COMPUTER AUGMENTATION OF HUMAN KNOWLEDGE WORK

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Abstract: Dr. Engelbart described the developments of ten years of co-ordinated effort, by the Augmentation Research Centre at Stanford Research Institute, towards enhancing basic operations such as composing, studying, and modifying of text, distributed collaboration, software documentation, etc. The goal is a coherent 'Knowledge Workshop System'. He also described some experience with the Arpanet, for which the ARC serves as the Network Information Centre. The ARC is also establishing an experimental 'Workshop Utility' service, with contracts to serve exploratory users of the Workshop System aids as delivered over the Arpanet.

Lecture 1

The purpose of the work of the Augmentation Research Centre (ARC), described in these lectures, is to make people more effective (Engelbart, Watson and Norton, 1973). The underlying belief is that computers can support the intellectual work of individuals and teams in dealing with the complexity and urgency of the problems of today, and computer and communications technology is studied at ARC for this reason. The approach is from an engineering, rather than a scientific, point of view; building, trying, evolving, learning and using concepts and techniques taken from many disciplines all with the common aim of seeking to make people more effective.

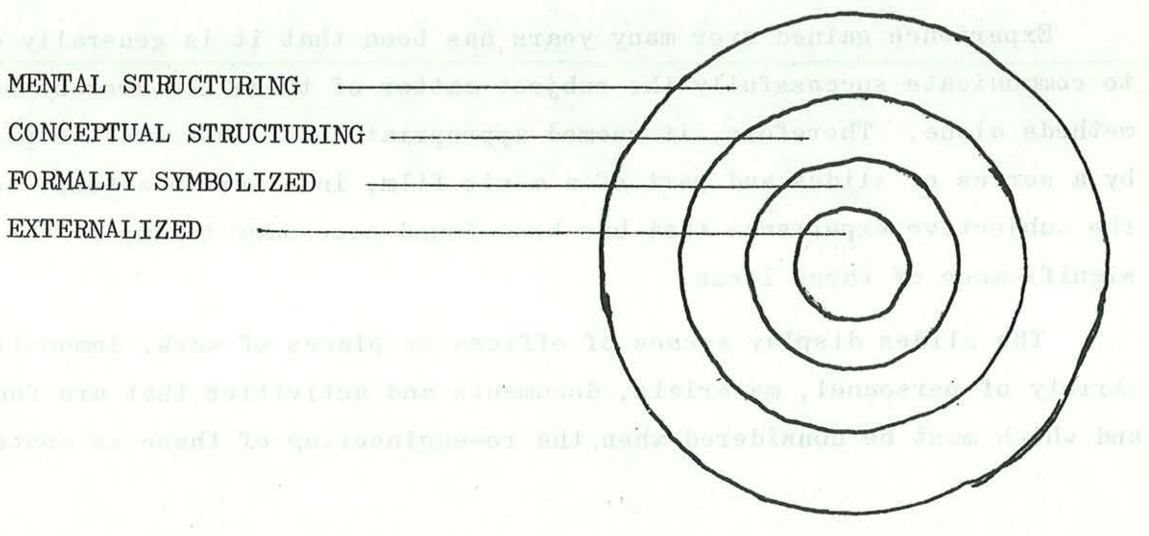

Figure 1 A rudimentary model of mental structure

Figure 1 illustrates a rudimentary model of what it is that it is being attempted to improve. Language tools and methods have been available for a long time to augment people. It is supposed that there is a large, undefined level called 'Mental Structuring' (the author's own term), which embraces all forms of intellectual activity. The part of this level that can be said to be concerned with readily identifiable concepts forms the next level, 'Conceptual Structuring'. A third, further contained level consists of those concepts that can be 'Formally Symbolized', using a commonly agreed upon language, and at a fourth level inside this, there are the language symbols that can be 'Externalized'.

The engineering approach adopted has been to build tools for working with those symbols that can be externalized, so as to represent more closely the structure of mental concepts. The computer offers a new opportunity here. Alongside any such radical change in the tools used for the external manipulation of symbols should be considered the possibility of similar radical change in the entire symbol structure and the methods of dealing with it, the language in fact. As it becomes easier to manipulate complex structured symbolizations, it is possible to start adopting new sorts of symbology and symbol structuring to represent what is being dealt with.

As a place to begin, a pragmatic choice was made to start with English text, a language in which much rational thinking and communication is expressed. Structuring was applied at an early stage; even if the contents of memory were all laid out in print the result might be much too complex to read and study flexibly, in a computer tool it is easier to map a mentally internal conceptual structuring into the computer memory with as many links and tags added as are necessary, so that the computer can be used as a tool to move around and create views as needed for comprehension at any instant.

Experience gained over many years has been that it is generally difficult to communicate successfully the subject matter of these lectures by conventional methods alone. Therefore, it seemed appropriate to illustrate the presentation by a series of slides and part of a movie film, in order to attempt to convey the subjective experience that has been found necessary to impart the real significance of these ideas.

