DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE
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Position Paper: A departmental computer facility

From: The Ad Hoc Committee on Educational Computing Resources

Summary:

The committee named above was chartered to work out a systematic plan for the use of computers, computer-based methods, and computational thinking in departmental education. It has reviewed the present ways in which computers are used, the opportunities that are apparent, and the changing state of computer technology and economics. In this paper, the committee makes four initial recommendations:

1. Universal availability. To encourage a modern way of problem solving and thinking about computing, the E.E.C.S. department should adopt a policy that interactive computing facilities be available to every department member without planning, justification, or argument for individual use.
2. Department facility. To assure that the policy of universal availability is not compromised by short-term pressures, the E.E.C.S. department should create an identifiable computation facility and make a commitment to its long-term existence.
3. Faculty involvement. Because true integration of computational ideas with education must come from individual faculty initiative, the department should adopt a policy that places interactive computing facilities directly in the hands (and the office) of every faculty member, and adopt strategies that make it attractive to achieve initial familiarity with the facility.

4. Central control. To assure that the first three recommendations are carried out with appropriate regard for educational/economic tradeoffs, the E.E.C.S. department should create a formally recognized management scheme for departmental use of computation. This management must include both policy-setting and operational components. Together, these management components would be responsible not just for the effective operation of the department facility but also for its effective application to education.

The remainder of this report consists of discussion of, and support for, these four recommendations. Although the discussion includes descriptions of some possible implementations of the department facility, it does not recommend a specific implementation. The committee must study further the available technical alternatives and costs before it can make a responsible specific recommendation. Two further position papers are planned. One will specify the technical requirements and desireable features of a departmental facility, the other will be a proposal specifying sources of hardware, software, and funding.

Background: Computers and Engineering Education

The committee started with the realization that the E.E.C.S. department is not currently utilizing computers and computational ideas in the undergraduate curriculum to the extent that it could, or should. This belief is based on the following line of reasoning:

The E.E.C.S. department has traditionally taught techniques that lead to closed form solutions, partly because the closed form solutions are directly useful, and partly because examination of the form of the solutions frequently leads to deeper insight about the physical processes being modeled. Correspondingly, numerical evaluation, even when closed form analysis is not achievable, has received little emphasis in the curriculum, partly because the amount of intellectual and mechanical effort required to achieve a similar level of insight is unreasonably large for subjects in which there are already too many ideas competing for time.

Computer technology has changed the balance among these pressures, and the practice of engineering is responding. However, it is the responsibility of our department not merely to respond to changing pressures, but to anticipate them, in educating engineers who can take best advantage of the problem-solving environment of the future. With modern computer technology, ranging from interactive time-shared use of an IBM 370/168 computer to hand-held problem solving with a Hewlett-Packard model HP-25 programmable calculator the mechanical and intellectual effort required to construct a numerical solution to a problem can be quite modest. The solution can be mechanically repeated for different parameters with almost no effort, and the results displayed in the form of the graph that often supplied much of the insight of closed form solutions. Finally, the algorithm used to obtain the numerical solution often provides a model of the physical processes involved. Invention of an algorithm often forces fuzzy thinking out into the open, and contemplation of an algorithm can provide much insight in its own right.

Thus, our starting position is that computer technology has made practical a form of problem analysis that previously had to be used sparingly if at all. Further, the department must take the initiative in making the computational form of problem analysis one of the tools in the repertoire of its graduates. Finally, the E.E.C.S. department has a large constituency in pure and applied computer science, for which the use of computation is especially important.

Observations such as these already have been used as arguments to require two subjects on computation of every E.E.C.S. undergraduate, and to introduce computational ideas into other selected undergraduate subjects. However, it is our basic position that these injections of computational thinking into the curriculum are only the starting point, and that much broader use of these ideas is warrented. This projected broader use must be accompanied by adequate access to computational facilities.

Universal Availability

From this background, it should be immediately apparent that one of the key elements involved in developing appreciation for when a computational approach is or is not suitable for a particular problem is frequency of contact with such decisions, and frequency of utilization of computational ideas. A conviction that the engineer of the future will always have an interactive computing facility of some kind immediately available leads to the conclusion that the student (and faculty member) of today should be immersed in an environment of universal availability of interactive computational resources.

