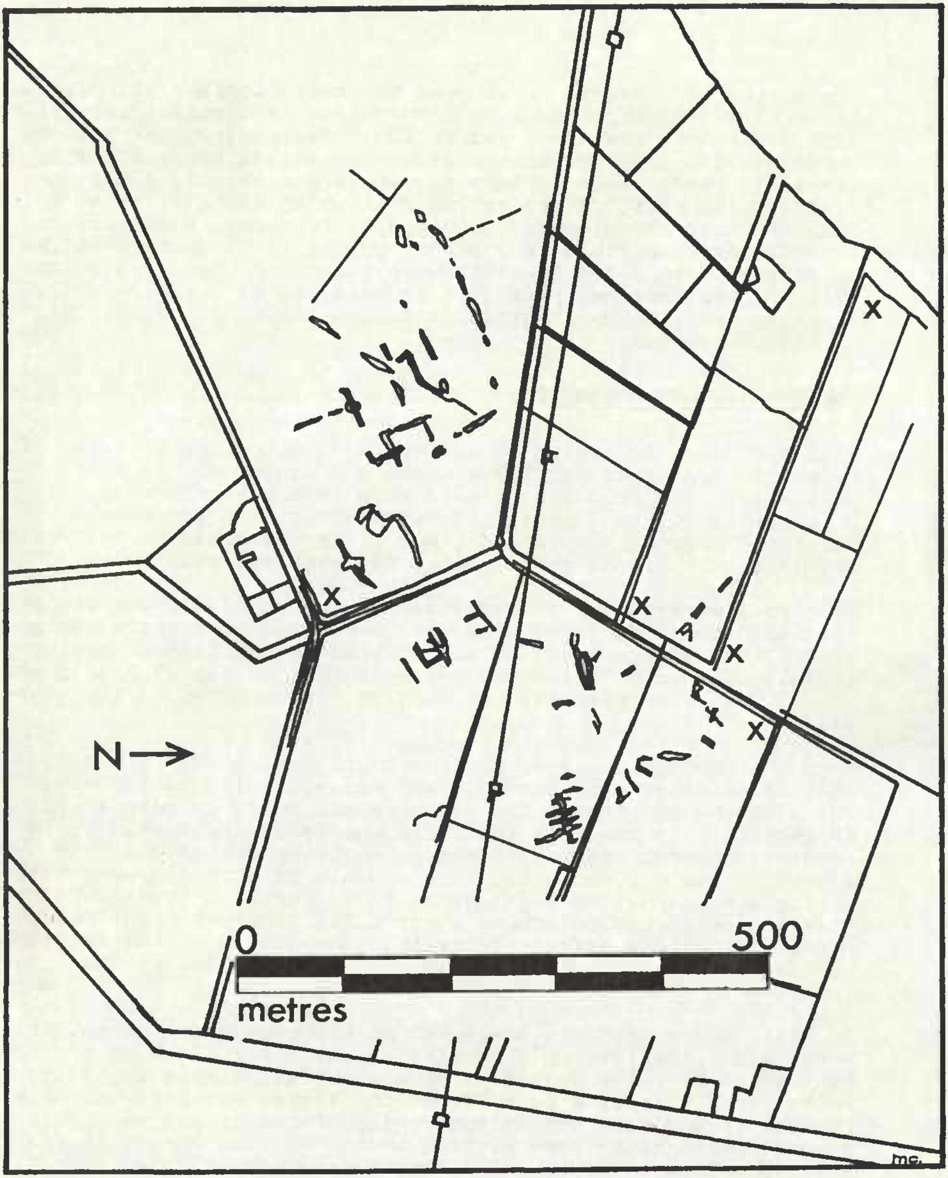

Fig 1: A photograph plotted against the base map. Note the deviation at points marked 'X'; caused by errors in control point placement.

