Possibilities for ARC Participation in ARPA Speech Project
Draft -- dce (1515) 9 Nov 70,

BACKGROUND: 1

At the ARPA meeting in New Orleans last February, Larry Roberts expressed interest in having the AI community develop a set of specific, coordinated goals. 1a

I assumed that his motivation stemmed in part from the "relevancy" push, as applied upon DOD by Congress, and from ARPA's concern about keeping important AI research on the "acceptably relevant" list. It seemed as though the "goals" might best be expressed in terms of performance capability of AI processes. 1a1

Larry suggested that speech analysis would be an especially interesting field from which to select such goals -- considering the range of AI-like problems thus encompassed, and the high degree of relevance associated with prospective developments. 1a2

The interest among the meeting's participants was relatively high, and from the subsequent dialogue arose the formation of continuing activity to explore this topic. A meeting was held in Pittsburgh (31 Mar 70) of representatives from interested groups. A study group was formed, which held further meetings, and which is producing a "Final Report." ARC has a reproducion of The Table of Contents, and of Part 1 (Conclusions and Recommendations) as XDOC(5182,) -- we'll take steps to procure the whole document. 1b

ARPA is interested in following up now with specific proposals for pursuing these goals. The result could be that one outfit gets a contract for ARPA's whole "Speech Project," or that the Project could be distributed among a number of groups. Apparently the field is open to groups other than current members of the ARPA (IPT) Community. 1c

Individual and groups at SRI are interested in participaing in the Speech Project, and Bert Raphael is now coordinating the development of a proposal (that the "whole project" be done at SRI). 1d

On Tues 3 Nov 70, I was invited to discuss this matter with Dave Brown, Bert, and Charlie Rosen. The particular topic was the proposal's approach on the performance objectives -- it being felt by B, R, and R that perhaps within some ARC user domain there would be services particularly appropriate for augmenting with speech-processing aids as a demonstration-test. The sort of usage-test environment apparently in their mind involved the man-computer dialogue during querying of an information base, and the use of speech-processing aids to support part (or all?) of it (in one, or both directions?). 1e

I suggested an alternative framework in which to consider the perfomance goals, and in which to do the experimental speech-processing development work. The reception to this suggestion was favorable, and Brown, Raphael and Rosen decided to follow up on it -- to see how well the formulation for the whole Project might look with this approach integrated into it. 1f

This memo is intended to serve two functions: To inform ARC personnel of this development; and to provide Raphael et. al. with a next-stage written input by me. 1f1

SPECIFIC FEATURES OF PROPOSED APPROACH: 2

The Project would begin (as had been already assumed) by developing a speech-processing laboratory -- computer(s), special analyzer-synthesizer equipment, speech-storage and -retrieval facilities, etc. Also, work would start on the associated research and development toward basic speech-processing capabilities. 2a

Parallel to this, ARC would initiate development of certain speech-string processes within the NLS environment, orienting toward three inter-dependent goals: 2b

For the NLS speech-manipulation facility initially to be significantly useful within the ARC/NIC environment, independent of any automatic speech-analysis capabilities which might become available; 2b1

For the NLS speech-manipulation facility to be of maximum value to the speech-processing experimentation of the Speech Project. Here I assume that ARC would cooperate fully in both a) developing service capacity adequate to support planned-for experimentation, and b) providing interface personnel and general cooperation in helping the Project as needed. 2b2

For the particular speech-string features developed within

NLS, and the way they are integrated into ARC/NIC services, to provide a framework within which piecemeal-emergent capabilities from the Speech Project could be integrated in ways that progressively enhance the net value to ARC/NIC utilization. 2b3

From the ARC viewpoint, I would like to plan for, once a particular experimental speech-processing service is seen to provide real value, that we would be ready from our end to cooperate with making this service available to ARC/NIC as a standard feature. This is not intended to impose upon the Speech Project the burden of becoming a supplier of services; but, assumedly ARC, or a third-party, could implement and operate the necessary speech-processing service facility if the Speech-Project group weren't interested. 2b3a

The Speech Project would assume the availability to them of this forthcoming speech-augmented NLS facility as they planned and launched ther work. Continuous dialogue between the Project and ARC would guide developments in both domains toward optimizing the net value of their cooperation. 2c

The hardware facilites associated with this cooperation would be something like this: 2d

A pair of analyzer-synthesizer processors would be acquired. They could be physically located in either laboratory, and would serve to convert speech signals back and forth between analogue (electric) and digital form. 2d1

Speech-signal communication links would be established between the two laboratories. 2d2

Digital communication links would be established between the two computers (assumedly this would be via the ARPA Network). 2d3

ARC would begin making use of the analyzer-synthesizer equipment as follows: 2e

Changes in NLS-File Structure: Provide for accommodating digitized speech strings as one of the several data forms that can be attached to a node in one of our hierarchical files. And where we now use "text pointers" (internal variables) for reference to arbitrary character points within the text strings of a file's nodes, we would add provision for "voice-string pointers" for reference to arbitrary time positions within our voice strings. 2e1

We call such a node a "statement." Within a statement, we already handle grahic-vector constructs as well as text strings. In anticipation of the increased data-form generality of these nodes, I've long assumed we'd shift terminology from "statement" to something like "Node.". 2e1a

Addition of Speech-String Manipulation Processes Within NLS: Develop internal processes for operations such as: 2e2

a) inserting, deleting, moving and copying these strings, 2e2a

b) operating on the voice pointers in starting and ending a voice-string transfer, or breakup, or etc., 2e2b

c) receiving a sequence of voice strings and forming a new file, 2e2c

d) gaining I/O access to the analyzer-synthesizer equipment, 2e2d

e) accepting and delivering strings from/to them in appropriate synchronism with real-time speech handling. 2e2e

Development of Interactive User-Command Facilities: Initially we'd develop control means for usefully applying functions such as: Playback Voice in Statement X (Sx); Delete Voice in Sx; Append Voice in Sx to Voice in Sy; Step Through Sx with t-Second Voice Segments -- By Step Command (e.g. whenever the user hits a specified key); Step backward (forward) by n periods; set up a voice pointer at the current stepping position; break the string at Voice Pointer A (VPa) and append the trailing segment to Sy. 2e3

We now can embed "reference links" at arbitrary points in our text, using text-syntax conventions for there referencing a given text position, in a given statement, in a given file, of a given user's collection. We would add to our link syntax so that a link could cite a given voice pointer (in given user's collection, file, and statement; i.e. UC-F-S). Seeing a link on his display, a user could (as now) ask to "Jump on Link" -- and where now his display screen (instantly, more or less) positions him to the cited text (in UC-F-S). the new provisions would recognize syntactically that this is a voice-string citation, and could act accordingly. It might then merely reproduce the cited voice string in the user's speaker or headphone. Or, it could reposition him in file space (to UC-F-S). display the corresponding view, and let him begin operating on the voice strings there. 2e3a

We'd like also to develop a coordinated set of control means for typewriter users, as we have done for text manipulation on our files. 2e3b

Expansion of our file-storage and -management facility: This would be done as required by utilization of voice-string storage and accessing in our usage activities. All of the file-management and retrieval processes that we are developing for text/graphics files will work nicely for the text/graphic/voice files. 2e4

MISCELLANEOUS 3

Feature possibilities 3a

Speech-word recognition as a retrieval aid -- at least for developing indexing data (digital) for improving the search process. Retrieve, say wihin the record of a long conference dialogue, all passages with given key-word content, as isolated by a pre-processing search by the speech-processing facility, which was given pointers to instances of these words as found uttered by the different participants, and went through producing a set of pointers for each word and user. 3a1

Speaker recognitioon very valuable. 3a2

Word isolation, even to a 90% probability, would be very useful. Sentence isolation, too. 3a3

Usage possibilities 3b

Suppose a bunch of voice has been transcribed by a human (or miscellaneous parts by a collection of people) -- provide the computer with both the voice and the text, and have it go through trying to find whatever gaps and inaccuracies it can. Anything it can do in this regard could be useful (not saying whether use value approaches cost). Possible to leave text/voice pointer pairs showing the suspected passages -- user can easily investigate these passages later. 3b1

Suppose that a translator that is 70 percent accurate is developed. It should be able to leave text/voice pointer pairs as to the places it couldn't do the job, or isn't sure, ec., to help the post-translation editing process. We can easily develop special interactive processes to help with such post editing. 3b2

Suppose a certain capability is developed in the SP for scanning recorded dialogue and recognizing terms, phrases, some meanings, some aspects of affective expression, etc. Long before this is accurate and reliable enough to be entirely depended upon for being the sole provider of such a service, its use within the interactive environment could have very high value. 3b3

