

XIV Congress of the International Society for Photogrammetry  
XIV Kongress der Internationalen Gesellschaft für Photogrammetrie  
XIV Congrès de la Société Internationale de Photogrammetrie

HAMBURG 1980

COMMISSION IV  
WORKING GROUP IV-1

Invited Paper

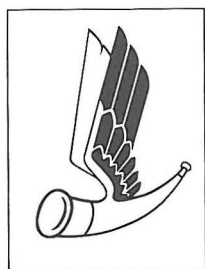
DIGITAL MAP PRODUCTION

by

J.D. Leatherdale & K.M. Keir

ABSTRACT

The Hunting digital system is used for aerial triangulation, mapping and engineering applications. It produces conventional maps, digital elevation models, volumetric assessments, vertical sections and digital output for databanks. The design and performance of the system are reviewed after four years of operation.



HUNTING SURVEYS LIMITED

ELSTREE WAY  
BOREHAMWOOD  
HERTS WD6 1SB  
ENGLAND

Cables: ASTEREO BOREHAMWOOD  
Telephone: 01 953 6161  
Telex: 23517

## DIGITAL MAP PRODUCTION

### INTRODUCTION

Profound changes of the products and methods of map production have been created by the introduction of digital techniques. Users may now choose to store and handle topographical information in the form of traditional line maps (which can be produced digitally or conventionally), as orthophotomaps or in any one of various digital forms which can range in complexity from the simplest elevation model to a full cartographic database. Each mapping organisation has to react to the new technology in its own way, in relation to its role for the future and current constraints of expertise, equipment and capital resources.

Hunting Surveys now has more than four years production experience of an on-line digital mapping system, first described by Keir (1976) at the ISP Congress in Helsinki and developed to meet the particular requirements of a private firm undertaking contract mapping at all scales anywhere in the world.

### THE HUNTING DIGITAL MAPPING SYSTEM

In relation to the overall potential of digital techniques applied to mapping, the Hunting digital system is a modest development designed to reduce the cost and time of map production by adding computer assistance to our existing human skills and equipment.

The hardware configuration, shown in Fig.1, comprises eight Wild A8 stereoplotters with linear encoders, one Ferranti Freescan digitiser table and a Ferranti flatbed plotter, all connected on-line to a PDP 11/50 computer with 192KB memory and a 40MB disc. Occasional use is made of other in-house facilities including HP-1000 and HP-3000 computers, a Calcomp 1051 drum plotter and a Cetec System-Four digitiser table.

The PDP 11 software is structured to permit twelve operations concurrently, all of which can relate to different projects with very different specifications. To ensure instant response, highest priority is given to on-line data capture at the nine digitising stations. Lower priority is allocated to driving the flatbed plotter and to magnetic tape archiving operations. The residue of computer resources is available for such tasks as background processing of previously captured data and adjustment of aerial triangulation blocks or indeed for any application, related or otherwise.

### AERIAL TRIANGULATION

The various methods that are available for observing and calculating triangulations give almost unlimited capacity and flexibility to meet every type of requirement. It is possible to handle any pattern and mixture of photography with vertical, horizontal, oblique or convergent attitudes from space, airborne, ground or underwater camera stations. Any reasonable pattern of control points can be used.