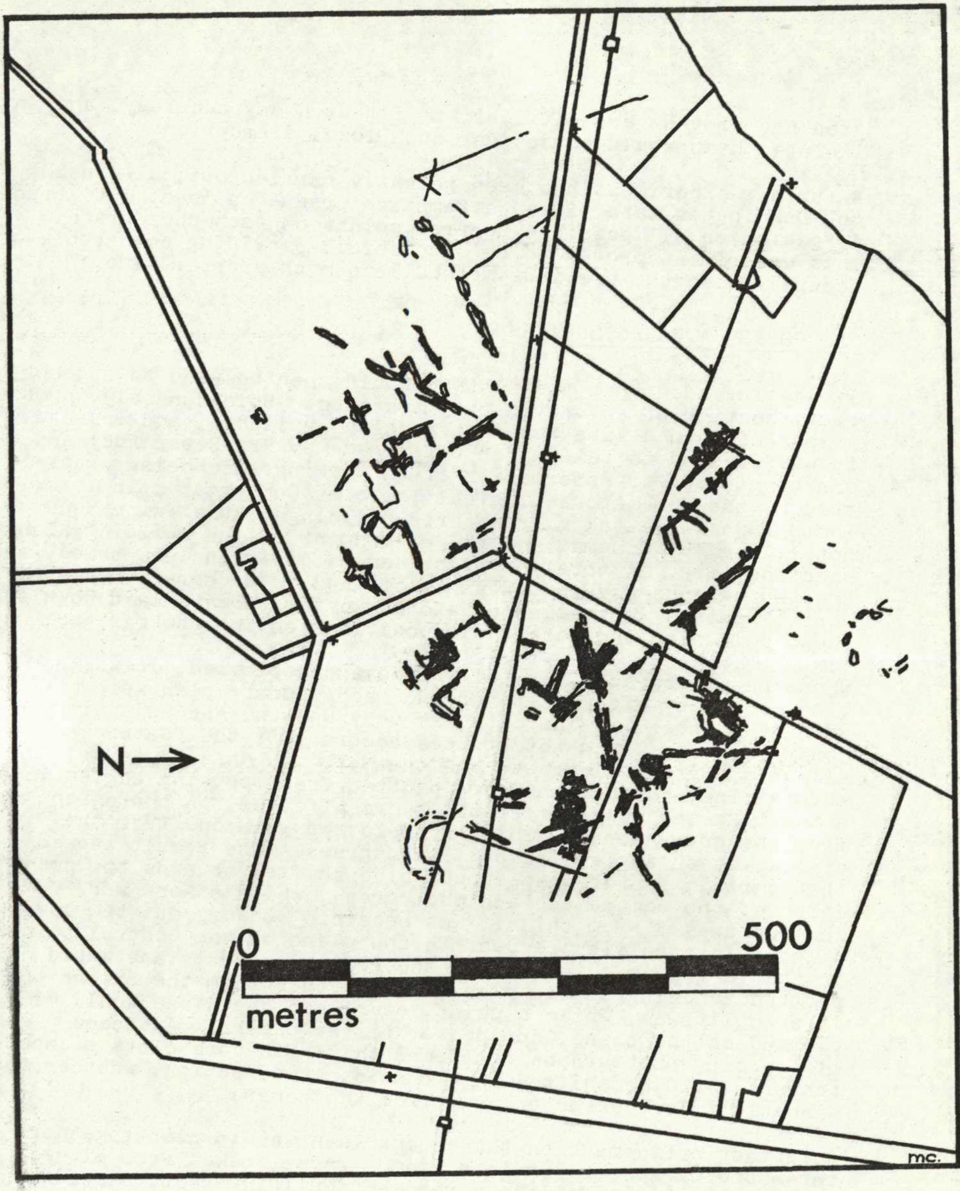

Fig 2: Five photographs plotted against the base map, after correction of control point errors.

area had proved very difficult to fit with any accuracy, and an isolated hump would cause just such local disruption.

A further experiment has been recently carried out, also using the Dunnington data, in an attempt to produce a 'best fit' transformation on all possible control points on each photograph. This experiment proved to be successful, providing comparable accuracy with the previous method in a much shorter time.

THE COPPERGATE PHOTOGRAPHS

It was intended that the system should then be used to attempt rectification of an uneven cropmark site. Unfortunately, photographs of such a site were not readily available, and instead it was decided to take up an offer made by Mr. Peter Addyman, and to attempt transformation of the Viking site being excavated by the York Archaeological Trust at Coppergate, in York. Photographs were taken from three buildings: the White Swan Hotel, the ABC Cinema, and the government office building alongside the site. A total of eight camera positions was tried, and the photographs covered an angle of about 270 degrees. Four control points were selected and surveying targets laid down at these points to indicate their positions on the photographs.

