EDUCATION OF STUDENTS TO COPE WITH PROBLEMS OF COMPUTERS AND SOCIETY

J.C.R. Licklider

The first third of the age of computers was devoted to achieving more and more function, more and more power, more and more cost-effectiveness. Those efforts were very successful.

The second third of the age of computers was devoted to preventing dysfunction, to keeping computers from having deleterious unintended effects. Those efforts were not very successful.

That is why there was no third third of the age of computers.

From a papyrus dated 2323 AD, found in a vault in Storm King Mountain on the Hudson River.

Introduction

The thesis of this talk is that computer science education should be concerned with the interrelations between computers and society as well as with the science and technology of computation and computers in and of themselves. The main reason for supporting that thesis, I think, is that the effectiveness and value of computing, which in past decades was limited primarily by the, then low, ratio of capability to cost, is now limited primarily by the difficulties that people, organisations, and societies have in understanding information technology, in exploiting the opportunities it offers, and in avoiding the pitfalls that accompany the opportunities. The main reason for not supporting the thesis, I am sure to be reminded, is that there is very little hard knowledge or formal theory to be taught about the interrelations between computers and society.

To try to neutralise the latter reason -- the latter objection -- at the outset, I shall foreswear making a plea that computers and public policy be taught as part of the introduction to programming languages. What I have in mind when I say "computer science education" is an interplay of individual study, classroom and tutored learning, laboratory and field experience, participation in projects, and plenty of hours at the console. That kind of education should be able to develop some pertinent knowledge and theory -- should be able literally to educe it. In any event, I have become convinced that computer science teaching and computer science research have concentrated too narrowly on tractable (which translates for some reason approximately into technical) subjects and not tried hard enough to deal with the obviously crucial but evidently more difficult problems that arise from interactions between computer systems and their organisational, social, economic, and political environments.

Let me end this introduction by admitting that I do not have a good solution to reveal or even a definite proposal to make. I just want to raise the issue and see whether or not there is any concurrence:

(1) with my perception that, in the over-all "analysis of variance" of the value of computers, the external variables and external-internal interactions are beginning to predominate over variables that are internal to the field of computers, and

(2) with my concern that the shift in what is actually and practically important is not being reflected by a shift in what is taught and learned in universities.

Problems of Computers and Society

The first step in an exploration of the thesis should be to identify the main problems and issues that arise in the interaction between computers and society. Let me present a briefly annotated list of ten of the problems and issues that I think computer scientists, including advanced computer science students, should understand in depth, and then let me merely name twenty more. That will define the general direction of my concern. At the same time, it will introduce the point that many of the problems and issues involve communications as well as computers.

1. Confluence of Computers and Communications: Despite great differences in substance and style, the two fields are becoming more and more interdependent. For example, modern computers communicate through communication networks, and modern communication networks are switched by computers. In most corporations and government agencies, however, computers and communications are still managed separately. Should the management be unified?

2. Free Enterprise vs. Regulation;Competition vs. Monopoly: In the United States, at least, the computer industry has been a paradigm of free enterprise while, almost everywhere, the telecommunications industry has been regulated by government. The computer industry has been strongly comp-titive, whereas the largest sector of telecommunications has been viewed as a natural monopoly. What adjustments should be made, if any, in response to the confluence of computers and communications.

3. Coherence: When computer systems were mainly local and largely independent of one another, it was only mildly inconvenient that there were so many imcompatible languages, formats, and protocols. As local independence gives way to corporation-wide, nation-wide, and eventually global interconnections and interdependence, however, diversity and incompatibility will seriously limit the effectiveness and value of information technology. Should coherence be left to the mercy of unguided evolution, or should it be planned and fostered?

4. Security: Computer security has been a relatively neglected subject, dealt with at the operational level mainly by isolating and guarding computers that process sensitive information. Technical work on secure operating systems has shown that one cannot make a system secure by adding and patching, that one must incorporate security into the system architecture and the basic system design. But there is so great an investment in software and computer-related business procedures that are based upon exisiting operating systems that few data processing managers are eager to make disruptive

changes to improve security. It appears that, unless government intervenes and strongly fosters the development of improved security technology and practices, the security situation will have to get much worse before basic steps will be taken to make it better.

5. Privacy: Informational privacy is a major issue for two reasons. First, modern information technology makes it possible to violate privacy massively, efficiently and profitably. Second, because it is difficult to control access to information selectively, there is a tendency to preclude access absolutely, that is, to prevent illegitimate access to the privacy sensitive part of a collection of data by preventing all access to the whole collection - and doing that, of course, interferes with legitimate applications (intentional sharing of information) as well as with illegitimate applications.

6. Robustness/Brittleness: As more of the processes upon which the life of the society depends are "computerised", there appears to result both a progressive increase in the efficiency of operations under expected (that is, more or less normal) conditions and a progressive decrease in ability to adjust to unexpected (that is, highly abnormal) conditions. The socio-economic machinery seems to lose its robustness and to become vulnerable. Perhaps the military machinery does too. This problem tends not to be faced. Sweepstakes tickets would never sell if people planned for improbable successes as they plan for improbable failures.

