Appendix C: Methods of representation and analysis

Representation of concept networks using graph theory: Appendix C1

Relationship to artificial intelligence projects: Appendix C2

Relationship to personal construct evaluation techniques: Appendix C3

Semantic matrices: Appendix C4

Use of input/output analysis: Appendix C5

Representation of Concept Networks using Graph Theory

This project is concerned with the collection of entities and the indication of relationships, if any, between those entities. Expressed in these general terms, the techniques of graph theory may be used in this project. Graph theory is concerned with the "arcs" (links or relationships) between "nodes" (entities) and the various structural properties of the network so constituted.

It can be of great assistance in dealing with a broad range of combinatorial problems which occur in various economic, sociological or technological fields. It is, perhaps, that aspect of the theory of sets which can produce the most fruitful results not only for the pure mathematician, the engineer, and the organizer, but also for the biologist, the psychologist, the sociologist and many others. Graphs can be used to represent structures such as: a network of roads, an electrical circuit, communication in a group, a complex chemical molecule, circulation of documents in an organization, kinship structures, etc. (*)

Its use in connection with relations between more abstract social entities such as organizations and nations is much less frequent (**).

(*) A. Kaufman. Graphs, dynamic programming and finite games. N.Y., Academic, 1967.

Claude Berge. Theorie des graphes et ses applications. Paris, Dunod, 1958, 277 p.

(**) Claude Flament. Theorie des graphes et structures sociales. Paris, Mouton, 1965 (English edition, Prentice-Hall)

J. Clyde Mitchell (Ed.). Social Networks in Urban Situations. Manchester U.P., 1969

Norman Schofield. A topological model of international relations. (Papter presented to Piece Research International meeting, London, 1971).

George M. Beal et al. System linkages among women's organizations. Department of Sociology and Anthropology, Iowa State University, 1967.

Robert O. Anderson. A sociometric approach to the analysis of inter-organizational relationships. Institute for Community Development and Services, Michigan State University, 1969

D. Cartwright. The potential contributions of graph theory to organization theory. In: M. Haire (Ed.) Modern Organization Theory, Wiley, 1959.

Its use for handling psycho-social abstractions appears to be even rarer (*).

The image of a 'network or web of ideas' to represent a complex set of inter-relationships in a sphere of knowledge, and particularly culture, is a fairly familiar one (**). This use of 'network', however, is purely metaphorical and is very different from the notion of a network of concepts as a specific set of linkages among a defined set of concepts, with the additional property that the characteristics of these linkages as a whole may be used to interpret the semantic significance of the concepts involved.

Some features of concept networks

Points 1 to 3 below are concerned with the shape of the network, 4 to 8 with interactions within the network.

1. Centrality. A measure (in topological not quantitative terms) of the extent to which a given theoretical entity (e.g. a concept) is directly or indirectly "related" via links to other entities i.e. the extent to which it is "distant" from another entity. One can speak of a "key" concept or of a concept being "central" to the concerns of a particular discipline. It may also be considered a measure of the degree of "isolation" of the entity. A systematic analysis of the centrality of theoretical entities could indicate where new concepts are necessary to bridge conceptual gaps and link isolated domains.

(*) Belief systems (see Appendix C2), Social science data management (see Appendix B2). In the field of documentation a thesaurus may be represented "graphically" but more for the visual presentation facility (see Appendix D3) than for any graph theoretic possibilities. For example: the "genetic maps" of the U.S. Armed Services Technical Information Agency (ASTIA), the concentric circle diagram of the Technische Dokumentatie - en Informatie Centrum voor de Krijgsmacht (TDCK, The Hague), the arrow diagrams used by EURATOM and the Bureau d'etudes van Dijk in Brussels (see Figure 1). See also the computer established "association maps" of Lauren B. Doyle. (Indexing and abstracting by association. American Documentation, October, 1962). See also: Kurt Lewin. The Principles of Topological Psychology. N.Y., McGraw-Hill, 1936; C. Zierer. The theory of graphs in linguistics. The Hague, Mouton, 1970, 62 p.; R. Quillan. Semantic memory. In: M. Minsky (Ed.). Semantic I formation Processing. Cambridge, M.I.T., 1968, p. 225-270; R.B. Banerji. A language for the description of concepts. Unpublished paper, System Research Center, Case Institute of Technology, 1964.

(**) For example, Ruth N. Anshen. "What World Perspectives means". Epilogue to Lewis Mumford. The Transformations of Man. N.Y. Collies 1962.

> "Man's situation is new and his response must be new. For the nature of man is knowable in many different ways and all of these paths of knowledge are interconnectable and some are interconnected, like a great network, a great network of people, between ideas, between systems of knowledge, a rationalized kind of structure which is human culture and human society."

