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A COMPUTER ASSISTED SYSTEM FOR LARGE SCALE ENGINEERING MAPPING

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ABSTRACT

A digital mapping system utilising existing analogue stereoplotting instruments, a minicomputer and microprocessors, which was developed under strict budget limitations over a three year period,is described.

The rationale of the development, applications of the system and the effect on personnel are considered.

INTRODUCTION

As the complexity of land management and civil engineering problems have increased, particularly in the urban and near-urban areas, engineers charged with the responsibility of finding solutions have naturally sought to use the latest technology available, with its inevitable use of the high speed digital computer.

As a map or plan is basic to finding these solutions it is simple logic that there is or will be, an increasing demand for maps and plans in digital form in the years ahead. Traditionally the provision of these maps and plans have been at large scales, sufficient for the project under consideration. The large scales have enabled the photogrammetrist to plot in much greater detail the man-made improvements on the topography, as well as contours at much closer intervals.

To produce this digital data will inevitably involve mapping organisations in a capital investment in new technology. The problem for small private organisations, with limited resources, is to decide whether to re-equip with sophisticated new instrumentation, such as the analytical plotter, or to attempt to upgrade existing equipment to meet the new challenge.

To quote Leatherdale and Keir (1979), "each mapping organisation has to react to new technology in its own way in relation to its role for the future and current constraints of expertise, equipment and capital resources."

Present day analogue instruments from the major manufacturers currently in use are more than adequate in terms of their precision for the task of providing digital map data. It would seem logical to upgrade this equipment with the addition of electronic components to acquire digital data as an alternative to, or during the process of, obtaining conventional line plotting. This is not to say that analytical plotters do not have a role to fill, but simply that if the objective is digital topographic data, the sophistication and expense of new instrumentation is hard to justify in terms of product cost.

This paper describes a digital mapping system which has been built up by stages over the past three years, utilising existing analogue instruments and minicomputer which have been upgraded to a full system with the aid of microprocessors.

HARDWARE CONFIGURATION

In 1976 the company was equipped with 11 analogue plotting instruments, including one capable of producing orthophotos, and its own minicomputer. This equipment had been purchased over the previous 16 years. The minicomputer was one of the later acquisitions, having been purchased some two years previously at a time when spending on timesharing bureaux had reached alarming proportions. It was also becoming increasingly obvious that many of the company's clients were awakening to the potential of the high speed computer.

In considering the hardware for a computer assisted system in the private enterprise environment, it was necessary to consider the main types of work to be served as well as the capital investment required. In the main we, as a private organisation, have no clearly defined task in hand and are often called upon to perform in widely diversified areas. (Cleaves, 1978).

Although the prime task would be large scale mapping it was considered unwise to exclude small scale topographic mapping, just as it would be unwise not to consider the physical location from which source data would be obtained. If all source data was to be obtained at the same location then a total 'on line' system could have been considered. However as the physical location from which some of the source data would be obtained was many miles away, it was vital that both 'on line' and 'off line' systems be considered.