Application possibilities 3c

General power of having full and immediate access to original voice strings, as cited within analysis files. For system study of collborative processes, of problem-solving protocol, tc. 3c1

Recording and processing, where we don't have to transcribe to study 3c2

conferences, work sessions, etc. 3c2a

group-dynamics experiments, analyzing, providing records of text/graphic analysis, with pointers to the cited speech, so that a subsequent studier or learner can have fll access ot all the original material. 3c2b

Verbal dialogue support could be tremendous. 3c3

People can speak, as they do now, in response to another's spoken statement(s). 3c3a

Only here, it can be in response to any past statement that the replier is scanning through, perhaps made but a few moments ago (replier may well be hearing the on-going dialogue in a headphone while he is simultaneously scanning for past utterances and speaking in his own comments and contributions. 3c3a1

Can have supportive people making textual annotations, summaries, linkages, indices, etc. over the dialogue to help the participants use the past records. 3c3b

Verbal dialogue can have a chance to be a time-distributed thing, now, more like the written dialogue has been. Telephone makes it both time and space distributed. 3c3c

Speech-string manipulation would let remote users with a typewriter and a telephone have much greater facility for studying through a bnch of material if voice rather than typed -- also, their voice contributions can be added to the dialogue with much greater information bandwith than by their typing. 3c3d

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HGL

This portion of document: (3906,) written in 1962 by DCE, is presented here for use in early FRAMAC meetings and has been re-structured by JCN for that purpose and for the purpose of starting the complete re-structure of the entire document.

Augmenting Human Intellect: A Conceptual Framework - A Structured Version

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INTRODUCTION

Note: The remaining parts of the original document are still in the process of being transcribed. This Introduction is produced now for use in early FRAMAC discussions. The rest will be forthcoming and entered into the Journal as soon as possible, hopefully in the next few weeks.

*** THIS VERSION HAS BEEN HIERARCHICALLY STRUCTURED TO LEVELS NOT SO STRUCTURED IN THE ORIGINAL DOCUMENT ***

JCN 5/12/72 2

A. GENERAL 2a

By "augmenting human intellect" we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems. 2a1

Increased capability in this respect is taken to mean a mixture of the following: 2a1a

more-rapid comprehension, 2a1a1

better comprehension, 2a1a2

the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, 2a1a3

speedier solutions, 2a1a4

better solutions, 2a1a5

and the possibility of finding solutions to problems that before seemed insoluble. 2a1a6

And by "complex situations" we include the professional problems of 2a1b

diplomats, 2a1b1
executives, 2a1b2
social scientists, 2a1b3
life scientists, 2a1b4
physical scientists, 2a1b5
attorneys, designers 2a1b6

--whether the problem situation exists for twenty minutes or twenty years. 2a1c

We do not speak of isolated clever tricks that help in particular situations. 2a1d

We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human "feel for a situation" usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids. 2a1d1

Man's population and gross product are increasing at a considerable rate, but the complexity of his problems grows still faster, and the urgency with which solutions must be found becomes steadily greater in response to the increased rate of activity and the increasingly global nature of that activity. 2a2

Augmenting man's intellect, in the sense defined above, would warrant full pursuit by an enlightened society if there could be shown a reasonable approach and some plausible benefits. 2a2a

This report covers the first phase of a program aimed at developing means to augment the human intellect. 2a3

These "means" can include many things--all of which appear to be but extensions of means developed and used in the past to help man apply his native sensory, mental, and motor capabilities--and we consider the whole system of a human and his augmentation means as a proper field of search for practical possiblities. 2a3a

It is a very important system to our society, and like most systems its performance can best be improved by considering the whole as a set of interacting components rather than by considering the components in isolation. 2a3b

This kind of system approach to human intellecutal effectiveness does not find a ready-made conceptual framework such as exists for established disciplines. 2a4

Before a research program can be designed to pursue such an approach intelligently, so that practical benefits might be derived within a reasonable time while also producing results of long-range significance, a conceptual framework must be search out 2a4a

--a framework that provides orientation as to the important factors of the system, the relationships among these factors, the types of change among the system factors that offer likely improvements in performance, and the sort of research goals and methodology that seem promising. 2a4a1

In the first (search) phase of our program we have developed a conceptual framework that seems satisfactory for the current needs of designing a research phase. 2a5

Section II contains the essence of this framework as derived from several different ways of looking at the system made up of a human and his intellect-augmentation means. 2a5a

The process of developing this conceptual framework brought out a number of significant realizations: 2a6

that the intellectual effectiveness exercised today by a given human has little likelihood of being intelligence limited 2a6a

--that there are dozens of disciplines in engineering, mathematics, and the social, life, and physical sciences that can contribute improvements to the system of intellect-augmentation means; 2a6b

that any one such improvement can be expected to trigger a chain of coordinating improvements; 2a6c

that until every one of these disciplines comes to a stand-still and we have exhausted all the improvement possibilities we could glean from it, we can expect to continue to develop improvements in this "human-intellect" system; 2a6d

that there is no particular reason not to expect gains in personal intellectual effectiveness for a concerted system-oriented approach that compare to those made in personal geographic mobility since horseback and sailboat days. 2a6e

The picture of how one can view the possibilities for a systematic approach to increasing human intellectual effectiveness, as put forth in Section II in the sober and general terms of an initial basic analysis, does not seem to convey all of the richness and promise that was stimulated by the development of that picture. Consequently, 2a7

Section III is intended to present some definite images that illustrate meaningful possibilities deriveable from the conceptual framework presented in Section II--and in a rather marked deviation from ordinary technical writing, a good portion of Section III presents these images in a fiction-dialogue style as a mechanism for transmitting a feeling for the richness and promise of the possibilities in one region of the "improvement space" that is roughly mapped in Section II. 2a7a

The style of Section III seems to make for easier reading. If Section II begins to seem unrewardingly difficult, the reader may find it helpful to skip from Section II-B directly to Section III. 2a8

If it serves its purpose well enough, Section III will provide a context within which the reader can go back and finish Section II with less effort. 2a8a

In Section IV (Research Recommendations) we present a general strategy for pursuing research toward increasing human intellectual effectiveness. 2a9

This strategy evolved directly from the concepts presented in Sections II and III; one of its important precepts is to pursue the quickest gains first, and use the increased intellectual effectiveness thus derived to help pursue successive gains. 2a9a

We see the quickest gains emerging from 2a9b

(1) giving the human the minute-by-minute services of a digital computer equipped with computer-driven cathode-ray-tube display, and 2a9b1

(2) developing the new methods of thinking and working that allow the human to capitalize upon the computer's help. 2a9b2

By this same strategy, we recommend that an initial research effort develop a prototype system of this sort aimed at increasing human effectiveness in the task of computer programming. 2a9c

To give the reader an initial orientation about what sort of thing this computer-aided working system might be, we include below a short description of a possible system of this sort. 2a10

This illustrative example is not to be considered a description of the actual system that will emerge from the program. 2a10a

It is given only to show the general direction of the work, and is clothed in fiction only to make it easier to visualize. 2a10b

Let us consider an "augmented" architect at work. He sits at a working station that has a visual display screen some three feet on a side; this is his working surface, and is controlled by a computer (his "clerk") with which he can communicate by means of a small keyboard and various other devices. 2a11

He is designing a building. He has already dreamed up several basic layouts and structural forms, and is trying them out on the screen. 2a12

The surveying data for the layout he is working on now have already been entered, and he has just coaxed the "clerk" to show him a perspective view of the steep hillside building site with the roadway above, symbolic representations of the various trees that are to remain on the lot, and the service tie points for the different utilities. 2a12a

The view occupies the left two-thirds of the screen. 2a12b

With a "pointer", he indicates two points of interest, moves his left hand rapidly over the keyboard, and the distance and elevation between the points indicated appear on the right-hand third of the screen. 2a12c

Now he enters a reference line with his "pointer" and the keyboard. Gradually the screen begins to show the work he is doing--a neat excavation appears in the hillside, revises itself slightly, and revises itself again. 2a13

After a moment, the architect changes the scene on the screen to an overhead plan view of the site, still showing the excavation. 2a13a

A few minutes of study, and he enters on the keyboard a list of items, checking each one as it appears on the screen, to be studied later. 2a13b

Ignoring the representation on the display, the architect next begins to enter a series of specifications and data--a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. 2a14

When he has finished, the revised scene appears on the screen. 2a14a

A structure is taking shape. He examines it, adjusts it, pauses long enough to ask for handbook or catalog information from the "clerk" at various points, and readjusts accordingly. 2a14b

He often recalls from the "clerk" his working lists of specifications and considerations to refer to them, modify them, or add to them. These lists grow into an ever-more-detailed, interlinked structure, which represents the maturing thought behind the actual design. 2a14c