The slides display scenes of offices as places of work, demonstrating the variety of personnel, materials, documents and activities that are found there and which must be considered when the re-engineering of these is contemplated;

but which however are not generally to be found described in any textbook. The slides also depict scenes belonging more particularly to the ARC; computer consoles, hardcopy, the computer in use itself (a PDP10 using the TENEX operating system), its on-line storage, an Arpanet Imp, and the TV cameras and video and projection equipment in use.

The sequence of the movie film shown illustrated the interaction between individuals which is possible. A demonstration was first given at the 1968 FJCC of AFIPS, and repeated a year later when the National Science Foundation subsidised a demonstration for a large audience from the American Society of Information Sciences in a conference room in San Francisco, forty miles from the ARC workshop laboratory. An Eidophor video projector, of a kind capable of projecting a TV show in a movie theatre, was used to cast the video images from TV cameras and from the computer display onto a 20-foot screen. Standard TV-studio equipment was used by the support crew to pick up auxiliary views of the home laboratory, or of the principal speaker seated at a console on the stage before the audience, and to select one or more of these at any one time to project -- sometimes using two images, splitting the frame to project part of each.

The film is a real-time record of the use of a video console equipped with a typewriter, 'mouse' and 'chord-keyset' control (see Figures). The interactive use of each of these controls is explained in turn, and their use demonstrated by an interactive dialogue between two members of the laboratory, using text from the nursery rhyme 'Old King Cole' for an exercise in text manipulation whilst sharing the common video display and a telephone link for conversation. The physical work on these techniques started about ten years ago, and since then there have been about 160 man-years of effort in continuously evolving, applying and using the tools that have been built in the environment of the augmented knowledge workshop. The real time interaction is designed to be fast and easy to use, and a large repertoire of commands has been built up over a long period; the use of these soon becomes automatic and consequently one is able to gain a mental picture of the structure being dealt with, to create views of it and to alter it at ease. The ARC is now ready to widen the scope of this work, and to offer it to others to try out in new environments for further stages of evolution.

Mr. Zell asked for more description of the left hand control. This is a five key, binary control which originally evolved from a game which was devised to entertain Dr. Engelbart's children. The game uses the algorithm which counts pulses by inverting bits, and the game is to imagine a man walking along, inverting picket fences. He has to change each picket up or down, every time he passes. Lifting one up is so tiring that he has to retire from that walk, but putting one down takes so little effort that he can continue with the same walk. This algorithm results in the binary sequence on the children's fingers. Initially the children found the length of time which it takes the man to change the fences puzzling, but the reason for this became apparent when the integers 1, 2, 4, 8, 16 were attached to the fingers - this was an encouragement to learn to count quickly. (It was also useful in school maths quizzes, for secretly telling each other the answers!). Later, the correspondence between the alphabet A - Z and the first 26 integers was learnt (giving much better answers) and rapid proficiency was attained. With this experience in mind, the one-hand, chord-keyset had been designed from the beginning with the aim of providing smooth fast control. Some experimentation had been necessary to obtain a correct design for the pressure, balance etc. of the five microswitch keys, but the same alphabet is still used - it has not been found necessary to recode the more common commands into 'easier' chords, for instance, and two hours' practice is sufficient for a novice to gain reasonable competence to be able to co-ordinate keys, mouse and keyboard successfully.

The techniques demonstrated in the film have formed a base for subsequent development over the past four years. The investigation has tried to determine what sort of evolution takes place when the individual 'knowledge worker' is given as much computer power as he needs, to anticipate the new demands and uses that might be made, the new kind of support clerical staff could provide, what new working relationships would be possible with similarly equipped colleagues, and the effect of large scale remote digital communications such as the ARPA network provides. Working contact between individuals and groups using the ARC system across a continent is already possible via this network. Communication of this kind, simultaneously sharing a common screen and speaking on the telephone provides a greatly superior way to collaborate at a distance. Both technologically and economically it is becoming possible for any knowledge worker to work this way, just as automobile transport became economically possible for those who needed to be mobile geographically. There are a great many people who need to be 'mobile' in information space, communicating and working together.

The impact on computer science will be felt in several ways. Firstly, the system or workshop described so far will be supported by tools provided by the computer scientists. There is a need for a co-ordinated discipline concerned with the workshop; the way people organise their work, habits, skills and communications, how organizations function and how roles differ within them. As yet there is no discipline which covers this; it might grow from computer science or from other disciplines such as management science, small group sociology, time and motion study, ergonomics, etc. The staff of the ARC have experimented with this enough to know that there is much more potential than we can explore ourselves. Furthermore, the advance of this discipline requires many people working at different levels. In the development of computers this did not happen until people started to use them for applications; for instance, it was realised that in running a computation service, support staff and operating systems are required, and improvements in efficiency resulted not so much from making an adder with fewer diodes as from making better peripheral equipment and better use of resources. So computer science is going to be involved in supporting this workshop discipline.

The second way in which computer science will be involved, is that workshops such as this will in turn become available, to support computer scientists, software engineers, applications programmers; this would be a sensible way of evolving, as computer science would be one of the key application areas to explore. There are a number of ventures in this field being undertaken in various parts of the world that might coalesce into something exciting.