The primary issue here is one of accountability and defense of computer use. As the price of computation has dropped, the purpose of requiring strict accountability for use of resources has slowly been eroded. Looking forward, we can project even lower costs, and therefore even less emphasis on accountability. If we are to develop an environment typical of the future, it must have (even if artificially supplied for the time being) this element of minimum accountability. Otherwise the administrative barrier--paperwork and defensive justification--will overwhelm the subtle virtues to be obtained by use of computational analysis, and it will be used only in those cases in which faculty or students have strong a priori cases that educational benefit will accrue.

A second issue underlying universal availability is a hypothesized "regenerative" effect in which availability encourages use, which results in wider familiarity, which encourages further use. For example, an inhibitor on use of computation in some undergraduate subjects is that, exactly because it is not widely used in other subjects, familiarity with a facility cannot be assumed, and the instructor would have to devote a portion of precious class time to achieving familiarity. Universal availability of interactive facilities for departmental undergraduates would help break that deadlock.

To meet these issues, we propose that the department make interactive computing facilities available to every department member, including both students and teaching staff. These facilities would not be tied directly to particular subjects, projects, or laboratories, and the user of the facilities would need provide no justification for use other than being a department member.* If time-shared facilities are used, as seems likely

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* Some provision would have to be made for out-of-department students taking in-department subjects. Perhaps they should be given temporary use privileges similar to our own students.

today, usage control would be accomplished by dividing the time available. The division might be adjusted to take account of registration in a subject that makes systematic use of computation. The student is free to use the computation facility in any way whatsoever, including solving homework problems in non-department subjects, or editing Humanities term papers. This apparent price is paid exactly to achieve penetration of computing into the student's way of thinking; not to turn the student into an automaton, but rather to provide practical experience about when and when not the computer can be valuable as a tool. This level of widespread computer usage appears finally to be economically feasible, with recent developments in the technology.

Computation Facilities

The modest steps taken by the faculty and students to date have been significantly hampered by lack of appropriate computational facilities. In order to teach the introductory computer science subject (6.031) it was necessary to fabricate a small department computer facility where there had previously existed neither hardware nor software. The teaching of other subjects using, for example, the APL language, has required considerable administrative attention to provide terminal areas, to provide budgets for the acquisition of a service, and to monitor the quality of the service. The teaching of higher-powered laboratory subjects in computer science is constantly under severe budget pressure, to the point that individual instructors are involved in helping justify the special grants that have been obtained for support.

The problem is not that the department does not have any access to technically adequate computational facilities. Between the M.I.T. Information Processing Center (I.P.C.) and the Laboratory for Computer Science (L.C.S., formerly Project MAC) some of the technically best facilities in the world are locally available.* Rather, the problem is primarily economic and administrative. The L.C.S. systems are engaged in supporting the research goals of that laboratory, and are usable at most to demonstrate

* These include an IBM 370/168 with a huge variety of batch-oriented software systems, a Honeywell Multics with a wide variety of languages, interactive software, and attachment to the ARPA computer network with its further range of computation facilities, and four Digital Equipment PDP-10 computers with software especially designed for interactive matching of computational facilities with human beings.

feasibility of educational ideas, certainly not for "production" use in supporting education. The I.P.C. facilities, while nominally available, are perceived as expensive and uncontrollable to a small user such as the instructor of an individual subject. Rental of computer time from the I.P.C. also suffers from an interesting structural defect, when compared with use of a dedicated system purchased with capital funds. Use of the rental facility comes up for review at least once each year, as budgets are examined, and short term budget pressures (e.g., an edict to cut expenses by 10%) can severely compromise the long-term policy goals. On the other hand, a facility purchased with capital funds is reviewed once, and its purchase can be authorized on the basis of the long term policy with confidence that later, short term budget pressures will be less able to compromise the policy.

