Application of computers to Cave Surveying

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The reduction of cave survey data is an essentially straightforward but repetitive mathematical task which can be carried out to advantage using virtually any type of computer from a programmable calculator upwards. The obvious benefits are speed and accuracy in reducing and adjusting the raw data to obtain the x,y,z coordinates (eastings, northings and elevations) of the surveyed points. Additionally, depending on the functionality of the software (program) and power of the hardware (computer), the user may be able to build up a data base of surveys, plot out on paper scaled plans and elecations of the cave and possibly even see a three-dimensional model of the cave, in perspective or some other projection, as an aid to understanding the spatial relationships of cave passages.

At the present time, computer hardware for cave survey applications can be classified into three main groups. At the bottom end of the range the programmable calculator of a few years ago has been superseded by what is perhaps best termed the 'pocket computer'. Typically these cost under £ 100, are programmable in BASIC and come with a few kbytes of memory. Additionally, they may have an interface for a printer and some kind of magnetic strip storage device. The mid-range group comprises 8-bit home micro-computers and the more powerful 16-bit personal computers (P.C.s). The former have typically 32 or 64 kbytes of memory and store data on either audio-cassettes or flexible ('floppy')disks. The latter are usually available with a minimum of 128 kbytes of memory and use floopy disks or hard (Winchester) disks for data storage. Some micros and most P.C.s support industrial standard operating systems and software packages and can output to printers and graph plotters. Prices vary from a few hundred to a few thousand pounds. Finally, at the top end of the range are the 32-bit mini-computers and larger machines, used for scientific and business applications. These have very fast processors, many megabytes of memory and often gigabytes of hard disk storage. Graphical output can be obtained form plotters for paper sizes up to twice A0, whilst high resolution colour displays (typically 1024 × 850 pixels) can provide interactive devices, 'hidden line' and 'colour shaded' three dimensional views in real time. For all but the most demanding tasks in cave surveying the 'pocket computer' and home P.C are quite adequate.

Programmable calculators and pocket computers

Ten or fifteen years ago scientific programmable calculators suitable for cave surveying applications were difficult to program, had limited memory, offered little or no storage facilities (for either software of data) and were expensive. The present day devices by comparison have enough memory to be able to hold and analyse data for perhaps 100 survey stations, a good days work for any surveying team. Moreover, because they are programmable in BASIC, and can usually display about 20 characters on the 'screen', software can be written which has a 'friendly' user interface (i.e. displays prompts, error messages etc.). The attachment of a small printer can provide hard copy output of data in numeric and sometimes graphical forms. Some machines also offer an industry stadndard serial interface permitting programs and data to be transferred to and from other computers. Being battery operated these small computers are ideal for expedition use as has been clearly demonstrated by White (1987). The essential steps in writing sofrware for machines at this level have been presented by Reid who has supplied a BASIC program for a Hewlett-Packard device but which could be converted to run on many other types of hardware (Reid 1983).

Home micro-computer and personal computers

The advent of the 8-bit micro-processor (a computer on a chip) brought computing into the reach of almost everyone. The introduction of the IBM PC to almost everyone. The introduction of the IBM PC to a certain extent legitimised this type of hardware by setting de facto industry standards for operating systems, magnetic media formats and display management, and as a result most hardware vendors have been forced to follow suit. This standardisation, combined with the low cost and high availability of this class of hardware makes it an ideal choich on which to develop cave surveying software at a level above that which the pocket computer will allow. Micros and P.C.s have the following benefits :

i) They support industry standard operating systems, scientific programming languages and storage media ii) They have sufficient memory and disk storage capacity to permit the reduction of large amounts of survey data (many hundreds of stations)

iii) They offer sophisticated keyboard and display management, permitting software to be written which allows the user to make selections from menus and/or function keys, and input and edit data in tabular form on the screen

iv) They offer sophisticated keyboard and display management, permitting software to be written which allows the user to make selections from menus and/or function keys, and input and edit data in tabular form on the screen.

v) They have sufficient memory and disk storage to permit the adjustment (closure) of complex networks

vi) They offer comparatively high resolution praphics displays

vii) They can support a wide range of printers and plotters to provide scaled plans and elevations on paper, which can be used as a basis for drawing up the final survey

viii) By virtue of (i) software and data should, in principle, be easilly transportable between different users' hardware.

The best examples known to the author of P.S software for cave surveying which incorporates many of the features outlined above is SMAPS (Survey Manipulation Analysis and Plotting System) written in the U.S. by Douglas Dotson. This runs on a wide range of hardware under CPM, MS/DOS and UNIX operating systems. The data is input and modified by a comparatively easy to use editor (although programming the function keys could have avoided the need to remember so many 'control codes') and stored in a well-structured filing system as individual traverses or more complex networks. Multiple closed loop adjustment is performed by a least squares method with the option to fix certain stations as desired. SMAPS version 3 does not provide any screen graphics, but does allow the output of scaled plans and elevations to a range of printers offering useful features such as the ability to include or exclude survey legs (e.g. surface traverses) used for closure checks. Whilst the data editor accepts passage cross section dimensions, if the user chooses to input them, SMAPS makes no use of this information. However, it does provide the ability to read and write ASCII 'dump' files of both raw and reduced data in a fixed format. Thus data reduced by SMAPS could be used by other software to generate a 3D solid model of the cave. SMAPS has a sizeable user base in North America but is not currently available in the U. K.

Unfortunately, the author is not aware of any cave surveying software developed in this country which is comparable to SMAPS both in terms of functionality and ease of use, and in its general availability. Nevertheless, a few interesting ideas and programs have appeared recently.