Lecture 2

It is clear, from what has already been said, that quite a small part of one's working conceptual framework is made explicit, and that only a small proportion of this is externalized. The choice of symbols for describing external concepts is governed by the environment; only those concepts which can be processed by our perceptual apparatus can be made external. The production of a new tool like the computer should lead to a reconsideration of concepts, since a new means of externalization may enable humans to deal effectively with new types of concept not accessible before. The ability to look at conceptual structures in a new way may mean that whole areas, which appeared unproductive before, may now be capable of being perceived in a new and productive manner. Therefore a new tool like the computer may not only bring faster and more flexible processing of existing concepts; it may lead to the perception of different portrayals of other concepts.

In this context, tools like the computer are used to make the external representation of external concepts more akin to the internal structure of mental concepts, so that more may be externalized. The file which was shown portrayed some new tools of this kind. In order to schieve a greater understanding of the advances such tools can promote, it is necessary to examine them in rather greater detail.

Firstly, by the use of a hierarchical structure for text stored on-line, it is possible to process different levels of text independently. An example of this is given in Figure 2; this table of contents was compiled by requesting a 'portrayal' (on to hard copy in this case) descending to a limiting depth in the document hierarchy according to a specified (level) contour. Also specified for this portrayal was that each item be truncated to a single line, and that the hierarchy location number for each entity be printed along the right hand margin, as illustrated in Figure 3. These numbers can be used to allow accurate reference to particular passages of text, as well as indicating the hierarchical structure intrinsic in the material. The number at the top right hand corner of the figure should be noted; it is a unique reference number for the whole document, by which it can be directly accessed, either on-line or in sequentially shelved hard copy archive, though the on-line catalogue. Such reference numbers may also be observed within the text of the document in Figure 3; these are used as a simple and quick method of citation. On -line entries in the document catalogue have been sent to the Journal file archives, an action which implies publication. Once sent, documents are unchangeable; subsequent revisions are treated as fresh documents with their own reference numbers.

Secondly, in addition to specifying level clipping and location numbers, other instructions for formatting can be embedded within the text, as 'directives' that control the action of a special output processor. As well as controlling formatting features such as those already described, and also such facilities as running headings, margins, indentations per level, pagination, page numbering, and a host of other details, a set of directives is available to control phto-typesetting of the text; these include

CONTOURED-LEVEL, FIRST-LINE CONTENT VIEW

Figure 2

a par with internally generated information in the organization's establishing of plans and goals; and adapting to external opportunities or dangers [38]. 5c7a

COMPUTER-BASED INSTRUCTION 5c8

This is an important area to facilitate increasing the skills of knowledge workers. ARC has as yet performed little direct work in this area. We hope in the future to work closely with those in the computer-based instruction area to apply their techniques and systems in the workshop domain. 5c8a

In training new and developing users in the use of the system, we have begun using the system itself as a teaching environment. This is done locally and with remote users over the ARPANET. 5c8b

SOFTWARE ENGINEERING AUGMENTATION 5c9

A major special application area described above, that has had considerable effort devoted to it, is support of software engineers. The software-based tools of the workshop are designed and built using the tools previously constructed. It has long been felt [24, 29] that the greatest "bootstrapping" leverage would be obtained by intensively developing the augmented workshop for software engineers, and we hope to stimulate and support more activity in this area. 5c9a

KNOWLEDGE WORKSHOP ANALYSIS 5c10

Systematic analysis has begun of the workshop environment at internal system levels, at user usage levels, and at information-handling procedure and methodology levels. The development of new analytic methodology and tools is a part of this process. The analysis of application systems, and especially of core-workshop systems, is a very important capability to be developed. To provide a special workshop subsystem that augments this sort of analytic work is a natural strategic goal. 5c10a

Figure 3

multiple high-quality fonts, with selectable size and density, proportional spacing, and so on.

Thirdly, within the field of text-editing commands a great range is available. It is possible to obtain a wide variety of views on the screen, with spaces between lines or not, varying widths and so on. Feedback information is presented at the top of the screen, so that the user is fully aware of his situation. Different levels of text may be requested; the user may wish to see just the first line of each paragraph or section, for instance. Structural modifications may be made in the text; when this is done, changes necessary to maintain the hierarchical structure in other levels are made automatically. The selection of items to be operated on within a screen of text is made by use of a cursor, controlled by a 'mouse'. A picture of the 'mouse' is given as Figure 4, and of the whole keyboard as Figure 5. This 'mouse' is easily held in the hand, and is moved on the table top in the way it is desired the cursor should move. The gearing between the two is easily adjustable. This 'mouse' is the product of a good deal of experimentation, and has proved in tests to be superior in our application to other similar devices; this is illustrated by the diagrams in Figures 6 and 7.