Prescribing different planes here and there, curved surfaces occasionally, and moving the whole structure about five feet, he finally has the rough external form of the building balanced nicely with the setting and he is assured that this form is basically compatible with the materials to be used as well as with the function of the building. 2a15

Now he begins to enter detailed information about the interior. 2a16

Here the capability of the "clerk" to show him any view he wants to examine (a slice of the interior, or how the structure would look from the roadway above) is important. 2a16a

He enters particular fixture designs, and examines them in a particular room. 2a16b

He checks to make sure that sun glare from the windows will not blind a driver on the roadway, and the "clerk" computes the information that one window will reflect strongly onto the roadway between 6 and 6:30 on midsummer mornings. 2a16c

Next he begins a functional analysis. 2a17

He has a list of the people who will occupy this building, and the daily sequences of their activities. 2a17a

The "clerk" allows him to follow each in turn, examining how doors swing, where special lighting might be needed. 2a17b

Finally he has the "clerk" combine all of these sequences of activity to indicate spots where traffic is heavy in the building, or where congestion might occur, and to determine what the severest drain on the utilities is likely to be. 2a17c

All of this information (the building design and its associated "thought structure") can be stored on a tape to represent the "design manual" for the building. 2a18

Loading this tape into his own "clerk", another architect, a builder, or the client can maneuver within this "design manual" to pursue whatever details or insights are of interest to him--and can append special notes that are integrated into the "design manual" for his own or someone else's later benefit. 2a18a

In such a future working relationship between human problem-solver and computer "clerk", the capability of the computer for executing mathematical processes would be used whenever it was needed. 2a19

However, the computer has many other capabilities for manipulating and displaying mathematical processes of planning, organizing, studying, etc. 2a19a

Every person who does his thinking with symbolized concepts (whether in the form of the English language, pictographs, formal logic, or mathematics) should be able to benefit significantly. 2a19b

B. OBJECTIVE OF THE STUDY 2b

The objective of this study is to develop a conceptual framework within which could grow a coordinated research and development program whose goals would be the following: 2b1

(1) to find the factors that limit the effectiveness of the individual's basic information-handling capabilities in meeting the various needs of society for problem solving in its most general sense; and 2b1a

(2) to develop new techniques, procedures, and systems that will better match these basic capabilities to the needs, problems, and progress of society. 2b1b

We have placed the following specifications on this framework: 2b1c

(1) That it provide perspective for both long-range basic research and research that will yield practical results soon. 2b1c1

(2) That it indicate what this augmentation will actually involve in the way of changes in working environment, in thinking, in skills, and in methods of working. 2b1c2

(3) That it be a basis for evaluating the possible relevance of work and knowledge from existing fields and for assimilating whatever is relevant. 2b1c3

(4) That it reveal areas where research is possible and ways to assess the research, be a basis for choosing starting points, and indicate how to develop appropriate methodologies for the needed research. 2b1c4

Two points need emphasis here. 2b1d

First, although a conceptual framework has been constructed, it is still rudimentary. 2b1d1

Further search, and actual research, are needed for the evolution of the framework. 2b1d1a

Second, even if our conceptual framework did provide an accurate and complete basic analysis of the system from which stems a human's intellectual effectiveness, the explicit nature of future improved systems would be highly affected by (expected) changes in our technology or in our understanding of the human being. 2b1d2

Are we going across the grain -

Helping teams deal with complex problems.

1. Learn how to function.
2. Drop off rules of thumb - handbook.

Developing in a vacuum ?

Integration of cultural change into other environments. Approach to marketing.

Being ready to ride through cultural change.

Sensing language difficulties.

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Putt - Kennedy : Framework
Interdisciplinary teams & integration of various frameworks or culture.

Problems inherent in integrating new people into our cultures.

Search - research.

SEAS framework - [search / re-search / development]

Where do candidates want to go? How flexible are they in modifying framework.

Interdisciplinary framework -
A synergistic combination of individual cultural framework.

Development thrusts require framework.

Can't push faster than belief grows and changes.

Belief investigation -

A research center for augmenting human intellect*

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1 SUMMARY

1a This paper describes a multisponsor research center at Stanford Research Institute in man-computer interaction.

1a1 For its laboratory facility, the Center has a time-sharing computer (65K, 24-bit core) with a 4.5 megabyte swapping drum and a 96 megabyte file-storage disk. This serves twelve CRT work stations simultaneously.

1a1a Special hardware completely removes from the CPU the burden of display refreshing and input sampling, even though these are done directly out of and into core.

1a1b The display in a user's office appears on a high-resolution (875-line) commercial television monitor, and provides both character and vector portrayals. A relatively standard typewriter keyboard is supplemented by a five-key handset used (optionally) for entry of control codes and brief literals. An SRI cursor device called the "mouse" is used for screen pointing and selection.

1a1b1 The "mouse" is a hand-held X-Y transducer usable on any flat surface; it is described in greater detail further on.

1a2 Special-purpose high-level languages and associated compilers provide rapid, flexible development and modification of the repertoire of service functions and of their control procedures (the latter being the detailed user actions and computer feedback involved in controlling the application of these service functions).

1b User files are organized as hierarchical structures of data entities, each composed of arbitrary combinations of text and figures. A repertoire of coordinated service features enables a skilled user to compose, study, and modify these files with great speed and flexibility, and to have searches, analyses data manipulation, etc. executed. In particular, special sets of conventions, functions, and working methods have been developed to air programming, logical design, documentation, retrieval, project management, team interaction, and hard-copy production.

2 INTRODUCTION

2a In the Augmented Human Intellect (AHI) Research Center at Stanford Research Institute a group of researchers is developing an experimental laboratory around an interactive, multiconsole computer-display system, and is working to learn the principles by which interactive computer aids can augment their intellectual capability.

2b The research objective is to develop principles and techniques for designing an "augmentation system."

2b1 This includes concern not only for the technology of providing interactive computer service, but also for changes both in ways of conceptualizing, visualizing, and organizing working material, and in procedures and methods for working individually and cooperatively.

*Principal sponsors are: Advanced Research Projects Agency and National Aeronautics and Space Agency (NAS1-7897), and Rome Air Development Center F30602-68-C-0286.

2c The research approach is strongly empirical. At the workplace of each member of the subject group we aim to provide nearly full-time availability of a CRT work station, and then to work continuously to improve both the service available at the stations and the aggregate value derived therefrom by the group over the entire range of its roles and activities.

2d Thus the research group is also the subject group in the experiment.

2d1 Among the special activities of the group are the evolutionary development of a complex hardware-software system, the design of new task procedures for the system's users, and careful documentation of the evolving system designs and user procedures.

2d2 The group also has the usual activities of managing its activities, keeping up with outside developments, publishing reports, etc.

2d3 Hence, the particulars of the augmentation system evolving here will reflect the nature of these tasks—i.e., the system is aimed at augmenting a system-development project team. Though the primary research goal is to develop principles of analysis and design so as to understand how to augment human capability, choosing the researchers themselves as subjects yields as valuable secondary benefit a system tailored to help develop complex computer-based systems.

2e This "bootstrap" group has the interesting (recursive) assignment of developing tools and techniques to make it more effective at carrying out its assignment.

2e1 Its tangible product is a developing augmentation system to provide increased capability for developing and studying augmentation systems.

2e2 This system can hopefully be transferred, as a whole or by pieces of concept, principle and technique, to help others develop augmentation systems for aiding many other disciplines and activities.

2f In other words we are concentrating fully upon reaching the point where we can do all of our work on line—placing in computer store all of our specifications, plans, designs, programs, documentation, reports, memos, bibliography and reference notes, etc., and doing all of our scratch work, planning, designing, debugging, etc., and a good deal of our intercommunication, via the consoles.

2f1 We are trying to maximize the coverage of our documentation, using it as a dynamic and plastic structure that we continually develop and alter to represent the current state of our evolving goals, plans, progress, knowledge, designs, procedures, and data.

2g The display-computer system to support this experiment is just (at this writing) becoming operational. Its functional features serve a basic display-oriented user system that we have evolved over five years and through three other computers. Below are described the principal features of these systems.

3 THE USER SYSTEM

3a Basic Facility

3a1 As "seen" by the user, the basic facility has the following characteristics:

3a1a 12 CRT consoles, of which 10 are normally located in offices of AHI research staff.

3a1b The consoles are served by an SDS 940 time-sharing computer dedicated to full-time service for this staff, and each console may operate entirely independently of the others.

3a1c Each individual has private file space, and the group has community space, on a high-speed disc with a capacity of 96 million characters.