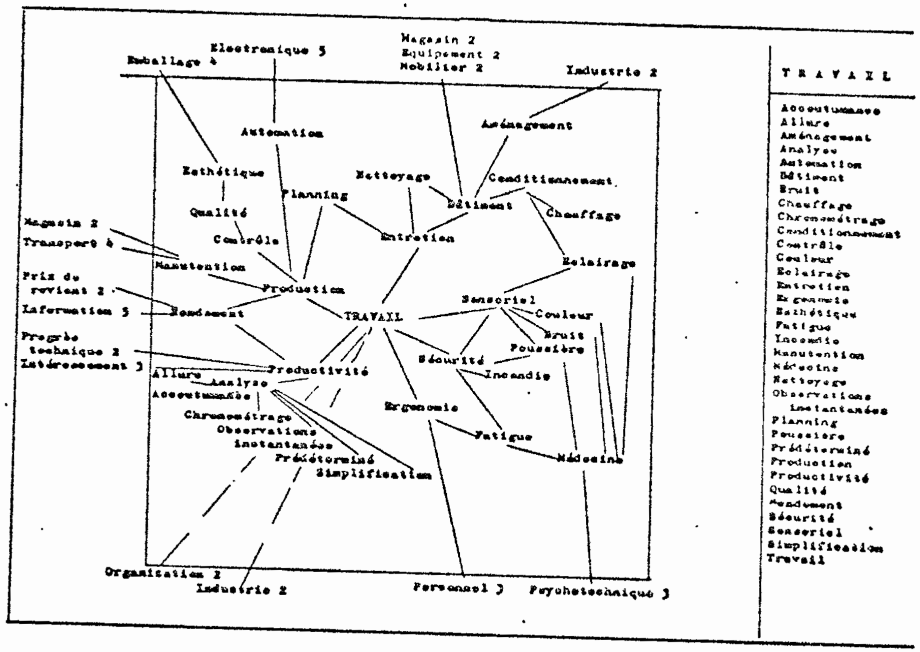

Figure 1. Arrow diagram used in special indexes

2. Coherence. A measure of the degree of "interconnectedness" or "density" of a group of concepts. This may be considered as the degree to which a system of concepts is "complete". Differences in density would reflect the tendency for more highly coherent concept systems to appear more self-reinforcing in comparison to less organized parts of the network. In some respects this is an indication of the degree of "development" of a group of concepts.

3. Range. Some concepts are directly related to many other concepts, others to very few. The range of a concept is a measure of the number of other entities to which it is directly related.

Range could be considered an indication of the "vulnerability" of a concept, to the extent that a high range concept would be less vulnerable to attack than a low range concept, since it has more bonds anchoring it to its semantic environment. High range points are therefore either key points in resistance to conceptual change or else key points in terms of which orderly change can be introduced.

4. Content. The "content" of a relationship between entities is the nature or reason for existence of that relationship. The different types of relationship are covered in Appendix A5 . In general; different relationship contents are required for each model (see Appendix A3).

Simple graphs have only one link between any two entities; multigraphs have two or more links, each of different content.

5. Directedness. A relationship between two entities may have some "direction" i.e. A to B, or B to A. The different types of directedness for different models is described in Appendix A3. The most important for this project is probably: A "is a subset of" B, i.e. directedness points to the more fundamental concept of a pair. In a multigraph, one link may point from A to B and the other from B to A -- where each is more significant in terms of different content.

6. Durability. A measure of the period over which a certain relaship between entities is activated and used. In fact, any entity may be considered, by someone, to be linked to any other. At one extreme, there are the links activated only on a "one-shot" basis (e.g. a "trial balloon" idea), at the other there are links, and sets of links, which are considered stable over centuries (e.g. the concepts associated with "property"). Links may be considered stable and durable, unstable and short-lived, and metastable. Metastable links are those which would disappear if the appropriate arguments were brought to bear -- but otherwise persist as a localized abnormality. Durability is clearly important for historical models (see Appendix A3).

7. Intensity. A measure of the strength of the link or bond between two entities. Two concepts may be said to be "strongly bound together". In some models, the intensity is a measure of the amount of the "flow" or "transaction" between the entities (see Appendix A3).

The link from A to B may be strong, and that from B to A, weak.

8. Frequency. A link between two entities may only be established intermittently. This measure is less significant to this project (except perhaps in cyclic approaches to the history of ideas or to the activation of concepts over a 24 hour period.)