It is also possible for references to be embedded in the text, of special format, called a 'link', to cite other on-line text, passages. This facility brings highly specific cross-referencing, and the computer can operate on a reference link as pointed to by a user at his display console, and bring forth the referenced passage for study. Successive Journal entries (short messages or long memoranda) freely sprinkled with links to prior-entry passages, and with fast, flexible means to compose and enter the text, and to retrieve and study, leads to fruitful dialogue. Circulation lists can be specified when entering documents into the Journal; when this is done, a brief 'announcement' will be inserted in part of the personal file belonging to each individual on the circulation list, which he will be able to scan for this information. This facility, in conjunction with the ability to link to other passages and to identify passages of text exactly by number, can become a highly productive tool both in co-operative work and in the sort of critical dialogue which often takes place in published journals, but over very long periods of time.

[illegible] necessary [illegible] like [illegible], [illegible] interactions.

Thirdly, within the field of text editing a number of aids are available. It is possible to obtain a wide variety of views on the system, with spacing between lines set out, viewing [illegible] and so on. Feedback information is presented at the top of the screen, so that the user is fully aware of his situation. Different levels of text may be requested; the user may wish to see just the first line of each paragraph or section, for instance. Structural modifications may be made in the text; when this is done, changes necessary to maintain the hierarchical structure in other levels are made automatically. The selection of items to be operated on within a screen of text is made by use of a cursor, controlled by a 'mouse'. A picture of the 'mouse' is given in Figure 4, and of the whole keyboard in Figure 5. This 'mouse' is easily held in the hand, and is moved on the table top in the way it is desired the cursor should move. The gearing between the two is easily adjustable. This 'mouse' is the product of a good deal of experimentation, and has proved in tests to be superior in our application to other similar devices; this is illustrated by the diagrams in Figures 6 and 7.

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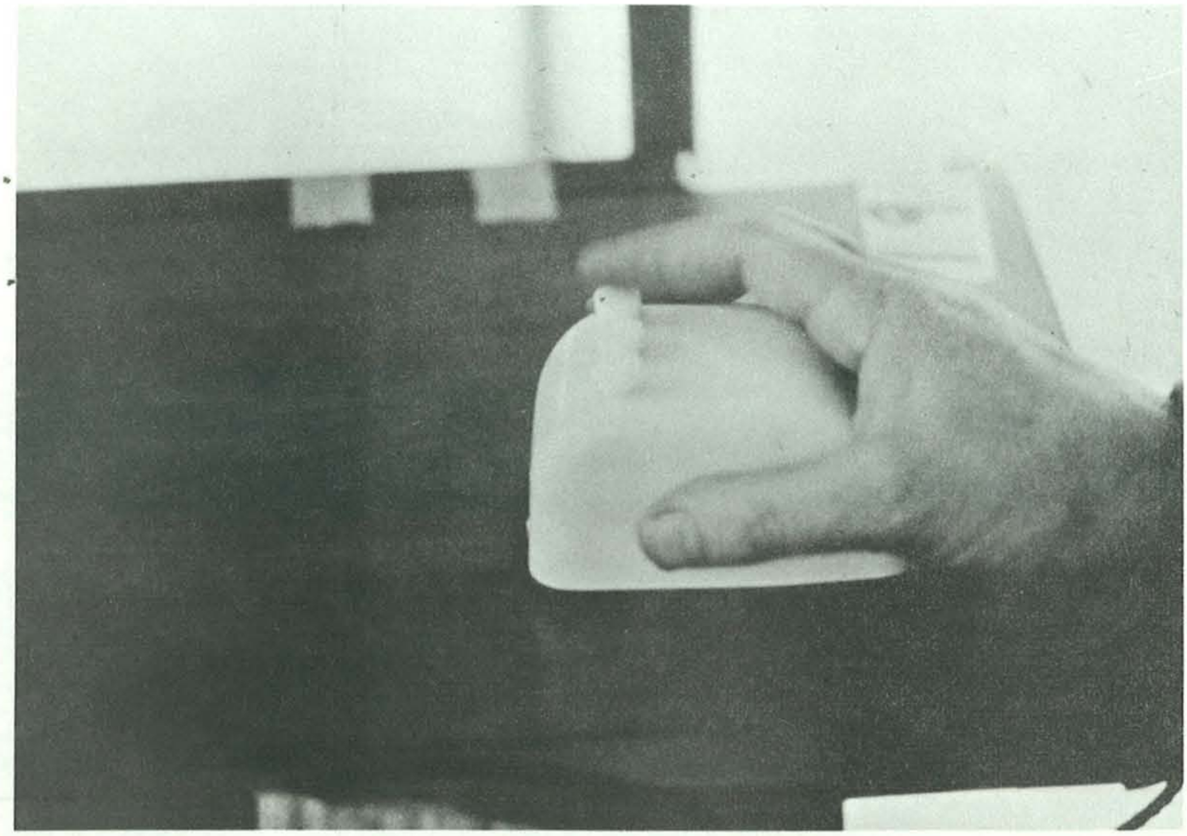


