August 1987

Atlas of International Relationship Networks

Review of the problems of mapping networks of organization/problem relationships in order to produce an "Atlas" as a complement to the Yearbook of International Organizations and to the Encyclopedia of World Problems and Human Potential

Union of International Associations
40 rue Washington, B-1050 Brussels, Belgium

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Project of the Union of International Associations, 40 rue Washington, B-1050 Brussels, Belgium.

SUMMARY

1. This document is concerned with presentations of information which will be possible once a particular computer software problem has been adequately solved. The problem can be illustrated by two examples:

   (a) Traffic network mapping: If a database contained entries on 300 subway stations (or airports, or bus stops) and their direct route links to one another, what is required is a software package to construct one or more possible maps of the resulting network. The important point is to be able to optimize the comprehensibility of such maps with minimum manual intervention in the construction process.

   (b) Hypercard stack mapping: With the widely acclaimed introduction of the Apple hypercard, whereby complex networks of relationships between database records can be handled, the problem remains of mapping the pattern of relationships in the resulting hypercard stack. The individual entries may be said to constitute "data", but it is the pattern of relationships between them which constitutes "knowledge" and "intelligence"

2. The conventional approach to databases, and to the reference books produced from them, is to focus on individual entries. The user is not assisted in understanding the relationships between entries, other than by fairly crude grouping of entries into categories.

3. With the development of interactive databases, hypertext (plus the new hypercard approach of Apple) and CD/ROM, data entries can be organized so that they cross-reference one another to a high degree and in a non-hierarchical manner.

   For example, the current Yearbook of International Organizations (1987/88) covering 27145 entries indicates 32692 relationships between them -- with the major organizations having an average of 70 each. Similarly the complemetary volume, the Encyclopedia of World Problems and Human Potantial (1986), covers 10233 world problems with 17636 relationships between them. Users can move from entry to entry without going via an index. In database terms this is a major step towards what is being called hypertext. Both publications are maintained on a computer network and the possibility of CD/ROM versions is being investigated.

4. Because of the overwhelming volume of data, users need "maps" of the pathway between entries, especially in complex subject areas. Such maps provide a sense of context which is lost in many hierarchical presentations of data in linear text form. It is only from such maps that users can quickly obtain an adequate overview of data in an unfamiliar area to guide their efficient use of conventional information tools. Such maps are of value precisely because they are richer than simple hierarchically structured thesauri.

5. Interesting examples of such graph displays are presented as annexes to this document. They include the route maps of the "ABC World Airways Guide", the concept maps in the "Encyclopedia Universalis" and the graphics displays used in the UNESCO "SPINES Thesaurus" for science policy and management. These are all hand drawn and based on relatively limited data sets. As such they are costly and difficult to modify. They do however illustrate different responses to a need felt by information users. The same may be said of networks of corporations grouped by holding companies -- as they are occasionally, and painstakingly, presented in the financial press.

6. Computer hardware and sofware for the construction and manipulation of such networks of relationships have only been developed for specific applications such as in chemistry, architecture and engineering (CAD), or electronic circuit board design (PCB). It would be possible to develop similar software to display relationships between database entries, but this would involve investments in excess of $100,000. This is presumably excessive before the nature and advantages of the final product can be demonstrated.

7. Once such maps can be succesfully produced and manipulated, computer tapes can be made to drive photocomposition machines (with vector generators -- as at Computaprint). These make high quality maps. Alternatively such maps could be generated by standard graph plotters into camera-ready form. A series of such maps, with facing explanatory text and/or mini-index, may then be bound together as an "atlas".

8. As a complement to the Yearbook of International Organizations, such an atlas might take the form of a 600 page A4 publication: 250 maps, 250 facing explanatory pages, 100 pages general index, prelims and comments. The cost of producing the first version might be reduced by generating the maps in-house as has been done in the case of organization charts in the current edition of the Yearbook. At a later stage the facilities of Computaprint might be used to generate maps of higher visual quality.

9. Maps would be designed to cover clusters of organizations and/or problems in a given subject or geographical area.

10. Such maps would have the advantage of provoking input of new organizations and/or relationships when used in the form of proofs. They also have important didactic uses. Enlargements of the maps could also be sold as wall-charts which would be of value for promotional purposes.

11. The accompanying annexes give further details of different approaches to this problem. However at this stage it should be stressed that the most effective approach would be through the use of pre-existing software with whatever constraints that implies.

LIST OF ANNEXES

1. Mapping networks
   (reproduced from Encyclopedia of World Problems and Human Potential)

2. Proposal: Development of an operational relationship mapping technique

3. Clarification of network map requirment

4. Examples and tests

   - Route map from "ABC World Airways Guide" (Africa)
   - Concept map from "Encyclopedia Universalis" (Image)
   - Terminological graphical display from "SPINES Thesaurus; a controlled and structured vocabulary of science and technology for polic-making, management and development" (Physical environment); global graph and associative relationships between top descriptors
   - Sketch of problem network
   - Schematic presentation of relationship network on a PC
   - Hierarchical non-graphic test presentation of problem relationships

Mapping networks

ANALYSIS OF NETWORKS

The data collected together in the sections of this publication has been deliberately organized in a manner which stresses the interrelationships between the entities within a section and between those in different sections. (Each section is characterized by entities of a different type, and several types of relationship may exist between the same two entities). In effect, therefore, the entities and relationships in each section constitute a network, possibly composed of many subnetworks. Similarly, since entities in each section may be linked to those in other sections, the whole is constituted by a system of interlinked networks in which the relationships have a limited number of distinct meanings. The entities and relationships are currently held in computer files in a form which should facilitate analysis of these networks. It is hoped that the availability of data in this form will encourage the development of new types of analysis more appropriate to the structural complexity portrayed, especially since both the quantitative data and the mathematical functions representing the nature of particular relationships under different conditions (which are a precondition for the application of current methods of quantitative analysis of social systems), are absent and in most cases unavailable.

As François Lorrain notes (1) the abstract notion of a network is undoubtedly called to play a role in the social sciences comparable to the role played in physics by the concept of euclidean space and its generalizations. But the poverty of concepts and methods which can currently be applied to the study of networks stands in dramatic contrast to the immense conceptual and methodological richness available for the study of physical spaces. A whole reticular imagery remains to be developed. At this time a network is understood to contain simply nodes and links and little else. An attempt to define anything like a reticular variable results in very little. This is not surprising, since to succeed would require the establishment of a general mathematical theory of networks which as yet has been little developed. In contrast to this situation, consider the multitude of spatial variables which are available: coordinates, length, surface, volume, curves, classes of curves, classes of surfaces, parameters of curves, parameters of surfaces, and so on, and all these in a space of any number of dimensions and manifesting any type of curvature.

1. Social Networks

The types of network which occur in the social sciences are of such a diverse nature that only a purely formal definition of this notion is of sufficient generality.

A network is constituted by a certain set of points. In the social sciences these points may represent any or all of the following: individuals, groups, organizations, beliefs, roles, *etc*. In this exercise they represent: international organizations, multilateral treaties, world problems, strategies, concepts (human development, integrative, patterns), metaphors, symbols, modes of awareness, values. Such points may represent the existence of entities at the present time, or they may represent the existence of entities at some past or future time (or such points may also be used to represent intervals of time).

The points in a data set may be linked by one or more kinds of relationship. In this exercise three basic types of relationship are distinguished: (a) **Simple relationship**, namely A is related to B which implies that B is related to A; (b) **Hierarchical relationship**, namely A is a part of B which implies that B is in contextual relationship to A; (c) **Functional relationship**, namely A acts on B which implies that B is acted upon by A.

In the first case above a relationship is further defined by the types of entity between which it occurs, namely whether they are of the same type, or whether they are of different types. In the second and third case, a relationship is further defined by distinguishing the direction of the relationship, which is further developed in the third case by distinguishing several ways in which A can act upon B.

2. Analysis of Networks

Classical mathematics, summarizing François Lorrain's (1) remarks, is not able to handle complex structural features characteristic of social systems. Organization is best depicted as a network. The mathematical theory of networks derives largely from certain branches of topology and abstract algebra rather than from analysis, which underlies classical mathematics. The theory of graphs is often presented as a kind of general theory of networks with numerous possible applications in the social sciences. However, other than in the area of operations research, the theory of graphs has not proved itself to be very useful in sociology. The reason is probably that the theory has mainly been developed in the context of relatively limited problems in such a way that the results collected under the graph theory label, although numerous and of great interest, have little unity. In addition, the theory rarely handles networks with several distinct types of relationships each with its own configuration of links. It is precisely such networks which are of most interest in sociology. The theory also tends to exclude networks in which some of the points have links back to themselves when it is often just such networks which are important in representing social structures.

