Appendix B: Computer techniques

Computer record handling software: Appendix B1

The ADMINS computer system: Appendix B2

Use of interactive graphic display techniques: Appendix B3

Online specification of possible graphics demonstration programs: Appendix B4
Appendix AB

Concept notation in documents

It has been stressed that this project does not require a complex notation system since each concept is represented by a single sequence number, plus an indication of the model number in question, if required. Nevertheless, since one object of this approach is to permit scholars to refer, with precision, to a particular concept in their papers, a standard method of indicating such a concept in print is required.

A similar problem arises in the natural sciences in distinguishing between different isotopes of the same atom (i.e., cases where slightly different versions of the same atom exist due to differences in atomic weight), where the same symbol does not distinguish between isotopes. The solution adopted is to indicate the atomic weight as a superscript to the standard symbol.

In the case of concepts, represented in print by the same word, one solution would be to use the sequence number of the concept as superscript to the word:

\[ \text{e.g. democracy} \text{ }^* \text{251} \text{ } \text{democracy} \text{ }^* \text{942} \]

To avoid confusion with bibliographical references, the number could perhaps be preceded by an asterisk.

Appendix B1

Computer Record Handling Software

In order to carry out the initial stages, very simple computer programs are quite sufficient. These may be used to accept records of new entities, produce entity lists, accept model coding, produce model lists of concept inter-relationships, accept authoritative terms and produce term thesauri.

At a later stage, which should however be kept in view in the design of the first stage program, it is possible to switch from sequentially ordered processing to processing networks of concepts. Sequential processing is highly convenient in computer terms in order to maximize the efficiency of the administrative aspects of record handling, sorting and list production. It does not however give direct access to networks of concepts (and other entities) indicating out from the central entity in which the user happens to be interested, nor does it allow him to switch rapidly from model to model for comparisons. In other words, for day to day operations resulting in the production of standard check lists and thesaurus updating, sequential processing is probably essential, whereas when the information stored is to be used via a direct access terminal or on a query by query basis, then some form of network processing is essential. It is a relatively simple matter to convert from one to the other provided this is planned for. The record handling could in fact be done (centrally) on a sequentially ordered file and institutions wanting copies could convert the file into a network order for direct access work within their institute.

Software already exists to handle "networks". A frequent application in the computer processing of Critical Path and PERT networks, these are networks over time and are less applicable than programs developed to handle parts listing and assembly and stock problems in manufacturing companies. One of these programs PLUTO (Parts Listing/Used-on Technique) developed by International Computers (UK) will be described as an illustration. (N.B. UNESCO (Paris) has installed an ICL computer which could use this software.)

PLUTO uses files record structures. That is, data about the entities that form structures and the relationships between them. Entities can be a person, an organization, a concept, a problem or any nameable thing. Many types of entity and relationship may be handled simultaneously. Information is held in the form of multiple inter-linked hierarchies of entities which greatly simplifies retrieval and presentation.

A distinction is made between master files (denoted by rectangles in Figure 1) which carry data about the entities within a structure and structure files (denoted by diamonds) which carry data about the relationship between entities. The files are linked together by cross-references to form a total information system or data base which can comprise a number of master and structure files. Information is retrieved under program control by following links from record to record and from file to file.
Each master file contains the entity records and each structure file contains the cross-references either between the entities in the same master file or to those in a second master file. The network of files may be added to or modified as new applications are envisaged.

In the management situations (for which the program was originally conceived) structure information is complex and affects many parts of an organization (see figure 1). The same is even more true of structure information in relation to concepts, theories, assumptions, methods, etc. The special diagrammatic notation (shown in figure 1) has been developed to facilitate thinking about the sort of interlinked system of files which is necessary in a given case. This notation is used in figure 2 to illustrate the power of this approach as a means of handling the different conceptual entities of interest to social science. Clearly this can only be an illustration for much thought is required to obtain the correct file design.

Special computer programs are used to explore at user request the structures created by complex file interlinkage of this kind. Searches down a hierarchy are termed explosions and searches up a hierarchy are termed implosions. These may be requested from any starting entity or file and can be governed by examination of qualifiers in link or entity records at each level encountered. It is this sort of feature which would be vital to obtaining full benefit from the graphics display (see Appendix D3).

It should be apparent that this, if not the software itself, is a very useful method of handling and exploring data on the relationship between concepts and other entities. In fact, the full power of the PLUTO software would not be required (although it has the advantage of being available) and it is possible to envisage a very much abridged version of it which would perform all the structural inter-linking required and be more easily related to the sequentially ordered file.

Computer programs relevant to this project have been produced for work on sociometric data. Programs are also mentioned in connection with citation indexing (Appendix D3), analysis of belief structures (Appendix C2), and personal construct theory (Appendix C3).

The ADMINS Computer System (*)

Work has been in progress for some years at the M.I.T. Center for International Studies on the development of very general systems for time shared computer data management. The key to the ADMINS data management concept is the maintenance of data content directories at the systems programming level normally reserved for computer operating systems and disk access control codes. The programming language allows the specification of relationships between named characteristics of entities and allows these relationships to be manipulated in several useful ways. Great stress is placed on using the computer to function as "office manager" in handling and checking incoming information to be inserted into the system.

An item of data is perceived to be a sequence of categories of information in n-adic relations applied to a specific entity. Relations may be:

a) monadic concerning one category (e.g. something exists);

b) dyadic concerning 2-categories (e.g. an entity has an attribute, an entity precedes another entity in time; an entity includes another entity, an entity receives information from another entity, etc.);

c) triadic concerning three categories (e.g. an entity sends a certain type of information to some other entity, an entity includes one entity which is related to a third entity, etc.);

d) etc. for four or more categories (**) N-adic data descriptions for social science propositional inventories are noted as being quite complicated e.g. 'violence' is 'power' over 'poorer' poor 'well-being'.