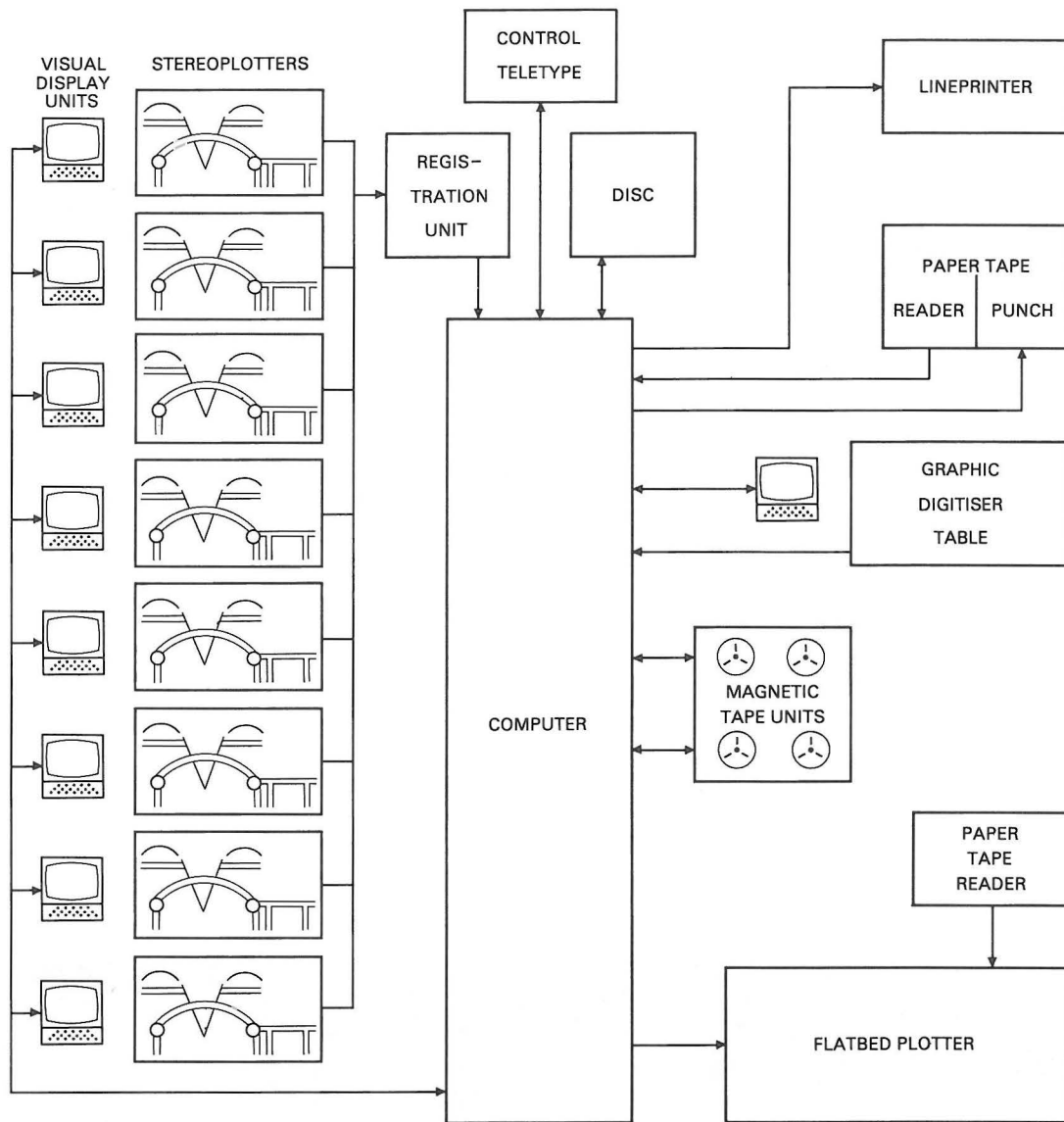


FIGURE 1. Hardware of the Hunting digital mapping system

Analytical methods are preferred for large blocks and for projects where high precision with compensation for lens and film distortion is essential. Observations are made on a Zeiss Jena stereocomparator registering on punched tape. Off-line Wild A7s are also used for independent model triangulation and are entirely adequate for most routine requirements. There are even occasions when we still find it convenient to observe short strips by the base in/base out aeropolygon method. Although we are unlikely to need yet more capacity, the eight on-line A8s could also be used for triangulation, registering either independent model coordinates or plate coordinates.

Block adjustment is by iterative spatial transformation of independent models, using a derivation of the technique developed at University College London and the Ordnance Survey and first described by Amer (1962). This is still one of the most effective methods of handling large blocks in small computers. Up to now our largest blocks have comprised about 850 models, though the system maximum is much higher.

Aerial triangulation gives useful by-products which aid the subsequent process of stereocompilation. Base sheets for conventional mapping can be prepared on the flatbed plotter with selected categories of points marked and numbered. After analytical triangulation, the elements of relative and absolute orientation are available for setting up the stereoplotters. Project diagrams can be produced showing sheet layout, photo centres and control and minor control points. The disc file of adjusted coordinates is immediately available for digital mapping purposes.

#### DIGITAL MAP PRODUCTION

During aerial triangulation it has to be decided which projects are to be plotted conventionally and which are to be produced by the digital mapping system, because rather less than half the plotting capacity is digital. The choice depends on current loading and preference for digital production is given to projects involving digital end products, fair drawing at more than one scale and minimal post-photogrammetric editing or field completion. Maps are sometimes produced partly by digital and partly by conventional methods, to exploit the advantages of both.