Figure 4

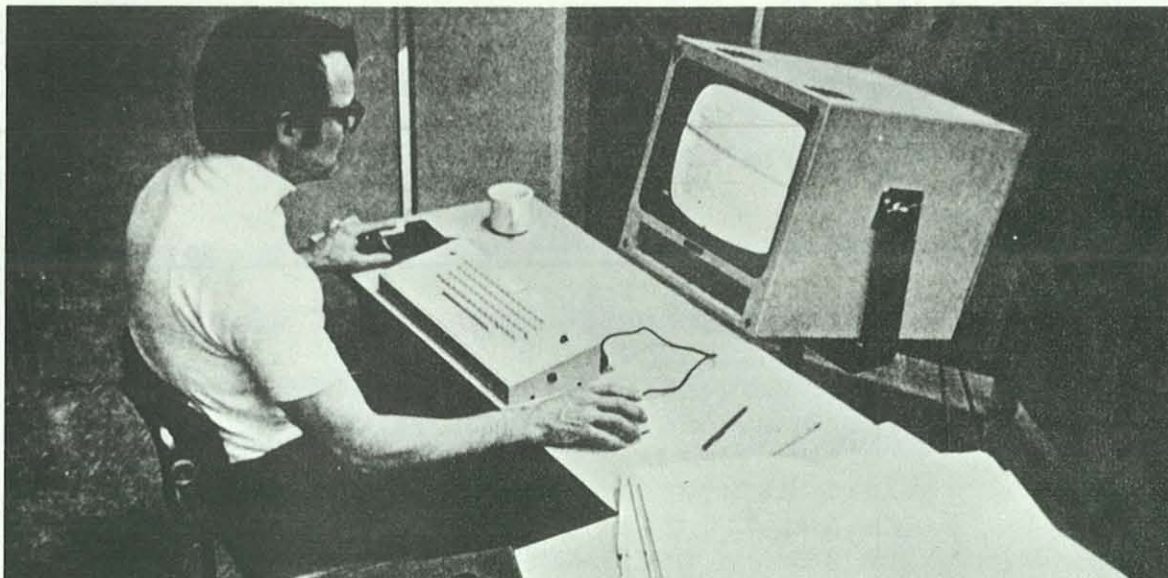
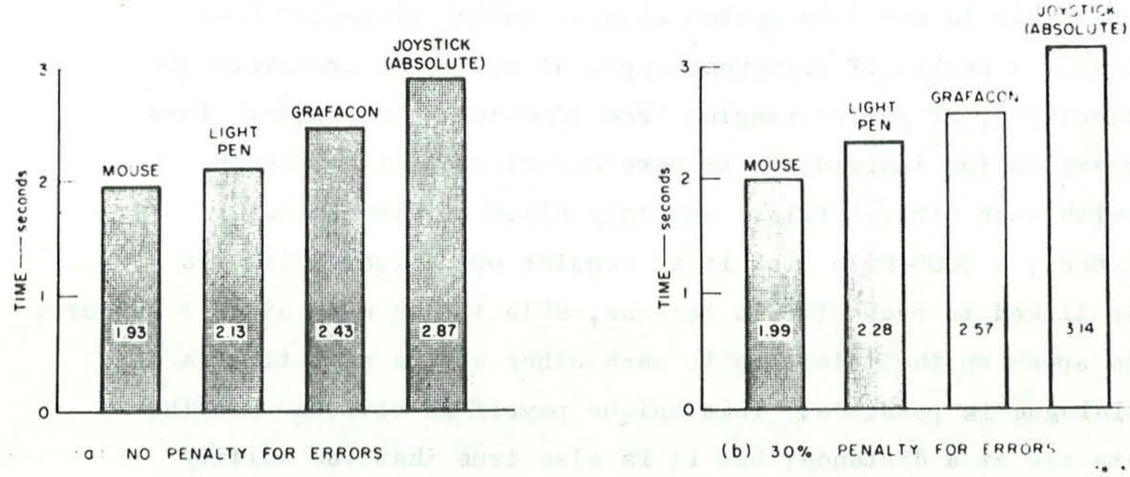
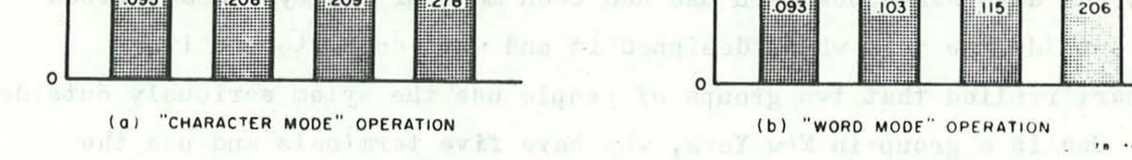


Figure 5



COMPARISON OF THE OPERAND-LOCATING DEVICES FOR "EXPERIENCED" SUBJECTS, "CHARACTER MODE" OPERATION. Vertical Scales Indicate the Total Average Time (Seconds) from Space Bar to Correct Selection.

Figure 6



ERROR RATES FOR "EXPERIENCED" SUBJECTS

Figure 7

It is possible to use this system at substantial distances from its home base. A number of different types of equipment are available or being developed, at prices ranging from 3000 dollars upwards. This makes it possible for individuals to have direct contact with each other and with each others' files, not only close at hand but over great distances; a 3000-mile link is in regular operation. With two individuals linked to each other's screens, able to see each other's cursors, and able to speak on the telephone to each other at the same time, a most fruitful dialogue is possible. This unique payoff is obvious when the participants are at a distance; but it is also true that the ability to interact not only in this 'conference' mode but with any part of another person's working files is valuable even when the two work in the same building. Another valuable facility of a similar kind is the ability to project the information on the screen onto a much wider area, so that a whole group may see it. This enables, for instance, a teacher to take a class through material in a quite different way, going quickly or slowly, straight through or branching on and back, handling material in a highly flexible manner; or, an author of a paper, plan or design to work effectively, with a review team.