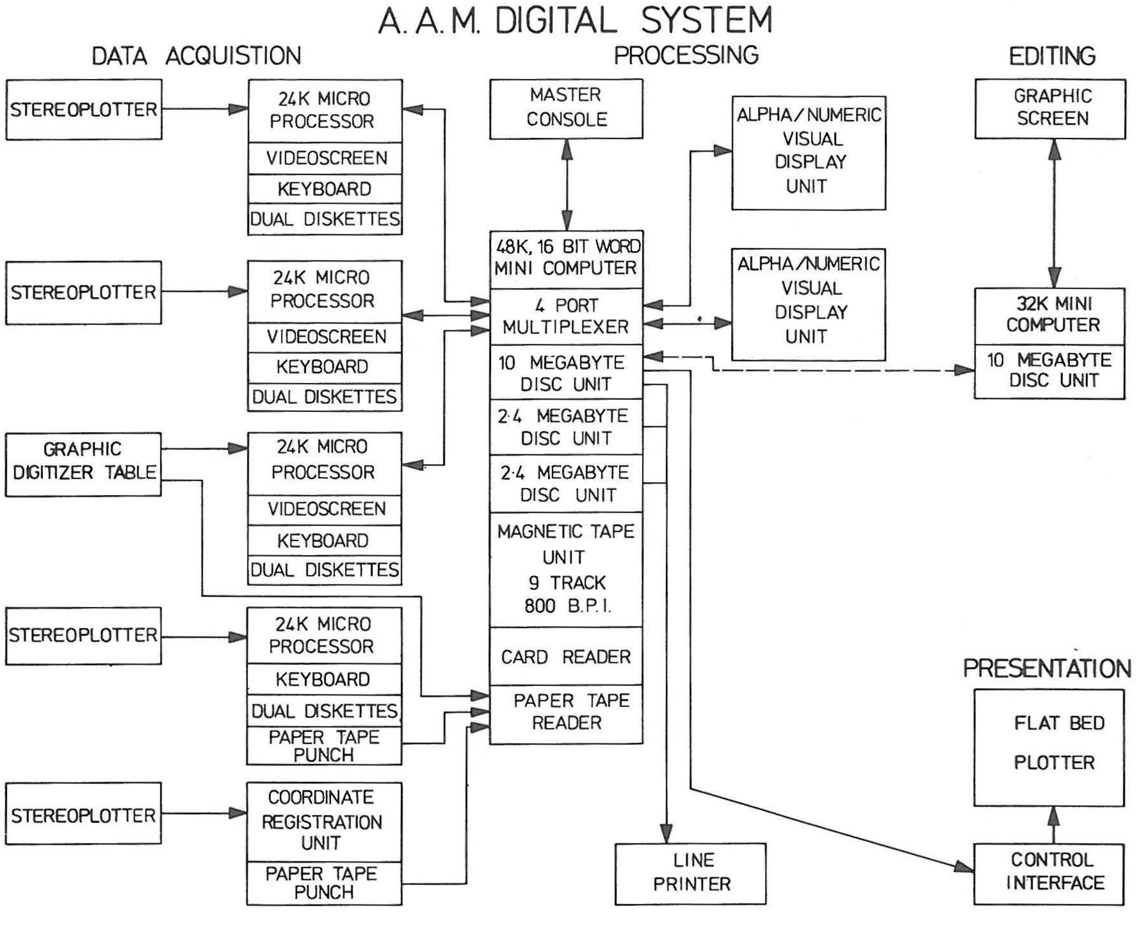
It soon became apparent that an 'on line' system would need a central processor of considerable power, in the order of 100K core memory at least, but that any breakdown, even a minor breakdown, could bring the entire digital system to a halt.

For production reasons it was decided this was unacceptable; the risk of 'down' time on the central processor being all too evident. The capital investment on a powerful central processor was also quite substantial when coupled with the equipment necessary for acquisition, editing and presentation of results.

For reasons of capital investment as well as a desire not to be dependant on a single central processor, an 'off line' system based on microprocessors at the various input and edit stations, interfaced to a minicomputer of lesser core memory, was designed. The design had a number of advantages, one being that it could be built up by stages as required, thereby reducing the demands on the limited capital available.

The microprocessor is a powerful tool with the advantage that as it was programmable it was possible to define the prime task, but retain the flexibility to modify and improve procedures as expertise increased. In terms of capital investment it was not necessary to commit the company to expensive equipment which could prove to be unsatisfactory, or to equipment which had been designed for specific tasks only.

The hardware configuration as shown below comprises acquisition, processing, editing and presentation equipment, which is discussed in greater detail in the following paragraphs.



By installing microprocessors it is possible to interface a single stereoplotting instrument to a minicomputer, to develop software, to learn and understand the problems of capturing(?) digital data and to acquire the necessary expertise, all at a relatively low capital cost.

Data Acquisition

The equipment currently capable of digital data acquisition consists of a Wild A10, two Wild A8s and a Wild B8, together with a recently acquired Summagraphic digitizer table which can be used to digitize existing plans, or to assist the editing function.

All of the stereoplotters were originally purchased as analogue plotting instruments for conventional line plotting and with the exception of the A10 have been fitted with 24K microprocessors which can be operated either 'off line' as stand alone equipment, or 'on line' interfaced directly to the minicomputer.

The A10, when originally purchased, was fitted with the EK8 for automatic co-ordinate registration to provide punched paper tape for aerial triangulation computations. To date the A10 has not been upgraded; partly because the EK8, although an unintelligent device, is capable of digitizing 'on the fly' and thus can be used to obtain limited digital data. The A10 and one of the A8s are located many hundreds of miles away from the central processor. Both instruments are fitted with a high speed paper tape punch which provides the means of transporting high volume digital data over long distances. Although it is feasible to interface these instruments to the central processor through a telephone land line, this is considered to be uneconomic at the present time.