Digital mapping procedure, already described elsewhere (Keir, 1976; Leatherdale, 1977), is summarised here with some production examples.

The alphanumeric display units and keyboards at each of the digitising stations (Fig.2) provide two way communication between operator and computer to assist, for example, in scaling and levelling the models and selecting appropriate feature codes from a menu display.



FIGURE 2. On-line stereoplottor and visual display unit

The footpedal which activates the A8 pencil chuck also controls the flow of digital information to the computer. The operator tracks all features continuously and the plot on the instrument table acts as a record of progress. Digital output is three-dimensional, with flow rates of up to 50 coordinate sets per second from each digitising station, and 10  $\mu\text{m}$  resolution. Fewer than ten percent of these points are normally required to define the shape of a feature; the computer makes the optimum selection, in real time, and discards the rest.

Detail and contours are digitised in any convenient sequence. Optionally, the operator can instruct the computer to ignore all but salient points (which he indicates by momentarily releasing the foot pedal) and to join them with straights or curves. Audible warning assists in the closing of loop features. For dual line features, only the centreline or one edge need be digitised. Erroneous digitising can be deleted by simple key-in. Annotations can be selected from a previously prepared library and positioned at will, without use of the keyboard. The manuscript plot, being merely a record of progress, requires no touching up.

Features that are clearly visible on the photography are plotted faster than is possible conventionally. However, features which need to be constructed rather than plotted directly can take longer by the digital method and can generate a considerable amount of checking and editing work later in the process. Where these abound, the project is better plotted conventionally.

The captured information is stored model by model on disc for off-line processing in stages, as outlined in Fig. 3. Cartographic enhancements are made to appropriate features for rectangularity and circularity; to close junctions; to generate parallel lines with either true-to-scale or conventionalised spacing; and to edge-match adjoining models. These adjustments are constrained within very small tolerances and buildings which are not square or model edges which do not match are left to be investigated.

Not until the draughting stage is it necessary to specify the scale, sheet layout and line styles and symbols for each feature code of the map series. The draughting specification can later be altered time and again to produce an endless variety of plots from one set of basic data. At the smaller scales a measure of generalisation is achieved by selective suppression of minor features, by smoothing and by varying the widths of casings, etc. Much work remains to be done in this field.

The Ferranti flatbed plotter can produce map sheets in separations up to 1.5 x 1.2 m in size using pens, tangentially controlled scribing tool or a lightspot projector exposing on photographic film. In practice, detail is usually exposed on film to make use of the projector symbols and variable line widths. However, photo-plotting is slow because commercially available film is not fast enough to register the passage of the lightspot at maximum plotter speed, unless the spot exceeds 0.25 mm in diameter. Contours, therefore, are usually scribed. Spot height values and most other annotations can be plotted but place names, cliff and slope symbols and contour values are all added more economically by hand.