Discussion

Dr. Browning asked whether the facility for reading others' files did not lead to security problems. Dr. Engelbart replied that while material available in the Journal was public to all, working files were private unless the user chose to make them public to some of his colleagues. Putting something into the Journal is similar to publishing it.

Professor Randell commented that he had the impression that Dr. Engelbart regarded the immediacy with which facilities were available as being vital, and asked what extent of operation can usefully be made immediate. He also asked how much use had been made of the system described by others outside the team which designed it and were committed to it. Dr. Engelbart replied that two groups of people use the sytem seriously outside his team. One is a group in New York, who have five terminals and use the system intensively. The other is a heterogeneous group which comprises a few serious users and many intermittent users.

Professor Randell pressed Dr. Engelbart to say something about the breakpoint in using such a system on the grounds of sheer size. Dr.Engelbart replied that this largely depended on the speed with which technology produced cheap storage; laser stores were expected to cost less than book-storage shelf space.

Professor Page asked whether it was really likely to be possible to implement systems like this on a large scale in the near future. Dr. Engelbart replied that his was a pioneering team, admittedly on a small scale, but that the problems of large-scale implementation would be solved eventually.

Professor Dijkstra asked why it was felt necessary to dispose of a good argument in a few days rather than years, since it then became necessary to discover another bone to chew. He also criticized the system as one which would produce even more information for an already overwhelmed audience to study. Dr. Engelbart replied that the net result would be beneficial, since the sytem improved the capacity for manipulating and processing information.

Lecture 3

In the first two lectures some of the qualitative differences between the characteristics of the on-line system, NLS, and other similar systems have been described. NLS provides such facilities as on-line file access, file storage, editing, file sharing, etc., the main differences being due to the flexibility of the manipulations provided.

In this lecture a general overview will first be presented of the system, its philosophy, and the services it attempts to offer potential users. This will be followed by some examples of particular software applications.

System Overview

Recalling the picture of mental structure discussed previously, it was shown how some smaller sections of this structure make use of explicit types of concepts. For some subset of these concepts, there exists a representation in terms of formalized external synbols and manipulation conventions, and some of these can be mechanized by the computer to help us with our work. At ARC, we have tried to develop a useful mapping of the internal conceptual structure. The aim is to enable users to make explicit much of the implicit structure and activity that human beings try to convey in linear discourse by the use of, for example, pronouns and such constructs as "as I said previously". We have been able to make very explicit the relations between kernels of concepts, and substructures of concepts, and we can obtain any desired degree of complexity in the internal representation of this mapping of the conceptual structure. The computer can then be used as an instrument to move through the mapping, in ways that will vary with different needs and perspectives, providing the required view for comprehending a particular aspect, or surveying the whole problem.

It was appreciated that the use of such a tool opens a whole new domain of new kinds of concepts, portrayals and manipulations. To investigate this we began with the basic idea of structured text, and applied the tool within our own work to do composing, modifying, studying, etc.. The effect has been that we work in our offices with an "editor", permitting us to work much in the same way as does a designer when "drafting", by allowing us to keep many aspects of the problem in mind. We have gone far beyond the facilities of simple text editing with our abilities to study, organize and manipulate our ideas as they develop, and we have already learnt a great deal from our experiments.

Thus, beginning with structured text, we have continued with a study of its effect on office relations. We have investigated how this tool can provide "task support" for "knowledge-work" in the environment of a given community. In order to do this, we first delineate a set of different "tasks", and then we recognize the existence of certain "means", that is, conventions and practices, in the performance of a given task.

The first task is what might be called PEOPLE SERVICES OPERATIONS. Within this we can list the various practices commonly adopted:

Clerical (typing, book-keeping, etc).
Formulation, studying, modifying of ideas
Communication
Dialogue (more than just back-and-forth discussion)
Cannibalising
Integration.

Then there is the task of INFORMATION MANAGEMENT. Here we are concerned more with the information in one's own office. We must keep track of that relating to oneself, the team, and various communities; the information may be of all degrees of currency and domains of coverage. There are many special problems in this area.

PRODUCTION OF DOCUMENTS. There is the problem of making formally approved, up-to-date documents, working documents, (logs, designs, policies), and other stable but evolving documents. This is different from the production of scientific papers.

CALCULATION. In some circumstances there is the need to perform small (back of envelope) calculations.

PLANNING AND MANAGEMENT.

STATISTICAL WORK. There is often the need to perform analyses of a statistical nature on large data bases.

HEAVY COMPUTATION. Many types of computer application systems are needed, for instance computer aided design.

