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Application of Computers to the Teaching of Mining Engineering

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The advent of relatively cheap computing power has precipitated a rapid growth of computer usage in the mining industry. In order to obtain most benefit from this development a need is recognised for the future mining graduate to be trained in computer literacy. This paper outlines the type of training required and describes progress to date with such a programme at the University of the Witwatersrand. Certain challenges concerning the teaching effort are discussed.

Introduction

It is a well known and documented fact that the cost of computer equipment has fallen at a rate unprecedented in the commercial history of any other commodity. This is especially true of micro-computers where, between 1982 and 1986, the cost of a unit fell by 90% whilst the computing power provided increased tenfold. Figure 1 graphically shows this reduction in the price of computing power using the example of five quoted prices for microcomputers having twin diskette drives. All prices are based on graphics screens with the exception of 1980 when such a feature was unobtainable.

If one considers the high South African rate of inflation and the drop in the foreign exchange value of the rand over the same period, the cost reductions in real terms are even more dramatic. Similar cost reductions are evident in computing peripherals, with an A3 size 8-pen plotter having fallen in price by 75% during a four-year period.

The nett effect of these price reductions has been to make computers much more affordable to all types of enterprises, with a consequent proliferation in the number of computer installations. Large multi-disciplinary concerns, such as mining houses, have not proved to be an exception to this phenomenon. The particular mani-festation in the mining industry has been a tendency to move away from the traditional data process-ing specialist department situated at some centralised facility. The modern trend is rather to provide decentralised computer facilities, to be operated by the different professional disciplines at their distributed work sites. Computers are therefore fast becoming simply

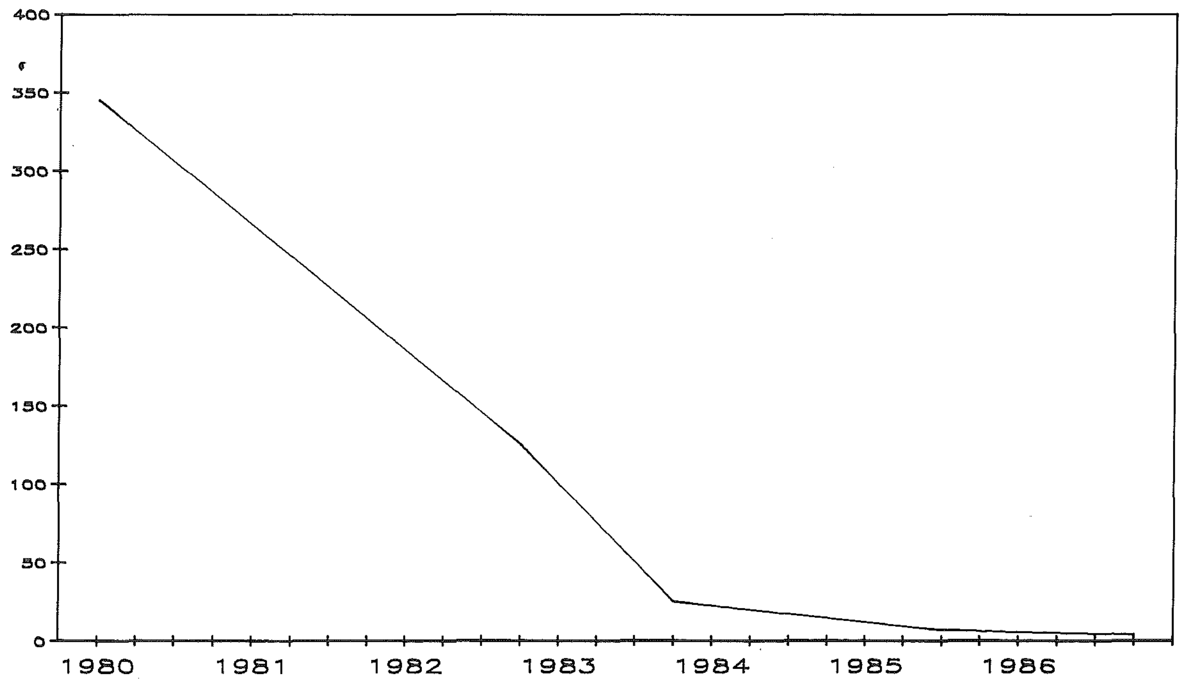

FIGURE 1. Cost of computing power (Rands per kB RAM)

one of the weapons in the arsenal of specialists, tackling problems in a vast range of disciplines.

Computers in the mining industry

In common with most other large industries, mining has had much experience in the use of computers for major administrative tasks such as stores control, payrolls, accounting systems and financial planning. More recently management information systems and planned maintenance have been subject to computerisation. To a large extent these applications show only minor differences between mining and any other industry.