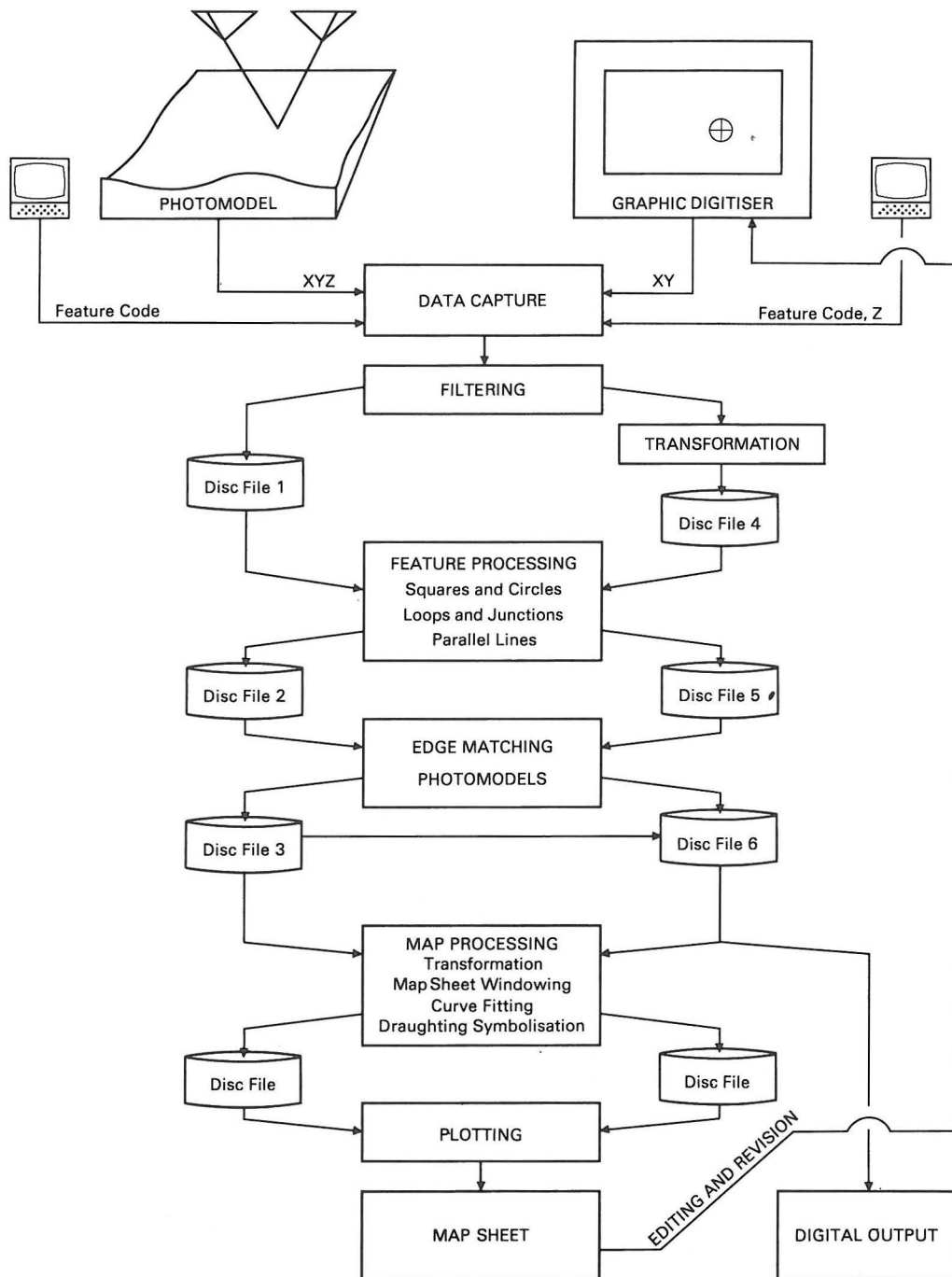


FIGURE 3. Cartographic data flow

Since most of our clients are not yet equipped to make use of digital map tapes and are interested only in the fair drawn map sheets, we generally use manual methods of correcting and completing the plots to final cartographic drawing standards. When the digital record is important, editing is performed at the Freescan and the datasets are then reprocessed and replotted. The final graphic is still the only satisfactory evidence of an error-free digital record.