Once we have agreed upon a set of tasks which we believe to be common to a large number of disciplines (biology, chemistry, physics,...), we may next examine some of these disciplines and try to find a task profile for each of them. Many will have special types of work to which computer techniques can be applied, but we can find a common set of practices which apply in every field. The objective is to find a set of common support systems, and to establish greater coherence among the different sets of workers. In fact there will be a heavy need for the first tasks mentioned above, namely PSO and information management. So we have this core for a task support system, providing the same 'front end' for such needs as collaboration, note-taking, issuing directives, examining results and integrating them into notes and so forth.

Having established the general type of service we wish to supply we can address ourselves to the problem of communication between different communities with overlapping interests via a computer network. Such communities will each have special concerns and activities, but will nevertheless wish to share common resources. Taking a "black box" attitude, we may view the network as a transportation system, conveying services between producers, wholesalers, retailers and consumers[1]. Consumers will fall into categories depending on the profile of services required, retailers correspond to consumer groups who arrange to buy packages of services, which are in turn manufactured more efficiently by the producers as their experience in serving the market grows. Our intention is to build up "community coherent" systems for centrally co-ordinated information services, which takes account of the various discipline-oriented interests among the members. It is important to provide means for collaboration and dialogue between members so that they may for instance develop, produce and control documentation in a coherent manner. Every social "organism", as represented by such a community, needs to collect

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1 The author is indebted to Mr. Einar Steffered for this analogy of "wholesalers" and "retailers" within a computer network.

information about its environment to enable it to decide about its opportunities, resources and impediments, and assess its internal values and goals. The aim is that all should contribute to the sytem to allow the whole community to collect its own bibliographic data and keep track of external events. This can be achieved if they are connected in such a way as to utilize common, coherent conventions among themselves. Another aspect is the need for meetings and conferences among the members to provide for overall community management.

The above discussion has led to the conclusion that there is a great potential value in the establishment of discipline-oriented communities which can make use of such common tools. It should be the job of a community, knowledge workshop, "architect" to take account of the common work amongst the members to accelerate their coherence. Present social communities have evolved slowly and are still fairly primitive: new tools will allow us to create new social organisms. The author's present interest is to explore the ways in which institutions and people can improve their co-ordination and integration for better functioning.

Our present fairly limited experiments have indeed already shown that networking and computer aid together contribute greatly to the community. The system is not just a substitute for blackboard or message-pad: it makes people immediately more aware of their environment. Consequently we have put a great deal of energy into making the system provide the correct services. So far it has been a slow process to get people to learn to use it, and for ourselves to learn what it takes to do this. We are now at a stage, however, where we need to extend the experiment. At present we have one node on the ARPA network which provides facilities for anyone of the network. Users can log in to our system and use it. The next step is to contract with an independent company, to supply another machine on the network. We shall retail software, and explore the needs of each community that uses it. Most attention initially will be paid to the PSO aspect of the knowledge-workshop utility, the operation will be costed and we shall sell subscriptions to the service. Already there are interesting communities gearing up to buy into this network: a computer-based instruction group at a research and training centre, an international group for collecting, storing and distributing seismic data, and the office management of an engineering research group. Referring to Figure 8, we can see the economic considerations needed for buying into the system. The cost curve is applicable to almost any kind of service: the cost drops as manufacturers gain experience in providing the service and as more people subscribe to it. A given user might initially place a certain value on the service, and determine that it will be advantageous to buy in at point A. However, the value of the service will rise as experience is gained with it, so point B would be a better estimate. Lastly, if one takes account of the induction time required, the point indicated by C will provide the best estimate.