The ADMINS system makes use of a "calculus of relations" for stating the derivation of a new relation that draws on those already existing, and which yields a new relational record between particular entities. It is in the structuring of the programming language around the relational record and in achieving intimate interaction with many storage levels that this system differs from most procedure languages.

(*) This Appendix is based upon the following materials:
- Stuart D. McIntosh and D.M. Griffin. The requirements for a computer-based information system. M.I.T., Center for International Studies, 1968, (c/68-14C), 82 p.
- ADMINS implementation. (M.I.T., Center for International Studies), 1971.

(**) In the Mark III version of the system only dyadic relations were possible. The Mark V version will permit four or more category relations.
One of the forms of analysis possible, which is relevant to this project, is that of cross-reference analysis. The system is designed to handle sociometric data, citation relationships, thesaurus structures, and "maps". The two main features are measurement of flows and logical operations on the cross-reference relations.

In responding to problems, including the non-hierarchical classification schemes noted with respect to this project, a simple matrix structure is ruled out (e.g. categories are columns, rows are items, cells hold entries). An "extended" type of complex matrix is used as the basis for the data structure which has "both vertical and horizontal pointers scaffolding small arrays."

The system is designed to facilitate "model building", particularly with the use of social statistics. It would also appear that the multiple model technique suggested for this project could be easily handled together with some of the problems of conversion between models. The system is of course especially designed to permit many researchers, each at different computer terminals, to experiment simultaneously with and redefine their own sets of categories from a common data base. Such "experimental models" can either be deleted when completed or stored for further use. The aim is to provide an environment where the researcher is really interacting with his data, so that he can make effective intellectual decisions in response to substantive results from the terminal at the pace at which he is able intellectually to deal with his problem.

The ADMINS system is a very ambitious one. It is designed at a high level of generality to handle many applications which are of little interest to this project. But it is quite evident that this project could be run at quite a high level of sophistication on the ADMINS system -- even, possibly, to the point of permitting a modelling group (with each member at a terminal) to interact with one another, and the model on which they are working, as a "computerized committee".

It is also obvious that the "large scale ADMINS" approach is too sophisticated and too dependent on access to large third generation installations. A "limited ADMINS installation" is possible however. The early success of this project, however, depends very much on the ability to use much simpler installations for the filing and listing operations, whilst always permitting a switch to a more complex mode, possibly a subset of ADMINS, for network analysis, graphics display, etc., for specific research projects on the data base for which resources can be obtained. Much interesting research can however be undertaken using low cost programs, many of which already exist.

Use of Interactive Graphic Display Techniques.

Description.

The suggestion has been made (see Appendix C1) that structuring the relationship between theoretical entities (concepts, propositions, problems, etc) could best be accomplished using graph theory methods. There are three disadvantages to this approach:

- graph relationships are tiresome and time-consuming to draw (and are costly if budgeted as "art work")
- once drawn, there is a strong resistance to updating them (because of the previous point) and therefore they quickly become useless.
- when the graph is complex, multidimensional, and carries much information, it is difficult to draw satisfactorily in two dimensions. The mass of information cannot be filtered to highlight particular features unless yet another diagram is prepared.

These three difficulties can be overcome by making use of what is known as "interactive graphics" (*). This is basically a TV screen attached to a computer. The user sits at a keyboard in front of the screen and has at his disposal what is known as a light-pen (or some equivalent device) which allows him to point to elements of the network of concepts displayed on the screen and instruct the computer to manipulate them in useful ways. In other words the user can interact with the representation of the conceptual network using the full power of the computer to take care of the drudgery of:

- drawing in neat lines
- making amendments
- displaying only part of the network so that the user is not overloaded with "relevant" information

In effect the graphics device provides the user with a window or viewport onto the network of concepts. He can instruct the device to either display only certain parts of the total network; to take care of drawing in neat lines; or to display only the network which is of particular interest to him.

(*) This term is used widely to cover both the "alpha-screens", which can display letters and numbers on predeter- mined lines, and the "vector displays" with light-pen facility, which can also generate lines and curves. It is the latter device which is discussed here. See, for example:

- Interactive graphics in data processing. IBM Systems Journal, 7, 3 and 4, 1968, whole double issue.
1. move the window to give him, effectively, a view onto a different part of the network -- another conceptual domain
2. introduce magnification so that he can examine (or "zoom in on") some detailed sections of the network
3. introduce disjunction so that he can gain an overall view of the structure of the conceptual domain in which he is interested
4. introduce filters so that only certain types of relationships and entities are displayed -- either he can switch between models or he can impose restrictions on the relationships displayed within a model, i.e. he has a hierarchy of filters at his disposal
5. modify parts of the network displayed to him by inserting or deleting entities and relationships. Security codes can be arranged so that: (a) he can modify the display for his own immediate use without permanently affecting the basic store of data, (b) he can permanently modify features of the model for which he is a member of the responsible body, (c) and so on.
6. supply text labels to features of the network which are unfamiliar to him. If necessary he can split his viewpoint into two (or more) parts and have the parts of the network displayed in one (or more) parts.
7. track along the relationships between one entity and the next by moving the viewport to focus on each new entity. In this way the user moves through a representation of "semantic space" with each move, changing the constellation of entities displayed and bringing new entities and relationships into view.
8. move up or down levels of "ladders of abstraction". The user can demand that the computer track the display (see point 7) between levels of abstraction, moving from subsystem to system, at each move bringing into view the semantic context of the system displayed.
9. distinguish between entities and relationships on the basis of user-selected characteristics. The user can have the "relevant" (to him) entities displayed with more prominent symbols and the relevant relationships with heavier lines.
10. select an alternative form of presentation. Some users may prefer block diagram flow charts, others may prefer a matrix display, others may prefer Venn diagrams (or "Venn spheres") to illustrate the relationship between entities. These are all interconvertible (e.g. the Venn circles are computed taking each network node as a centre and giving a radius to include all the sub-branches of the network from that node.)
11. copy a particular display currently on the screen. A user may want to keep a personal record of parts of the network which are of interest to him. (He can either arrange for a dump onto a tape which can drive a graph plotter, a microfilm plotter, or copy onto a videocassette, or, in the future, obtain a direct photocopy.)
12. arrange for a simultaneous search through a coded microfilm to provide appropriate slide images or lengthy text (which can in turn be photocopied).
13. simulate a three-dimensional presentation of the network by introducing an extra coordinate axis.
14. rotate a three-dimensional structure (about the X or Y axis) in order to heighten the 3-D effect and obtain a better overall view "around" the structure.
15. simulate a four-dimensional presentation of the network by using various techniques for distinguishing entities and relationships (e.g. "flashing" relationships at frequencies corresponding to their importance in terms of the fourth dimension.)
16. change the speed at which the magnification from the viewpoint is modified as a particular structure is rotated.
17. simulate the consequences of various changes introduced by the user in terms of his conditions. This is particularly useful for cybernetic displays.
18. perform various topological analyses on particular parts of the network and display the results in a secondary viewport (e.g. the user might paint a light-pen at an entity and request its centrality or request an indication of the interconnectness of a particular domain delimited with the light pen.)