3a2 The system is not intended to serve a general community of time-sharing users, but is being shaped in its entire design toward the special needs of the "bootstrapping" experiment.

3b Work Stations

3b1 As noted above, each work station is equipped with a display, an alphanumeric keyboard, a mouse, and a five-key handset.

3b2 The display at each of the work stations (see Figure 1) is provided on a high-resolution, closed-circuit television monitor.

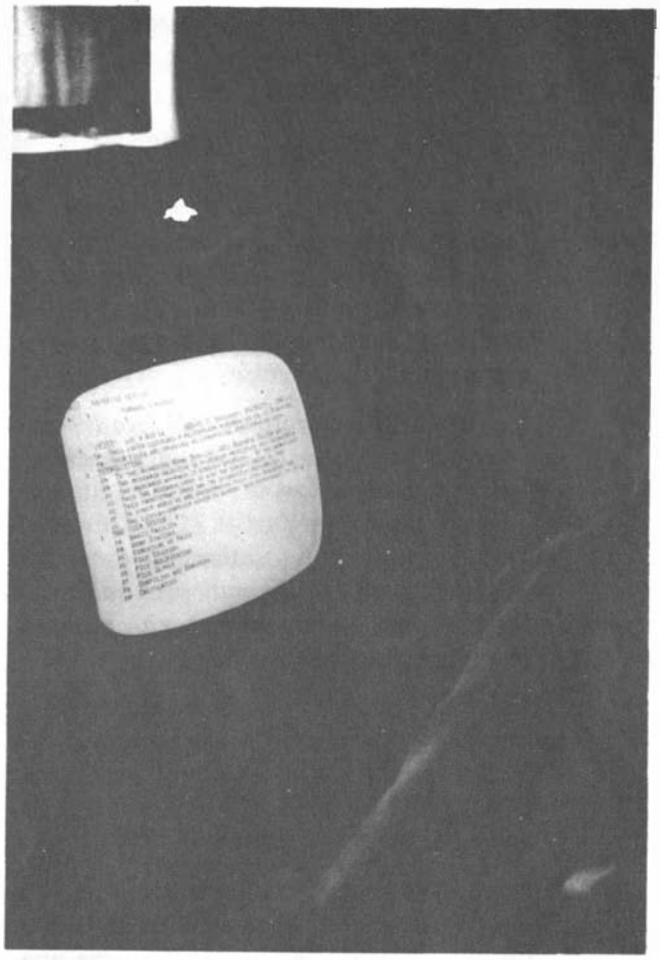


FIGURE 1—Typical work station, with TV display, typewriter keyboard, mouse, and chord handset

3b3 The alphanumeric keyboard is similar to a Teletype keyboard. It has 96 normal characters in two cases. A third-case shift key provides for future expansion, and two special keys are used for system control.

3b4 The mouse produces two analog voltages ast het wo wheels (see Figure 2) rotate, each changing in proportion to the X or Y movement over the table top.

3b4a These voltages control—via an A/D converter, the computer's memory, and the display generator—the coordinates of a tracking spot with which the user may "point" to positions on the screen.

3b4b Three buttons on top of the mouse are used for special control.

3b4c A set of experiments, comparing (within our techniques of interaction) the relative speed and accuracy obtained with this and other selection devices showed the mouse to be better than a light pen or a joystick (see Refs. English 1 and English 2).

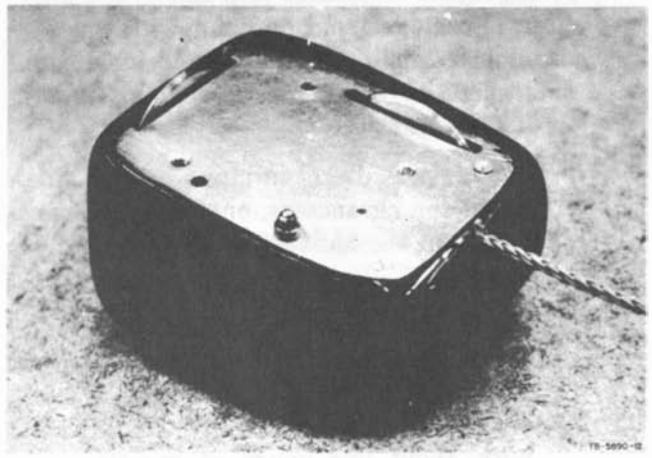


FIGURE 2—Underside of mouse

3b4c1 Compared to a light pen, it is generally less awkward and fatiguing to use, and it has a decided advantage for use with raster-scan, write-through storage tube, projection, or multiviewer display systems.

3b5 The five-key handset has 31 chords or unique key-stroke combinations, in five "cases."

3b5a The first four cases contain lower- and upper-case letters and punctuation, digits, and special characters. (The chords for the letters correspond to the binary numbers from 1 to 26.)

3b5b The fifth case is "control case." A particular chord (the same chord in each case) will always transfer subsequent input-chord interpretations to control case.

3b5c In control case, one can "backspace" through recent input, specify underlining for subsequent input, transfer to another case, visit another case for one character or one word, etc.

3b5d One-handed typing with the handset is slower than two-handed typing with the standard keyboard. However, when the user works with one hand on the handset and one on the mouse, the coordinated interspersion of control characters and short literal strings from one hand with mouse-control actions from the other yields considerable advantage in speed and smoothness of operation.

3b5d1 For literal strings longer than about ten characters, one tends to transfer from the handset to the normal keyboard.

3b5d2 Both from general experience and from specific experiment, it seems that enough handset skill to make its use worthwhile can generally be achieved with about five hours of practice. Beyond this, skill grows with usage.

3c **Structure of Files**

3c1 Our working information is organized into files, with flexible means for users to set up indices and directories, and to hop from file to file by display-selection or by typed-in file-name designations. Each file is highly structured in its internal organization.

3c1a The specific structure of a given file is determined by the user, and is an important part of his conceptual and "study-manipulate" treatment of the file.

3c2 The introduction of explicit "structuring" to our working information stems from a very basic feature of our conceptual framework (see Refs. Engelbart1 and Engelbart2) regarding means for augmenting human intellect.

3c2a With the view that the symbols one works with are supposed to represent a mapping of one's associated concepts, and further that one's concepts exist in a "network" of relationships as opposed to the essentially linear form of actual printed records, it was decided that the concept-manipulation aids derivable from real-time computer support could be appreciably enhanced by structuring conventions that would make explicit (for both the user and the computer) the various types of network relationships among concepts.

3c2b As an experiment with this concept, we adopted some years ago the convention of organizing all information into explicit hierarchical structures, with provisions for arbitrary cross-referencing among the elements of a hierarchy.

3c2b1 The principal manifestation of this hierarchical structure is the breaking up of text into arbitrary segments called "statements," each of which bears a number showing its serial location in the text and its "level" in an "outline" of the text. This paper is an example of hierarchical text structure.

3c2c To set up a reference link from Statement A to Statement B, one may refer in Statement A either to the location number of B or to the "name" of B. The difference is that the number is vulnerable to subsequent structural change, whereas the name stays with the statement through changes in the structure around it.

3c2c1 By convention, the first word of a statement is treated as the name of the statement, if it is enclosed in parentheses. For instance, Statement 0 on the screen of Figure 1 is named "FJCC."

3c2c2 References to these names may be embedded anywhere in other statements, for instance as "see(AFI)," where special format informs the viewer explicitly that this refers to a statement named "AFI," or merely as a string of characters in a context such that the viewer can infer the referencing.

3c2c3 This naminga nd linking, when added to the basic hierarchical form, yields a highly flexible general structuring capability. These structuring conventions are expected to evolve relatively rapidly as our research progresses.

3c3 For some material, the structured-statement form may be undesirable. In these cases, there are means for suppressing the special formatting in the final printout of the structured text.

3c4 The basic validity of the structured-text approach has been well established by our subsequent experience.

3c4a We have found that in both off-line and on-line computer aids, the conception, stipulation, and execution of significant manipulations are made much easier by the structuring conventions.

3c4b Also, in working on line at a CRT console, not only is manipulation made much easier and more powerful by the structure, but a user's ability to get about very quickly within his data, and to have special "views" of it generated to suit his need, are significantly aided by the structure.

3c4c We have come to write all of our documentation, notes, reports, and proposals according to these conventions, because of the resulting increase in our ability to study and manipulate them during composition, modification, and usage. Our programming systems also incorporate the conventions. We have found it to be fairly universal that after an initial period of negative reaction in reading explicitly structured material, one comes to prefer it to material printed in the normal form.

3d **File Studying**

3d1 The computer aids are used for two principal "studying" operations, both concerned with construction of the user's "views," i.e., the portion of his working text that he sees on the screen at a given moment.

