IMPACT OF MICROPROCESSORS ON TRAINING DEVICES

GERRY C. WHITE
Naval Training Equipment Center

INTRODUCTION

Simulation has long been accepted as a cost-effective training method and is becoming more valuable due to the energy crisis. By simulating operational systems, trainers reduce the use of operational equipment and contribute to fuel savings. Not only do savings result from reduced energy consumption, but also from fewer operational units being required and from a decrease in potential accidents during training.

The computer system in training devices must be capable of performance necessary to meet system requirements. Generally, this will mean a high degree of complexity at both the hardware and software levels. Maintenance and reliability require that the system architecture be the simplest that will meet system performance requirements, yet the complexity of the simulation demands the most mature design within the state-of-the-art.

Early simulators were analog devices. Reprogramming them required extensive circuit modifications and involved considerable expenditures of time and money.

The advent of general-purpose digital computers led to the development of algorithms suitable for modeling both discrete and continuous systems. When these computers became sufficiently fast, real-time digital simulation was a reality. Digital computers were being used in trainers as early as 1962.

The use of digital computers in simulators has resulted in more flexible training devices. Digital computers may require only relatively simple changes in the simulation program to incorporate enhancements in the model. A greater part of modification cost is in the software area. This additional software cost can be somewhat offset by reduced hardware cost. The life of a trainer can also be extended by reprogramming to incorporate various changes in the operational equipment.

Although simulation is a cost-effective training method, the simulators themselves can be expensive. The 2F92 training device cost $16.5 million.(1) Cost constraints now and in the future require that a high degree of effectiveness be obtained at the same or at reduced costs. Devices such as low-cost microprocessors should be considered in the design of training devices.

THE MICROPROCESSOR

Microprocessors are chips that function somewhat like a minicomputer, usually at a slower speed and with a shorter word length. They are, or will become, an important part of common devices in the home and in industry. Point-of-sale terminals, cash registers, television sets, traffic lights, and even pinball machines are currently being controlled by microprocessors. It has been estimated that by 1980 there will be 60 million microprocessors used in microcomputers alone.(2) Microprocessors replace hardwired logic or minicomputers in such applications, but are often used for entirely new purposes.

The microprocessor's rapid growth is due to its great computing power at low cost. Although hardware cost will decrease drastically as microprocessors assume more functions in training devices, the total system cost is likely to remain constant. Software will become even more complex and, therefore, software support will consume a larger part of the total cost.

The use of microprocessors to replace hardwired logic gives the designer the opportunity to make easy production changes. New features can be added in the prototype stage without laying out new circuit boards.

Microprocessor controllers can be applied to most devices and optimized for a particular application. Development time for a microprocessor controlled system can be as little as one-third that of a hardwired system.(3) The actual time depends upon support software available and on the designer's experience with microprocessors. It can be anticipated that most devices requiring logic controls will eventually include one or more microprocessors.

Debugging microprocessor systems presents few problems, being no more difficult and requiring no more time than for hardwired logic systems.(4) The process can be accelerated by simulating the microprocessor on a larger machine and testing the programs prior to implementation.

There are numerous reasons for considering the use of microprocessors in training devices. A few of these are:

a. More powerful simulation systems may result if microprocessors are used as building blocks.

b. Power consumption is low.

c. Systems can be more flexible when microprocessors are incorporated into their design.

d. Overall system reliability is increased by using high-reliability microprocessors and from reducing parts count and decreasing the number of interconnections.

e. The microprocessor is smaller than the circuits it replaces and its use results in smaller equipment.

f. The microprocessor may be used for new applications in the training device. Over 40 percent of the microprocessors now in use are being used for entirely new purposes.

g. The microprocessor may introduce a cost saving when used to replace hardwired circuits.

h. Design time can be decreased resulting in a reduction in cost.

SOFTWARE FOR MICROPROCESSORS

As simulation becomes more realistic, providing better sensory effects, software may become more complex. Microprocessors and other developments in electronics will likely result in better simulation at a lower hardware cost but will place greater demands on software engineering.

A good software system requires thorough analysis prior to design. A systems engineering approach is essential to minimize the cost of the trainer, the initial software cost, and software modification throughout the life of the trainer.

Programming, coding, and assembly of programs require extensive effort. Debugging and verification of programs are time consuming tasks. Program modification at a later date will require extensive effort and special skills. In the past, management has directed its attention toward hardware (and also has placed budget emphasis in this area).

Performance requirements are increasing rapidly, and although software cost is increasing, its rate is not as fast. It has been estimated that computer software costs are three-to-four times as great as computer hardware costs. Forty-to-fifty percent of software cost occurs during hardware-software interaction checkout. Additional demands will be placed on the software staff as microprocessors assume more functions in operational equipment and in simulators.