Graphs and Communication.

In order to understand the value of interactive computer graphics, a few basic principles of communication should be considered. Languages are used to convey thoughts. Languages may be gestural, verbal, written, notational, or graphic. The effectiveness of a language depends upon its ability to retain and transfer meaning and this in turn depends upon the complexity of the language. One can conceive of a spectrum of "language and medium" from primitive gestures through to sophisticated computer environments. At each point in the spectrum there are disadvantages and advantages for communication. An attempt has been made to list those out in Figures 1 and 2. These should be considered as very tentative schemes only. (*)

(*) Figure 1 was inspired by a similar tentative effort by Colin Cherry to relate communication equipment (radio, TV, press, etc.) to psycho-social qualities. See: World Communication, threat or promise? New York, Wiley, 1971, p. 53.
These figures suggest that most of the advantages of the early portions of the spectrum are combined together in the later problems where interactive graphics is used in various ways. The question in why do graphics help to convey more information than words. One reason is that as concepts become more complex they do not lend themselves to easy encapsulation verbally (cf. the classic example of the spiral staircase). The pressure is of course that many subtle invariants and relationships are ignored unless they can be represented in meaningful graphical form (*)

Some current interactive graphics uses include, for example, calculation and analysis of electronic circuits, design of aerodynamic shapes and other mechanical pieces, design of optical systems and plasma chambers, simulation of prototype aircraft and rocket flight, visualization of complex molecules in 3 dimensions, air traffic control, chemical plant control, factory design and space allocation, project control, primary, secondary and university education and educational simulations.

In every case above there is some notion of geometry and space, but the geometry is always the three-dimensional conventional space. There is no reason why "non-physical spaces" should not be displayed instead -- and this is the domain of topology. The argument has been developed by Joan Brown and Joan Lewis (**).

"Both geometry and topology deal with the notion of space, but geometry's preoccupation with shapes and measure is replaced in topology by more abstract, less restrictive ideas of the qualities of things... Being more abstract and less insistent on fine points such as size, topology gives a richer formalism to adopt as a tool for the contemplation of ideas... Concepts can be viewed as manifolds in the multidimensional varieties space spanned by the parameters describing the situation. If a correspondence is established that represents our incomplete knowledge by altitude functions, we can seek the terra incognitae, plateaus, enclaves of knowledge, cusps, peaks, and saddles by a conceptual 'photogrammetry'. Exploring the race of a new concept would be comparable to exploring the topography of the back of the moon. Commonly heard remarks such as "Now I'm beginning to get the picture" are perhaps an indication that these processes already play an unsuspected role in conceptualization.

Topology is thus a generalization of the idea of diagram. Traditional in teaching (grammatical diagrams of sentences, genealogies of kings, swirling models of solar systems), it extends easily to the machine. By sketching tentative three-dimensional perspectives on the screen and "rotating them on the tips of his fingers", one internalizes ideas nonverbally and acquires a sensation of spinning through structures of concepts much as a competent sailing through constellations of stars.

Such new ways of creating representations break ingrained thought patterns and force re-examination of preconceived notions. A mapping is a correspondence is an analogy. Teaching by analogy, always a fertile device, can be carried out beautifully by topological means... Topological techniques are useful at even the most advanced levels of scientific conceptualization...

Most traditionally educated humans are brought up with the belief that thinking is synonymous with verbal thinking. The time seems ripe to make a break with this limiting concept. Psychologists and educators are coming to the realization that man often has to get away from speech to think clearly. Scientists and creative artists have testified that to create they had to regress at times from the word to the picture, from verbal symbolism to visual symbolism.

Whether the concept seems spontaneous or belabored, there comes a point in its evolution when the mind transduces its accounting for the elements of information one by one, and begins to form an integrated impression. The whole is quantitatively differentiated from the sum of its parts to become conceptually quite different."

It is useful to introduce C.S. Peirce's term "iconic", namely "a diagram ought to be as iconic as possible, that is, it should represent (logical) relations by visible relations analogous to them."(**) Iconics is therefore connected with the degree to which features of the graphics display contribute towards (or

(*) See, for example, R. Bach, Graphical national patterns; a new approach to graphical presentation of statistics. London, Humphrey, 1958.