Two of the instruments, one A8 (Fig. 1) and the B8, together with the graphic digitizer table (Fig. 2), which are located with, and interfaced directly to, the central processor via their microprocessors, are also equipped with video screens which have a switch capability enabling them to be used as either alpha/numeric terminals or as graphic screens, using a 256 square dot matrix.

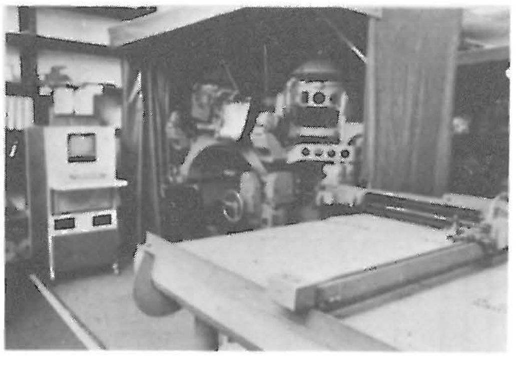


Fig. 1

Fig. 2

These microprocessors are programmed to sample through the up/down counters, the square save impulses from the shaft encoders, or in the case of the graphic digitizer table the inbuilt microprocessor, on a continuous basis, so long as the foot switch of the equipment is depressed. In theory they are capable of sampling at the rate of 2400 characters per second, but in practice this is reduced by time filtering to approximately 20 to 25 per second.

The registrations are retained in the machine system, that is a local system of co-ordinates, and are computed and displayed on the video screen when used as a graphic screen. As each planimetric feature or complete contour is digitized it is displayed and the operator has the ability to either reject or save the data according to his assessment of its correctness. If he chooses to save the data it is stored on a permanent file on one of the diskettes. On completion of the digitizing of model or plan the data is transferred to the minicomputer.

The microprocessors can be operated in either of two modes, one mode is 'transparent' where the microprocessor behaves essentially as a non-intelligent Visual Display Unit, the other mode is intelligent where the microprocessor responds to and transmits data to the minicomputer.

In its 'transparent' mode the microprocessor (Fig. 3) is 'signed on' to the minicomputer, enabling it to be identified. In this mode the microprocessor is under the control of the minicomputer, which establishes and allocates file space.

Once the microprocessor has been 'signed on' it reverts to its second mode, that of an intelligent unit, acting together with the minicomputer, and begins to transmit the stored data. The data is transformed by the minicomputer into the terrain system of co-ordinates, mathematical filtering of the data, based on a simple test of the deflection angle at the third point in any trio, is applied, and the data is stored on the 10 megabyte disc.

Processing

The processing equipment consists of a Data General Nova 840 (Fig. 4), which was enhanced with various add-on units to enable the storage of high volume digital data. The computer is memory-mapped and can be operated foreground/background in time shared Basic and Fortran dedicated to a single application. It is disc based and supports in-house 'time sharing' using Basic, thus the full core memory available in Basic is available to each user.

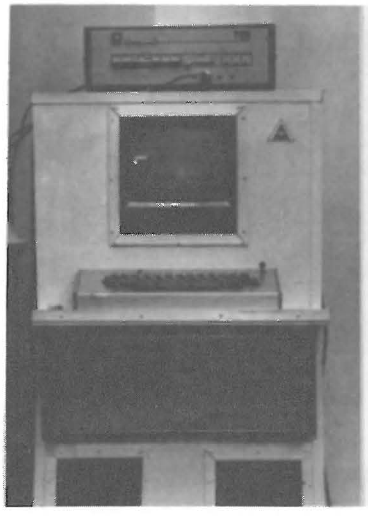


Fig. 3

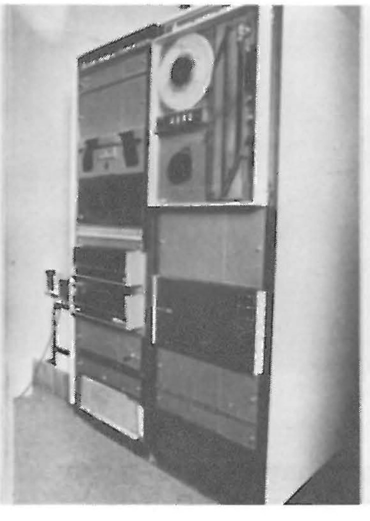


Fig. 4

Fig. 5

There are no hard and fast rules applying to operation of the system, but usually it is operated in time shared Basic during the day, with batch Fortran run overnight.