When the photographs were digitized and replotted, it was obvious that any attempts to produce an accurate plan were not going to succeed. The site was very uneven, and adjusting the control points would not produce accuracy if the features were all on different planes to one another. In default of producing such a plan, photographs were plotted from opposing angles in an attempt to see how the features were affected. A photograph from the government building was plotted with one from the cinema, at an angle of about 160 degrees. The result showed that certain features appeared to be shifted towards the position of the camera on each photograph, while others were shifted away. From this it was possible to work out the level of each feature with respect to the plane of the control points, in that a feature higher than the control point plane would be plotted as being on the plane, but further from the camera than it actually was, while a point lower than the plane would be plotted on the plane, but nearer to the camera. A second plot of opposing photographs confirmed this: in both plots a chosen feature would be shifted in a consistent direction, whether that direction was towards or away from the camera.

A further refinement on this comparison was to plot together three photographs taken in a line. These, taken from either end and the middle of the government building roof, showed a definite progression of each feature. Those features that were shifted towards the camera were set out with the plot from the 'northern' camera position at the top, that of the middle camera position in the middle, and that of the 'southern' camera position below. Features which moved away from the camera were set out with the northern and southern plots transposed. It was also noted that features parallel to the line of the camera

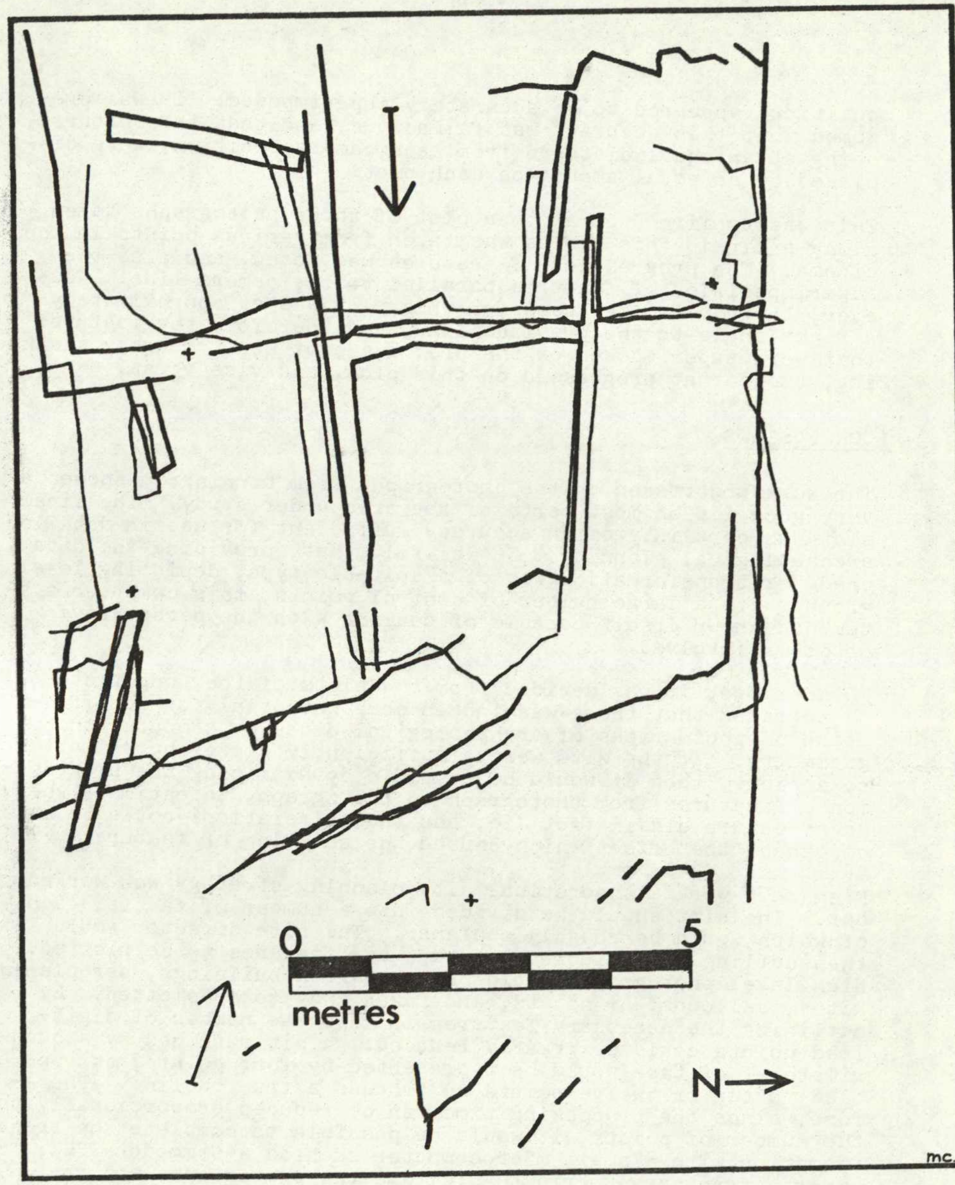

Fig 3: Two photographs from Coppergate, York; each is a different line thickness, direction of each shot is indicated by the arrows.