A final disadvantage of the theory of graphs is that it only offers a fairly limited number of means of global analysis of networks. It seriously neglects an important aspect of the study of any type of mathematical structure, namely the level of transformation relations between graphs. Because of its composition, a category possesses a richer structure than a simple graph, and it is therefore possible to define more rigorous and fruitful criteria of transformation (namely the concepts of function and functional reduction). In addition a set of points and a set of relations can be treated in their totality and simultaneously, in contrast to the methods of graph theory which considers individual paths between particular points in the graph. In the universe of categories (the universe of objects and relationships), transformations between categories may also be considered as relationships within a category whose objects are themselves categories, and so on. All this emerges from consideration of the global structure resulting from the manner of composition which relates the relationships themselves, thus providing a dialectic of levels of structure and a new imagery of networks. At all levels of this universe, the functional relationships between categories play a central role. They are the fundamental instruments which may be used in the exploration of structural complexity and the tools for extraction of information in global studies.

3. Use of graph theory methods

Despite the limitations noted above, graph theory methods have been applied to the analysis of social structures although such applications are not very common (see references below).

The image of a "network or web" of problems (or organizations, *etc*) to represent a complex set of interrelationships 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.

4. Some features of graphs

Using graph theory, a number of characteristics of networks can be determined. 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 entity (*eg* a problem) is directly or indirectly "related" via links to other entities (*ie*, the extent to which it is "distant" from another entity). One can speak of a "key" problem or of an organization being "central" to the concerns of a particular complex. It may also be considered a measure of the degree of "isolation" of the entity. A systematic analysis of the centrality of entities in a network could indicate where new entities are necessary to bridge gaps and link isolated domains.

2. Coherence: A measure of the degree of "interconnectedness" or "density" of a group of entities. This may be considered as the degree to which a system of problems is "complete". Differences in density would reflect the tendency for more highly coherent problem 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 problem system.

3. Range: Some entities are directly related to many other entities, others to very few. The range of an entity 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 problem to the extent that a high range problem would be less vulnerable to attack than a low range problem, since it has more relationships anchoring it to its problem environment and preserving it in existence. High range points are therefore either key points in resistance to problem 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. 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" (*ie*, A to B, or B to A). There may be several types of directedness. Two types are important for this project: A is a sub-element of B; A acts on B. In a multigraph, one link may point from A to B and the other from B to A.

6. Durability: A measure of the period over which a certain relationship between entities is activated and used. At one extreme, there are the links activated only on a "one-shot" basis (*eg* a single crisis), at the other there are links, and sets of links, which are considered stable over centuries (*eg* between the more permanent problems).

7. Intensity: A measure of the strength of the link or bond between two entities. Two problems may be said to be "strongly bound together". In some cases, the intensity is a measure of the amount of the "flow" or "transaction" between the entities. 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.

9. Rearrangeability and blocking: A connecting network is an arrangement of entitites 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: (a) rearrangeability (a network is rearrangeable, if alternative paths can be found to link any pair of entities by rearranging the links between other entities); (b) blocking (a network is in a blocking state if some pair of entities cannot be connected).

5. Implications of artificial intelligence research

In considering the possibility of analyzing networks of problems (organizations, concepts, *etc*), it is important to benefit as much as possible from related work on artificial intelligence, and possibly pattern recognition. Artificial intelligence projects to simulate human personality or belief systems have had to develop mathematical techniques and computer programmes which can handle and interrelate entitites such as concepts and propositions, some of which may be positively or negatively loaded to represent positive values and perceived problems (the credibility and importance of a belief in a network, and the intensity with which it is held, may also be indicated). Clearly the objective of such projects is not achieved once a simple inventory of entities can be examined, even if it is highly structured in the form of a thesaurus. Of particular interest is the work on "dialogues" with such belief systems, some of which are established over a period by extensive interviews with individuals and others which are specially constructed to simulate paranoia, for example (see references). Presumably it would be possible to conduct somewhat similar dialogues with the collective beliefs constituted by problem/value netwroks such as might be developed during the course of this project.

6. Comment

Despite the available techniques noted above, and others which have been applied to non-social networks, much would seem to remain to be accomplished, as François Lorrain's (1) remarks indicated, in order to grasp networks in their totality.

The question is what it would be useful to know about networks at this time. What indicators would it be useful to attach to individual problems (organizations, *etc*) to indicate the characteristics of their relationship to the network(s) in which they are embedded? What similar indicators would be useful in describing the relationships between relatively dense networks and the larger network in which they themselves are embedded? What sort of concept about networks need to be embodied in a **network vocabulary** so that such matters can be discussed intelligently and unambiguously in public debate? In other words, what are the elements of an adequate vocabulary of structure and in what disciplines has the basis for such a vocabulary already been established: chemistry, crystallography, architecture, design in general, *etc*? What can be learnt from biologists about the growth and development of the many reticular structures they encounter (*eg* radiolaria)? More interesting perhaps, in which occupations do some individuals develop a special (instinctive or intuitive) sensitivity to the structural and dynamic characteristics of the networks with which, or within which, they work: airline pilots, urban bus drivers, electricity grid controllers, counter-espionage directors, factory process controllers, computer-based data network designer/controllers, telephone exchange designer/ controllers, institutional fund controllers, *etc*? What do such people say, or want to say, about their networks? Why has the term "networking" suddenly sprung into common use and consequently what could "to network" mean? It is questionable whether any adequate organizational response (a **network strategy**) to the world problem complex can be elaborated until such rich experience is collected together and matched to an elaborated, mathematically-based concept structure, and an associated vocabulary. A conceptual quantum jump is required to grasp problem (and other organized) structures in their totality and be able to communicate such insights.

It is hoped that the availability of the data in this publication will help to stimulate such fresh thinking on the conceptual containment of societal networks.

USE OF INTERACTIVE GRAPHICS

1. Description

The suggestion has been made above that the representation of the relationship between theoretical entities (concepts, organizations, problems, *etc*) could best be accomplished using methods based on graph theory, network theory and topology. The relationships registered in this project could be plotted manually as networks. However, particularly since the relationships are already coded on computer tape in a suitable format, there are three major disadvantages to this manual approach:

- graphic relationships are tiresome and time-consuming to draw, and are costly if budgeted as "art work" (for a comprehensive review of the current possibilites and limitations, see reference 28);
- once drawn, there is a strong resistance to updating them (because of the previous point) and therefore they quickly become useless (as is frequently the case with organization charts);
- 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" (29). This is basically a television-type 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 over-loaded 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 computer, via the keyboard, to:

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 **diminution** 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, *ie* 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 to 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 viewport into two (or more) parts and have the parts of the network displayed in one (or more) part(s). He can then use the light pen to point to each entity or relationship on which he wants a longer text description (*eg* the justifying argument for an entity or the mathematical function, if applicable, governing a relationship, and have it displayed in an adjoining viewport);

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 or "**ladders of abstraction**". The user can demand that the computer track the display (see point 7) between levels of abstraction, moving from sub-system to system, at each move bringing into view the 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" in 3 dimensions) to illustrate the relationship between entities. These are all interconvertible (*eg* 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 its turn be photocopies);

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 view "around" the structure;

15. Simulate a **four-dimensional presentation** of the network by using various techniques for distinguishing entities and relationships (*eg* "flashing" relationships at frequencies corresponding to their importance in terms of the fourth dimension);

16. Change the **speed** at which the magnification from the viewport 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 **analyses** on particular parts of the network and display the results in a secondary viewport (*eg* the user might point a light-pen at an entity and request its centrality or request an indication of the interconnectedness of a particular domain delimitted with the light pen.);

19. Use **colour** (when a colour screen is available) to distinguish between different concepts or networks of relationships on the same display. Several hundred colour codes are available under computer control (3);

20. **Experiment** with the generation of paths for the construction of hypothetical larger conceptual units (*eg* organizations) from available smaller units, as suggested by equivalent work on computer-assisted design of complex organic syntheses (2).

In every current use of interactive graphics 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 Dean Brown and Joan Lewis (3):

"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 adapt as a tool for the contemplation of ideas....Concepts can be viewed as manifolds in the multidimensional variate 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 terrae incognitae, plateaus, enclaves of knowledge, cusps, peaks, and saddles by a conceptual photogrammetry. Exploring the face 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....By sketching tentative three-dimensional perspectives on the screen and "rotating them on the tips of his fingers", one internalizes ideas non-verbally and acquires a sensation of sailing through structures of concepts much as a cosmonaut 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...."