There is, however, a question of "iconicity for whom". Philip Hendren (*) cites a well-known survey by Anne Roe (The Making of the Scientist) in which a high correlation was found between (1) visual imagery and experimental inclination, (2) non-visual imagery and preference for theoretical science. Many theoretical scientists prefer not to use visual imagery -- which may explain their difficulty in communicating with other sectors of society. Don Fabun (***) points out in the following tractions. Jay Forrester (***) makes this same point with explain their difficulty in communicating with other sectors of society. Don Fabun (***) points out in the following that non-Americans may not find the display of concepts and their relations by network structures very meaningful (**). "Americans tend to see the edges of things and the location points of crossing lines, and attach importance to them. Thus our streets are normally laid out in a grid pattern and we identify places by their proximity to intersections. Europeans and Orientals, however, are inclined to attach importance to an area; thus a French street or avenue may change its name every few blocks; and houses in Japan may not have street numbers but be identified by name and area or the time at which they were built." The fundamental importance of interactive graphics, in whatever form, is its ability to facilitate understanding. Progress in understanding is made through the development of mental models or symbolic notations that permit a simple representation of a mass of complexities not previously understood. There is nothing new in the use of models to represent psycho-social abstractions. Jay Forrester (***) makes this same point with respect to social systems, stating: "Every person in his private life and in his community life uses models for decision making. The mental image of the world around one, carried in each individual's head, is a model. One does not have a family, a business, a city, a government, or a country in his head. He has only selected concepts and relationships which he uses to represent the real system. The human mind selects a few perceptions, which may be right or wrong, and uses them as a description of the world around us. On the basis of these assumptions, a person estimates the system behavior that he believes is implied....The human mind is excellent in its ability to observe elementary forces and actions of which a system is composed. The human mind is effective in identifying the structure into which separate scraps of information can be fitted."


(***) Although, in the case of France, there has been a marked increase in attention to "communication networks" and "organizational networks" But when the pieces of the system have been assembled, the mind is nearly useless for anticipating the dynamic behavior that the system implies. Here the computer is ideal. It will trace the interactions of any specified set of relationships without doubt or error. The mental model is fuzzy. It is incomplete. It is irreproducable. Furthermore, even within one individual, the mental model changes with time and with the flow of conversation. The human mind assumes a few relationships to fit the context of a discussion. As the subject shifts, so does the model. Even as a single topic is being discussed, each participant in a conversation is using a different mental model through which to interpret the subject. And it is not surprising that conscious loads to actions which produce unintended results, fundamental assumptions differ but are never brought out into the open.

These structured models have to be applied to any serially ordered data in card files, computer printout or reference books to make sense of that data. Is there any reason why these invisible structural models should not be made visible to clarify differences and build a more comprehensive visible model? The greater the complexity, however, the more difficult it is to use mental models. For example, in discussing his examination of an electronic circuit diagram, Ivan Sutherland writes (**) "Unfortunately, my abstract model tends to fade out when I get a circuit that is a little bit too complex. I can't remember what is happening in one place long enough to see what is going to happen somewhere else. My model evaporates. If I could somehow represent that abstract model in the computer to see a circuit in animation, my abstraction wouldn't evaporate. I could take the vague notion that "fades out at the edges" and solidify it. I could analyze bigger circuits. In all fields there are such abstractions. We haven't yet made any use of the computer's capability to "firm up" these abstractions. The scientist of today is limited by his pencil and paper and mind. He can draw abstractions, or he can think about them. If he draws them, they will be static, and if he just visualizes them they won't have very good mathematical properties and will fade out. With a computer, we could give him a great deal more. We could give him drawings that move, drawings in three or four dimensions which he can rotate, and drawings with great mathematical accuracy. We could let his work with them in a way that he has never been able to do before. I think that really big gains in the substantive scientific areas are going to come when somebody invents new abstractions which can only be represented in computer graphical form."
Graphics and education.

A visual display unit linked to a computer has considerable advantages as a technique for the communication of new concepts (1), since the multiplicity of conceptual frameworks increases in complexity. New techniques must be sought to simplify education concerning them. The problems posed by the time currently required to communicate even a superficial knowledge of the existing frameworks, and the difficulty of building up an integrated picture of their complexity, suggest that a visual display unit with computer mass memory support may have many possibilities.

An important reason for using this approach is the tendency to consider the recognized complexity of the system of disciplines as a whole, viewed in terms of the present unified trend. Normal instruction methods, in the case of such complexity, would have to cross so many discipline boundaries that they necessitate concentration on one particular feature of the system at the expense of the others, and any integrated picture of the whole.

An important possibility in building understanding is the ability to manipulate part of a multidimensional network, via the visual display unit, so as to portray the system of conceptual frameworks from an origin chosen anywhere within the network. Thus a concept (or even organization) known and understood by a particular user, may be used as visual origin and all other concepts (or organizations) displayed in terms of their relationships to it — according to a variety of models helpful to different personalities, different types of concepts, and different learning rate styles. Certain terms can be reduced in visual importance, whereas "nearby" concepts of relatively little "absolute" importance can be made of greater significance (approximating the recognition normally accorded them by the user).

The newcomer to a conceptual framework has a known system base from which to start his exploration of the neighboring systems which interact with it. In a programmed learning mode, he is able to understand how his known systems are "nested" within any larger system. He can work from his base system by reorganizing the restructuring of the display in terms of other systems beyond him as he builds up knowledge of, and "feel" for, those originally conceptually distant from his starting point. Text can be displayed concerning the new system, interaction or perspective, before any "jump" is made. In this way, he can progress toward the more fundamental levels of any conceptual framework or into other areas of detail.

A valuable feature of an interactive system is the possibility given to a student of simulating the result on the system of "wiping out" a single sub-system or class of systems which he believes to be of little value. Of greatest importance, the student can work out and locate which conceptual frameworks (or organizations) offer the best avenue of approach for him, or, alternatively, precisely in what way he must initiate ([1] See, for example, Douglas Engelbart. Augmenting Human Intellect. A Conceptual Framework. Stanford Research Institute, 1962.

some new activity to achieve such a measure of satisfaction. By exploring the network the student is, in a sense, engaged in a parallel exploration of "semantic space." This is of some value according to some perspectives.

Just as world unity is a long way off in organizational terms, and yet a multidimensional network of organizations can be "held" in computer memory for exploration, so unification of knowledge can be simulated by holding and linking concepts in different frameworks between which links have been suggested during the course of research. In both cases the dynamic collection of data stands as a symbol of the goal. Built up empirically, the systems must be exploited by research workers and students alike in order to improve their concepts of the more general systems. The details of interactions can be provided in considerable amounts, but the problem for both is to build up more integrative concepts.