7. Vested Interest: Information technology has been advancing at a fantastic rate, paced by semiconductor chips that have doubled in cost-effectiveness every 14 or 15 months for more than a decade. There are strong forces, however, that resist the "push" of the technology. As evidence, consider that, although pulse-code modulation was developed during World War II, and telecommunications have been "going digital" ever since then, the "digital revolution" in telecommunications (as measured by actual conversion of channels from analog to digital) has not yet reached its midpoint. Advances in information technology have to overcome the inertia of about three hundred billion dollars investment in the global telecommunications plant and an equally large investment in System-360/370-era computers, software, and related business procedures. They have to overcome, also, the inertia of a very large investment in skills and procedures based in ink and paper. Should those investments be protected by public policy, or should adoption of more advanced technology be fostered in the interests of effectiveness and productivity?

8. Copyright: Recent legislation in the United States requires the payment of royalty fees at the time information is put into a data base rather than at the time it is retrieved and used. That requirement will be an obstacle to the development of comprehensive "knowledge bases".

9. Productivity: Will advanced information technology actually increase the production of office work as much as implied by the enthusiasm of advocates of "the office of the future"? Is it the responsibility of information technologists to provide application techniques and measures of effectiveness?--or only the hardware and the software?

10. Standards: Should an effort be made to develop "leading standards" in order to minimise the diversity and incompatibility referred to earlier in connection with Coherence and in order to create a situation in which interchangeability of components will foster competition among suppliers?--or should standardisation in the field of information technology follow the pattern of other fields in which, over time, the practices of industry converge upon a few tried-and-true designs and then, after everything is settled, a standards committee gives formal recognition to each de facto standard?

11-30. Other Problems and Issues: Planning and fostering of information technology by government vs. evolution of information technology in response to the forces of the marketplace; Education of citizens for "the information age"; Exploitation of information technology to improve education; Exploitation of information technology to improve (the function served by) libraries; Allocation of radio spectrum to foster new computer-communication-based services; Allocation of satellite slots in geostationary orbit; Anti-trust; The "transparent conduit" vs. integration of computer-based services into telecommunications tariffs; The value of world leadership in information technology; Transfer of information technology to economically and militarily competitive countries; Transfer of information technology to developing and undeveloped coutries; Information pollution; Information a free good or a priced commodity?; Red tape in government acquisition of computer systems and its consequences in obsolescence of government computers and ineffectiveness of government programs; "The software problem", or "The failure of software technology is spoiling the magic of hardware technology"; Human acceptance of or resistance to artificial intelligence and robots; Freedom of information; Transborder data flow; Impact of "computerisation" on the nature of work and the workforce; The feasibility of "telework" as an energy saver.

The foregoing lists are not exhaustive, of course, but they will serve to suggest what it is that I think we are neglecting in computer research and education.

Are the Problems and Issues Serious?

There are two facets to my concern -- indeed to any concern -- that we are neglecting the problems and issues: First, is it true that we are doing little about them? Second, is it true that they are important enough to warrant more? I think that there is little question about the first. No one ever comes up with a long list of pertinent university courses taught in the subjects I consider neglected. But there is some question whether or not problems and issues of the kind listed actually are limiting the values of information technology to mankind and actually do need to be understood deeply by computer scientists and engineers. Let me mention just two of the many things that convince me the problems and issues are serious.

In the United States and, no doubt, elsewhere also, the future of distributed information processing is being shaped by administrative decisions, judicial decisions, and legislation as much as by the marketplace or by advances in information technology.

From the Telecommunications Reform Act (of 1979?), Computer Inquiry II, a series of competition fostering decisions of the Federal Communications Commission, the government's suit against IBM, legislation governing electronic funds transfer, and other public policy actions will emerge the structure of the information industry of the future. And it will be the largest industry.

In the United States government, and evidently in other governments, also, there is much more to acquiring a major computer system -- or, especially, computer-communication system -- than simply to purchase it or even than to develop it or have it developed. The accompanying talk is a simplified map of the administrative obstable course that must be run by a program manager in a typical government agency who wants to acquire a system. The difficulty of the course has discouraged many managers from trying to acquire new systems. In the United States, the Federal Data Processing Reorganisation Project recently reported that the average age of data processing systems in the government is about 11 years, almost twice the average age of comparable systems in United States industry. The project associated the ages (indeed obsolescence) of the government inventory with the difficulty of the obstacle course. Among the systems which came a cropper on the course, some of you may remember FEDNET (a joint computer-network plan of the General Services Administration and the Department of Agriculture), the proposed Tax Administration System of the Internal Revenue Service, and the proposed telecommunications upgrade of the Federal Bureau of Investigation's National Crime Information Center. They were rejected or withdrawn to avoid rejection, not because they were technically deficient, but because the planning had not taken sufficiently into account such issues as protection of informational privacy and assurance against misuse of priveleged information. In these cases it is clear that people working in the computer field needed to master the issues relating to social inpact quite as much as they needed to understand computer logic, system architecture, or programming languages.