3d1a Display Start

3d1a1 The first operation is finding a particular statement in the file (called the "display start"); the view will then begin with that statement. This is equivalent to finding the beginning of a particular passage in a hard-copy document.

3d1b Form of View

3d1b1 The second operation is the specification of a "form" of view—it may simply consist of a screenful of text which sequentially follows the point specified as the display start, or it may be constructed in other ways, frequently so as to give the effect of an outline.

3d1c In normal, off-line document studying, one often does the first type of operation, but the second is like a sissors-and-staple job and is rarely done just to aid one's studying.

3d1d (A third type of service operation that will undoubtedly be of significant aid to studying is question answering. We do not have this type of service.)

3d2 Specification of Display Start

3d2a The display start may be specified in several ways:

3d2a1 By direct selection of a statement which is on the display—the user simply points to any character in the statement, using the mouse.

3d2a2 If the desired display start is not on the display, it may be selected indirectly if it bears a "marker."

3d2a2a Markers are normally invisible. A marker has a name of up to five characters, and is attached to a character of the text. Referring to the marker by name (while holding down a special button) is exactly equivalent to pointing to the character with the mouse.

3d2a2b The control procedures make it extremely quick and easy to fix and call markers.

3d2a3 By furnishing either the name or the location number of the statement, which can be done in either of two basic ways:

3d2a3a Typing from the keyboard

3d2a3b Selecting an occurrence of the name or number in the text. This may be done either directly or via an indirect marker selection.

3d2b After identifying a statement by one of the above means, the user may request to be taken directly there for his next view. Alternately, he may request instead that he be taken to some statement bearing a specified structure relationship to the one specifically identified. For instance, when the user identifies Statement 3E4 by one of the above means (assume it to be a member of the list 3E1 through 3E7), he may ask to be taken to

3d2b1 Its successor, i.e., Statement 3E5

3d2b2 Its predecessor, i.e., Statement 3E3

3d2b3 Its list tail, i.e., Statement 3E7

3d2b4 Its list head, i.e., Statement 3E1

3d2b5 Its list source, i.e., Statement 3E

3d2b6 Its subhead, i.e., Statement 3E4A

3d2c Besides being taken to an explicitly identified statement, a user may ask to go to the first statement in the file (or the next after the current location) that contains a specified word or string of characters.

3d2c1 He may specify the search string by typing it in, by direct (mouse) selection, or by indirect (marker) selection.

3d3 Specification of Form of View

3d3a The "normal" view beginning at a given location is like a frame cut out from a long scroll upon which the hierarchical set of statements is printed in sequential order. Such a view is displayed in Figure 1.

3d3b Otherwise, three independently variable view-specification conditions may be applied to the construction of the displayed view: level clipping, line truncation, and content filtering. The view is simultaneously affected by all three of these.

3d3b1 Level: Given a specified level parameter, L (L = 1, 2, . . . , ALL), the view generator will display only those statements whose "depth" is less than or equal to L. (For example, Statement 3E4 is third level, 3E second, 4B2C1 fifth, etc.) Thus it is possible to see only first-level statements, or only first-, second-, and third level statements, for example.

3d3b2 Truncation: Given a specified truncation parameter, T (T = 1, 2, . . ., ALL), the view generator will show only the first T lines of each statement being displayed.

3d3b3 Content: Given a specification for desired content (written in a special high-level content-analysis language) the view generator optionally can be directed to display only those statements that have the specified content.

3d3b3a One can specify simple strings, or logical combinations thereof, or such things as having the word "memory" within four words of the word "allocation."

3d3b3b Content specifications are written as text, anywhere in the file. Thus the full power of the system may be used for composing and modifying them.

3d3b3c Any one content specification can then be chosen for application (by selecting it directly or indirectly). It is compiled immediately to produce a machine-code content-analysis routine, which is then ready to "filter" statements for the view generator.

3d3c In addition, the following format features of the display may be independently varied: indentation of statements according to level, suppression of location numbers and/or names of statements, and separation of statements by blank lines.

3d3d. The user controls these view specifications by means of brief, mnemonic character codes. A skilled user will readjust his view to suit immediate needs very quickly and frequently; for example, he may change level and truncation settings several times in as many seconds.

3d4 "Freezing" Statements

3d4a One may also pre-empt an arbitrary amount of the upper portion of the screen for holding a collection of "frozen" statements. The remaining lower portion is treated as a reduced-size scanning frame, and the view generator follows the same rules for filling it as described above.

3d4b The frozen statements may be independently chosen or dismissed, each may have line truncation independent of the rest, and the order in which they are displayed is arbitrary and readily changed. Any screen-select operand for any command may be selected from any portion of the display (including the frozen statements).

3d5 Examples

3d5a Figures 3 and 4 show views generated from the same starting point with different level-clipping parameters. This example happens to be of a program written in our Machine-Oriented language (MOL, see below).

3d5b Figure 5, demonstrates the freezing feature with a view of a program (the same one shown in Figure 8) written in our Control Metalanguage (CML, see below). Statements 3C, 3C2, 2B, 2B1, 2B2, 2B3, and 2B4 are frozen, and statements from 2J on are shown normally with L = 3, T = 1.

3d5b1 The freezing here was used to hold for simultaneous view four different functionally related process descriptions. The subroutines (+ BUG1SPEC) and (+ WAIT) were located by use of the hop-to-name feature described above.

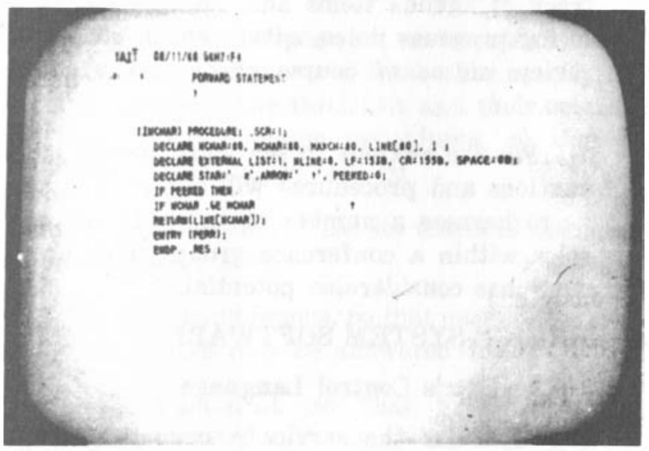


FIGURE 3—View of an MOL program, with level parameter set to 3 and truncation to 1

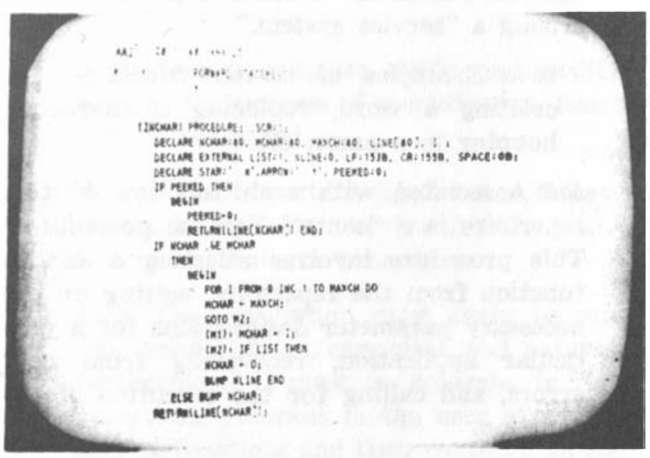


FIGURE 4—Same program as Figure 3, but with level parameter changed to 6 (several levels still remain hidden from view)

FIGURE 5—View of CML program, showing six frozen statements and illustrating use of reference hopping

3e **File Modification**

3e1 Here we use a standard set of editing operations, specifying with each operation a particular type of text entity.

3e1a Operations: Delete, Insert, Replace, Move, Copy.

3e1b Entities (within text of statements): Character, Text (arbitrary strings), Word, Visible (print string), Invisible (gap string).

3e1c Entities (for structure manipulation): Statement, Branch (statement plus all substructure), Group (sublist of branches), Plex (complete list of branches).

3e2 Structure may also be modified by joining statements, or breaking a statement into two at a specified point.

3e3 Generally, an operation and an entity make up a command, such as "Delete Word." To specify the command, the user types the first letter of each word in the command: thus "DW" specifies "Delete Word." There are occasional cases where a third word is used or where the first letter cannot be used because of ambiguities.

3f **File Output**

3f1 Files may be sent to any of a number of different output devices to produce hard copy—an upper/lower-case line printer, an on-line high-quality typewriter, or paper tape to drive various typewriters.

3f1a In future it will be possible to send files via magnetic tape to an off-line CRT-to-film system from which we can produce Xérox prints, Multilith masters, or microform records.