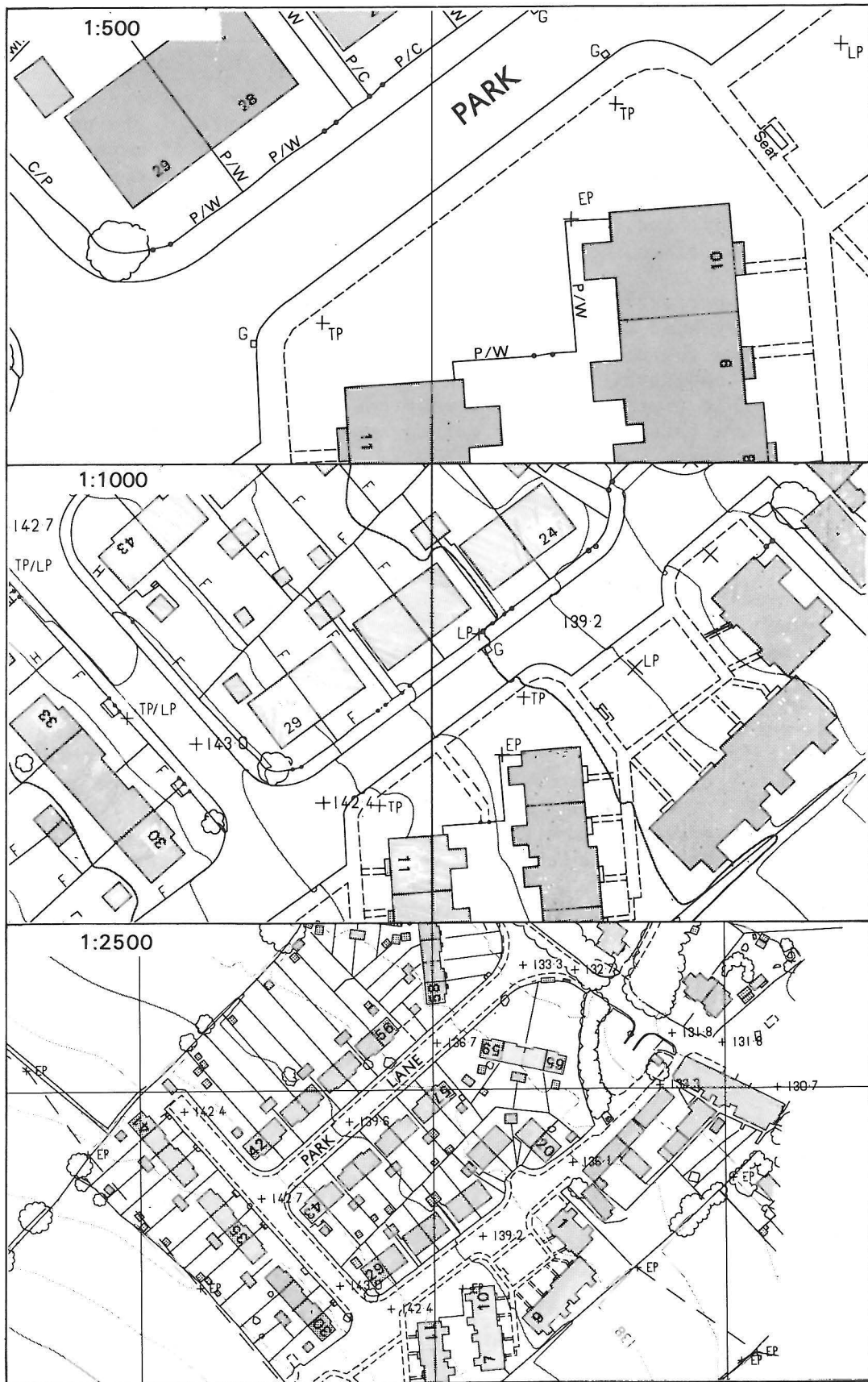


FIGURE 4. Mapping at scales of 1:500, 1:1000 and 1:2500 produced from the same input.

The digital mapping system has been used for mapping throughout the scale range 1:200 to 1:50000, both in the United Kingdom and overseas. Some typical products are shown in Fig.4, which is an example of the use of different draughting specifications to produce a variety of maps from the same data. All symbolisation including the tree canopy is computer generated, as are the horizontally aligned annotations and spot heights except where they have had to be repositioned manually to avoid clashing with other information.

Although it is perfectly possible to match almost any cartographic drawing specification by hand embellishment of the computer plots, fewer and fewer users can afford the additional time and cost involved. Increasingly they are demanding topographic information clearly but simply presented in the shortest possible time and at the lowest possible cost. Digital techniques can help achieve this though many cartographers will mourn the passing of the age of artistry.

#### DIGITAL PRODUCTS

In favourable circumstances digital techniques may be used to advantage in the production of conventional maps but the greatest benefits are to be expected when the user requires digital output. Physical planners, engineers and government administrators are making increasing use of computer databanks which in turn is expanding the demand for topographical information to be supplied in digital form. The Hunting digital mapping system is well suited to producing digital models of ground elevation, cultural details, property lines and most other geographically based information. It can also be used for the assessment of areas and volumes.

The technique used for volumetric surveys is thought to be unique. Complex surfaces cannot be represented adequately by elevation grids whilst contours, besides being less accurate, provide too much information on steep ground and too little in flat areas. The most effective representation is given by parallel profiles, variably spaced to suit the irregularities of the surface and with static height readings taken at all breaks of slope. For speed and convenience, profiles are observed parallel to the X or Y axis of the instrument. Computation by the average end area method would be straightforward were it not that the upper and lower surfaces have to be surveyed at different times, so that the two sets of profiles can seldom be planimetrically coincident. Superimposed, they would form a skew lattice. The problem is solved by redefining one of the surfaces with interpolated levels at every lattice intersection. Since the original levels include all change of slope points, the interpolations are effectively error free. The ends of each section are closed by one of the two methods indicated in Fig. 5.