9. Rearrangeability and blocking. A connecting network is an arrangement of entities and relationships allowing a certain set of entities to be connected together in various possible combinations. Two suggestive properties of such networks, which are extensively analyzed in telephone communications (*), are:

rearrangeability: a network is rearrangeable, if alternative paths can be found to link any pair of entities by re-arranging the links between other entities.

blocking: a network is in a blocking state if some pair of entities cannot be connected.

Examples of types of network patterns

Some of the above features of networks of concepts (or other entities) may be illustrated by the set of diagrams in Figure 1. Each entity is represented by a letter of the alphabet. Four simple types of entity groups are shown. Each type is further distinguished if the relationships between entities are directed.

a) In the non-directed examples of group (1), A is the central concept in (1.3), A and D in (1.4), A and F in (1.2). In (1.1), there is no central concept.

b) In group (1), peripheral concepts are D and C in (1.2); B, C, E and F in (1.3); B, C and F in (1.4). There are no peripheral concepts in (1.1).

c) In group (1), the range of A in (1.3) is 4, in (1.4) it is 3.

d) In group (1), the reachability of A in (1.1) and (1.2) is 3, in (1.3) it is 1, and in (1.4) it is 2.

(*)V.E. Benes. Mathematical Theory of Connecting Networks and Telephone Traffic. N.Y. Academic, 1965, p. 53

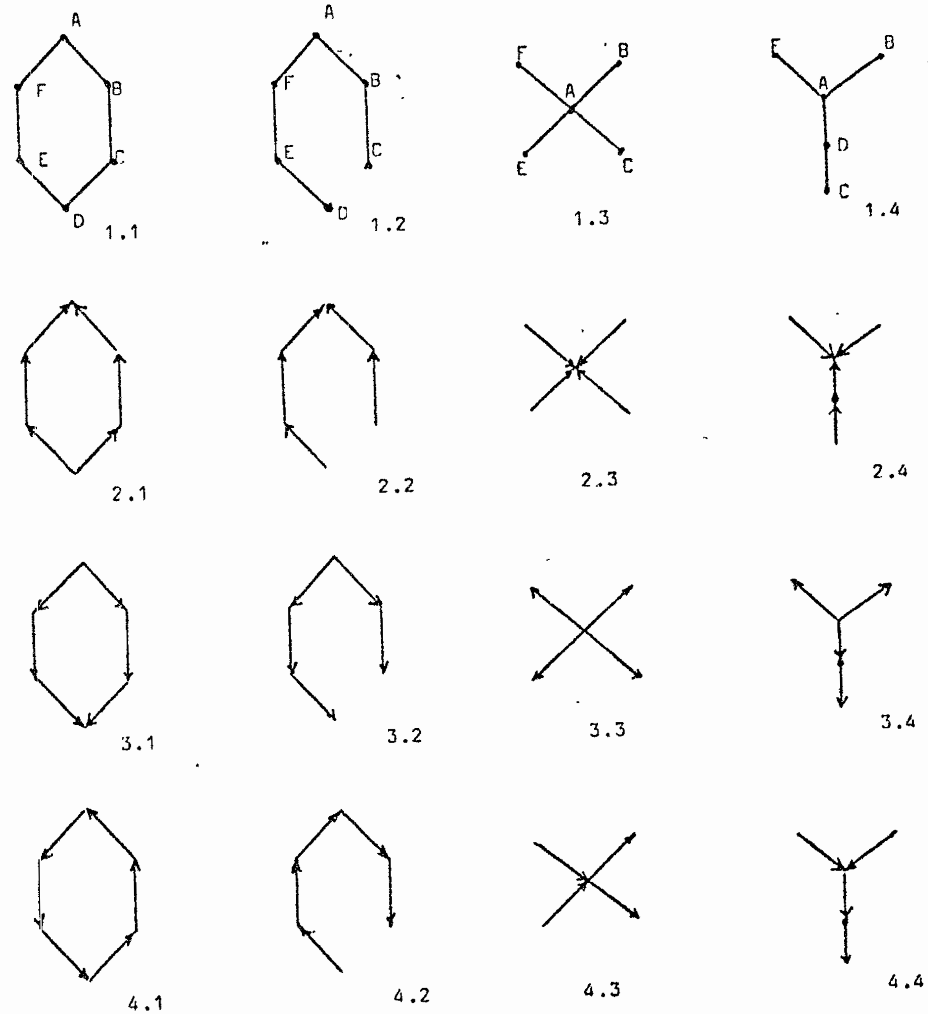

Figure 2 \ Examples of simple networks of entities

e) In all the directed examples of group (2), A is the central concept with at least B and F as direct component concepts (*). In all except (2.3), there are even sub-sub-components of A.

f) In all the directed examples of group (3), A is the central concept but only as a common sub-component. D is also a common sub-component in (2.1).

g) In all the directed examples of group (4), there is a chain of component/sub-component links. In (4.1), this is continuously forming a loop. In (4.2) and (4.4), C is the major concept. In (4.3), A is the central concept but only by having F and E as sub-components and being itself a common sub-component to B and C.