Another trouble with incremental purchase of computer time is the psychological effect of constant financial pressure pushing back at every incremental use. This effect is exactly opposed to the psychological climate that the policy of universal availability intends to provide. With a purchased, dedicated system, resource allocation can be done by dividing the time available rather than by budgets, with the possibility that at 2:00 a.m. a student can run a very large program without either incurring the wrath of others or running up unreasonable bills. This positive psychological climate, which encourages use, has been enjoyed by many research groups, and is an important goal for educational use of computing as well.

Thus we feel that to achieve the policy of universal availability it will be necessary to recommend purchase of a departmental facility. We believe also that there are reasonably good technical arguments for purchase, despite rapidly falling prices for computer hardware. These technical reasons go as follows:

1) The latest, fastest, and cheapest hardware facilities often have the shortest history of software development. Usability of a department facility demands that it come equipped with seasoned, documented, interactive software, and a variety of good languages. We must recognize that our primary interest lies in acquiring software, which is not usually available separately, and any particular hardware base is in effect a vehicle for software acquisition. Technologically driven reductions in hardware prices are not helpful to us unless they produce equipment that runs old software; manufacturers have noticed this fact and have placed high prices on new hardware that is compatible with old software.

2) Hardware developments and system improvements today are being focused on decentralized individual or even "personal" computers. Time-sharing and information-sharing systems have reached a plateau of development in which there is little pressure for additional functions. Newly created time-sharing systems (such as the Hewlett-Packard HP-3000 and our own DELPHI system,) rather than providing new functions, are reproducing old functions at lower cost, but with the hidden price of abandoning a large catalog of seasoned software. It seems unlikely that radically improved software function will appear soon, at least at the underlying system level, so it may be a good time to acquire a system based on present software.

3) As the "personal" computer moves from the laboratory to the marketplace, its arrival is likely to be compatible with any previously acquired central computer facility. Personal computers can be expected to absorb the increased computational load that our students and faculty will eventually learn to demand; they can also be expected to come with interfaces that allow connection with a central facility that can provide communication, libraries, and sharing among users. Thus the role of a purchased central facility would slowly shift from providing time-shared computation to providing intercommunication without becoming obsolete.

There are, of course, many other technical issues involved in the choice of a particular facility. These three points bear primarily on the question of technical advisability of equipment purchase.

Note that this discussion has not set out a specification for a department computer facility, nor chosen a particular implementation. We have assumed as a model that a system such as Bolt, Beranek, and Newman's TENEX on Digital Equipment Corporation's DECSystem 10 computer or Multics on the Honeywell model 68/60 computer provides approximately the right capacity, interactive function, languages, documentation, maintenance, and availability.

It is almost certainly impossible to acquire a facility from a manufacturer's catalog that is perfectly matched to our needs, and some compromise among function, availability, cost of purchase, and cost of development is inevitable. Some occasionally mentioned functions such as direct interconnection with television facilities for dynamic display of algorithms or simulation results require further research or cost breakthrough before they could be considered. The decision to acquire a particular facility requires further study and may interact with sources of capital funding, so it is not pursued further in this paper.

Faculty Involvement

Acquisition of a computation facility and administration by universal availability would place students immediately in contact with computation in two ways: 1) use in subjects already requiring computer-oriented homework, and 2) haphazard use by students as they discover applications on their own. However, the department would move too slowly toward the goal that students fully appreciate the implications of computation. That goal requires more active intervention, with many core and elective subjects demonstrating the relation between analytical and computational approaches both in class and homework.

The injection of computational approaches cannot happen overnight, but must occur over a period of time, as subjects are revised, and instructors-in-charge develop their own personal views about the usefulness and wisdom of such injection. Our initial goal then, is not instantaneous injection, but rather to provide an environment in which individual faculty members find that computation is easily accessible, use in education is encouraged, and incentives to become familiar with the facility are strong.