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 (4), making this same point with respect to social systems, states:

"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 percpetions, 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 behaviour that he believes is implied....The human mind is excellent in its ability to observe the 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. But when the pieces of the system have been assembled, the mind is nearly useless for anticipating the dynamic behaviour 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 imprecisely stated. Furthermore, even within one individual, the mental model changes with time and with the flow of conversation. The human mind assembles 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 consensus leads 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 (5):

"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 the 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 him 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."

The availability of devices to restructure information in this way would seem to offer some hope that insights could emerge which respond more adequately to the recorded complexity of societal structure, whilst at the same time being more easily comprehensible to the uninitiated - because of the ease with which such devices can be used as educational tools to develop understanding and comprehension of the same structural data from which the research insights are being derived. Such displays of course lend themselves to videotape recording for wider distribution.

2. Implications of computer augmentation of intellect

There are important intellectual implications emerging from work on advanced computer systems. Of particular interest is the work of Douglas Engelbart's team at the Center for Augmentation of Human Intellect (Stanford Research Institute) which is a centre for the US ARPA Data Network (which links the computers of major universities in the USA). Engelbart has worked on the means of creating an "intellectual workshop" to facilitate interaction between conceptual structures (6). He considers that:

"Concepts seem to be structurable, in that a new concept can be composed of an organization of established concepts and that a concept structure is something which we might try to develop on paper for ourselves or work with by conscious thought processes, or as something which we try to communicate to one another in serious discussion....A given structure of concepts can be represented by any of an infinite number of different symbol structures, some of which would be much better than others for enabling the human perceptual and cognitive apparatus to search out and comprehend the conceptual matter of significance and/or interest to the human. But it is not only the form of a symbol structure that is important. A problem solver is involved in a stream of conceptual activity whose course serves his mental needs of the moment. The sequence and nature of these needs are quite variable, and yet for each need he may benefit significantly from a form of symbol structuring that is uniquely efficient for that need. Therefore, besides the forms of symbol structures that can be constructed and portrayed, we are very much concerned with the speed and flexibility with which one form can be transformed into another, and with which new material can be located and portrayed. We are generally used to thinking of our symbol structures as a pattern of marks on a sheet of paper. When we want a different symbol-structure view, we think of shifting our point of attention on the sheet, or moving a new sheet into position. With a computer manipulating our symbols and generating their portrayals to us on a display, we no longer need think of our looking at the symbol structure which is stored - as we think of looking at the symbol structures stored in notebooks, memos, and books. What the computer actually stores need be none of our concern, assuming that it can portray symbol structures to us that are consistent with the form in which we think our information is structured. A given concept structure can be represented with a symbol structure that is completely compatible with the computer's internal way of handling symbols, with all sorts of characteristics and relationships given explicit identifications that the user may never directly see. In fact, this structuring has immensely greater potential for accurately mapping a complex concept structure than does a structure an individual would find it practical to construct or use on paper. The computer can transform back and forth between the two-dimensional portrayal on the screen, of some limited view of the total structure, and the aspect of the n-dimensional internal image that represents this "view". If the human adds to or modifies such a "view", the computer integrates the change into the internal-image symbol structure (in terms of the computer's favored symbols and structuring) and thereby automatically detects a certain proportion of his possible conceptual inconsistencies. Thus, inside this instrument (the computer) there is an internal-image, computer-symbol structure whose convolutions and multi-dimensionality we can learn to shape to represent to hitherto unattainable accuracy the concept structure we might be building or working with. This internal structure may have a form that is nearly incomprehensible to the direct inspection of a human (except in minute chunks)."

These insights have been incorporated into the design of an operational computer system which is now being developed so that it will be possible to use computer devices as a sort of "*electronic vehicle with which one could drive around with extraordinary freedom through the information domain. Imagine driving a car through a landscape which, instead of buildings, roads, and trees, had groves of facts, structures of ideas, and so on, relevant to your professional interests? But this information landscape is a remarkably organized one; not only can you drive around a grove of certain arranged facts, and look at it from many aspects, you have the capability of totally reorganizing that grove almost instantaneously. You could put a road right through the center of it, under it, or over it, giving you, say, a bird's eye view of how its components might be arranged for your greater usefulness and ease of comprehension. This vehicle gives you a flexible method for separating, as it were, the woods from the trees."* (7)

3. Conclusion

Application of this kind of technology to an understanding of the world problem complex has not been attempted. As explained above, such devices offer a means of developing improved conceptual (and associated organizational) structures to contain the complexity with which humanity has to deal at this point in time. Of vital importance is the ability of these devices to portray the information in a more meaningful (or "iconic") form than emerges from conventional quantitative studies. This is particularly important in communicating with the informed public but specially so with the policy-making community, as Harold Lasswell notes (8): *"Why do we put so much emphasis on audio-visual means of portraying goal, trend, condition, projection, and alternative? Partly because so many valuable participants in decision-making have dramatizing imaginations...They are not enamoured 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."*

NETWORK MAPS

1. Acceptability of network maps

It is now considered quite acceptable in many major cities to print and make available to the general public (often on notice boards or in tourist literature) various schematic maps: the subway (underground, or metro) network; the urban bus network; and the suburban railroad network. Travellers are also accustomed to exposure to documents showing the airline network. Other kinds of network are mapped for the benefit of workers in specialized sectors (*eg* oil pipeline networks, electricity distribution networks, telephone networks, military communication networks, goods distribution networks, *etc*). The most complex map of this type would seem to be that used to summarize (on a surface 100 x 132 cm) the relationships between over 1000 biochemical compounds involved in metabolism (See: Gerhard Michal. Biochemical Pathways. Mannheim, Boehringer Mannheim GmbH, 1974; also, but less complex: D E Nicholson. Metabolic Pathways. Colnbrook, England, Koch-Light Laboratories, 1974).

The point is that people are now very familiar with such maps in one form or another and use them, like road maps, to organize their thinking about the movement of themselves or items with which they are concerned between distant points embedded in a complex network. No such network maps are currently available to show the relationships between distant points representing particular features of the social system. As a result thinking about the social system and its problems is somewhat chaotic, as would be any discussion about travel in the absence of adequate maps to provide the necessary frameworks for such discussion.

2. Reasons for the lack of societal network maps

1. There is much confusion concerning the kinds of entities that can be distinguished in the social system, due to overlapping systems of categories, needs, and the maze of associated terminologies.

2. Where clarity emerges, it is usually in relation to one particular entity (*eg* one holding company and its network of subsidiaries, or one government agency and its associated bodies); any maps produced then have that body as the central reference point.

3. Much of the required information is scattered through a variety of reference books and no research has justified its systematic organization.

4. Systematic sociological research in the past inverts the focus so that, for example, instead of determining how many organizations (problems, *etc*) there are in a sample in order to determine the number per capita, the mean number of personal relationships to such entities is determined on a per capita basis, so that there is no means of determining how many distinct entities there are to which the relationships are established.

5. Where such information is collected it is often considered secret because of its political or economic significance. Examples are (a) the collection of data on organizations in every country by the civil or military intelligence units; and (b) the secrecy associated with the subsidiaries owned by a major (multinational) corporation at any one time and their interrelationships.

6. Where the data can be collected, and there is a strong case for doing so, there is often reluctance to do so because of the problems of data handling. This is best seen in the (non-societal) case of mapping ecosystem food webs in which animal species are embedded. There is a multiplicity of inter-specific "food chains", together with many branches and cross-connections among food chains making a structure of interactions called "food webs". The complexity of these food webs is such that no one has yet worked out the complete pattern of food relationships and interactions in any natural community. The relationships between 50 species in a given community results in a diagram so full of lines that it is difficult to follow and this only represents one quarter of the 210 known species in a "simple" community. (David Pimental. Complexity of ecological systems and problems in their study and management. In: K E F Webb (Ed) Systems Analysis in Ecology. New York, Academic, 1966, p.15-35).

7. Where the research has been done, there is a reluctance to produce maps because of the tiresome, time-consuming and often costly nature of the task of doing so, particularly when the networks are complicated.