positions appeared to be accurately superimposed: it was presumed that this accuracy was fallacious, and that the features, being at an equal distance from each camera position, were displaced by an equal amount on each plot.

This was confirmed on another plot of three photographs taken along a line: this series was taken from various points in the cinema. The progression of features was noted, and also the superimposition of features parallel to the camera line. However, the camera line used for this plot was at approximately a right angle to the previous line, and therefore the features that were superimposed on the previous plot were, roughly speaking, those that progressed on this plot, and vice versa.

CONCLUSIONS

The work undertaken on the photographs from Dunnington showed a very good fit on most parts of the area under study. The final plot was certainly of an accuracy sufficient for use in detailed archaeological planning. It was felt that, providing the data used for transformation was of a suitable type, depicting level ground with a large number of control points, this computer system had shown itself capable of dealing with the perspective problems involved.

Furthermore, it was decided from the plots of the Coppergate photographs that there was indeed some potential for rectification of photographs of archaeological sites by computer photogrammetry. If the site were a sufficiently close approximation to a plane, then it would be possible by examining the progression of features from photograph to photograph, to estimate where each feature did in fact lie, and thus alterations could be made to cancel the effect which caused the shifting of features.

From this work a theoretical site planning strategy was worked out. The site should be divided into a number of facets, each of which would be roughly coplanar. The site director would then outline with fluorescent tape any features to be plotted. High level photographs could be taken from buildings, aeroplanes, kites, balloons, or hoists, and taken away to be plotted. By outlining the necessary features in tape the number of digitized points could be greatly reduced: a pit outlined by a quadrilateral of tape would be represented by four points, as opposed to ten or twelve points to produce a true outline. Therefore, since the processing time can be reduced proportionally to the number of points, it would be possible to complete the transformation with a small microcomputer such as a Commodore PET, using a transparent grid to digitize the photographs and replotting them by hand on graph paper.

It may be noted here that such a planning strategy would involve control points that were precisely located in three dimensions, and photographs which were taken with a camera of known type and focal length. The ready availability of such extra information would certainly make the application of Scollar's method a practical alternative for the computer transformation, and one that would produce more accurate results for the plan.

Whichever method was used for the transformation, the end result in either case would be a site plan of a large area, produced with good accuracy in about 24 to 48 hours after the photographs were taken. Such a site plan could greatly assist in rescue and salvage archaeology, where time and manpower resources are short, and the system could also be used to plan accurate sections in an emergency. In addition to the possibilities raised by the site planning strategy, the computer system appeared to have proved itself as an accurate, simple and swift method of converting oblique photographs to maps and plans.

One author (MPC) would like to acknowledge the support given to him, both financially and in services, during the undertaking of an MA project on the topic described in this paper.

REFERENCES

Haigh, J.G.B. 1980 'A small computer system to provide direct transformation of oblique aerial photographs.' in: PROCEEDINGS OF THE CBA SYMPOSIUM ON AERIAL RECONNAISSANCE. Nottingham, December 1980 (forthcoming).

Hallert, B. 1960 PHOTOGRAMMETRY; BASIC PRINCIPLES AND GENERAL SURVEY. McGraw-Hill Book Company, Inc., New York.

Palmer, R. 1976. 'A method of transcribing archaeological sites from oblique aerial photographs.' JOURNAL OF ARCHAEOLOGICAL SCIENCE 3: 391-394.

Palmer, R. 1977 'A computer method for transcribing information graphically from oblique aerial photographs to maps.' JOURNAL OF ARCHAEOLOGICAL SCIENCE 4: 283-290.

Scollar, I. 1975 'Transformation of extreme oblique aerial photographs to maps or plans by conventional means or by computer.' AERIAL RECONNAISSANCE FOR ARCHAEOLOGY, ed. Wilson, CBA Research Report no.12, pp.52-59.