Are the Problems and Issues Understandable? Teachable?

Problems and issues of the kind under discussion appear to be qualitatively different from problems and issues of the kind that are dealt with in most computer science research and in most computer science teaching. Can the present problems and issues be understood well enough to be taught? Is there any way to educate students about them?

Obviously they call for multidisciplinary approaches. Most of the problems and issues are mixes of economics, politics, psychology, and other ingredients in addition to computer, communication, and information science and technology. Obviously they call for methods beyond those familiar in the digital electronics laboratory and in the lecture room. Perhaps that is all which is obvious. I think that progress could be made -- both toward understanding and toward education -- in seminars, in project laboratories, and in cooperative programs combining field experience with study at the university. But my purpose is not to propose a solution -- it is only to raise the questions: Are we not neglecting the part of our field that is becoming the most crucial? Should we not increase the effort to prepare our students to deal with

COORDINATION TABLE FOR SYSTEM ACQUISITION IN U. S. FEDERAL GOVERNMENT

o action point
O critical action point
X dangerous action point
  or point at which action and inaction
  are about equally risky
. no action required

	"Get Ticket Punched"	Co-Opt	Project Proposal	A-109 (Acquisition) Strategy	Requirements Definition	Contract "Flap"	Concept Demonstration	Budget (Annually)	Prototype	Production	Procurement	Frequency Allocation	Transition
Congressional Committee 1	o	o	.	.	.	o	o	o	.	o	o	.	p
Congressional Committee N	o	o	.	.	.	o	o	o	.	o	.	.	o
Office of Management and the Budget	o	X	.	o	o	o	.	o	.	o	.	?	.
General Services Administration	o	X	.	.	.	o	.	.	.	o	o	.	o
National Telecommunications and Information Agency	o	X	.	.	.	.	.	.	.	.	o	o	.
Institute for Computer Science and Technology	.	.	.	.	.	.	.	.	.	.	o	.	.
Own Agency Head	o	o	o	o	o	o	o	o	o	o	o	.	o
Own Agency Subhead	o	o	o	o	o	o	o	o	o	o	o	o	o
External Advisory Board	.	.	.	.	.	.	o	.	o	o	.	.	o
User's Liaison Committee	.	.	.	.	.	.	o	.	o	o	.	.	o
Unions	.	X	.	.	O	.	.	.	o	o	.	.	o
Opionion Leaders	.	o	.	.	.	.	o	.	o	o	.	.	o
Industry Associations	.	X	.	.	.	o	.	.	o	o	o	.	o
Potential Contractors	.	O	.	.	X	o	.	.	.	.	o	.	.
Actual Contractors	.	.	.	.	.	o	o	.	o	o	o	.	o
Internal Users	.	X	.	.	X	.	X	.	o	o	.	.	o
External Users (Clients)	.	.	.	.	.	.	.	.	.	.	.	.	X

interactions between their technology and its social, economic, political, and psychological environment?

Discussion

Professor Randell thought that the problems of transitions were very relevant to the communications industry, where the pace at which development could take place was often delayed by transition problems. Professor Licklider did not see why transitions should inherently slow development down so much, and had the idea that people who had experienced transitions should meet to collect together and recount their experiences to other people. An accumulation of experiences would be a valuable source of information to other people.

Professor Dr. Dijkstra wanted more theory to be applied to this area. He consider,ed that there is a reasonable amount of mathematical theory available to consider for instance how in a large network it is possible to propagate changing protocols over a network into time as the components of the network are replaced by new models. The main problem considered is that each component may have a life of 5-10 years, and will have to be replaced without disrupting the system, probably with components that are not functionally identical as use will be made of newer technology. By altering nodes in time to take account of changes in components, we eventually derive a time net which, spread over time and space, represents a network controlled by different communication protocols from the original one.

Professor Randell asked whether such theory could produce any result concerning the maximum rate at which transitions can be made. Professor Dr. Dijkstra replied that the rate of change is absolutely controlled by (a) rate of production of replacement components, (b) effect of replacement of nodes on other nodes (star function-type problems), and (c) availability of people with experience of transitions.

Professor Whitfield considered the usefulness of critical path analysis, but doubted whether it would be of any use in this area as it was only applicable to well-understood situations. Dr. Whitby-Strevens wondered whether we would be more concerned with designing systems that were easy to change from. We should design new systems to be changed easily to avoid problems in the future, just as if we want a reliable system we should have reliability as an objective at the outset. Professor Licklider very much agreed with this. CAP CYCLE PARA 10 SENT 3 WIDTH 68 TEXT 3 10 INDENTS (8,0) (19,0) (39,0) KEYPUNCH LIST TABS 10,20,30,40,50 CARD FIELD IS 130 translate input 70 4F translate input 71 8A PAGE 39 RIGHT GO