3. Psycho-social significance of maps: a parallel

The current ability to map the societal system may be usefully compared to that of the European geographical mapping ability during the Middle Ages and earlier. The changing psycho-social significance and status of maps, since such early times, provides many clues for understanding the present situation. Maps in that period were often closely guarded secrets, for military and economic reasons. And just as the understanding in Europe of non-European continents was very limited at that time, so today there are only a few well-known problem areas (such as: population, food, peace, *etc*). Each such territory (or "feudal state") is more or less poorly controlled by a few major organizations (the "cities") with a few well-established links between them (the "roads" or "rivers"). The relations between these feudal states are the limit of concern. Few people travel long distances and when they do, in the absence of readily available maps, they use "experts" to guide them from point to point. Other continents are only vaguely known (and are widely held to be populated by mythical monsters). Each group is content with artistic or impressionistic two-dimensional maps centred on its own organization (or field of concern), confidently held to be the prime mover in the social system as perceived from that point of reference. The significance of any three-dimensional representation is not recognized and a flat-earth perspective prevails.

Under such conditions, it is easy to understand the psychological and communication difficulties which make it impossible to achieve any general galvanization of political will in response to world problems. Each sector is content with its own sketchy local map (if any is held to be required) of the problem environment, and there is little concern for whether such local maps mesh together with those of neighbouring territories or into a general map of the region. Communication therefore frequently breaks down and moments of solidarity are soon forgotten. Warring between feudal territories is common. The state called "energy", clashes with that called "environment". Alliances are formed and each state has imperialistic ambitions: "development" wants to incorporate "environment"; "environment" lays claim to the territory of "development", and all are claimed by the territory called "peace". Lacking maps, assemblies of individuals and groups from different problem territories are pathetic. The people from "heavy rainfall" areas cannot understand the constant harping on water by people from "desert" areas; the people from "arctic" areas cannot relate meaningfully to those from "tropical" zones.

The history of the evolution of geographical perceptions, and the tools that have been required to move humanity towards a global perception, indicate the kinds of difficutly which have to be faced. (The much-used NASA photograph of Earth from space is only significant as a symbol because people know that they can relate its features to the map of the world in their own atlas in order to be able to locate their home town, for which they also have a detailed local map, to which they can relate their personally acquired knowledge.) Local maps are needed which mesh into global maps, so that each can see his place in any world problem strategy and so that global decision-making can relate to the tactical problems of groups as perceived in each community.

Problem maps (bound together into "atlases") are needed to help individuals see and appreciate the relationships, distances and differences between problem territories. And it should be possible to relate these to organization (and other) maps, just as any atlas has contour maps, climatic maps and political maps of the same region. Individuals, whether students, executives, researchers, or policy makers, have at least as much need for such visual devices to orient themselves in the social system as they have for road and other currently available maps.

Hopefully it will be possible to reach a stage at which such maps can be produced as standard conference documentation as a means of providing background documentation for debates, and in order to sharpening the focus of debate. Clearly the debate itself should lead to proposals for the amendment of such maps (as a result of the recognition of: new issues, relationships between problems, proposals for organizations or programmes, or new relationships between organizations, *etc*). New versions of such maps, or hypothetical maps (*eg* of organizational systems) could be fed into later sessions of the same meeting or used as one form of summary of the achievements of the meeting.

4. Production of network maps

Once the information on societal entities is held on computer it becomes possible to overcome many of the obstacles to map production noted above. Computers are currently used to plot out electronic circuit diagrams and other types of network onto large charts. The computer programmes handle the tedious problem of designing such charts, including the use of appropriate colours to distinguish between different features of the network (or networks) on the same chart. (Artists, designers and communications psychologists can also introduce an aesthetic component to facilitate comprehansion). This approach has the considerable advantage that different designs (based on the same data) may be tried or used for different purposes. Some designs may be highly simplified, others may be very complex. New maps can be easily produced if the original data is modified. The data base used may be the same as that used for interactive studies of the network so that both approaches may be integrated under the control of a researcher.

However, although the computer programmes exist for the production of two-dimensional maps, there are difficulties still to be overcome in the representation of three (or n) dimensional networks on a two-dimensional surface, if such complex representations are necessary. Some of these mathematical and associated problems (of projections) have been examined by geographers interested in producing a more accurate representation of the spherical Earth on a map. Experiments have been made with a number of alternatives which each have their advantages. The data collected together on computer for this publication should encourage and facilitate similar experiments in societal network map production.

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Proposal : Development of an operational relationship mapping technique.

General description of problem

Documents in linear text form are at present the main vehicle for communicating insights on conditions and problems of many kinds, whether social, scientific, environmental, philosophic, cultural or administrative. No comment is necessary on the difficulties created by the information explosion as reflected in the proliferation of documents "relevant" to meeting, programme or policy concerns. At the same time, it is increasingly difficult to communicate key insights and concerns and the nature of their inter-relationship. They are too easily ignored or lost in the flood of information. Documents tend to be indigestible even if available in the appropriate language. Each person is necessarily protected by strategies to avoid "unnecessary" reading. The value of new "insightful" papers and reports is thus relatively limited. The insights are effectively entombed in documents despite efforts by documentalists to provide sophisticated systems of access. Abstracting systems and reviews of the state of the art do not respond to the condition. Reading/attention time is an increasingly scarce resource, particularly amongst those in a position to act on the insights. Too often such systems provide answers to less significant questions, whilst failing to assist users to formulate questions more appropriate to their concerns.

Mapping possibilities

"Mapping" has been used in the sense of compilations of relevant texts into a macro-document. It has also been used as a synonym for certain mathematical modelling techniques. Many attempts have been made to represent system and network relationships in different types of diagram - from the blackboard sketch to the sophisticated flow chart (1, 3) and the glossy artwork presentation (2). All these have obscured the possibility of a different approach whose advantages have not been fully explored.

A simple technique is required for visually recording "entities" of any kind (concepts, problems, organizations, animal species, etc.) and the relationships between them. The initial problem does not lie in the conception of such displays. Indeed network displays of concepts ("arrow diagrams"), molecules ("metabolic pathways"), groups/people ("social networks", "organization charts"), species ("food webs"), etc. have already been produced.

The initial problem lies in the fact that so much effort is required to display the information in that form, that there is very little incentive to experiment with improvements and complementary information aids. In their present form they are classed as relatively expensive "artwork", involving difficult decisions of positioning and balance. The design process is very time-consuming and any feedback concerning modifications means the process must be recommenced. Feedback and experiments with alternatives are therefore not encouraged and the technique lacks the dynamism and immediacy it might otherwise have. The maps are quickly outdated and become indicative rather than significant.

Proposal

It is proposed that :

1. Appropriate steps be taken to design and test a sequence of three computer programs :

   a. An input program whereby users can conveniently define and record :

      - the range of entities in which they are interested and certain user-defined characteristics (importance, type, quantity, etc.)

      - the relationships between those entities (again with user-defined characteristics (importance, type, quantity, etc.)).

   b. A program to manipulate the data and order it such that each entity/relationship is provided with coordinates on a 2-dimensional grid in a format suitable to drive the plotting program (c). It is in this program that display design considerations of balance and positioning must be resolved using mathematical optimization routines (probably already available).It should also permit (re)definition of the coordinate system and selection of subsets.

   c. Program(s) to portray the diagram on the basis of the coordinates generated by the previous program (b). Three forms of output should be considered :

- graph plotters, capable of producing large diagrams, possibly in colour. (Note that appropriate software already exists)
- terminal displays (CRTs), whether remote or free-standing, and particularly of the "home-computer" variety
- line printer, in the event that neither of the above is available

The above programs should, to the extent possible, not be hardware bound. They should be written in a common language such as FORTRAN.

2. Efforts should be made to test the above system on large tape-based data sets (e.g. that arising from the Yearbook of World Problems and Human Potential).

3. Particular attention should be given to the user's perspective :

   a. Ease of "associating" onto the input form (or device) and objectifying a "mental map"

   b. Ease of modifying or changing the importance of items on a map at any stage (e.g. as a result of discussion during a meeting)

   c. Ease of combining and separating input from several users, so that "personalized" maps reflecting the reality of different biases may be obtained.

4. Efforts should be made to test the above system as an aid to clarifying the areas of concern, agreement and disagreement, whether for meetings, programme elaboration, or general information (wall charts, etc.). It is important to know how well people can use such maps as a means of communicating their own perceptions of the complexity of a situation and comprehending how it is reinforced or negated by other perceptions. Whether it is possible to use such maps as a sort of questionnaire to provoke a series of feedback/modification iterations (a mapping analogue to the Delphi method), remains to be determined.

Further work

Whilst the emphasis should be on production of a simple operational system, possibilities (and costs) of extending and improving the system should be investigated.