The above features are all evident, almost to the point of being trivial. But most cases of interest are likely to be much more complex, with many nested levels of concepts and cross-linking relationships. These may be examined by matrix analysis techniques, particularly using computers (to which the proposed record layout is suited) (**). Computer programs exist to detect properties of networks.

Specific reference is made to the use of network techniques in domains related to this project. Mention has been made of citation indexing (Appendix D3), artificial intelligence (Appendix C2), personal construct theory (Appendix C3).

(*)The set/subset relationship is used to illustrate these directed examples but other meanings are also possible (see Appendix A3). In particular, time order of formulation of concepts, and cybernetic information flows between problem areas or within organizational networks.

(**)C. Berge. The Theory of Graphs and its Applications. London, Methuen, 1962.

C. Flament. Applications of Graph Theory to Group Structure. Englewood-Cliffs, Prentice-Hall, 1963.

F. Harary and R.Z. Norman. Graph Theory as a Mathematical Model in Social Sciences. Ann Arbor, University of Michigan, 1953

F. Harary, R.Z. Norman and D. Cartwright. Structural Models: an introduction to the theory of directed graphs. N.Y., Wiley, 1965

Relationship to Artificial Intelligence Projects

In considering the possibility of coding definitions of concepts, propositions and like entities, it is important to benefit as much as possible from related work on artificial intelligence, and possibly pattern recognition. Artificial intelligence and projects to simulate human personality or belief systems have had to develop methods and computer techniques which can handle and interrelate entities such as concepts and propositions. Clearly the object of such projects is not attained once an inventory of entities can be examined, even if it is highly structured in the form of a thesaurus. It is therefore interesting to look at both the techniques used to handle concepts and the types of computer-based interrogations that are then possible.

The suggestion that techniques of handling individuals' "beliefs" about interpersonal relations should have some parallel to a community of scholars' attitudes towards the concepts, propositions, etc., which constitute its territory, may appear somewhat provocative. Does a school of thought constitute a belief system?

T.S. Kuhn (*) uses the terms "belief","metaphysic","commitment", and "conversion" in connection with a scientific community's attitude towards a paradigm and paradigm change. He mentions a non-scientific relationship between the community and its current paradigms. In addition, the direct structural relations between belief and thought are conveniently summarized by Milton Rokeach (**).

It is not necessary to go into this point, however, because it is only the insights concerning the approach to handling highly-interrelated "entities" which are of immediate interest.

The points made in this section are a summary, mostly direct extracts, of a paper by Kenneth M. Colby and colleagues (***). Colby is a psychiatrist working on the Stanford University Artificial Intelligence Project.

There exists a class of problems in the behavioral sciences that

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(*) T.S. Kuhn. The Structure of Scientific Revolutions. Chicago, University of Chicago Press, 1962.

(**) Milton Rokeach. The Open and Closed Mind; investigations into the nature of belief systems and personality systems. New York, Basic Books, 1960. (see pages 16-19, and Part III)

(***) L. Terler, H. Enea and K.M. Colby. "A directed graph representation for computer simulation of belief systems." Mathematical Biosciences, 2, 1/2, Feb. 68, 19-40.

has been difficult to manage satisfactorily with information-processing methods because of a lack of a good computer representation for very large memory structures. One example is the abstract representation linguists term a "deep structure" into which natural language is translated and to which transformational grammar is applied in generating natural language sentences. Another example consists of the large data bases required in computer simulation of human belief systems.

The paper describes a directed graph used for the representation of the data base of a computer model that simulates the formation and processing of an actual person's or an artificial system's beliefs about interpersonal relations. The graph constitutes a formal structure capable of abstractly representing the great variety of semantic relationships found in human concept and belief systems.

The basic component of the data base is the abstract entity "concept". Examples of concepts are: parents, fear of women, old men, hating authority, John, hatred.

Kinds of concepts used are: sets, individuals, and propositions.

A "belief" in the model is an attitude toward a proposition about concepts. It is convenient to regard a proposition as a special case of a concept. A proposition is considered to have one of two functions -- to represent a "fact" or to impart a "rule".

Not all propositions need to be beliefs in the model. The degree to which the model is willing to accept a proposition is called the "credibility" of the proposition, while the degree to which evidence substantiates a proposition is called its "foundation". Credibility and foundation are useful criteria determining whether a proposition is rejected or retained. They are measured on arbitrary scales from 0 to 100. In addition, without regard for their status as beliefs two propositions can still differ only in "intensity"; for example, "John strongly believes in 'x'", and "John weakly believes in 'x'".