During the daytime processing the data acquisition stage is given priority over other users when data is to be transferred from the microprocessors. The system is used for all computations, including commercial processing, job costing, payroll, management reports etc., aerial triangulation computations, volume capacity and earthwork calculations.

The minicomputer also provides the drive to the flatbed plotter through use of the spooling device. The plot instructions are computed in Fortran overnight, the data having been set up in Basic during the previous daytime processing. Usually the plotter is left on overnight and commences plotting during the night until it needs operator intervention. The remainder of the plot instructions are left in the spool and provides the data to keep the plotter going during the next day's processing.

Editing

Editing of the digital data before any hard copy plotting is attempted is in all probability the most vital stage in a digital system. The equipment utilised here consists of a Tetkronix 4010 storage diaplay screen (Fig. 5) connected to a Nova 4, 32K minicomputer which provides the computing power. Data to be displayed and edited is stored on a 10 megabyte disc which is interchangebale with the 10 megabyte disc on the central processor.

The digital data is displayed on the screen and edited by use of the cross hairs. Software has been developed to enable the data to be windowed, deleted, moved, added to, displayed at different scales, automatically squared, contours to be joined and so on.

The procedure adopted has been to digitize data either on the stereoplotter or the graphic digitizer table and display it on the video screen, using the raster scan dot matrix. The data is transferred to the minicomputer, transformed into terrain units and re-displayed on the storage screen where final editing is completed prior to hard copy plotting.

Presentation

At the present time flatbed plotting is achieved by using a hybrid plotter (Fig. 6) consisting of an analogue instrument plotting table which has been modified by the addition of stepping motors to the X and Y drive spindles (Fig. 7) and interfaced to the minicomputer.

Fig. 6

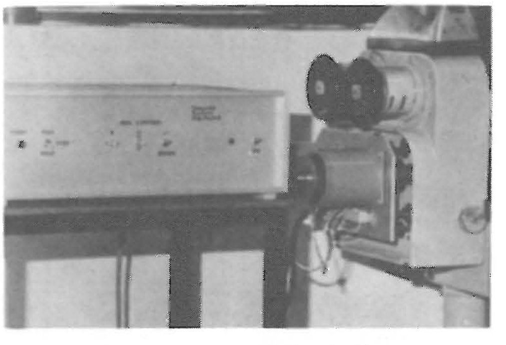


Fig. 7

The equipment does not have the quality of line work produced by a recognised flatbed plotter; however this is often unimportant in civil engineering work provided it is capable of maintaining required accuracies. Final cosmetics are still obtained in the conventional way.

Software routines have been developed for a wide range of graphic output, from edited and reduced detail or contour plots to capacity curves, contour generation from random input, gridded control sheets, point plots of field generated 'string' data, long sections, cross sections and so on.

Ultimately it is intended to install a high speed flatbed plotter which will enable plans to be produced with a higher presentation quality, so that with the minimum of additional work they can be reproduced and delivered to the client.

Cost Effectiveness

Most if not all, private mapping concerns are faced with a restricted capital budget and this company was no exception. The hardware capital cost of the digital system, excluding the original cost of the stereoplotters, has been $A160,000 which is comparable with the price quoted in Australia for one analytical plotter, and this amount has enabled four analogue stereoplotters to be integrated into the system.

Before purchasing equipment cost effectiveness has to be carefully scrutinised. To be cost effective in the commercial world all equipment purchased must be utilised to the maximum and must improve upon the efficiency or accuracy of a current procedure. It must also produce a marketable product which is otherwise unobtainable, or a product at least comparable with and at lower cost than existing products. (Cleaves, 1978).

It is very difficult to assess the cost effectiveness of a digital system. Contrary to many opinions digital data is not obtained almost as a by-product of the plotting procedure. In fact the cost of producing digital data can be almost 100% on the cost of producing a graphical result. The true cost effectiveness or advantages are not experienced at the acquisition stage but rather at the user stage.

We have found that stereoplotting time for man-made features has increased by up to 25% and that plotting of contours and drainage increases plotting time by 15%. Onto these increased times must be added the time taken to edit the data, which we have found to be around 40% to 50% of the plotting time, including the time needed to edge match model joins and sheet edges.

Besides the increase in time necessary to produce a digital map there is the additional capital investment in the equipment necessary to produce this data, which has to be offset against the cost of the product.

However if the product being produced is a new product, providing data that will be analysed many times by the introduction of new parameters, then it can certainly be considered to be cost effective, particularly if the new parameter permutations are innumerable.