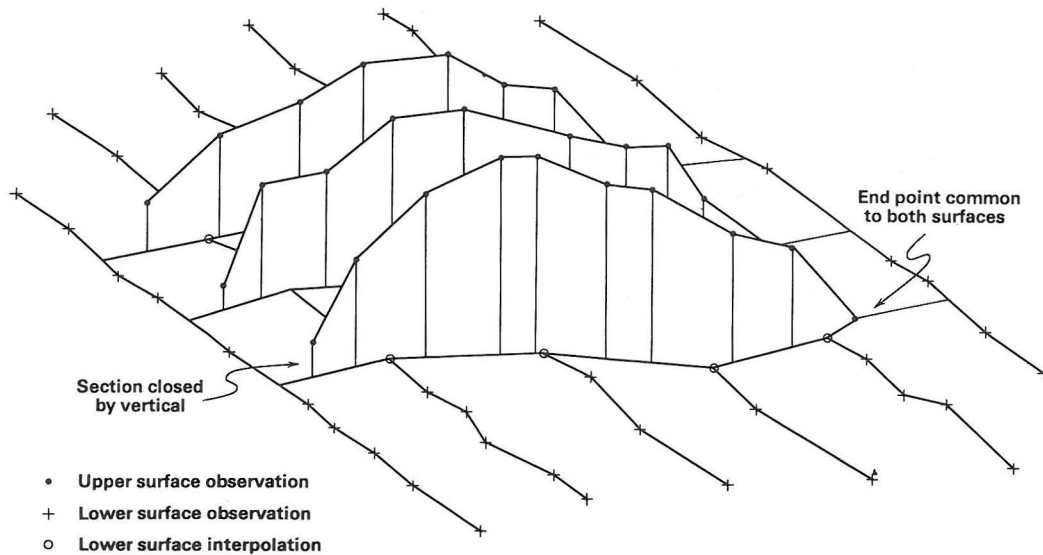


FIGURE 5. Model for inter-surface volume calculation

The accuracy, reliability and speed of volumetric assessment by this method have made it one of the most successful applications of the digital system. Both aerial and terrestrial photography are employed and the subjects have included stockpiles, quarries, opencast mines, reservoirs and engineering construction and demolition works. Many sites are surveyed several times a year to monitor change.

Digital contours can be used to generate the profile scan lines for computer-driven orthophotography equipment. Vertical sections for highway and other projects can be observed in the on-line instruments and plotted on the flatbed or drum plotter. The on-line stereoplotters also provide a precise and convenient method for digitising existing maps and drawings, either photographically reduced to diapositive size or viewed on closed circuit television which brings the image from the A8 table to the operating position.

The system has proved remarkably successful in producing all these types of output without the need for interactive graphic displays for editing. As the demand for map products in digital rather than graphic form increases, interactive editing facilities become more attractive in relation to the hardware and software costs involved. For the moment, however, the required results are achieved more economically without them.

#### ECONOMIC AND HUMAN CONSIDERATIONS

For a private company the economics of digital mapping are simple. The investment must be recovered by reducing production costs, by increasing throughput and by generating new marketable products. Commercially there is probably a very narrow margin for success, between investment in a system which is too small and too simple to produce significant benefits and over-investment in elaborate hardware and software which can never repay the capital outlay.

A computer assisted mapping system can succeed only if it gains the interest, support and confidence of mapping staff. It should relieve operators of the more tedious and repetitive tasks but must not usurp their decision-making function. In the commercial environment at least, it must have the versatility to handle a wide variety of surveys but it should never be used on those that are better done conventionally. It must be simple to operate, easy to maintain and, in the event of breakdown, there must be a rapid recovery procedure. The system will have no sterner critics than the production staff who are required to use it and their involvement from the very first stages of development is the key to success.

#### REFERENCES

- KEIR, K.M., 1976. A digital mapping system designed for the commercial air survey market. *Presented papers of the XIIIth International Congress of Photogrammetry, Helsinki*. Commission IV. Paper 4 26. 18 pages.
- AMER, F., 1962. Digital block adjustment. *Photogrammetric Record* 4 (19): 34-49.
- LEATHERDALE, J.D., 1977. Production experience with the Hunting digital mapping system. *Proceedings of the 36th Photogrammetric Week, Stuttgart*: 251-268.