Whilst there are many attractive possibilities for hand-drawn maps, it is strongly recommended that the investigation focus on the means whereby such work can be <u>facilitated</u> through dynamic interaction with data bases or displays extracted from them. Otherwise it will not be possible to breakout of the inertia of the present dependence on scarce, costly and time-consuming graphic stills.

Conclusion

This project should provide (groups of) users with a means of portraying an overview of their area of concern with whatever detail is required on its underlying structure.

Clearly such displays could condense and "pack" information present in a multiplicity of reports. The displays themselves could be presented in an interlinked pattern exploring detail reflected in a "large scale" display (on the "atlas" principle). They would be easy to reproduce and convenient to use either as a focus for meeting discussions, for educational purposes or as "memory aids" on an office wall. Transparent overlays are also an interesting possibility.

There are a multitude of uses for such a technique. A good example is the ability to input several hundred species, their food chain relationships, and entry points for accumulating pollutants (e.g. mercury). The technique would be available just as home-computers reached the point of accessibility at which people could make use of an associating aid to "sort out" their mental maps as a basis for a more adequate response to complex situations. Information in this form is more effective than an abstract or a verbal summary and as such appropriate maps could provide the first "non-linear" meeting agendas.

<u>Annex</u>

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CLARIFICATION OF NETWORK MAP REQUIREMENT

1. Background

The Union of International Associations is recognized as a non-profit scientific research institute under Belgian law governing international bodies established there. It functions as a clearing house for information on 15,000 international nonprofit organizations and their preoccupations. As such it produces a series of reference book from a data base shortly to be placed on-line via the European Span Agency (ESA-IRS). The books are:

- -Yearbook of International Organizations
- -International Organization Participation
- -Global Action Networks
- -International Congress Calendar
- -Yearbook of World Problems and Human Potential

2. Data

Magnetic tape files are generated or maintained as part of the production of the references books. In all they currently represent in excess of 60 megabytes of data. The tapes are all 1600 bpi, EBCDIC, odd parity, composed of fixed records of 180 characters, 20 records per block.
This note concerns the further processing of a subset of the above data taking the form of cross-references between (the numbered) entries of a certain type. At the present time interest is focussed on 12,000 such relationships between some 3,000 "world problems". The cross-references are of different types, denoted by a 2-digit numeric code. They indicate a relationship between two entities, each denoted by an alphanumeric 5-digit code (ANNNN). The relationships include: more general problem, more specific problem, aggravating problem (and aggravated problems), alleviating problem (and alleviated problems), associated problem, concerned organizations, concerned discipline, relevant human values, etc. The entities may be international organizations, world problems, treaties, or various kinds of concepts.

3. Preliminary analysis of the cross-reference tape

This is being undertaken by a separate programme (in Brussels). Basically this takes each entity (of the 3,000) as a starting point and produces a record tracing the chain of relationships out from it along each branch. The trace can be continued through up to 9 relationship links. Each record contains the chain for one branch out from the starting entity for one type of relationship.
The programme also produces complementary records on a parallel file with the name of each entity registered in the above trace (partly for use as an index). Other products of the programme enable loops in the network to be detected and corrected if appropriate. A statistical summary enables especially interesting nodes to be selected.

4. General processing requirement

The data on the above tapes must be analyzed in such a way as to produce a set of coordinates on tape which can be used to drive a graph plotter of one form or another so as to portray suitable representations of such networks of relationships. At this point two possibilities are envisaged:

- generation of "maps" as a substitute for questionnaires to the concerned international bodies and to enable the relationships networks to be "cleaned up" by editorial staff (Ideally this would be done in-house).
- generation of clean maps with higher quality typography for publication in the 1985 edition of the Yearbook of World Problems and Human Potential. This can be done by Computaprint (London) once the drive tape is formatted.

Briefly explained the problem may be compared to that of getting a computer to plot a suitable schematic map of a subway system (or a road network) when only the links between locations are given. In other words the optimal position must be determined for each location and the links between them. An additional desirable constraint is that the geometry should be relatively comprehensible namely ordered rather than arbitrary.

5. Breakdown of the task

The task may be split into the following problem areas.

- Processing strategies and run time choices between them
- Optimal distribution of network across selected surface ("packing")
- Determination of suitable scale for map(s)
- Determination of mapping details (typrography etc)
- Fitting in entity name text.

These points are discussed separately in the following sections.

6. Processing strategics and run time choices between them

The following strategics might be envisaged as run time options:
6.1 Global: Get tops of all "most connected" trees out onto a single map with whatever detail density considerations will permit.
6.2 Sub-global: Split global map into N sub-maps on which greater detail is possible
6.3 Top-of-tree focussed: Work out maps for many individual problem clusters, each map being centred on the top of the relevant tree.
6.4 Chain-focussed: Work out maps for networks ignoring links to top of trees or to unnecessary details.
6.5 Selection: Work out only from nodes specified individually at run time, whether according to the 6.1 or 6.3 strategy.

7. Optimal distribution of network across selected surface ("packing")

Various strategies might be used depending partly on the surface chosen.

7.1 Cluster analysis: Some variant of multi-dimensional factor analysis might be used. The weighting of the entities could be determined by the number of their direct and/or indirect relationships of specific types.

7.2 Iterative procedure: It is possible that a fairly simple iterativ procedure could be used to determine the optimal locations on a surface. This might be initiated by first positioning (selected?) tops-of-trees in an equidistant (regular) pattern across the surface before inserting nodes of a more detailed level.

7.3 Planar surface: Given the objective of plotting the maps on a planar surface, one option is to project the results of any multi-dimensional analysis onto such a surface and thus determine the plotting coordinates. A planar surface would also simplify any iterative procedure.

7.4 Spherical surface: Determining the positions of the nodes on a sphere is conceptually more attractive since it preserves and emphasizes the "globality" of the network in contrast to the arbitrarily bounded planar surface. The results of any multi-dimensional analysis could b projected onto such a surface. In the case of any iterative procedure this could be initiated with (selected) tops-of-trees positioned in an equidistant (regular) pattern over that surface. Such a surface of course raises questions as to how the results are to be represented on a plane surface.

7.5 Triangulated spherical surface: In order to be able to plot a map represented on a spherical surface, this may be represented by a suitably triangulated polyhedral approximation onto which the spherical results are projected. Coordinates for each triangular map can then be plotted. The set of triangles may subsequently be edge-linked to provide a map of larger positions of the network.

8. Determination of suitable scale for map(s)

The following factors determine the possible scale of the map:

8.1 Size of plotted map: This would normally be A4-pages size but chart size maps could be produced for certain purposes.

8.2 Plotting constraints: These would be determined by how much data could be fitted on without running the risk of over-writing.

8.3 Readability: Clearly whilst it may be possible to plot a very detailed map this may be undesirable if the map thereby becomes unreadable. The desirable "density" limits must be a run time option.

9. Determination of mapping details (typography, etc)

In order to increase the readability of the map it is valuable to take advantage of the sophisticated typographical possibilities when the map is directly projected onto print-ready film via a vector generator as opposed to being plotted by computer driven pens. Codes to trigge such typographical features need to be provided with the coordinates for the drive tape. Possibilities include:

9.1 Size of node: The size of the "dot" representation. A problem (etc) may be determined by its connectedness (whethere at the same level or at a lower level of detail)

9.2 Thickness of link: The thickness of the line representing the link between two problems may be dependent on the relative importance ('size') of the nodes so connected and possibly also on their distance apart.

9.3 Type of link: Possibilities such as using full line, dotted line, or some other variant may also be envisaged to distinguish different types of relationship or different levels of detail.

9.4 Colour: Whether plotted or vector-generated, different colour conventions may be envisaged to distinguish different types of relationship. When vector-generated onto film, this possibility is related to that of overlays in general.

9.5 Overlays: It may be useful to envisage the possibility of overlays in order to produce maps of higher density and to print those using several colours.

9.6 Stero-effect: In order to facilitate comprehension of complex networks, consideration should be given to the production of maps overlays (in red and green) calculated to create a stereo-effect (as is done with the representation of complex molecules).