Different concepts in a model can vary in their importance to the train of thought and a single concept can vary in its importance from time to time. The attribute measuring their differences is called "charge", e.g., "sex" may be a permanently charged concept, whereas "washing the dishes" might be temporarily charged.

Other distinctions can be made between concepts on the basis of their "longevity" (how long ago formed) and "inhibition" (tendency to be avoided in communication and reasoning).

In addition to quantitative measures, concepts have qualitative aspects. The "kind" (set, individual, or proposition) and the "origin" (a priori, observed, or reasoned).

Concepts are represented in the model by nodes of a directed graph. Simple relationships are represented by directed arcs between pairs of nodes. Each arc is labelled e, s or p, depending on the type of relationship. The types of arcs are distinguished by their formal properties, but notions of their approximate meanings can be outlined:

A e B = individual A is a member of set B
A s B = set A is a subset of set B
or proposition A is a consequence of proposition B
B p A = A has B, or A has property B, or B belongs to A, or B is part of A, or the idea of A suggests the idea of B, or A does B

The same mode can be an individual, set, or proposition in different "contexts". The formal properties distinguishing the three types of arcs are given by seven axioms of valid graph enlargement.

Axiom 1	A s A	s is reflexive
Axiom 2	A s B BsC — AsC	s is transitive
Axiom 3	AeB BsC — AeC	A member of a subject is a member of the set
Axiom 4	AsB CpB — CpA	A property of a set is had by its subsets
Axiom 5	AeB CpB — CpA	""
Axiom 6	BpA BsC — CpA	Having a specific property implies having the more general property
Axiom 7	BpA BeC — CpA	""

There are two ways to look at a directed graph: locally and globally. Local examination implies that examination begins at some node and proceeds only by following the arcs (in either direction) that touch that node. Global examination requires "stepping back" from the graph and looking for patterns. Three basic methods of graph (or tree) searching are available in sequential processing: depth-before-breadth, breadth-before-depth and a partially random approach. Special computer programs have been developed to do this.

<u>Comment</u>.

It is clear that with the introduction of such additional features as "credibility", "foundation", "charge", "longevity", "inhibition", "mode", and "origin", a much more dynamic picture of the belief system emerges. For each of them, an equivalent exists within a discipline's conceptual world, but whether it would be possible or useful to attempt to incorporate all such information is another matter. At first sight, it would be particularly appropriate to attempt to do so for the educational or historical model types.

Use of computer models of belief systems.

Once a data base exists, it is possible to interrogate it and discover what its beliefs are on particular topics (*). More ambitiously, it is possible to enter into dialogue with it, such that it will examine and accept or reject propositions made, and thus extend or modify the data base on the basis of the credibility of the informant. (**))

Work in this area is relatively advanced, although bound by important constraints due to simplifying assumptions. (As an illustration, a "paranoid" model permitting natural language dialogue has been constructed by altering the sensitivity of the model to statements on certain topics in terms of three scales of "fear","anger", and "mistrust". (***)

Comment.

There is no technical reason why the concepts and propositions of a given discipline should not be handled in this way. The fact that they do not all tie together into a consistent, coherent whole represented by a monolithic hierarchy of concepts is no obstacle. Individual belief systems are not consistent or coherent, either. (The standard sentence forms used in such models can be taken not as crude approximations to English verbalization, but as quite general representations of properties and relations among objects. Such relations and properties can be expressed in a variety of symbolic forms other than verbal. Thus the forms in which the model's beliefs are cast can be seen as general and powerful cognitive schemas, and not merely as exercises in Dick-and-Jane prose. (****)

(*) K.M. Colby, L. Tesler, H. Enea."Experiments with a Search Algorithm on the Data Base of a Human Belief Structure. " Stanford University, Artificial Intelligence Project, 1969, (Memo AI-94).
John C. Loehlin. Computer Models of Personality. New York, Random House, 1968.

(**) K.M. Colby and D.C. Smith. "Dialogue Between Humans and an Artificial Belief System." Stanford University, Artificial Intelligence Project, 1969. (Memo AI-97)

(***) K.M. Colby, S. Weber and F.D. Hilf. "Artificial Paranoia." Stanford University, Artificial Intelligence Project, 1970, (Memo AIM-125).
K.M. Colby, and J.P. Gilbert. "Programming a Computer Model of Neurosis". Journal of Mathematical Psychology, 1964, 1, 405-417.

(****) J.C. Loehlin, op.cit. p. 111.

In thinking of the application to schools of thought, it is interesting to note the comment made by Colby and his colleagues on the status of the model held by the computer.