There exists, however, a range of applications highly specific to mining where the computer's speed, accuracy and ability to cope with large volumes of data opens up the opportunity for optimal solutions to problems which could previously only be superficially examined.

A complete list of these tasks would be far too large to include in this paper, but areas such as geological modelling and reserves estimation, process control, mine planning and many others readily come to mind.

Many of these applications are common to the entire industry or to a large sector of it, such as a specific mineral or all divisions of a mining house. For these tasks general solutions, perhaps of a modelling nature, are often used. A typical example of this type of tool is the spreadsheet, whereby the same package can be modelled by its various users to provide solutions to a wide variety of problems. Such packaged products are available to the computer user from three major sources, i.e. off-the-shelf from a computer supplier, from a specialist mining software company or from a central in-house software development team. From whichever source the software emanates, the user has a product to which he must apply the data of his specific problem.

Many problems, however, whilst being complex enough to warrant computerisation, are not of such a widespread potential use that they justify software development on a commercial scale. In these cases the user has no ready-made package to fall back on and must therefore develop his own software or engage a programmer to write software to a specification.

The computer-literate mining engineer

The Department of Mining Engineering at the University of the Witwatersrand has considered the situation described in the introductory sections above and has come to the conclusion that future generations of mining engineers must be computer-literate in order to perform their expected duties.

The type of computer awareness required falls into three distinct categories. Firstly, the mining engineer must be capable of using packages, and hence must be aware of what the marketplace can offer. Secondly, he must be capable of designing software specifications, a process which necessitates a systematic engineering and data-processing methodology. Thirdly, he must be able to write his own programs. This entails familiarity with various operating systems and computer languages.

Perhaps most importantly, only a truly computer-literate person can determine whether an off-the-shelf purchase, a customised third party product or a self-written system will be the most suitable and cost effective solution for a given problem. Paradoxically, only the computer-literate person can judge when it is advisable not to use a computer, but rather to use some other problem-solving tool.

Computer literacy is a mental quality not easily defined. The child leaving school in 1990 will be computer-literate, whereas his counterpart of 1970 most certainly was not. The difference is mainly attitudinal, but it is an attitude which can, to some extent, be acquired by exposure to computers. The first conclusion drawn by the Department therefore was that the students should be afforded free access to as much computer hardware as possible, concomitant with security considerations.

Simply providing free access to hardware is, however, no guarantee that it will be used. A principal problem in this regard is that many people are wary of computers. They perhaps fear being proven to be inadequate to the challenge, of not being able to make the machine work correctly, of damaging the machine or of wasting their time without obtaining answers.

The classic solution to this problem, and the one adopted by the author, is carefully to guide the student through his earliest exposure to computers, telling him what to do but permitting him to make errors. This teaching format shows that the computer will not berate the student for his being stupid, neither will it be damaged if told to perform the impossible. The student learns that mistakes can be rectified and achieves the satisfaction of obtaining results from his first computing sessions.

An almost irreplaceable ally in overcoming fear of computers was found in a most unorthodox form - the computer game. Games of manual dexterity such as Pacman and Space Invaders rapidly familiarise one with the keyboard layout, whereas numerical games such as Chess and Othello encourage logical thought processes. Furthermore, when the student succeeds in defeating the computer, he begins to appreciate the limitations of the machine and the complexity and importance of well-thought-out software.

Whilst the Department did not actively encourage the playing of computer games, neither did it discourage such experimentation provided that it was restricted to times outside the normal lecture periods. The result was very rapid empathy for computers on the part of students. This familiarisation process was observed to last for approximately one month for a new computer user. After this period the games lost their novelty and the students began using computers for problem-solving purposes.

Once the fear of computers has been overcome a programme aimed at achieving a more complete level of computer literacy can be embarked upon. The major elements to be learned are:

- knowledge of computer hardware
- how and when to use packaged software
- how and when to write one's own software

The Department has developed and implemented such a programme.

Modus operandi for developing computer literacy

Hardware

As a result of a fire the entire Departmental computing facility was destroyed. Fortunately, the insurance cover was sufficient to permit replacements to be bought. A fortuitous benefit of the fire was that certain of the equipment destroyed could not be replaced by identical units, as these were no longer on the market. Consequently the insurance payments could be used for the purchase of whatever else was capable of performing the same duty as the previous models.

These funds were augmented by a generous grant from the Chamber of Mines of South Africa for the specific purpose of introducing computers into the teaching of mining engineering, in particular in geostatistics. This combination of circumstances meant that the Department was in the enviable position of being able to plan and purchase an entire new computer facility.

It is a contentious issue as to whether a new computer user should first obtain hardware and then the software to run on it, or whether to first obtain the software and then the hardware on which it will run. The latter school of thought is tending to prevail.