10. Fitting in entity name text

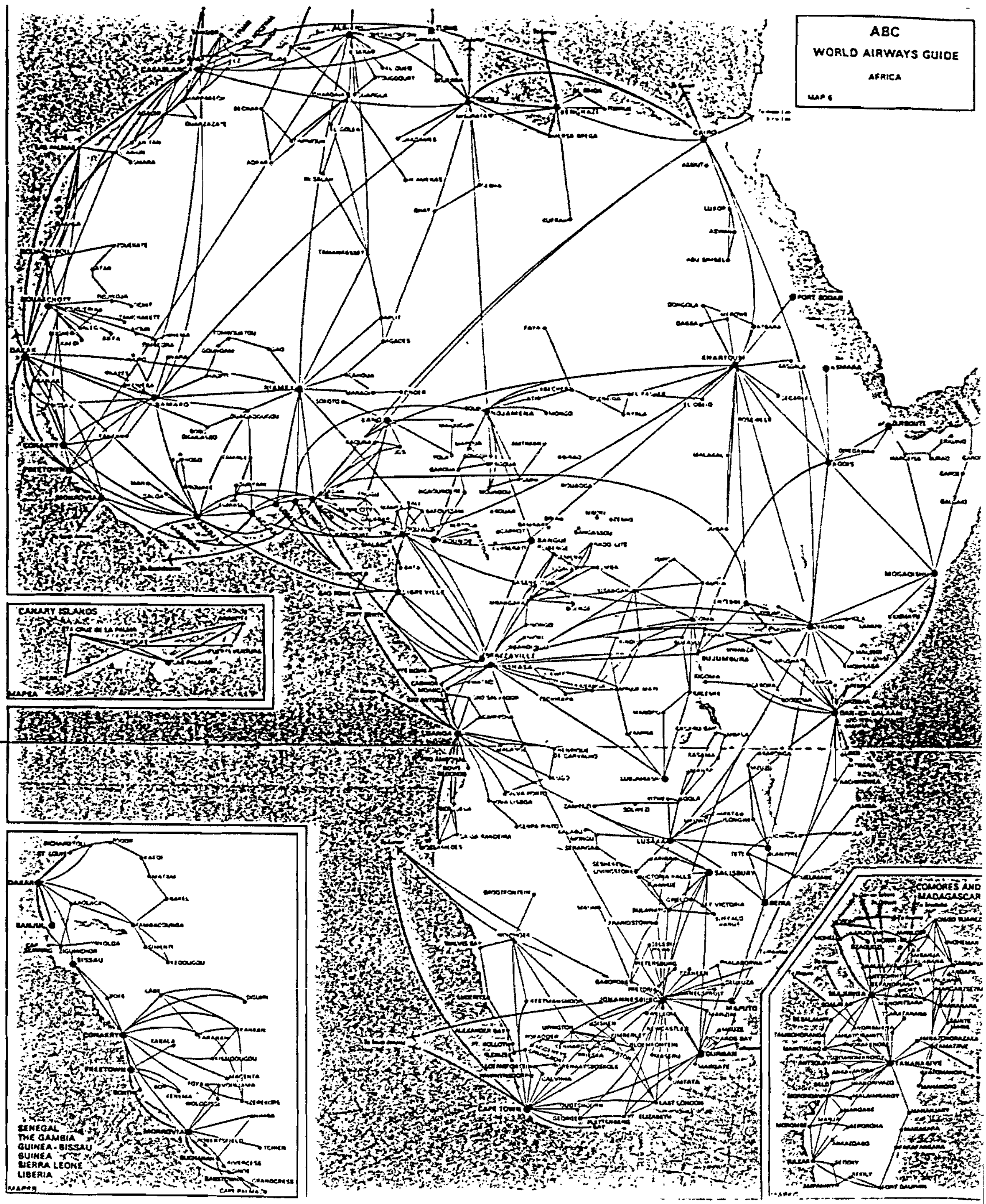
This is the problem of leaving space beside nodes for a name to be inserted (by vector generator or plotter). Various techniques can be used to achieve this and avoid over-writing:

10.1 Vary type size: According to the "size" of the node, more or less space may be reserved. Smaller typesizes may be used for less connected nodes.

10.2 Truncate names: This possibility may be explored given that the names tend to be long

10.3 Omit names: This technique can be used for the smallest nodes or least connected nodes.

Union of International Associations
40 rue Washington
B-1050 Brussels, Belgium


ABC
WORLD AIRWAYS GUIDE
AFRICA
MAP 6
CANARY ISLANDS
LAS PALMAS
COMORES AND MADAGASCAR
TANANARIVE
SENEGAL
THE GAMBIA
GUINEA - BISSAU
GUINEA
SIERRA LEONE
LIBERIA
DAKAR
BANJUL
BISSAU
CONAKRY
FREETOWN
MONROVIA
CAIRO
KHARTOUM
PORT SUDAN
DJIBOUTI
MOGADISHU
NAIROBI
DAR-ES-SALAAM
BUJUMBURA
BRAZZAVILLE
KINSHASA
LIBREVILLE
LUSAKA
SALISBURY
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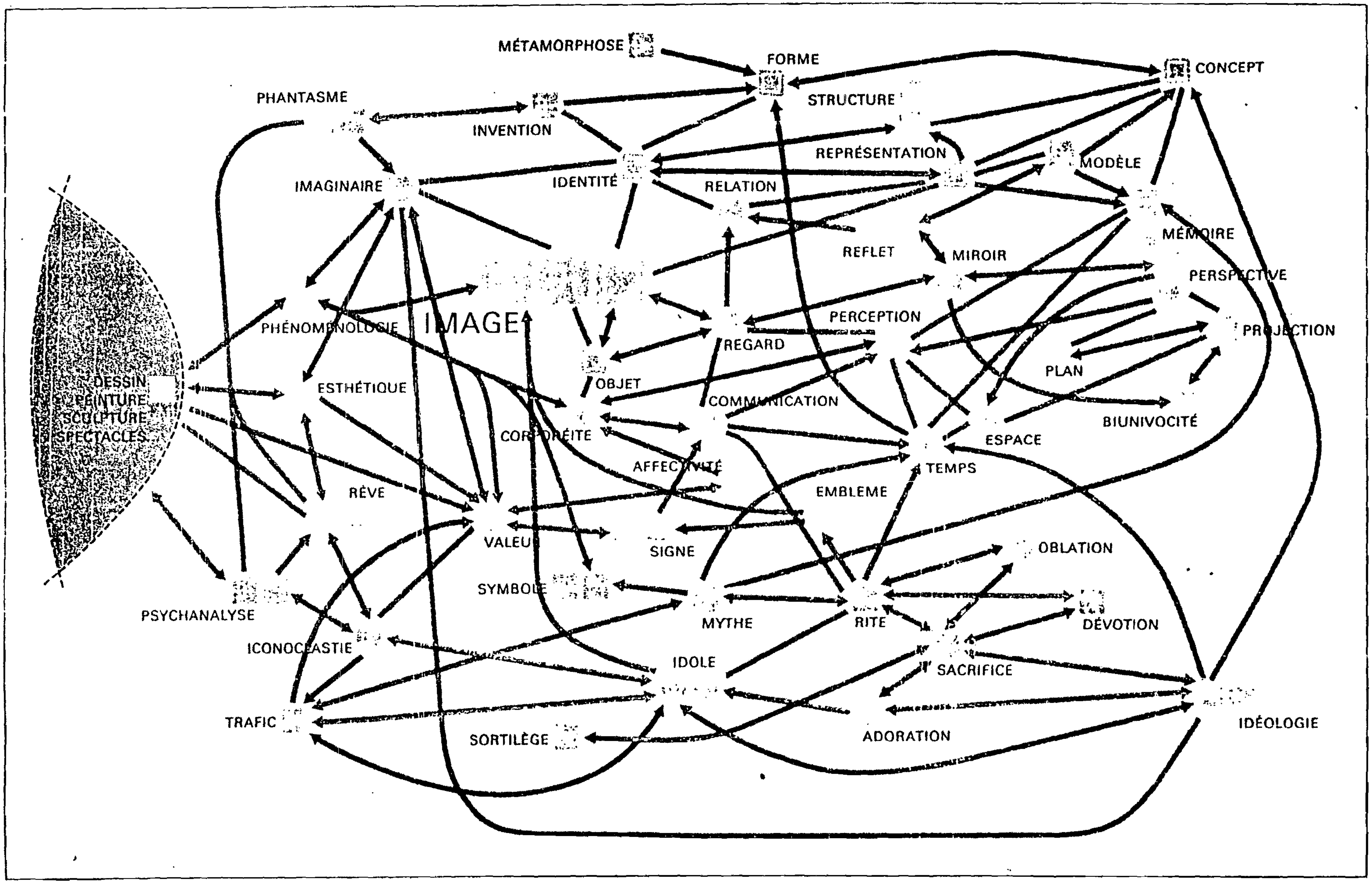
JOHANNESBURG
DURBAN
CAPE TOWN
EAST LONDON
NIAMEY
BAMAKO
KANO