> Our problem -- how to construct a good model of the informant's belief process. The criteria for "good" can be varied --are we getting at what the informant "really" believes? What "really" means here is obscure, but it is common knowledge that people have limited accessibility to their beliefs at a given moment. Even worse, they have the capacity to deceive themselves, to rationalize, and to distort their own beliefs ...In worrying about what is "really" believed, we found it useful to keep in mind that we were constructing a model of a model. A belief structure is a representation,and in giving information about himself, an informant tells us what he believes he believes. He simulated himself and it is his accessible model of himself that becomes the data base of a computer model. Humans' ability to simulate themselves and to make models of other models is of course a most interesting property for a sumbolic system to have. (*)

Elsewhere he notes that a belief system (like a school of thought) is itself a model (if only partial) of the universe. He considers that reasoning processes are aided in the individual by his simulation of his own mind -- by "autosimulation". It might be useful for disciplines to examine their own conceptual structures in the same way as an aid to the development of the discipline. It could be particularly important as a means of highlighting tensions within the conceptual structures which lead up to Kuhn's paradigmatic changes.

This approach suggests a number of stages of sophistication in the possible development of this project.

1. A static inventory of concepts and propositions
2. A static network of interrelated concepts and propositions
3. "Activation" of propositions as rules governing the relationships between entities
4. Treatment of a school of thought as a belief system
5. Extension to natural language interaction

On this last point, it may be possible to allow a (non-computer-oriented) specialist in a particular field to "dialogue" with the concept data base to permit him to discover and indicate where he differs from its contents and what new he thinks should be included (**) This approach might be a useful method of getting

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(*) K.M. Colby, L. Tesler, H. Enea, op.cit., page 9.

(**) See: K.M. Colby and H. Enea. Heuristic method for computer understanding of natural language in context-restricted on-time dialogue. Mathematical Biosciences, 1,1-25, 1967.

around the behavioural problems associated with the power position of official classifiers in committees.

It is even possible to have many such people interacting in natural language with the data base via terminals to facilitate communication (e.g., at a special seminar).

This last stage raises the serious problems of "deep structure" in linguistic analysis, the formalization of natural language semantics within the limits of particular scientific dialects, the need to relate such languages to one another through semantic and symbolic manipulations and the question of mechanized translation. These difficult problems are avoided or by-passed in the early stages because it is not the "words" in the "surface structures" which are coded but the meanings of these words as "terms". In other words, this project is significant because it attempts to code the elements of the deep structure directly and in a manner which avoids the verbiage (and of course much richness) of the "carrier wave" functions of natural language. Efforts at mechanized translation seem to be attempting to translate natural language into terms. This approach treate terms as conventional labels but not as the goal of translation. Consultation at an early stage with specialists in these areas would be vital.

Future

As a future development of the application of techniques of simulating belief systems to simulating schools of thought, one can envisage the possibility of an individual being able to interrogate, or dialogue with, different schools of thought, each represented in a model. The individual could compare responses and examine their incompatabilities. This might have some application in the policy sciences where experts from different disciplines in effect each submit different models of a problem situation and its solution. It would however be particularly useful as an educational tool and for interdisciplinary research. (The individual is here an active participant in the dialogue. Of possible interest would be a "dialogue" between computer models of two or more disciplines sparked off by a topic selected by the individual to be educated. This would probably be of more value as an investigation of belief system behaviour under threat to conceptual territory.)

Other references:

C.M. Eastman. In: H.S. Brinkers (Ed). Decision-making; creativity; judgment, and systems. (in press).

F.H. George. "Formation and analysis of concepts and hypotheses on a digital computer." Mathematical Biosciences, 3, 91-113,1968.

K.M. Colby. "Computer simulation of change in personal belief systems." Behavioral Science, 12, 248-253, 1967.

R.P. Abelson and J.D. Carroll. "Computer simulation of individual belief systems." American Behavioral Scientist, 1965, 8, 24-30.

M.R. Quillan. Semantic Memory. Bolt, Berenek and Newman. DDC Report AD 641-671, Oct.1966. Also published in:M. Minsky (Ed.) Semantic Information Processing. M.I.T.,1968.

Relationship to Personal Construct Evaluation Techniques.

There exists a school of thought in psychology concerned with the evaluation of "personal constructs" (*). The arguments in this Appendix are based on extracts from the most recent book summarizing the field (**). A "construct" is the basic contrast between two conceptual groups. When it is imposed, it serves both to distinguish between its elements and to group them. Thus the construct refers to the nature of the distinction an individual attempts to make between events, not to the array in which his events appear to stand when he gets through applying the distinction between each of them and all the others. A construct system is made up of nothing but constructs, and its organization is based on constructs about constructs, which may be set up in concretistic pyramids or abstractly cross-referenced in a hierarchical set of relationships.