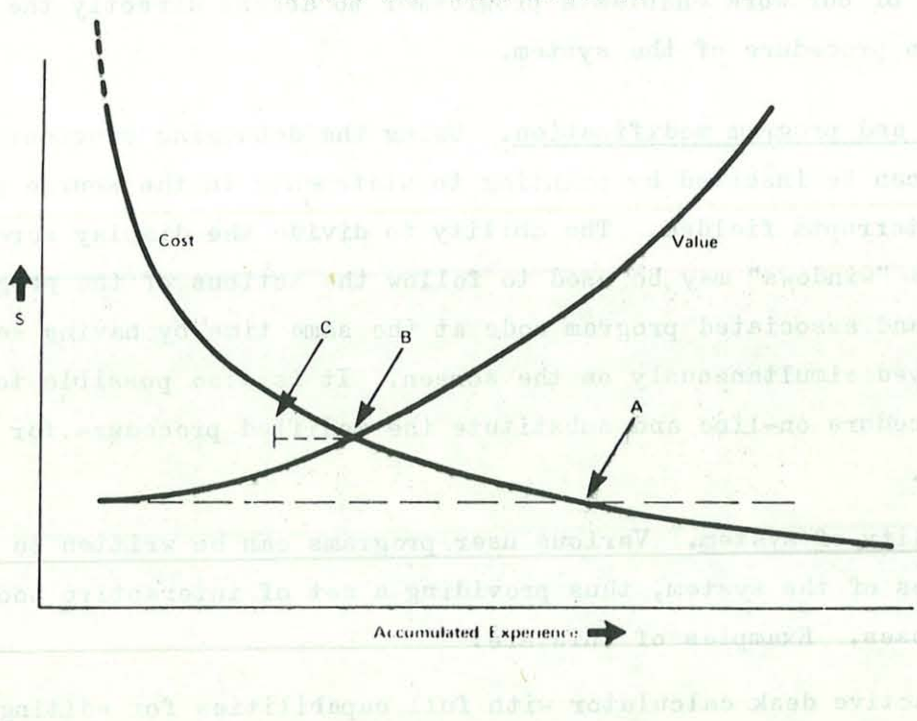

Figure 8

Software applications

Source code development. The facilities provided by the NLS file system for structuring text are utilized directly by the language processors and are of great assistance in writing, reading and modifying programs. Different levels of the structure of the program can displayed separately or together, comments may be expanded or hidden, and flow of control between sections may be followed. The system guide is generated from comments in programs.

Program Documentation. The system guide is maintained on-line and in hard copy. Using the Jump-to-Link feature, within the source-code files as maintained by our formatting conventions, the same text manipulation system used for all of our work enables a programmer to access directly the full code for any given procedure of the system.

Dubugging and program modification. Using the debugging procedure, breakpoints can be inserted by pointing to statements in the source program text, and interrupts fielded. The ability to divide the display screen into separate "windows" may be used to follow the actions of the program, input text, and associated program code at the same time by having several views displayed simultaneously on the screen. It is also possible to modify a system procedure on-line and substitute the modified procedure for testing by that user.

Extensibility of system. Various user programs can be written to extend the facilities of the system, thus providing a set of interactive tools for special purposes. Examples of this are:

An interactive desk calculator with full capabilities for editing and storing results.

A "special index" prepared for a working group for storing communiques and keeping a shelf list of borrowed material.

Documentation aids for turning graphical displays into portraits for published notes.

Discussion

Professor Page remarked that the principal motivation seems to have been to find how the computer extends human ability in a given area. Was this in fact the dominant research interest? Could the speaker also say anything about the cost-effectiveness of the tools provided? Agreeing with the first, the speaker said that the problem of cost-effectiveness had not been examined in detail as yet. In the past eighteen months a senior operations research man has studied the group's progress and confirmed that the bootstrapping techniques had been successful. The operation was not necessarily cost-effective yet, but they had reached the state of providing adequate solutions to application problems and had gained much experience in this area. It was now time to exploit the effects of the service on the users. It seemed to Professor Page that the speaker's approach was closer to that of a scientist than an engineer, despite his earlier remarks to the contrary. The basis of engineering was to build something with a certain level of cost-effectiveness. The speaker countered that the system could be regarded as a prototype in engineering terms. In constructing it the principal considerations had been what should be included and how the whole thing should look when put together. In the next pass in the development process costs would be of more concern.

Pursuing the question of cost-effectiveness, Professor Galler said that one measure was what subscribers to the system were prepared to pay in real money. He asked whether the subscriptions were subsidized in any way. In reply the speaker said that there was a subsidy for government organizations, who had the network cost paid, but private industry paid the full price. Initial costs of training and set-up had been estimated at about 800,000 dollars p.a.

Professor Pyle suggested that in some areas, for instance that of graphic portrayals, there was far more potential than the achievements already made. He asked what were the principal constraints against development. The speaker replied that they had definite committments to fulfil, and were limited by human resources. Their aim had been to provide a basic system which worked, was easily serviced, and included those features deemed to be essential, especially those for collaboration. They had to forego many potentialities which they saw could be done but for the lack of human resource. The need now was for a community to accept this as a starting-place and to evolve it cooperatively.

The discussion was brought to a close by Professor Page.

Reference

Engelbart, D.C., Watson, R.W., and Norton, J.C. (1973): The Augmented Knowledge Workshop. Proc. Nat. Comp. Conf. and Exposition, AFIPS vol. 42, (June 4-8, 1973), AFIPS press, Montvale, New Jersey.

[illegible] earlier remarks to the discussion. The aim of [illegible] was to build something with a certain level of cost-effectiveness. The speaker considered that the system could be regarded as a prototype in engineering terms. In constructing it the principal considerations had been what should be included and how the whole thing should look when put together. In the next pass the development process costs would be of more concern.

Pursuing the question of cost-effectiveness, [illegible] said that one measure was what subscribers to the system were prepared to pay in hard money. He asked whether the connection [illegible] subsidized in any way. In reply the speaker said that there was a subsidy for government organizations, who had the network cost paid, but private industry paid the full price. Initial costs of training and set-up had been estimated at about 200,000 dollars p.a.

Professor Pyle suggested that in some areas, for instance that of graphic portrayals, there was far more potential than the achievements already made. He asked what were the principal constraints against development. The speaker replied that they had definite commitments to fulfil, and were limited by human resources. Their aim had been to provide a basic system which worked, was easily survived, and included those features deemed to be essential, especially those for collaboration. They had to forego many potentialities which they saw could be done but for the lack of human resources. The need now was for a community to accept this as a starting-place and to evolve it cooperatively.

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