There are some cost savings to be made by a mapping organisation with a digital system. These savings are mostly seen in the areas of aerial triangulation and the computation of volumes where the digital system enables rapid on-the-spot checks to be made on data which is otherwise hard to check, or which, when checked, involves costly re-observations.

PERFORMANCE, APPLICATIONS & STAFF SATISFACTION

As with any new technology it is necessary to evaluate performance against expectation. The expectations for the digital system were threefold:

(1) Aerial Triangulation
(2) Engineering Computations
(3) Digital Map Production

Prior to establishing the hardware necessary to interface analogue instruments to a computer, considerable expertise had been built up in aerial triangulation and engineering computations using batch processing and time sharing bureaux. The transition from external computers to an 'in house' minicomputer had already been made and much of the expertise built up with outside computers was transferred and enhanced with the company's own computer.

(1) Aerial Triangulation

Computation procedures for strip and two-dimensional block adjustments were firmly established. After purchase of the minicomputer a three-dimensional block adjustment program was developed, based on the XY program developed at Melbourne University by Bervoets (1971).

Using a microprocessor 'on line' to the computer, the assembly of models into strips takes place as each model is read, with residuals on the pass points displayed on the video screen. Operator job satisfaction is enhanced and job costs reduced as less mistakes and re-observing of models have occurred.

Procedures have now been developed which retain the digital data in the system from the time of original observation until gridded control sheets are returned to the instruments for the scaling of individual models. The operators are supplied with elements of orientation, together with a model diagram which displays all points to be found on the model in their approximate position, plus the residuals of that model with respect to the final mean values.

Flatbed plotted control sheets for all plans on the job are provided, each sheet having a punch register position plotted which enables the sheets to be accurately joined on a stud register to all the surrounding sheets, thus removing all the problems of edge matching of sheets both on the plotting table and in the drawing office. If required, punch registered overlays for all control sheets can also be provided with the computer accurately controlling the punch register positions.

Job satisfaction has been considerably enhanced for almost all personnel as a result, with ready acceptance of the benefits that the system provides. Cost savings have also been measured, both in the reduction of personnel directly involved plus an increase of throughput as a result of the increased accuracy and reliability of the products produced during this phase of plan production.

(2) Engineering Computations

For some years prior to the installation of the digital system programs had been developed to compute volumes, areas, capacity diagrams and earthwork quantities. The data preparation for these types of calculations had been either by hand or by point mode registration units onto punched paper tape or punched cards, with processing carried out on computer time sharing bureaux.

With the installation of the microprocessors 'on line' to the computer, the observation and recording of input data was greatly simplified and checking of the complex shapes is overcome by displaying the profiles on the video screen at the acquisition stage.

In simple cases where one of the surfaces is a plane, such as a reservoir capacity, it is also possible to compute volumes and areas as the observation of the data is proceeding, such that there is no time delay between completion of observations and achieving a final result. Hard copy of these results is easily obtained by storing progressive figures in a file in the computer and printing the results on the line printer.

The methods of digitizing, joining of two irregular surfaces and computation of volume has been adequately described by Leatherdale and Keir (1979). However for a number of reasons clients still require their results in terms of horizontal profiles, as represented by contours, rather than vertical profiles which clearly define the complex shapes found in quarries or open cut mining.

A method of translating data digitized in vertical profiles into horizontal profiles has been developed, which enables these complex shapes to be digitized in the most accurate and economical way and yet satisfy client requirements for area and volumes to be presented in a form most usable by them.

Over the past few years all of the major reservoirs which have either been investigated or built in the vicinity of Melbourne, a city of about three million meople, have been surveyed by use of digital photogrammetry. Some five major reservoirs have been, or are being built. Initial capacity tables and capacity diagrams were prepared during the investigation stage, earthwork volumes were computed for the dam wall construction, both the material removed in excavation to bedrock and the materials placed in the wall construction. On completion as-built plans and final capacity tables and capacity curve diagrams have been prepared.

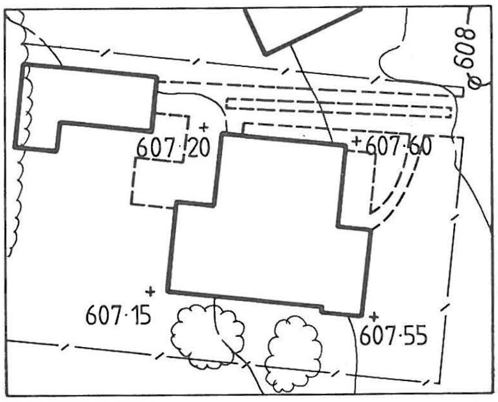
A particular problem on which the digital system is used has been the monitoring of quarries, both during their excavation and afterwards, when they are generally taken over by local councils, who use them as rubbish dumps until refilled. They are then landscaped and returned to the community as parkland or recreational areas. Although an apparently mundane problem, considerable sums of money are involved as well as safety and public health risks where clay or sand pits are close to, or now within, the suburban sprawl of a major city.