The system of constructs which a person establishes for himself represents the network of pathways along which he is free to move. When a person must move, he is confronted by a series of dichotomous choices -- each choice being channelled by a construct. Each construct represents a pair of rival hypotheses, either of which may be applied to a new element which the person seeks to construe. The construct system sets the limit beyond which it is impossible for the person to perceive. Many constructs have no word labels and represent nonverbal and preverbal bases of discrimination and organization, and these may occupy important and even central places in the economy of a person's orientation towards himself and the world.

The construct system is evaluated using a grid-based interview method, which results in a matrix giving the interrelationships between the elements of the system. This matrix can then be scanned by computer to highlight clusters. A number of computer programmes have been developed for this purpose.(***) Slater (****) has prepared a program which accepts grids cast in

(*) G.A. Kelly. The Psychology of Personal Constructs. New York, Norton, 2 vols., 1955.

(**) D. Bannister and J.M.M. Mair. The Evaluation of Personal Constructs. London, Academic Press, 1968.

(***) For a summary see: J.C.J. Bonarius. "Research in the Personal Construct Theory of George A. Kelly." In: B.A. Maher (Ed.) Progress in Experimental Personality Research. London, Academic Press, 1965, vol. 2.

(****) P. Slater. The Principal Components of a Repertory Grid. London, Vincent Andrews, 1965.

________. "Notes on Ingrid 67." London, Biometrics Unit, Maudsley Hospital, 1967.

any form and is a form of principal component analysis. This analysis delineates significant orthogonal structure both of constructs in relation to elements, and of elements in relation to constructs. Thus a fairly detailed overview can be obtained in mathematical terms, and this can be examined visually in terms of a hypersphere which represents a person's psychological space as subsumed by grid method.

Comment

The authors of the volume, from which the above extracts were obtained, point out that "...we have presented grids with only one type of element -- namely, people. The limitation was accepted for the sake of simplicity in presentation. We cannot too strongly emphasize that the content of grids (the constructs and elements) is, for practical purposes, very variable." (p. 72)

In their discussion of uses other than interpersonal relationships, they mention only relations between individuals and such elements as films, paintings, inanimate objects, emotions, problem situations in a person's life. But Kelly himself points out that "not only can the grid notion be generalized to all conceptualizations, but this mathematical notion can also be generalized. The incidents and voids which populate a grid of intersects provide the binary numerical basis for a mathematics of psychological space... Thus we may have a mathematical basis for expressing and measuring the perceptual relationship between the events which are uniquely interwoven in any person's psychological space." (op.cit. 301-2)

On this basis, therefore, it would seem that this technique could be applied to determine the constructs used by a school of thought or a discipline in ordering its own perception of significant elements in its world view.

One advantage of this approach is that it does not necessarily impose any content dimensions on the subject (in this case a school of thought). Each subject can be encouraged to express the constructs which he uses to make sense of areas of his life. In a sense the resulting picture is culture-free and sub-culture free in that the subject has been allowed to work in terms of his own preferred language -- rather than in terms of an "alien tongue" chosen by the investigator. This lack of an imposed language is most essential to any proposed effort to handle the concepts of different schools of thought -- if only to avoid any form of conceptual imperialism.

It is interesting to see that these same authors reflect some of the preoccupations of Fred Riggs and G. Sartori (*).

(*) Fred Riggs. Words, concepts and terminology. Hawaii, Social Science Research Institute, University of Hawaii, 1971 (COCTA Working Paper n° 1.

G. Sartori. Concept misformation in comparative politics. American Political Science Review, 64, n° 4, December 1970, p. 1033-1053.

"Many constructs are symbolized by verbal labels -- a word or a group of words. All words in general usage in any language have commonly-agreed dictionary meanings; but individuals may often use similar words to describe different experiences or ideas, or different words to describe similar experiences or ideas. Almost all psychological measures dependent on words have relied heavily on the assumption that different people will understand broadly the same thing where a standard set of words is used (e.g.,in a questionnaire) and will mean the same thing when they reply in some standard form. Grid method does not assume that the subject means what the experimentor means by particular verbal labels involved in the test -- on the contrary, the method is designed to help ascertain what the subject means by particular verbal labels....It is then possible to compare their personal "meanings" for words either with their public meaning (the construct interrelationship implied by dictionary definition, or normative relationships yielded by grid administration to groups), or with the experimenter's meanings (either by having the experimentor complete a similar grid, or by having him predict the construct relationships which would reflect his particular explanatory stance)."
p.143)

Clearly this approach could be used by a modelling body:
(a) to obtain a systematic check on the degree of consensus amongst its members
(b) to interview members of the school of thought on particular concepts, propositions, etc., their interrelationship and their importance. In this case, the individual grids are averaged by computer to obtain the dominant clusters (which would seem to be the beginnings of a fairly "democratic"modelling system).