3f2 Flexible format control may be exercised in this process by means of specially coded directives embedded in the files—running headers, page numbering, line lengths, line centering, suppression of location numbers, indenting, right justification (hyphenless), etc., are controllable features.

3g Compiling and Debugging

3g1 Source-code files written in any of our compiler languages (see below), or in the SDS 940 assembly language (ARPAS, in which our compiler output is produced) may be compiled under on-line control. For debugging, we have made a trivial addition to the SDS 940's DDT loader-debugger so as to operate it from the CRT displays. Though it was designed to operate from a Teletype terminal, this system gains a great deal in speed and power by merely showing with a display the last 26 lines of what would have been on the Teletype output.

3h Calculating

3h1 The same small innovation as mentioned above for DDT enables us to use the CAL system from a display terminal.

3i Conferencing

3i1 We have set up a room specially equipped for on-line conferencing. Six displays are arranged in the center of a square table (see Figure 6) so that each of twenty participants has good visibility. One participant controls the system, and all displays show the same view. The other participants have mice that control a large arrow on the screen, for use as a pointer (with no control function).

3i2 As a quick means of finding and displaying (with appropriate forms of view) any desired material from a very large collection, this system is a powerful aid to presentation and review conferences.

FIGURE 6—On-line conference arrangement

3i3 We are also experimenting with it in project meetings, using it not only to keep track of agenda items and changes but also to log progress notes, action notes, etc. The review aid is of course highly useful here also.

3i4 We are anxious to see what special conventions and procedures will evolve to allow us to harness a number of independent consoles within a conference group. This obviously has considerable potential.

4 SERVICE-SYSTEM SOFTWARE

4a The User's Control Language

4a1 Consider the service a user gets from the computer to be in the form of discrete operations—i. e., the execution of individual "service functions" from a repertoire comprising a "service system."

4a1a Examples of service functions are deleting a word, replacing a character, hopping to a name, etc.

4a2 Associated with each function of this repertoire is a "control-dialogue procedure." This procedure involves selecting a service function from the repertoire, setting up the necessary parameter designations for a particular application, recovering from user errors, and calling for the execution of the function.

4a2a The procedure is made up of the sequence of keystrokes, select actions, etc.

made by the user, together with the interspersed feedback messages from the computer.

4a3 The repertoire of service functions, together with their control-dialogue procedures, constitutes the user's "control language." This is a language for a "master-slave" dialogue, enabling the user to control application of the computer's capabilities to his own service.

4a3a It seems clear that significant augmentation of one's intellectual effectiveness from the harnessing of computer services will require development of a broad and sophisticated control-language vocabulary.

4a3b It follows that the evolution of such a control language is a very important part of augmentation-system research.

4a4 For the designer of user systems, it is important to have good means for specifying the nature of the functions and their respective control-dialogue procedures, so that a design specification will be

4a4a Concise, so that its essential features are easily seen

4a4b Unambiguous, so that questions about the design may be answered clearly

4a4c Canonical, so that information is easily located

4a4d Natural, so that the form of the description fits the conceptual frame of the design

4a4e Easy to compose, study, and modify, so that the process of evolutionary design can be facilitated.

4a5 It is also important for the user to have a description of the service functions and their control-dialogue procedures.

4a5a The description must again be concise, unambiguous, canonical, and natural; furthermore, it must be accurate, in that everything relevant to the user about the service functions and their control-dialogue procedures is described, and everything described actually works as indicated.

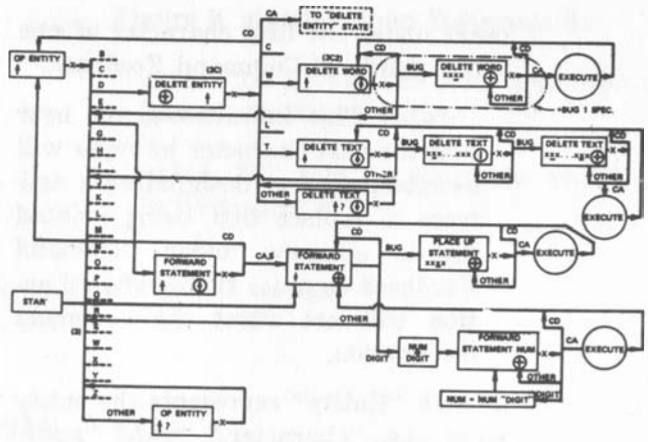


FIGURE 7—State-chart portrayal of part of the text-manipulation control language

4b State-Chart Representation of Control-Language Design

4b1 Figure 7 shows a charting method that was used in earlier stages of our work for designing and specifying the control-procedure portions of the control language. Even though limited to describing only the control-dialogue procedures, this representation nonetheless served very well and led us to develop the successive techniques described below.

4b2 Figure 7 shows actual control procedures for four service functions from the repertoire of an interactive system: Delete Word, Delete Text, Place Up Statement, and Forward Statement.

4b2a The boxes contain abbreviated descriptions of relevant display-feedback conditions, representing the intermediate states between successive user actions. Both to illustrate how the charting conventions are used and to give some feeling for the dynamics of our user-system control procedures, we describe briefly below both the chart symbols and the associated display-feedback conventions that we have developed.

4b2a1 The writing at the top of each box indicates what is to be shown as "command feedback" at the top of the display (see Figures 3, 4 and 5).

4b2a1a An uparrow sometimes appears under the first character of one of the words of Command Feedback.

4b2a1a1 This indicates to the user that the next character he types will be interpreted as designating a new term to replace that being pointed to—no uparrow under Command Feedback signifies that keyboard action will not affect the command designation.

4b2a1b "Entity" represents the entity word (i.e., "character," "word, "statement," etc.) that was last used as part of a fully specified command.

4b2a1b1 The computer often "offers" the user an entity option.

4b2a2 The circle in the box indicates the character to be used for the "bug" (the tracking spot), which alternates between the characters uparrow and plus.

4b2a2a The uparrow indicates that a select action is appropriate, and the plus indicates that a select action is inappropriate.

4b2a3 The string of X's, with underlines, indicates that the selected characters are to be underlined as a means of showing the user what the computer thinks he has selected.

4b2b There is frequently an X on the output line from a box on the chart. This indicates that the computer is to wait until the user has made another action.

4b2b1 After this next action, the computer follows a branching path, depending upon what the action was (as indicated on the chart) to reach another state-description box or one of the function-execution processes.

4c **The Control Metalanguage**

4c1 In search for an improvement over the state chart, we looked for the following special features, as well as the general features listed above:

4c1a A representational form using structural text so as to harness the power of our on-line text-manipulation techniques for composing, studying, and modifying our designs.

4c1b A form that would allow us to specify the service functions as well as the control-dialogue procedures.

4c1c A form such that a design-description file could be translated by a computer program into the actual implementation of the control language.

4c2 Using our Tree Meta compiler-compiler (described below), we have developed a next step forward in our means of designing, specifying, implementing and documenting our on-line control languages. The result is called "Control Metalanguage" (CML).

4c2a Figure 8 shows a portion of the description for the current control language, written in Control Metalanguage.

4c2a1 This language is the means for describing both the service functions and their control-dialogue procedures.

4c2b The Control Metalanguage Translator (CMLT) can process a file containing such a description, to produce a corresponding version of an interactive system which responds to user actions exactly as described in the file.

4c3 There is a strong correspondence between the conventions for representing the control procedures in Control Metalanguage and in the state chart, as a comparison of Figures 8 and 7 will reveal.

4c3a The particular example printed out for Figure 8 was chosen because it specifies some of the same procedures as in Figure 7.

4c3b For instance, the steps of display-feedback states, leading to execution of the "Delete Word" function, can readily be followed in the state chart.

4c3b1 The steps are produced by the user typing "D," then "W," then selecting a character in a given word, and then hitting "command accept" (the CA key).

4c3b2 The corresponding steps are outlined below for the Control Metalanguage description of Figure 8, progressing from Statement 3, to Statement 3c, to

Statement 3c2, to Subroutine +BUG-SPEC, etc.

4c3b3 The points or regions in Figure 7 corresponding to these statements and subroutines are marked by (3), (3C), (3C2), and (+BUG1SPEC), to help compare the two representations.