The process of interaction between display and person is really one in which the display is used as a crutch until the mind can hold a more integrative concept. The mind is the most potent display device. The problem is how to "jump" it (in larger terms) to an optimum operating frequency with the aid of interactive displays. It may be possible to use the graphics display unit as a focusing device when "hunting" intuitively for a purely conceptual solution. At a certain point the mental display abilities can be "launched" from the sophisticated back-up or standing platform provided by the display unit. If necessary the display can be improved prior to a "relaunch." It is with this sort of approach that the speed of convergence on unifying concepts can be increased.

In order to improve the rate of generation of more integrative concepts, it may be valuable to examine the validity of some of the following assumptions:

1. "Highly general and integrative concepts can be adequately communicated through symbol on paper." It may be that the more abstract concepts required cannot be adequately grounded in symbols on paper (that is without merely using the symbol as an ideogram). It is possible to conceive of an equilibrium diagram which would indicate in what communication media, or combination of media, a given concept could be "held," and in which it was metastable or unstable.

2. "Once a concept is "discovered," we ourselves can remember it and hold it effectively in our own minds." To hold a concept however, requires a constant stream of appropriate environmental stimuli to reinforce it. This is particularly the case if the concept is highly sophisticated and "delicate" (even if, and perhaps particularly if, very simple). Conventional media may be associated with a characteristic reinforcement rate which may be too low to permit certain concepts to be held for long.
It may be that sufficiently rapid reinforcement can only be provided with interactive graphics devices. One author emphasizes their importance for maintaining "thinking momentum". We may have to keep using such devices to aid us in focusing our thinking to recover the concept "which we have already discovered", until we have built up an attitude which permits us to pick out sufficient reinforcing evidence from the environment unaided.

3. "Highly integrative concepts can be developed by interaction between specialists using conventional communication and storage media and traditional academic interaction procedures." It may be that for purely technical reasons (despite the possible wishes of the people concerned) interaction may not permit the generation of unifying concepts of great generality. Interactive devices create a man-machine environment with properties which differ from those of the traditional concept-generating environments. Skillfully used it may be possible to ensure the interaction of specialists, manipulating related concepts through interactive devices, in such a way that progressive convergence towards increasingly more general concepts is built into the interaction process.

4. "The discovery of general integrative concepts crossing discipline boundaries would of itself lead to solutions to many problems of modern society. It may be that the place allocated to such concepts in modern society is far from adequate, that they may be "contained" in a position in culture space in such a way that they are prevented from having any marked effect on society -- even those which have not yet been developed. This is a reason for studying the system in which such concepts are developed. It may be a question of the speed with which the concept can be got over (and "anchored") relative to that of the reaction or compensating social mechanisms coming into play to counteract any implied changes.

5. "Old or primitive unifying concepts are irrelevant in the 20th century." It may be the case that for some groups of personality types certain "enchanted" integrative concepts are the most useful in terms of the process to which they are exposed in the light of their conceptual apparatus. Similarly, it may not necessarily be true that the learning path for some students and schoolchildren is optimized if the latest theories are stressed at the expense of their historical predecessors.

A major function of systems thinking could be to determine the inter-relationship between historical viewpoints -- particularly since many of them are still held in some parts of the world system. With appropriate techniques a student could locate the unifying concepts most in sympathy with his current understanding of his environment. Related techniques could then be used to expose him as rapidly as possible to the evidence which outdates his view. The system framework could then speed his conceptually through the succession of systems perspectives up to the present. Should he "stick" at any point, then it would be in a context which for him possesses lower entropy than that which he perceives in later points. He thus sticks at the point which most reinforces his concept of himself as a whole person in a unified conceptual environment.

Further graphic possibilities

1. It is technically feasible to copy a displayed conceptual network onto a videocassette. These can be recopies for distribution and are played back over normal television sets. This gives a non-interactive, low-cost access to the same information. This technique has considerable potential for education, briefings, and research.

2. Microfilm plotters are currently used to copy the contents of a display directly onto microfilm. They have the advantage of being extremely fast. In addition, unlike current display screens, they can handle very complicated diagrams with thousands of lines and symbols. The microfilm can then be processed automatically and mounted on aperture cards or enlarged to hard copy.

This gives an excellent method of building up low cost "hardcopies" of the conceptual remains in which one is interested. Alternatively, the film itself can be used for preparing demonstration movies. It would also be technically feasible to arrange for the microfilm frames to be coded under computer control so that the film can be optically scanned to permit later display of a user-specified frame (as on the Kodak Miracode system).

3. Colour graphics units are in use (some up to 150 x 150 cm in size). These permit entities and relationships to be coded so that even more information can be held in one image. The use of colour is however more applicable to diagrams of areas, such as might be used with a Venn diagram, rather than a network presentation. (*)

4. It is possible to plot any diagram using drum (simple graphs) or flatbed (complex diagrams) plotters. The latter occur in sizes up to 150 x 1000 cm.

5. Helmets fitted with display screens for each eye have been developed (to train pilots in landing complex aircraft). The wearer is provided with a perspective on displayed structures which changes.

as he moves his head(*). It could be used to fill a
semantic space with structures through which the individ-
ual could move i.e. he is completely surrounded by
computer generated structures (with which he could
interact).

A number (up to hundreds) of display terminals may use
a common data base. This permits users to interact with,
and explore, each other's "semantic space" in a very
intimate manner (**). A team can work together on the
additions to some complex structure - users from different
disciplines each contributing elements and linkages. This
technique is currently used in the allocation of structures
in three-dimensional space in the design of complex factor-
ies, where ventilation, electrical, piping, chemical, and
many other engineers have to interlink the structures with
which they are concerned (**). 