MÉTAMORPHOSE
FORME
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MÉMOIRE
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MIROIR
PERSPECTIVE
PHÉNOMÉNOLOGIE
IMAGE
PERCEPTION
REGARD
PROJECTION
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OBJET
DESSIN
PEINTURE
SCULPTURE
SPECTACLES
ESTHÉTIQUE
COMMUNICATION
BIUNIVOCITÉ
CORPORÉITE
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TEMPS
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TRAFIC
SORTILÈGE
ADORATION
IDÉOLOGIE

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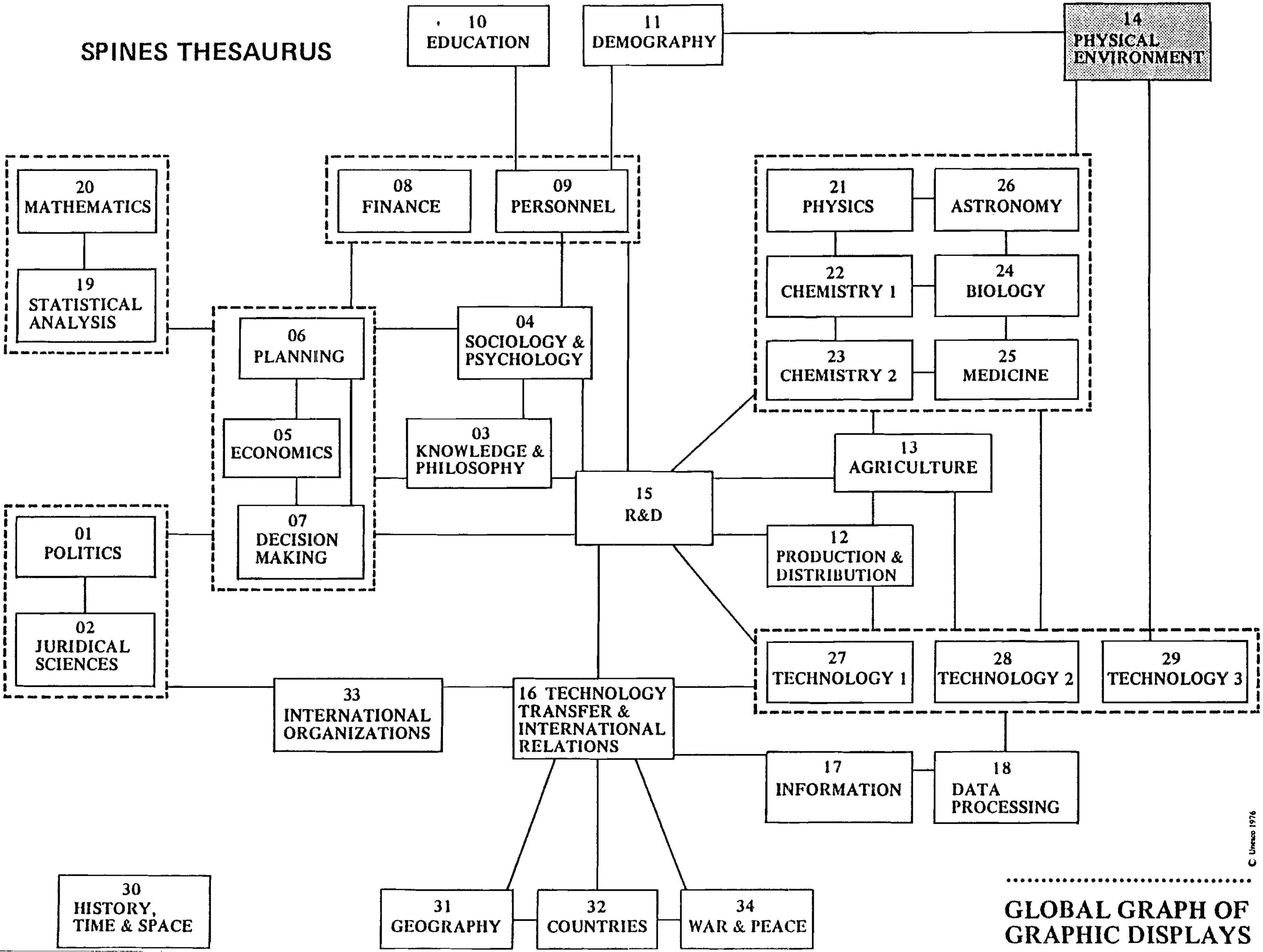