4c3c These same steps are indicated in Figure 8, starting from Statement 3:

4c3c1 "D" sets up the state described in Statement 3C

4c3c2 "W" sets up the state described in Statement 3C2

FIGURE 8—Metalanguage description of part of control language

```
3  (wc:) zap  case

   3A (b) [edit]  dsp(backward ↑es*) .  case
   .
   .
   .

   3B (c) [edit] dsp(copy ↑es*) :s true => <am>adj1: . case

      3B1   (c)   s*=cc dsp(↑copy character) e*=c,character +bug2spec
      +cdlim(b1,p1,p2,p3,p4) +cdlim(b2,p5,p6,p7,p8)
      +cpchtx(b1,p2,p4,p5,p6) ;

      3B2  (w)   s*=cw dsp(↑copy word) e*=w,word +bug2spec
      +wdr2(b1,p1,p2,p3,p4) +wdr2(b2,p5,p6,p7,p8)
      +cpwdvs(b1,p2,p4,p5,p6) ;

      3B3  (l)   s*=cl dsp(↑copy line) e*=l,line +bug2spec
      +ldlim(b1,p1,p2,p3,p4)  +ldlim(b2,p5,p6,p7,p8) :c st b1←sf(b1) p2,
      rif :p p2>p1 cr: then (cr) else (null) ,  p5 p6, p4 se(b1): goto
      [s]

      3B4  (v)   s*=cv dsp(↑copy visible) e*=v,visible +bug2spec
      +vdr2(b1,p1,p2,p3,p4) +vdr2(b2,p5,p6,p7,p8)
      +cpwdvs(b1,p2,p4,p5,p6) ;
      .
      .
      .
      3b10   endcase +caqm ;

   3C (d) [edit] dsp(delete ↑es*) . case

      3C1 (c)   s*=dc dsp(↑delete character) e*=c,character +bug1spec
      +cdlim(b1,p1,p2,p3,p4) +del;

      3C2 (w)   s*=dw dsp(↑delete word) e*=w,word +bug1spec +wdr
      (b1,p1,p2,p3,p4) +del ;

      3C3 (l)    s*=dl dsp(↑delete line) e*=l,line +bug1spec...
      .
      .
      .
```

4c3c3 The subroutine +BUG1SPEC waits for the select-word (1) and CA (2) actions leading to the execution of the delete-word function.

4c3c3a Then the TWDR subroutine takes the bug-position parameter and sets pointers P1 through P4 to delimit the word in the text data.

4c3c3b Finally, the + DEL subroutine deletes what the pointers delimit, and then returns to the last-defined state (i.e., to where S* = DW).

4d **Basic Organization of the On-Line System (NLS)**

4d1 Figure 9 shows the relationships among the major components of NLS.

4d2 The Tree Meta Translator is a processor specially designed to produce new translators.

4d2a There is a special language—the Tree Meta Language—for use in describing the translator to be produced.

4d2b A special Tree Meta library of subroutines must be used, along with the output of the Tree Meta Translator, to produce a functioning new translator. The same library serves for every translator it produces.

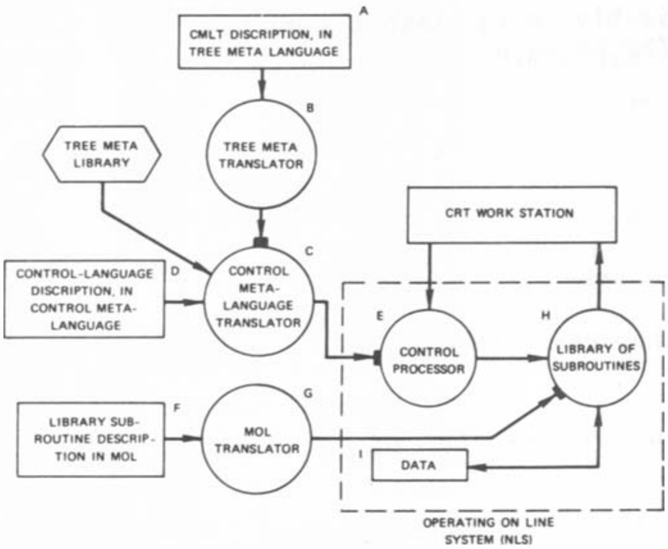


FIGURE 9—Basic organization of NLS showing use of compilers and compiler-compiler to implement it

4d3 For programming the various subroutines used in our 940 systems, we have developed a special Machine-Oriented Language (MOL), together with an MOL Translator to convert MOL program descriptions into machine code (see Ref. Hay1 for a complete description).

4d3a The MOL is designed to facilitate system programming, by providing a high-level language for iterative, conditional, and arithmetic operations, etc., along with a block structure and conventions for labeling that fit our structured-statement on-line manipulation aids.

4d3a1 These permit sophisticated computer aid where suitable, and also allow the programmer to switch to machine-level coding (with full access to variables, labels, etc.) where core space, speed, timing, core-mapping arrangements, etc., are critical.

4d4 The NLS is organized as follows (letters refer to Figure 9):

4d4a The Control Processor (E) receives and processes successive user actions, and calls upon subroutines in the library (H) to provide it such services as the following:

4d4a1 Putting display feedback on the screen

4d4a2 Locating certain data in the file

4d4a3 Manipulating certain working data

4d4a4 Constructing a display view of specified data according to given viewing parameters, etc.

4d4b The NLS library subroutines (H) are produced from MOL programs (F), as translated by the MOL Translator (G).

4d4c The Control Processor is produced from the control-language description (D), written in Control Metalanguage, as translated by the CMLT (C).

4d4d The CMLT, in turn, is produced from a description (A) written in Tree Meta, as translated by the Tree Meta Translator (B).

4d5 Advantages of Metalanguage Approach to NLS Implementation

4d5a The metalanguage approach gives us improved means for control-language specification, in terms of being unambiguous, concise, canonical, natural and easy to compose, study and modify.

4d5b Moreover, the Control Metalanguage specification promises to provide in itself a users' documentation that is completely accurate, and also has the above desirable characteristics to facilitate study and reference.

4d5c Modifying the control-dialogue procedures for existing functions, or making a reasonable range of changes or additions to these functions, can often be accomplished solely by additions or changes to the control-language record (in CML).

4d5c1 With our on-line studying, manipulating and compiling techniques, system additions or changes at this level can be thought out and implemented (and automatically documented) very quickly.

4d5d New functions that require basic operations not available through existing subroutines in the NLS library will need to have new subroutines specified and programmed (in MOL), and then will need new terms in CML to permit these new functions to be called upon. This latter requires a change in the record (A), and a new compilation of CMLT by means of the Tree Meta Translator.

4d5d1 On-line techniques for writing and modifying the MOL source code (F), for executing the compilations, and for debugging the routines, greatly reduce the effort involved in this process.

5 SERVICE-SYSTEM HARDWARE (OTHER THAN SDS 940)

5a In addition to the SDS 940, the facility includes peripheral equipment made by other manufacturers and equipment designed and constructed at SRI.

5b All of the non-SDS equipment is interfaced through the special devices channel which connects to the second memory buss through the SDS memory interface connection (MIC).

5b1 This equipment, together with the RAD, is a significant load on the second memory buss. Not including the proposed "special operations" equipment, the maximum expected data rate is approximately 264,000 words per second or one out of every 2.1 memory cycles. However, with the 940 variable priority scheme for memory access (see Pirtle[1]), we expect less than 1 percent degradation in CPU efficiency due to this load.

5b2 This channel and the controllers (with the exception of the disc controller) were designed and constructed at SRI.

5b2a In the design of the hardware serving the work stations, we have attempted to minimize the CPU burden by making the system as automatic as possible in its access to memory and by formatting the data in memory so as to minimize the executive time necessary to process it for the users.

5c Figure 10 is a block diagram of the special-devices channel and associated equipment. The major components are as follows:

5c1 Executive Control

5c1a This is essentially a sophisticated multiplexer that allows independent, asynchronous access to core from any of the 6 controllers connected to it. Its functions are the following:

5c1a1 Decoding instructions from the computer and passing them along as signals to the controllers.

5c1a2 Accepting addresses and requests for memory access (input or output) from the controllers, determining relative priority among the controllers, synchronizing to the computer clock, and passing the requests along to memory via the MIC.

5c1b The executive control includes a comprehensive debugging panel that allows any of the 6 controllers to be operated offline without interfering with the operation of other controllers.

5c2 Disc File

5c2a This is a Model 4061 Bryant disc, selected for compatibility with the continued 940-system development by Berkeley's Project GENIE, where extensive file-handling software was developed.

5c2b As formatted for our use, the disc will have a storage capacity of approximately 32 million words, with a data-transfer rate of roughly 40,000 words per second and average access time of 85 milliseconds.

5c2c The disc controller was designed by Bryant in close cooperation with SRI and Project GENIE.