A number (up to hundreds) of display terminals may use
a common data base. This permits users to interact with,
and explore, each other's "semantic space" in a very
intimate manner (**). A team can work together on the
additions to some complex structure - users from different
disciplines each contributing elements and linkages. This
technique is currently used in the allocation of structures
in three-dimensional space in the design of complex factor-
ies, where ventilation, electrical, piping, chemical, and
many other engineers have to interlink the structures with
which they are concerned (**).

Very suggestive of new approaches to experimenting with
concept, problem or organizational structures in the work
underway using graphics to detect all the different possible
ways of constructing a specified chemical structure, given
a set of specified possible sub-units and restrictions on
the way they can be combined (****). One possible appli-
cation in this context, is the charting of possible
sequences of concepts leading to the understanding of
some more general concepts. This would be of interest in
programmed learning work.

There is much parallel interest in interactive graphics
for art. A definite convergence of interest in the handling
of structures and relations is now evident (****). Hopefully this will lead to the development of even more
sensitive interactive devices which could be used to
contain and reflect even subtler concepts - a sort of

(*) Ivan Sutherland. Computer displays. Scientific American,
222, June 1970, p. 56-81

(**) Nilo Lundgren, Toward the decentralized intellectual
workshop, Innovation, Technology Communication, 1971,
24, p. 50-60 (reporting on D. Englund's work at Stanford).

(*** H.J. Gentner, Interactive computer graphics. Computer and

(****) E.J. Corey and W. Todd Wipke. Computer-assisted design of
complex organic syntheses. Science, 166, 16 October 1969,
p. 178-192 (see also the third footnote on next page)

(*****)) See: Papers on computer graphic art (Int: Computer Graphics 70;
Bruno University, 1970, 3 vols.); papers on art and decision-
making information (In: H.S. Brinkers (Ed.). Decision-
making - creativity, judgement and systems in press).

dynamic interactive ideograph (*).

Perhaps it will only be such devices which will ensure
the adequate utilization of theoretical knowledge. As
Harold Lasswell points out:

"Why do we put so much emphasis on audio-visual
means of portraying goal, trend, condition, pro-
duction, and alternative? Partly because so
many valuable participants in decision-making
have dramatizing imaginations ... They are not
encumbered of numbers or of analytic abstractions.
They are at their best in deliberations that
encourage contextuality by a varied repertory of
means, and where an immediate sense of time,
space, and figure is retained." (**)

(*) Some interesting theoretical and technical suggestions towards
such a device have been made by Gordon Hude (a device for
generating a universal binary metalanguage for computer
operation. London, Prov.Oat.Spec. 69.212;also other unpub-
dlished documents from Gordon Hude, 11 The Close, Dunmoe,
Essex CM6 1EW, England.)

(**) Harold D. Lasswell. The transition to more sophisticated
procedures. In: Davis B. Bobrow and J.L. Schwartz (Ed.)
Computers and the Policy-making Community; applications to

(*** For suggestive uses of computers to construct potential fields
around interacting entities (in this case atoms), see:
Arnold C. Wahl. Chemistry by computer. Scientific American,
April 1970, p. 54-70.
Arnold C. Wahl, et.al. BISON: a new instrument for the exper-
imentalist. International Journal of Quantum Chemistry, Sympo-
A.C. Wahl. Chemistry from computers. Argonne National Labora-
<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gesture</td>
<td>direct and to the point; dramatic impact</td>
<td>no abstraction possible</td>
</tr>
<tr>
<td>Speech</td>
<td>personalized, subtle, poetic, imageful, analogy-full, adjusted to audience</td>
<td>no permanent record, meanings and novels shift from phrase to phrase</td>
</tr>
<tr>
<td>Writing</td>
<td>permanent record; words weighed and compared in context; document forms an intelligible whole</td>
<td>meaning of words undefined, or differ between documents; definitions become concretized and language dependent; complexity of abstractions limited by syntax of language; problem of jargon</td>
</tr>
<tr>
<td>Image</td>
<td>provides context in physical terms, involving highly complex, high information content, high interrelationship</td>
<td>superficial and unstructured</td>
</tr>
<tr>
<td>Maths</td>
<td>handles very complex abstractions and relations and a multiplicity of dimensions</td>
<td>loss of intuitive appreciation of the concepts involved; impracticable without length; initiation; system of notation becomes more complex than the concepts describable; impractical</td>
</tr>
<tr>
<td>Diagram</td>
<td>structured to make a specific point</td>
<td>over-simplification; exaggeration of some features at expense of others; process only displayed statically</td>
</tr>
<tr>
<td>Artistic</td>
<td>complex, new and unpredictable relationships</td>
<td>experience primarily incommunicable</td>
</tr>
<tr>
<td>mobiles</td>
<td></td>
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</tr>
<tr>
<td>Diagram</td>
<td>portrays all detectable interrelationships in precise manner, panoramic view of system</td>
<td>visually complex to the point of impenetrability; processes still conveyed statically; difficult to modify</td>
</tr>
</tbody>
</table>

### Method Advantages Disadvantages

- **Interactive precise messages; responsive; contents can be (alphacope) oriented to suit user**
  - no structured overview
  - bounded by language code of program; processes conveyed as a sequence of isolated messages (or as a game experience)

- **Psychodynamic very subtle and complex environment; imagery and relationships; process oriented; integration of visual and audio; psychologically involving**
  - no scientific content
  - no significant invariants; experience primarily incommunicable

- **Interactive greater user selectivity; graphics (structured image) and control on content; complex abstractions held on display; processes displayed as flows; dynamic; enhanced creativity; 2D dimensions**
  - highly structured without the subtle relationships characteristic of art; user still centred "outside" the structure "looking in"

- **Computer graphics art**
  - generation of new and unpredictable dynamic imagery
  - no scientific or "real world" predictive value

- **Interactive images working simultaneously; highly on their ideas; access to each other; "semantic space"; interactive thinking**
  - fundamental distinction remains between artistic use of the display or surface volume and scientific interest in structure and data base; still only reflects a portion of the subtleties of all invariants and processes known to psychologists, diplomats, etc.