GLOBAL GRAPH OF GRAPHIC DISPLAYS

ASSOCIATIVE RELATIONS BETWEEN TOP DESCRIPTORS OF GRAPHIC DISPLAY 14, AND EXTERNAL TOP DESCRIPTORS

14-01 SEASONS

AGRICULTURE	13-09
PERIODICITY	30-03

14-02 WEATHER

14-03 CLIMATOLOGY

GEOGRAPHY	31-06
REGIONS	31-02

14-04 HUMIDITY

14-05 ENVIRONMENT DEGRADATION

HAZARDS	25-03
SOCIAL PROBLEMS	04-04

14-06 ENVIRONMENT SERVICES

AGRICULTURAL SERVICES	13-10
S&T SERVICES	15-02

14-07 ENVIRONMENT MANAGEMENT

CIVIL ENGINEERING	29-11
ENVIRONMENTAL TECHNOLOGY	29-14
MANAGEMENT	07-12
RESOURCES MANAGEMENT	06-14

14-08 NATURAL RESOURCES SERVICES

AGRICULTURAL SERVICES	13-10
S&T SERVICES	15-02

14-09 OCEANOGRAPHY

GULFS	31-04
OCEAN CURRENTS	31-03
OCEANS	31-09

14-10 METEOROLOGY

14-11 SURVIVAL

DEFENCE	34-08
HAZARDS	25-03
HEALTH	25-02
WELFARE	04-03

14-12 ENVIRONMENT QUALITY

WELFARE	04-03

14-13 ECOLOGY

ANTHROPOLOGY	24-05
BIOLOGY	24-03
PEST CONTROL	13-05

14-14 HYDROLOGY

DRAINAGE	13-17
LAKES	31-14
WATERCOURSES	31-13
WATERWAYS	31-15

14-15 ATMOSPHERIC PHYSICS

PHYSICS	21-08

14-16 PHYSICAL ENVIRONMENT

ENVIRONMENTAL TECHNOLOGY	29-14
GEOGRAPHY	31-06
WORKING CONDITIONS	09-08

14-17 WATER

14-18 CARTOGRAPHY

CIVIL ENGINEERING	29-11
GEOGRAPHY	31-06
MAPS	31-11
SURVEYS	19-05

14-19 ATMOSPHERES

INTERPLANETARY MEDIUM	26-02

14-20 MINERAL DEPOSITS

MINES (EXCAVATIONS)	29-21
MINING TECHNOLOGY	29-20

14-21 ICE

14-22 SOILS

LAND	13-16

14-23 ROCKS

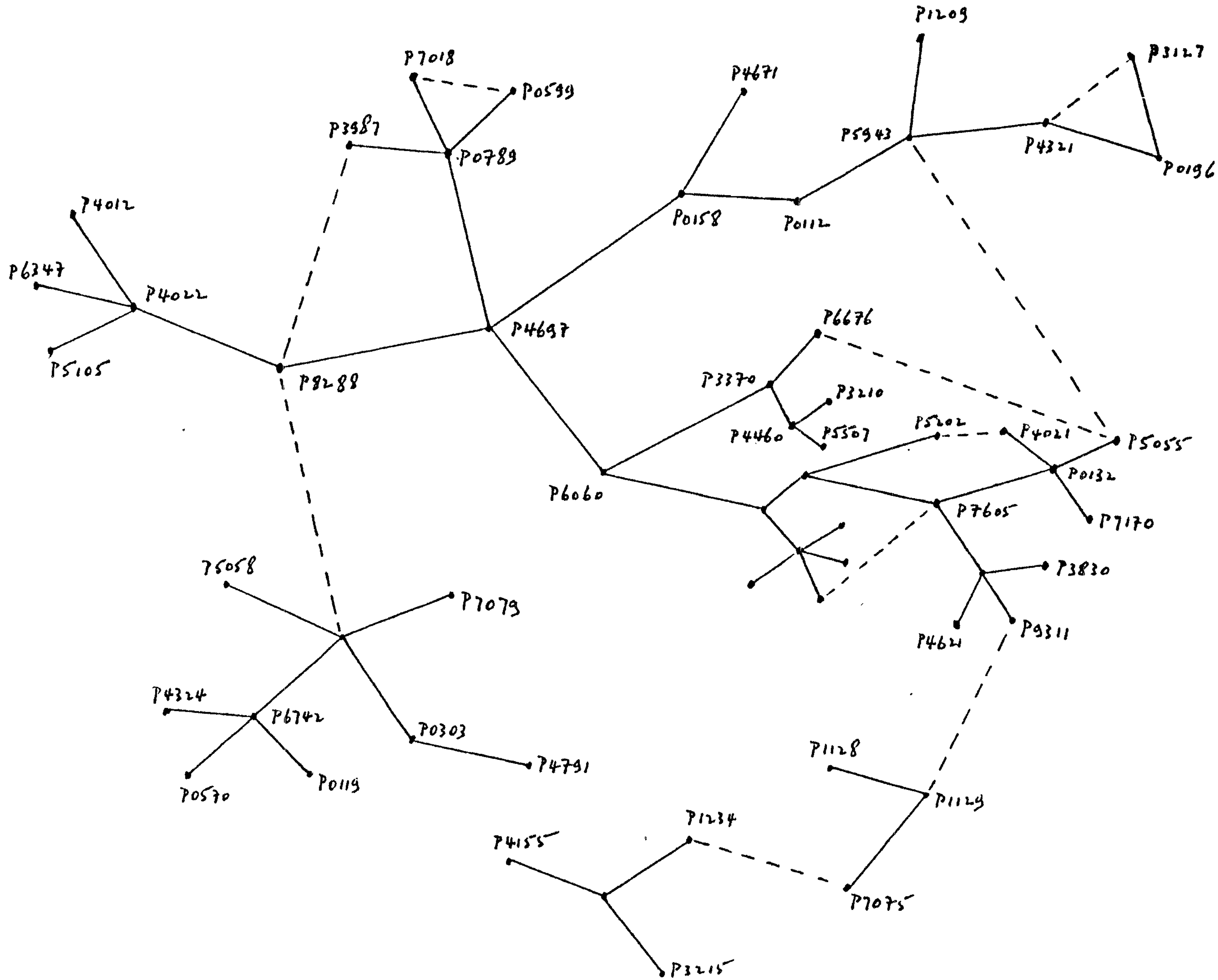
MINES (EXCAVATIONS)	29-21

14-24 SOIL SCIENCES

14-25 GEOLOGY

14-26 GEOPHYSICS

PHYSICS	21-08
RADIOACTIVITY	21-22
TOPOGRAPHY	31-12



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P4021
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P7605
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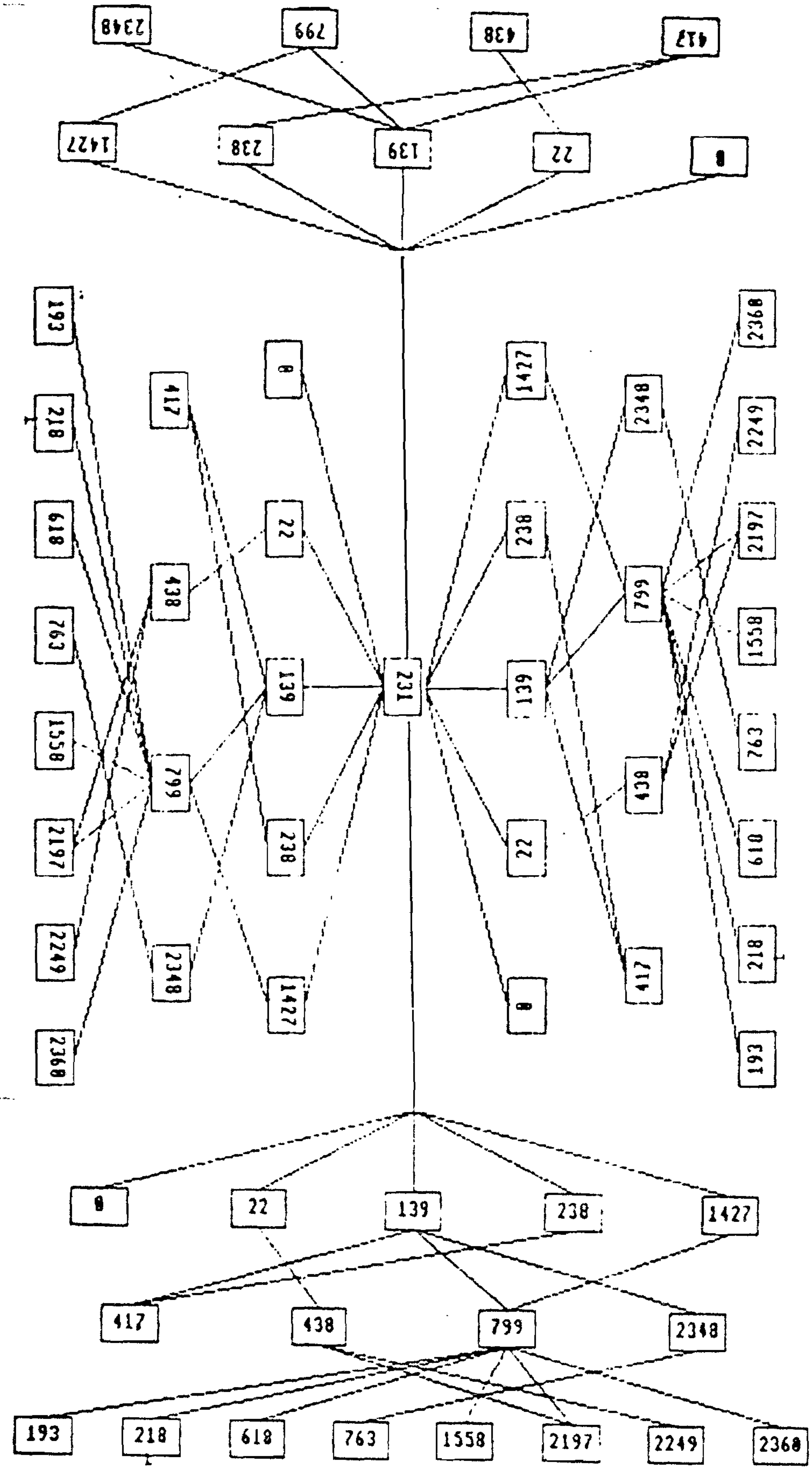

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22
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2197
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2368

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SHEET A: CROSS REFERENCE OVERVIEW BY TYPE *   SOURCE: PROBLEMS (TESTS)   * TYPES : 50 51 60 61                DATE : 19/04/85

FOR : P0001     = ENVIRONMENT<
                                                                                                    LEVELS SEARCHED: 5
51 TYPE RELATIONSHIP = NARROWER PROBLEMS

P0001 ---- P0000 ---- *ENDS
  |
  |-------- *LOOPS
  |
  |-------- P0002 ---- *LOOPS
  |           |
  |           |-------- P0044 ---- *ENDS
  |
  |-------- P0003 ---- *ENDS
  |
  |-------- P0004 ---- *PRECIP
  |           |
  |           |-------- P0007 ---- P0009 ---- P0012 ---- *ENDS
  |           |           |           |
  |           |           |           |-------- P0013 ---- P0014
  |           |           |           |
  |           |           |           |-------- P0014 ---- *ENDS
  |           |           |           |
  |           |           |           |-------- P0015 ---- *ENDS
  |           |           |
  |           |           |-------- P0010 ---- *ENDS
  |           |
  |           |-------- P0008 ---- P0011 ---- *ENDS
  |           |
  |           |-------- P0099 ---- *ENDS
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  |-------- P0005 ---- P0016 ---- *ENDS
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  |           |-------- P0017 ---- *ENDS
  |           |
  |           |-------- P0018 ---- *ENDS
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  |-------- P0006 ---- P0020 ---- *ENDS
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  |-------- P0007 ---- P0009 ---- P0012 ---- *ENDS
  |           |           |
  |           |           |-------- P0013 ---- P0014 ---- *ENDS
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  |           |           |-------- P0014 ---- *ENDS
  |           |           |
  |           |           |-------- P0015 ---- *ENDS
  |           |
  |           |-------- P0010 ---- *ENDS
  |
  |-------- P0015 ---- *ENDS
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