By now, most E.E.C.S. department faculty are familiar with at least one computational facility and computer language, and many younger faculty used computation techniques extensively doing their own graduate education. In many cases, this experience has led not only to appreciation for the power of computational ideas, but also to reservations about the difficulty of use of computers, their cost, and formidable administrative encounters. These reservations are more relevent to past and some present use of computers than to anticipated future use of interactive shared or private facilities but nevertheless they provide a psychological climate in which initial reactions to computer use are often negative. Overcoming these negative reactions is therefore a prerequisite to successful educational innovations using the computer.

We propose to overcome these objections by providing a modern, easy-to-use, computational environment, and placing it directly in the hands of every department faculty member. This placement would be accomplished by installing a modern, quiet, medium-speed display terminal in every faculty member's office, attached to the same departmental facility that students would be using. Further, we propose three incentives to the faculty member to encourage acquisition of at least the skills needed to minimally use the department facility:

1) each faculty member would receive access to computer time and storage space, free of accountability for use, although limited by a governor on the rate of usage.
2) the department would adopt a policy of using a "computer mail" subsystem of the facility as a method of informal communication, replacing "speed messages", weekly calendar distribution, and similar short-lived memoranda. Since the same system would be used by all department students, it would also provide another path of informal communication with them. This kind of message facility has received rapid acceptance in other environments.
3) the department facility would be interconnected to a local network that allows data movement to and from other computation facilities, such as research computers, the IPC systems, and the L.C.S. facilities. Thus several forms of computer use by one faculty member could be integrated.

The goal of this approach is primarily to introduce the faculty member to the system so that the extension to invention of educationally-related ideas requires a minimum of non-productive effort.

Finally, the sure knowledge that every department student has similar, unhampered access to exactly the same facility and some familiarity with it we expect to overcome the often-expressed concern that the effort of introducing a student to a computation facility can overwhelm the benefit of using it.

Central Control

Our last proposal is less specific than the rest, but it rests on several observations. The present impact of computation on the undergraduate educational process is not visible, and is quite uncoordinated. It is difficult to obtain even a rough estimate of the amount of department funds being spent for computer services, since use is not coordinated. Individual department members are uncertain of the current policy regarding computer use in subjects. These observations lead to a proposal that educational computer use by the E.E.C.S. department should be formally recognized as requiring explicit management.

There are at least two kinds of management involved. First, the operational management of a departmental facility requires attention to direct costs, to consumable supplies, to facilities in the terminal rooms, to installation and movement of terminals, to authorization for use of the facility, and to monitoring the quality of service provided and the amount of resources being used. This kind of activity should be coordinated out of a single office, and will require supervisory attention of some member of the departmental administrative staff, plus footwork by assistants. The amount (and importance) of this function must not be underestimated, since it is largely high-quality operational administration that makes the difference between an easy-to-use, hassle-free computation facility and one that is disappointingly awkward to use. The exact amount of manpower required depends on the particular facility and should be one of the considerations in choosing a facility; the administrative effort required to operate an extension of an existing facility would probably be less than that required for a completely new facility. It may be feasible to subcontract some of the operational responsibility to some other organization such as the Information Processing Center; nevertheless many of the operational concerns mentioned above remain, and should be coordinated from a single office.

The second kind of management required is policy management. This management probably requires a small faculty committee that can monitor the overall departmental approach to educational computation, advise the department head about adverse pressures on educational policy, make technical proposals, and generally monitor the compromises that must exist among policy goals, budgets, and faculty initiatives. One of the members of this committee should be specifically a protagonist for educational innovation, and be given a departmental assignment to help other faculty members develop computationally based subject material.

Conclusion

This paper has outlined a policy position calling for universal availability of computing resources implemented by acquisition of a departmental computation facility, for strong incentive and encouragement of faculty involvement in its use, and for careful management and policy control.

The policy has been framed in terms of overall goals and objectives without tie to a specific proposal, so that the intent can be separated from the implementation. The real-world environment in which these policies must be implemented is characterized by limited financial resources and also a limited range of technical (that is equipment and supporting software) choices. This real-world environment can force compromises; by having the policy goal already in mind we can better understand the compromises.

Succeeding position papers from this committee will describe the technical specifications of systems that can meet the policy goals we have described, compare those specifications with the available choices, and propose a specific course (or courses) of action.

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