- **Interactive high information content; visually more intriguing; closer to artistic media; more powerful presentation of processes**

- **Interactive user psychologically graphic (3D - holotrack)**
  - central within the structure
  - still only a scaffolding for disciplined thought

- **Interactive continuous graduation and interaction between scientifically structured and aesthetically structured display; enhanced creativity; reflects subtleties of psychologists, diplomats, etc., able to convert to and from a "field theory" presentation of structures**
Figure 2: Cross-comparison of different methods of communicating concepts

<table>
<thead>
<tr>
<th>Method</th>
<th>Gesture</th>
<th>Speech</th>
<th>Writing</th>
<th>Image</th>
<th>Math</th>
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<th>Multi-terminal</th>
<th>Colour Graphic</th>
<th>3D-Helmet</th>
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| Interactive graphics | M       | M      | H      | M     | M    | M      | H       | H        | H          | H           | M              | M            | M             | M             | M         | M         |
| Graphics art       | M       | M      | N      | M     | H    | M      | M       | H        | H          | H           | H              | H            | H             | H             | L         | L         |
| Multi-terminal     | M       | M      | H      | M     | H    | M      | M       | M        | M          | H           | M              | M            | M             | M             | M         | M         |
| Colour Graphic     | M       | M      | H      | M     | H    | M      | M       | M        | M          | H           | M              | M            | M             | M             | M         | M         |
| 3D-Helmet          | M       | M      | H      | M     | H    | M      | M       | M        | M          | H           | M              | M            | M             | M             | M         | M         |
| Ideograph          | M       | H      | H      | H     | M    | H      | H       | H        | H          | H           | M              | M            | M             | M             | M         | M         |

Contd. Figure 2
Outline Specification of Possible Graphics Demonstration Programs

A computer program is required, for use at an interactive graphics display console, which would allow an uninstructed person to sit down at the console and "associate into" the screen on the basis of:

(i) firstly of a field of knowledge (organizations, problems, etc.) well known to him (i.e. of which he has a "model" in his head)

(ii) and, later, of the structures already built up by him on the screen which can be amended or completed.

From computer data processing point of view, it is obviously immaterial what meaning the user attaches to the entities and the relationships which he inserts - in each case, the meaning is represented by a user selected label. There is therefore a clear advantage, in designing the demonstration program, to make it of use for entities as diverse as:

(i) concepts and theoretical formulations. It can then be used with groups interested in relationships between concepts - in knowledge structure.

(ii) organizations. It can then be used with groups interested in inter-organizational systems and in social systems in general.

(iii) problems. It can then be used with groups interested in relationships between problems e.g. in environmental systems.

(iv) personal beliefs. Though less relevant to the immediate concern of this report, the program could also be of great use to psychologists working on the visualization of an individual's belief system i.e. a medium into which the subject can subjectively associate.

For example, in the organization case, the programs are to be used to illustrate the importance of visual display units as a means of clarifying the relationships between complex groups of organizations. Examples of such groups are (c) networks of international agencies, such as the United Nations, where an unknown number of commissions and sub-commissions whose interconnection is currently impossible to handle on conventional media; (b) networks of governmental agencies within any given country, where the same situation applies, particularly with regard to the difficulty of making evident cases of overlapping between lower levels of different ministries; (c) networks of business corporations and holding companies which take much study to unravel but which even then are difficult to make comprehensible.

The programs will therefore draw the attention to a new management tool for examining data bank held information to determine activities of distant departments of an organizational network and the extent of their interaction. Specifically in this way such networks can be "explored" from the known to the unknown. Where conventional retrieval systems require a key to be specific, the proposed system would draw onto the screen the required item plus any other organizational units which had been directly or indirectly related to it, thus causing management's attention to unexpected links. This facility becomes increasingly important as organization groups become more complex.

Exactly the same technique can be used in library systems to explore the manner in which concepts are linked in indexing systems and thus detect new key areas under which relevant material may be held. To date, no solution has been found to the problem of showing the interrelationship of organizational, activity, geographical or conceptual entities. The visual display unit could prove to be the significant breakthrough in this area.

Demonstration program A

Specific features required are:

(i) insert entity by pointing to a position on the screen where it is to be placed.

(ii) label entity with mnemonic code which can be called onto the screen against the node. Insert explanatory paragraph or phrase of text which can be called onto a window on the screen by pointing at the node in question.

(iii) means of coding entity type so that entities of a given type can be called onto the screen as needed.

It should be possible to type code entities at two levels. Firstly, a "major" range of types should be selectable (e.g. A, B, C, etc. where each refers to a different coding dimension, such that A might be "organization category" and B "organization budget"). Within each major range, it should be possible to provide detailed-coding.

(i) Range A = "organization category"
   - A1 = governmental
   - A2 = business
   - A3 = academic
   - A4 = etc.

(ii) Range B = "budget"
   - B1 = "$1,000,000"
   - B2 = "$10,000,000"
   - B3 = "$100,000,000"
   - B4 = etc.

Diachronic change can be shown by arranging that one of the type ranges is a time period i.e.

- C1 = "1900 - 1910"
- C2 = "1910 - 1920"
- C3 = "1920 - 1930"
- C4 = etc.

Thus by simply pushing the "type" button, the user advances a period and has the new entities and new links added.

(iv) insert link (as per (i))
(v) insert link label (as per (ii))
(vi) insert link type code (as per (iii))
(vii) Some means of building up the structure in a simulated 3-dimensional coordinate system
- Either by rotating the structure and adding elements to the 2-dimensional plane so exposed
- Or by using a program routine to "rearrange" the network of entities periodically so that they are clustered such that certain parts of the display are not overly crowded.

(viii) Converting to the distance matrix of which the network is a representation. (It may be possible to avoid computing this by simply editing the data structure held in memory.)

(ix) "Redefine" the display so that sub-network making up any node in the main network may also be inserted.

(x) "Integration calculation" by computing the inter-connections of the partial network constituted by entities specified with a light-pen.