The Department then found itself in a rather conflicting situation. Firstly, for those applications requiring a mainframe computer the only viable route was a linkage to the University computer. For this level of sophistication the hardware came first, followed by the software. The opposite applied in the case of microcomputers. A vast amount of software is available to the Department at very low cost. Much of this software is highly specific to mining, often having been written by the various mining houses. As virtually all of the major mining companies in South Africa have standardised on the IBM PC, the Department was obliged to acquire the same machines, or compatibles, in order to run the software.

In between the mainframe and the microcomputers a need was felt for a high-resolution graphics machine of medium power. In this range neither of the previously quoted constraints applied. No hardware precedent existed, nor was there any readily available software for which suitable hardware had to be purchased. For this category of machine expert advice was obtained from the Computer Centre of the University, which recommended a Hewlett Packard system.

In retrospect, this decision proved to have been a mistake. To purchase hardware for which no software existed essentially meant that there was no system. With the wealth of software available for the IBM-compatible PCs most of the teaching effort tended to focus on the latter equipment. The Hewlett Packard system has unfortunately not been developed in line with original thinking, and indications are that this hardware will remain the preserve of the postgraduate researchers.

A major reason for this scenario is that, despite the advantages of the H.P. system over IBM-type PCs, a far greater learning effort is required in order to make use of the enhanced H.P. features. With undergraduate students the time is just not available to pursue this avenue. It was therefore decided to attempt to cover a wider range of computing applications using the easiest system to learn, i.e. the PC route, rather than a lesser range using a more sophisticated system.

Numbers of computers required

The number of computers which are required for teaching purposes is naturally governed by the number of students. At present, and for the foreseeable future, classes of 15 to 25 students are anticipated. Whilst it would be ideal for each student to work individually at a machine, the comparatively short formal teaching time available for computer education did not appear to justify such a large capital outlay. A decision was therefore made to obtain 5 PCs along with 5 terminals to the mainframe, thus requiring students to work in groups of between 3 and 5 on the same machine. The cost of this quantity of equipment could be accommodated within the hardware

TABLE 1. Equipment installed

Item	Quantity
IBM PC	1
SPERRY PC	1
OLIVETTI M24	5
IBM Mainframe Terminal	3
Printers	5
Plotters	2
HP 9816	1*
HP 9836	1*
Digitiser (CALCOMP 9100)	1

* Capable of being used as a mainframe terminal

budget. Ultimately, however, the hardware situation was improved even more as Sperry (Pty) Ltd. donated a PC to the Department. The end result was the suite of equipment listed in Table 1.

Once again, in retrospect, this thinking has proven imperfect. It was found that equipment usage fluctuates widely. The seven PCs are not fully utilised for 20 weeks of the year outside teaching terms. During term time they are generally well used, but during formal computing teaching sessions they are inadequate. When students work in pairs the quality of the learning experience deteriorates sharply. There appears to be no easy substitute for the previously stated ideal of one machine per student.

Mining Engineering was not the only department at the University of the Witwatersrand to encounter this difficulty. It was in fact found to be common to all branches of engineering. A joint venture was thus entered into whereby all engineering branches contributed towards the cost of establishing a pool of 25 PCs. Departments can book the entire pool according to a roster. From 1987 the Department of Mining Engineering will make use of this pool for the formal teaching and laboratory sessions whilst continuing to give students access to its own computers for assignments and private study.

Computing teaching

A four-phase campaign was mounted to teach students to use computers as a tool to solve problems of a mining engineering nature. These phases were:

- Basic computing concepts
- The approach to using computers in engineering
- Computer applications in mining
- Computers in specific problem-solving.

The first three phases take the form of lectures and laboratory classes, whilst the fourth stage is the integration of computing into the core subjects of the curriculae for both undergraduate and postgraduate programmes. The four phases should ideally follow a strict chronological order.

Phase I: Basic computing concepts

A mining students' first encounter with computers is during his first year Applied Mathematics course. The main elements of programming languages are taught during this phase, using the medium of FORTRAN on a mainframe. Severe financial limitations unfortunately preclude these first year students from making use of on-line terminals, and consequently they must use a technically obsolete card punch and reader system. This phase has been operational for a number of years.

Phase II: Computer applications in engineering

This phase was introduced during the 1986 academic year as a first semester subject for second year students. During this course the students are taught how to analyse engineering problems and structure computerised solutions to them. Use is made of IBM PCs and, where self-written programs are encountered, the medium used is PASCAL.

Phase III: Computers in mining

Phase III follows phase II as a second semester subject for second year students. Here the emphasis falls on pre-developed solutions to mining industry problems. Use is made of software obtained from industry, stressing the usability and applicability of the software to everyday situations. In those cases where user-written software is required, the preference is to use BASIC.

Phase IV: Computers in specific problem-solving

Though phase IV is logically the final stage of computer literacy training, this phase was the first to be introduced. This was so that even those students who never had the opportunity to pass through the first three phases could still obtain some exposure to computing in mining-specific situations.