The digital system is a fast, economical way of monitoring these problems and enables accurate volume and area figures to be produced which engineers use to specify rate of fill, final desired surface as well as reserves, in terms of remaining space and so forth.

(3) Digital Map Production

Digital map production is the last of the three objectives of the digital system and could not be attempted until a successful interface between stereoplotting instruments and computer had been achieved. Development of the procedure, both hardware components and the considerable software requirements, has dominated the activities of the computer room staff.

The digital map production procedure has been developed around a modified feature code based on a recommended standard of feature codes developed by the National Mapping Council of Australia (Standards Association of Australia, 1980). The modified feature code of four digits can be computer-extended to the eight digit feature code required by the standard.



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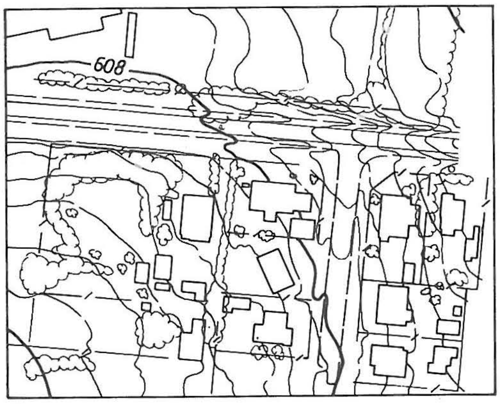

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Fig. 8

The microprocessors have been programmed to provide a prompt facility in the form of a menu display, as an aid to the stereoplotter operators in selecting the feature codes to be used. The stereoscopic models can be digitized in any sequence and it is not necessary to maintain a particular feature code once selected, although for convenience this is usually attempted.

The microprocessors are wired into the footswitch of the instruments so that they are activated as soon as the footswitch is depressed. The method of operation is for the stereoplotter operator to key in the feature code and proceed to plot. The data recorded by the microprocessor consists of a pen command activated by the action of the footswitch and the XYZ co-ordinates of the instrument axis. In this way the data recorded is minimised, with sufficient information to enable identification by the computer at presentation stage.

Data is separated into its respective feature code and colour code when it is transferred to the minicomputer. This facilitates editing and flatbed plotting, as line sizes and types, symbols etc. are matched up with particular feature or colour codes.

The digital system has been used for mapping in the scale range 1:500 to 1:100,000 with magnetic tape supplied to clients for further use. An example of digital mapping is shown at Fig. 8 with 1:500 and 1:2,500 maps produced from the same data.

The fundamental aim of this organisation has been to upgrade existing analogue instruments by the addition of microprocessors and related peripherals to acquire digital map data in the most economical way. The minimum data necessary to describe any line is captured by sampling at a high rate, and mathematically reducing this data such that the plot produced from the reduced digital data would faithfully reproduce a plot produced from the table of a stereoplotting instrument.

Conclusion

In development of the digital system our aim has been one of staff involvement in new technology to produce a new product efficiently.

Staff must obtain job satisfaction and must not feel their security is threatened by the instrumentation of new technology. It is very difficult to obtain co-operation and feedback from highly skilled stereoplotter operators by telling them that the new equipment can be operated by semi-skilled people. Equally, job satisfaction deteriorates rapidly if all so-called tedious tasks are removed only to be replaced by a lesser number of even more tedious tasks.

There is no job satisfaction whatsoever to a highly skilled stereo plotter operator who is asked to spot height a stereo model on a tight grid mesh for the computer to produce contours. He would much rather produce the contours and acquire digits during the process. The fact that this does not lend itself to easy computer processing is of no interest, for computers are supposed to enhance his lifestyle.

The social consequences of the new technology have to be considered if retrenchment of skilled staff, or lack of opportunity to young eager graduates of academic colleges is to be avoided. It is very difficult for a small company faced with an explosion in costs, particularly labour costs, to consider this last point, but if a successful transition to a digital system is to be attempted it has to be considered. After all, a digital system is complex and requires highly intelligent people to develop and operate it.

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