Demonstration program B

Data input could be from tape onto disc or perhaps directly into memory. Format is:

<table>
<thead>
<tr>
<th>reference number</th>
<th>record type</th>
<th>cross-reference</th>
<th>geographic code</th>
<th>numeric value</th>
<th>descriptor</th>
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<tbody>
<tr>
<td>(entity 1)</td>
<td>94301</td>
<td>0</td>
<td>U.K.</td>
<td>A B C D E F G</td>
<td>Comm. on.</td>
</tr>
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<td>etc.</td>
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<td></td>
<td></td>
<td>3219</td>
<td>U.S.A.</td>
<td>S T U V W X Y</td>
<td>etc.</td>
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<td>etc.</td>
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<td>etc.</td>
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<td>India</td>
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<td>S T U V W X Y</td>
<td>etc.</td>
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To be effective the number of entities displayable and the number of their inter-connections (i.e. the P, Q, R type records) should be large enough to show the value of the visual display unit as a means of ordering a complex situation for convenient examination. Clearly they should not all be on the screen at the same time, but it should be possible to draw them onto the screen from memory.

Program B requirements

1. Show menu of descriptors A to G on screen. User picks three to be used as the three coordinate dimensions and specifies the range of values to be covered. Program then displays all entities on the screen according to these coordinates, giving reference numbers as identification. (This bears some resemblance to the 101100 molecular rotation display.)

Descriptive A to G may be verbally described (i.e. in presenting the program) as representing such means of describing an organization as: size of budget, size of personnel, assets, type (governmental, business, academic, etc.)

2. Show menu of link types P, Q and R of which one may be chosen by user. Program now draws in links between entities displayed for the type chosen (i.e. from reference to cross-reference in each case for all P types, for example). Again this bears some resemblance to the molecular rotation program.

3. User may be able to manipulate the structure shown to clarify "hidden features." Program must permit rotation of the structure, increase in size and reduction in size. Parts going outside the screen must be chopped off. (Again this bears resemblance to the molecular rotation program.)

This procedure allows the user to view how different organizational units are linked in terms of, for example: P, where P is interpreted as meaning a flow of funds; Q, where Q is interpreted as meaning a flow of decisions; or R, where R is interpreted as meaning a flow of information. Other such flows could be envisaged, different flows being more significant for the four types of body likely to be interested in this application. Thus commercial organizations are likely to be more interested in share allocation voting power, and the manner in which funds are allocated. Others will be interested in the flow of information, memberships, etc.

4. The link display can now be refined by displaying a menu of numeric value descriptors S to Y. Users may select one of these. This causes the links to be re-displayed in terms of their significance as given by the numeric values. The techniques may be envisaged. The links may be increased in brightness according to the values given in each record in each case. Or the links may be blinked according to a frequency governed by the value. A third possibility exists that the links might be made dotted.

This approach enables the user to determine which are the active or important links according to particular criteria which he defines. Clearly it would be of benefit to him to alternate fairly rapidly between different descriptors S to Y, and even between different link types P to R. This might show how the funds flow was related to the decision or information flow pattern, for example.

5. As a refinement on point 1, the entities could be displayed such that the values of one of the descriptors A to G governed the number of rings (concentric) around the point, thus giving a size indication of importance.

6. One argument against this type of display for management purposes is that it lacks descriptive detail. There is however no reason why the light-pen cannot be used to indicate nodes or links on which textual comment is required. This can be retrieved and displayed on the whole screen or in an appropriate window.
7. The user should be able to work with the display to explore parts of the network not held on the screen:
   (a) point to given node, program re-displays with that node at centre/origin, drawing in and pushing out parts of the network.
   This is used to focus on an organization previously on the periphery of the display and to determine its contacts.
   (b) Nodes as concepts or organizations, may be envisaged as having other nodes (i.e. sub-concepts or subsidiary organizations) nested within them. Such nesting could be made evident by instructing the program to "explore" a given node identified by the light-pen. This new information fills the whole screen.
   (c) The converse of (b) may also be envisaged. The whole of a display may be considered as an organizational or concept system which can be considered as a node. The display may therefore be "imploded" (using a key or part of the menu) to re-display the network in terms of that node taken as the origin.

Techniques (b) and (c) can be used as means of exploring organizational hierarchies in a "vertical" direction, whilst permitting the program to remove all information from a higher or lower level of the hierarchy. Technique (a) permits horizontal exploration of hierarchies and organizational networks.

8. Visual examination of a network is not sufficient. The eye cannot always focus on or detect significant features of the network. Programs could be envisaged to perform the following:
   (a) Examine a displayed network and then display a list of nodes, ranked in order of the number of links to them (i.e. most linked to organization first). This is a means of focussing on key organizations in a network. A very practical follow up is to then select those titles for which name and address lists are required on the terminal. This permits rapid transfer from deciding that a given organization is in a key position and making arrangements to write or send something to it.
   (b) Similarly, a list out could be envisaged of organizations in terms of the extent to which they function as "bottle-neck" for flows through them.
   (c) If some of the descriptors are considered to cover information transfer and processing rates at and between nodes, then node pairs can be ranked in terms of the time taken for information to travel along the most direct route between them.

These techniques are extremely useful for the analysis of organizational networks as information transfer systems, prior to recommending the creation of a new organizational unit to improve the performance of the system. Much time and money is currently spent on this in a very ad hoc manner. A future development might for example permit the user to add in an organizational unit at a particular point in the network, defining its characteristics, and then recompute the characteristics of the system.

9. Additional possibilities in summary are
   (a) listing of "opposite numbers" in organizational hierarchies i.e. who is concerned with a given subject in another part of the network.
   (b) listing of projects undertaken by an organization (held as text), or products sold by an organization
   (c) development of techniques to compute cases of overlap and duplication
   (d) use of such displays in educational environment to permit exploration of national or international organizational structures in conjunction with a programmed learning type environment where a particular step in the exploration was not understood.
   (e) linking use of the system to EVR for educational purposes.