5c3 Display System

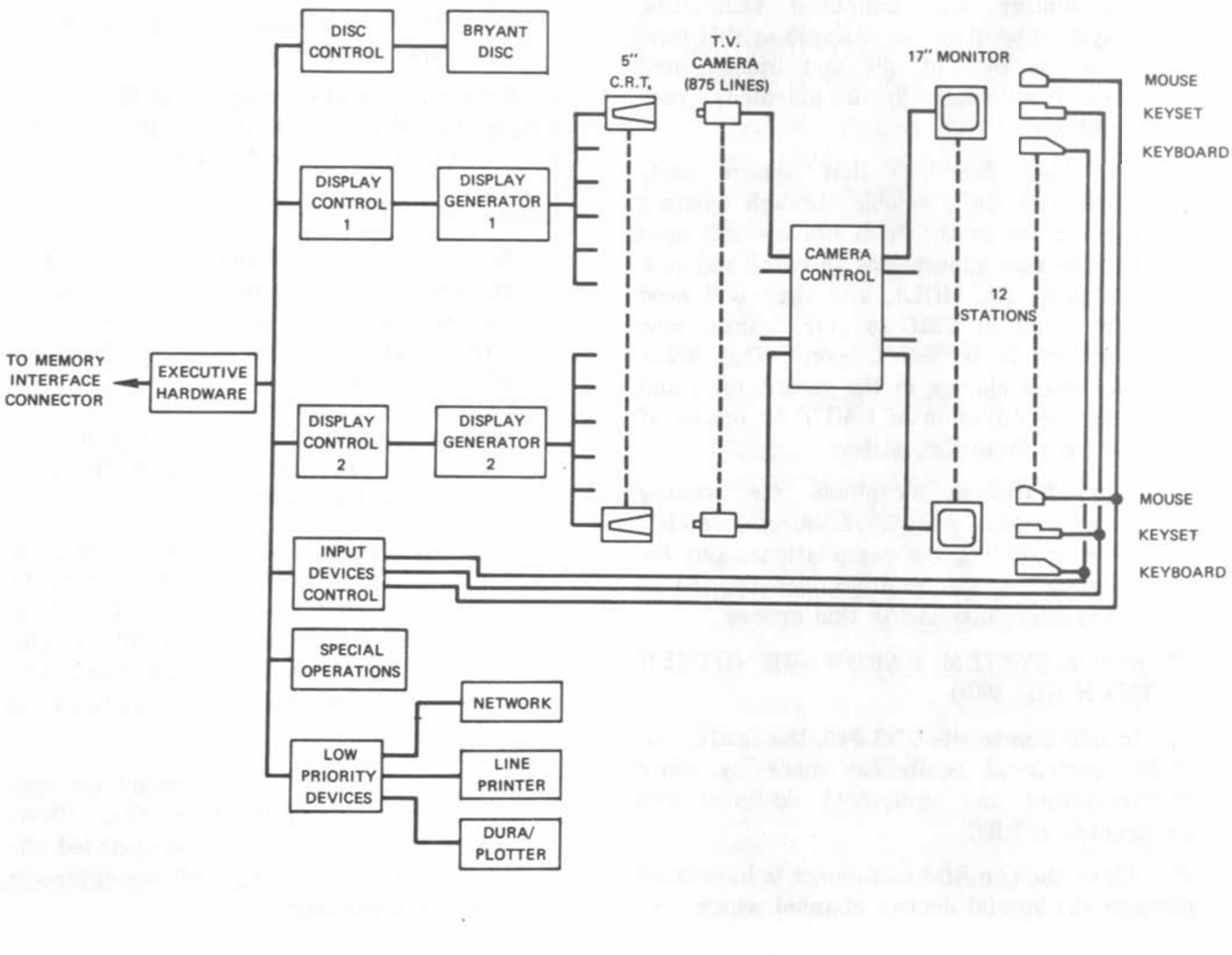
5c3a The display systems consists of two identical subsystems, each with display controller, display generator, 6 CRT's, and 6 closed-circuit television systems.

5c3b The display controllers process display-command tables and display lists that are resident in core, and pass along display-buffer contents to the display generators.

5c3c The display generators and CRT's were developed by Tasker Industries to our specifications. Each has general character-vector plotting capability. They will accept display buffers consisting of instructions (beam motion, character writing, etc.) from the controller. Each will drive six 5-inch high-resolution CRT's on which the display pictures are produced.

5c3c1 Character writing time is approximately 8 microseconds, allowing an aver-

FIGURE 10—Special devices channel



age of 1000 characters on each of the six monitors when regenerating at 20 cps.

5c3d A high-resolution (875-line) closed-circuit television system transmits display pictures from each CRT to a television monitor at the corresponding work-station console.

5c3e This system was developed as a "best solution" to our experimental-laboratory needs, but it turned out to have properties which seem valuable for more widespread use:

5c3e1 Since only all-black or all-white signal levels are being treated, the scan-beam current on the cameras can be reduced to achieve a short-term image-storage effect that yields flicker-free TV output even when the display refresh rate is as low as 15 cps. This allows a display generator to sustain about four times more displayed material than if the users were viewing direct-view refreshed tubes.

5c3e2 The total cost of small CRT, TV camera, amplifier-controller, and monitor came to about $5500 per work station—where a random-deflection, display-quality CRT of similar size would cost considerably more and would be harder to drive remotely.

5c3e3 Another cost feature which is very important in some system environments favors this TV approach: The expensive part is centrally located; each outlying monitor costs only about $600, so terminals can be set up even where usage will be low, with some video switching in the central establishment to take one terminal down and put another up.

5c3e4 An interesting feature of the video system is that with the flick of a switch the video signal can be inverted, so that the image picked up as bright lines on dim background may be viewed as black lines on a light background. There is a definite user preference for this inverted form of display.

5c3f In addition to the advantages noted above, the television display also invites the use of such commercially available devices as extra cameras, scan converters, video switches, and video mixers to enrich system service.

5c3f1 For example, the video image of a user's computer-generated display could be mixed with the image from a camera focused on a collaborator at another terminal; the two users could communicate through both the computer and a voice intercom. Each user would then see the other's face superimposed on the display of data under discussion.

5c3f2 Superimposed views from cameras focused on film images or drawings, or on the computer hardware, might also be useful.

5c3f3 We have experimented with these techniques (see Figure 11) and found them to be very effective. They promise to add a great deal to the value of remote display terminals.

5c4 Input-Device Controller

5c4a In addition to the television monitor, each work-station console has a keyboard, binary keyset, and mouse.

5c4b The controller reads the state of these

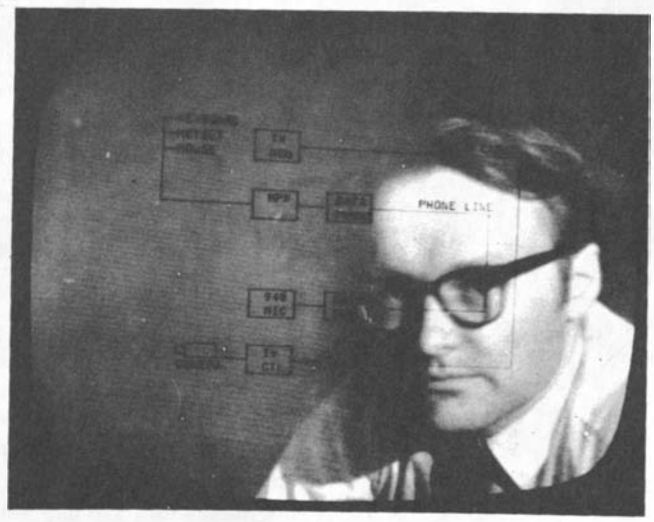


FIGURE 11—Television display obtained by mixing the video signal from a remote camera with that from the computer-generated display

devices at a preset interval (about 30 milliseconds) and writes it into a fixed location table in core.

5c4b1 Bits are added to information from the keyboards, keysets and mouse switches to indicate when a new character has been received or a switch has changed state since the last sample. If there is a new character or switch change, an interrupt is issued after the sample period.

5c4b2 The mouse coordinates are formatted as a beam-positioning instruction to the display generator. Provisions are made in the display controller for including an entry in the mouse-position table as a display buffer. This allows the mouse position to be continuously displayed without any attention from the CPU.

5c5 Special Operations

5c5a The box with this label in Figure 10 is at this time only a provision in the executive control for the addition of a high-speed device. We have tentative plans 'for adding special hardware here to provide operations not available in the 940 instruction set, such as character-string moves and string-pattern matching.

5c6 Low-Priority Devices

5c6a This controller accommodates three devices with relatively low data-transfer rates. At this time only the line printer is implemented, with provisions for adding an on-line typewriter (Dura), a plotter, and a terminal for the proposed ARPA computer network.

5c6a1 The line printer is a Potter Model HSP-3502 chain printer with 96 printing characters and a speed of about 230 lines per minute.

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