The manner of teaching applied during this phase tends to follow a certain form. Firstly, lectures are delivered on the theory of a topic, with the relevant equations being derived and explained. The students are then instructed to perform an exercise using whatever method they feel to be suitable. The results of the exercise are checked and the correct problem-solving mechanics are reviewed. Finally the class adjourns to the computer room to use a pre-defined program to solve the same problem.

To date this approach has been applied to third and fourth year undergraduate exercises in such diverse fields as rock mechanics, ventilation, coal quality analysis and financial appraisals, as well as in investment decision making and geostatistics for postgraduate students.

When initially faced with class exercises, seldom has any student chosen to use a computer to solve the problem. It has been observed, however, that the situation alters dramatically after exposure to specific software. Aacademic staff receive numerous requests from students for copies of programs which they wish to use for their mine design projects.

Review of results

A comprehensive evaluation of the success or failure of this venture would be premature. Rather, it is more pertinent at this stage to make a few, possibly unexpected, observations regarding the initial programme.

Student preparedness

The vast majority, estimated at 90%, of mining engineering undergraduate students have not had any exposure to computers either at school or in the home. In spite of this inauspicious start, students appreciate the need for computer-literacy and are generally eager to learn. Whilst some of this eagerness may be attributed to the mystique surrounding computing, it is reflected in honest effort far beyond the level necessary simply to obtain course credits.

Problem-solving

Student assignments, as far as possible, take the form of current problem-solving studies rather than sterile exercises which can be repeated by successive classes of students. The degree curriculum structure means that most of these exercises involve technical issues not yet studied by the student, for example mining techniques or financial evaluation. This means that the student must establish a close liaison with a member of the academic staff who can explain the specifics of the problem. Such a relationship results not only in greater interest in mining on the part of the student, but also in deeper involvement in computing on the part of the lecturer.

Report writing

A frequently quoted shortcoming on the part of engineering graduates is their widespread inability to communicate effectively. This is particularly true with respect to technical reporting. One of the most surprising, and gratifying, results of the computer-literacy training programme is the very high quality of documentation of problem-solving assignments. Most of the reports submitted to date are characterised by their solid approach to problem definition, good descriptions of procedures and sound evaluations of the solutions offered. The surprising fact is that these high-quality reports had not been preceded by formal communications training, whereas the results from such a training programme with fourth year students over the past few years have been disappointing.

This unexpected success remains so far unexplained. It is felt, however, that a major contributing factor was the very nature of the assignments. The exercises, which require the students to undertake basic investigations before they embark on the detailed design of a final product (which must solve a specific problem), seem to be more suited to systematic analysis and presentation than do conventional academic exercises.

Student assessment

The most telling assessment of computer-literacy training comes from the students themselves. In a scientifically conducted survey the statement '(As a result of the course) I developed skills which will be useful later in my degree course' elicited a positive reply from 92% of the 1986 class.

Challenges for the future

Computers for their own sake

This paper has concentrated on one aspect of the use of computers in mining, namely computer-literacy. This concept should, however, be seen in its widest possible sense, encompassing knowledge not only of what computers can do but also whether they are the most suitable tool in any given situation. There is a great temptation for people who know how to use computers to exercise this skill in every task they undertake, even if some other tool, such as a calculator, could have done the job more cheaply and speedily. It is imcumbent on the providers of computer education to stress this potential pitfall.

Computer fallibility

Computers do not make mistakes, but programmers most certainly can and do. One of the unfortunate side effects of the recent rapid worldwide computerisation process is the unquestioning acceptance of computer outputs as gospel. A very real danger exists that, unless students are systematically taught the solution process itself, the situation may result where they understand how to compute answers but not how to verify or apply those answers. Should the software concerned be suspect, and yet be applied unquestioningly, the consequences could be catastrophic.

Computer obsolescence

Computer technology has developed, and is expected to continue to do so, at such a rate that one may predict rapid obsolescence of any particular item of computer hardware or software. Universities do not tend to be financially able to modernise their facilities at the same pace as new products reach the market. The teaching emphasis must therefore be placed on basic concepts of mining engineering and computing, in the belief that the correctly trained graduate will be more readily able to adjust to future technology changes.

Staff computer literacy

The greatest challenge involved in producing computer-literate mining engineering graduates is the lack of computing skills on the part of academic staff. It is envisaged that the situation will shortly be reached when students will insist on the use of computers to solve problems which the lecturer still tackles by more laborious means.

In order for academics to take the initiative some form of staff training becomes imperative, to which end introductory courses are being organised. The teachers are in fact becoming the pupils in order to learn the skills needed to produce a future generation of mining engineers who will be able to perform the duties required of them in an automated society.