The authors note a major disadvantage of the grid method: "...it is already apparent that the original binary grid and its more recent variations cannot adequately subsume all the ingenious and sometimes contorted forms of constructing which men have undertaken. Not least among its limitations is its fixity in expressing only one type of linkage between constructs (the reciprocal linkage represented by a unitary index of associations), and its failure to incorporate some important aspects of construct theory." (p.74)

Finally, it is very instructive to examine the formal description of personal constructs theory replacing "person" and "user" by "school of thought" or "discipline" (see Figure , reproduced from Bannister and Mair, op.cit.)

Use of Input/Output analysis (*)

Network analysis is closely related mathematically to input-output analysis which has been used for some years by economists to analyze the trading transfers between different sectors of industry.

"It has long been recognized that in the economy of any town, city, state or nation, each business depends on products and services of other industries in order to produce products or services of its own. This interdependence of industries within an economy is entirely obvious, but difficult to measure, and becomes more difficult as the economy becomes more complex and more mature. The "square matrix" of interindustry transactions -- which shows these interdependencies and measures them for a given period -- is, in combination with electronic data processing, becoming a valuable basis for future economic planning for business, industrial firms, and governments -- local, regional or national. For both sudden and gradual changes in industrial, government of consumer areas of supply and demand alter all other relationships, and individual companies stand to profit or suffer in the transition....Application of Input/Output to marketing problems assures improved information generated through the use of a systems approach: analyzing a problem in relation to the whole economy, rather than as a series of unrelated cases." (**)

It is quite clear from this that interdependence of industry sectors and the constituent enterprises has been widely recognized. This recognition is of course limited to interactions detectable from an economic perspective. The same principle applies, however, to all interactions (funds,information, goods, etc.) concerned with all subject areas (development, environment, education, etc.). This is not generally recognized.

It is interesting to note that Wassily Leontief, who developed the input-output technique, now foresees that input-output tables might be expanded to quantify the byproducts with which the various industries pollute the atmosphere. He considers this would lead to a sharp understanding of the connections between economic processes and the environment and thus help to solve this major problem in the developed countries, namely the rapid deterioration in the quality of life (Business Week, 22 November 1969, p.126).

"The unique service of input-output analysis is its ability to give a detailed picture of the industrial

(*) This appendix is based on extracts from: Jere W. Clark and A.J.N. Judge. Development of transdisciplinary conceptual aids. Brussels, Union of International Associations, 1970.

(**) Facts on Fortune's 1966 Input/Output Matrix -- Computer-age Tool. p.2-5. See also: Wassily Leontieff. Input-output analysis. Oxford U.P., 1967.

structure by putting numbers on all the complex interconnections that link the various sectors of the economy." (*)

The ability of this technique to highlight interdependencies and weaknesses in a system of producers and consumers of goods (represented by their funds' equivalent) suggests a similar use to highlight interdependencies between different sectors of the psycho-social system. In this case it is necessary to deal in terms of producers and consumers of information --in its broadest sense. This technique could then be used with the cybernetic models (Appendix).

The situation becomes very complex since the table or network becomes multidimensional. There are many methods of avoiding these problems and obtaining new insights. As an example, an "information map" in input-output table form was developed for the State of California by concentrating on information flows. A survey was carried out to indicate "every instance where information was exchanged between a particular organization and the State government and the local government." These interchanges were shown by means of a code on an input/output table covering all of the State organizations, cities, counties, Federal Government agencies, and private enterprises. Aside from giving an overview of the State information network, the table highlighted cases where one group of organizations needed information from another group but could not obtain it because it was not available. (**)

It might be possible to employ the same technique to handle information between disciplines and thus provide one aspect of the interdisciplinary chart mentioned by René Maheu, Director-General, UNESCO:

"One of the most significant results that should naturally emerge from a study such as this, is the preparation of a chart -- admittedly provisional and subject to constant revision -- of the strong points and weak points of interdisciplinary cooperation and of their substratum, and the identification of priority areas to which research scientists should direct their thinking and institutions their activities." (***)

(*) Business Week, 22 November 1969, p. 125.

(**) Hearings before the Special Subcommittee on the Utilization of Scientific Manpower of the Committee on Labor and Public Welfare, United States Senate, 89th Congress,S.2662, 1965-66, p. 35-38.

(***) René Maheu in the preface to: Main Trends of Research in the Social and Human Sciences. Part one: social sciences. Paris, Unesco, 1970, p. xv.