Ellis (1987) has rather ingeniously made use of a number of popular commercial spreadsheet programs including 'SUPERCALC2', 'LOTUS 1-2-3' and others to accept cave survey data, reduce it and perform closures of single loops. Although the software is not specific to cave surveying it has the advantage of being able to output reduced data in a file having a format which could be accepted by other P.C. graphics packages to generate scaled drawings.

Irwin (1987) continuing his long-standing interest in the difficult problem of network adjustment, has recently written a suite of three programs on the Amstrad PCW8256 to carry out this task. These facilitate the input, editing and reduction of survey data, followed by the adjustment of either single loops or complex networks, taking into account fixed stations as required. No graphical output is currently available and rather unfortunately the hardware uses non-standard disks and offers no communications interface, so that data transfer to other types of hardware is not possible.

At the 8-bit micro end of the range at least one system running on a BBC machine has been exhibited at a recent BCRA conference whilst an interesting network closure program has been developed by Warren and Warren (1986) which runs on rather esoteric home built hardware.

32-bit Computers

When John Wilcock (1976), wrote the section on computers in 'Cave Suveying', ten years ago, most of the software he described ran on large 'mainframe' devices. Many of these have probably been melted down for scrap by now and, one suspects, the software lost. The computing power of some of these old machines is now available on the larger P.S.s and for many applications of cave surveying, this is quite adequate, although network adjustment may be slow. If one wants to build 3D 'solid' models of cave systems, i.e. ones which recognise that a passage has a volums rather than just a length and direction, and view such models in a variety of 3D projections (perspective, isometric, axonometric etc.) then even some of the more powerful P.C.s may be inadequate. The combined advances in Computer Aided Design (CAD) software and in 32-bit mini-computer hardware, particularly with respect to the VLSI chip and Winchester disk technology, have given rise to what is now commonly referred to as a graphics workstation. A typical workstation would be linked to a computer having a powerful processor (1 Mip or greater), a few Mbytes of memory, and a fast access, hard disk storage system with a capacity in excess of 50 Mbytes. The display would be a high resolution (typically 1024 × 850 pixels) 19 inch (50cm) colour graphics monitor capable of producing pictures of outstanding definition, often much better than from a domestic TV set. A 'single user' device could be purchased from around £20,000 and this type of facility is to be found increasingly in university and polytechnic computing and engineering departments, commercial organisations. Sadly, cave survey software to utilise the features of this class of hardware is scarce. The techniques required to build and view a 3D model, such as that of a cave, are complex and mathematical. They are descrived in general terms in a number of standard texts on computer graphics (Newman & Sproull, 1979; Rogers, 1985; Angell, 1981; and Foley & Van Dam, 1982). The author has developed some software in this area but the only complete package at present seems to be the Swiss system TOPOROBOT has been successfully used to analyse data from and generate 3D models of a number of large Swiss caves including the Holloch and Siebenhengste systems as well as the Flint Ridge- Mammoth complex in the U.S.A.. In order to obtain a good model some care must be taken in recording passage cross section detail (as distances to left and right walls, and to floor and roof) and in choosing the positions of survey stations at verticals and passage junctions. Most of this information should be recorded as a matter of course when surveying, and in any case the additionsl effort is rewarded by impressive 3D views of the cave system either asa colour shaded model or with hidden lines removed. Using these techniques enormous benefits are to be gained in terms of understanding the 3D spatial relationships of complex caves. A TOPOROBOT user qroup exists but unfortunately does not extend to the UK, despite a number of attempts to contact the author of the software, each eliciting no reply. It is to be regretted that the product of Mr Heller's considerable talents cannot be appreciated in this country and applied to the large cave systems of Yorkshire and South Wales.

The future

Undoubtedly the trend for computer hardware to become physically smaller, more powerful and cheaper will continue. The IBM PC and its many clones have led to a number of important de facto industrial standards for operating systems and storage media. This in turn has led to increased portability of both software and data between computer systems. Thus the P.C has at last provided a low cost, high performance environment on which sophisticated cave survey software can be made available to a large number of people.

To date much effort has been expended by individuals and small groups in surveying caves and writing software to analyse this data. Much of the original data has since been lost, and many of the computers used are no longer available. The only records of the work done are the final surveys. We are currently witnessing a massive amount of re-surveying in South Wales and Yorkshire, with the extension and linking of many caves. One can only speculate as to how much of this could have been avoided were the original data still extant. Increasingly, cave survey data is being processed by computers and stored on computer magnetic media. The need for a commonly agreed format for data exchange between computer systems and for a central archive for cave survey data is now of paramount importance in order that this information may be available for use by future generations of cavers. It can only be hoped that some central organisation such as the BCRA, will address itself to this problem in the near future.

With regard to the cave surveying software currently available in this country, it is the author's opinion that there is a lot of scope for improvement in terms of functionality, ease of use and portability. SMAPS and TOPOROBOT have been cited as two particular examples of what is achievable. If others exist, the author would be interested to learn of them. Most, if not all of the techniques required to perform the more complex mathematical operations in network adjustment and 3D visualisation and modelling are already documented. It now requires an individual or group with the expertise, hardware and enthusiasm to incorporate these into a software package which is freely available to as many cavers as possible.

Finally, now that the technique of modelling cave passages in 3D has been developed, the logical progression is to generate a 3D computer model of the ground surface under which the cave systems lie. The 3D cave models could then be located precisely with respect to the terrain model, and the whole 'assembly' viewed in a variety of 3D projections so that the spatial relationships of the caves with each other and with the ground surface might be understood more clearly. As a further extension to this model one could include additional surfaces for important geological horizons for the area, if sufficient data were available. This technique could be of use to both explorers and cave scientists. The author has begun to investigate this application area but currently lacks adequate cave survey data from which to work.

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