LANGUAGES FOR PROGRAMMING MICROPROCESSORS

Despite the many advantages quoted for microprocessors, their use requires a thorough knowledge of the relationship between software and hardware. The programming of microprocessors takes considerable effort. Texas Instruments (5) estimates that a small program of less than 2000 instructions can consume 20, to 30 working days if sufficient support software is available. Other estimates (6) range as low as 50 instructions per man-month.

The most direct means, but also the most time consuming programming method, is the use of machine language. At this level, the programmer is closest to the internal operations of the microprocessor and must maintain full knowledge of register usage and memory allocation. Programming of microprocessors, however, can be simplified with any of several languages.

Assembly language, with its mnemonic op-codes, symbolic addresses, and one-to-one correspondence with machine language, makes programming somewhat easier. Assembly language also has advantages over higher level languages. About one-half the code generated by the high-level compilers is produced by an assembler. This results in shorter execution time (for assembled programs) which is especially important in real-time simulation. Trainers, for example, must respond rapidly if they are to reproduce actual system response.

Higher level languages eliminate the need for the programmer to manage register usage or to allocate memory. In addition, structured programs are possible, leading to more reliable programs with fewer opportunities for errors. Documentation is better and enhancements are easily added. A possible disadvantage is that the programmer is further removed from the machine and has less control over memory allocation and register usage. More memory is required and execution time is also increased. Higher level language is presently new and largely unused in the microprocessor field.

Assembly language is commonly used for writing microprocessor programs and accounts for about 75 percent of the programming in this area.[7] Although resident assemblers are available, cross-assemblers (if a host computer is available) seems to be the usual method for programming microprocessors. Macro-instruction facilities may be desirable and are easily made available on the host computer.

MICROPROCESSORS AND TRAINING DEVICES

The development of training devices utilizing microprocessors as controlling subsystems requires reorientation of priorities and resources. Programs written for microprocessors in control applications consist of a sequence of instructions to implement the desired behavior. Programming these devices requires the skills of a person who is familiar with both hardware and software. A major part of the cost when using microprocessors is in the design of software. In order to obtain the potential benefits offered by microprocessors, additional emphasis must be placed on software engineering and program development.

Medium-scale computers now provide sufficient control for modern training devices. As equipment being simulated become more complex, more powerful simulation will be required if the training device is to provide adequate training. Microprocessors can be key elements in such systems. Providing control and some computing functions at physically separated locations, microprocessors will allow a more complex simulation and provide for improved performance.

An example of current applications of microprocessors in training devices gives an indication of the potential uses of microprocessors in simulation. Hydrosystem's air-traffic-control/radar simulator, interfaced with on-site radar systems, presents both live and simulated radar returns to the trainee. Pseudo-pilots enter commands in response to the audio communications from the trainee and simulated aircraft respond according to parameters stored in read-only-memories. Microprocessors perform block-transfer of data and transformations from rectangular to polar coordinates.

The microprocessor in this training device also stores and updates velocity and climb/dive rates, sums velocity vectors, computes radar slant ranges and target elevation angles.[8] The functions handled by the microprocessors would have previously required a minicomputer.

CONCLUSIONS

Numerous innovative applications of the microprocessor are an indication of its versatility. Uses of the microprocessor in training devices include the replacement of hardwired logic and some functions currently being performed by minicomputers.

Although the microprocessor should be considered as a means of reducing hardware costs, other benefits of its use should not be overlooked. Microprocessor programs are easily altered and can extend the life of the training device by facilitating equipment modifications or by providing for enhancements necessary for improved simulation.

With their low cost and large computing power, microprocessors may be used as building blocks throughout the training device. Each of these microprocessors can contribute to the effectiveness of the simulation by providing for data acquisition and data conversion, by performing simulation functions, or in control applications.

Potential applications of the microprocessors in simulators are not limited to replacing existing hardware and minicomputer functions. Because of its availability and flexibility it is likely that entirely new functions for the microprocessor will evolve that will contribute to more effective simulation.

Future applications of microprocessors in training devices are limited by both the imagination of the design engineer and his knowledge of programming techniques. Until engineers acquire the programming skill that can only be obtained through years of programming experience, they must depend upon software experts to assist them in their work with microprocessors.

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ABOUT THE AUTHOR

DR. GERRY C. WHITE is a Software Engineer in the Digital Program Support Branch of the Naval Training Equipment Center. Previously, he was President of John E. Pochie Systems Consultants and was employed by the Memphis State University as Associate Professor of Computer Systems Technology. He received the B.S. and M.S. degrees in electrical engineering from Christian Brothers College and the University of Tennessee and his Doctorate from Texas A&M University. Dr. White is a member of the Institute of Electrical and Electronics Engineers.