Information and an Organized Process of Design

A Research Project Proposed
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Warren Weaver once drew attention to what he called problems of organized complexity, as being the most pressing in the modern world. It is no secret to anybody that designers today are being overwhelmed by many kinds of complexity.

This paper will discuss two topics concerned with complexity today, and try to make some connection between them. The first topic, that of information storage and retrieval, is really nothing but a slightly sophisticated modern version of the old question, "How shall we classify material in a technical library?" The second topic deals with the obvious answer to this question, "It all depends on how you intend to use the material in the library." Again, this answer will be given a slightly sophisticated twist by relating the use of information to the sequence of decisions that go to make a process of design. Let us first focus our attention on some sources of complexity in these two topics.

First, whether you are trying to design a radio, a house, or a chemical plant, the problems which have to be solved today are actually more complex than they used to be, in the sense that there are more stringent requirements to be met, so that the conflicts between these requirements have become more intricate, and therefore harder to resolve. What is perhaps most important is that their resolution is, for the first time, clearly beyond the capacity of individual designers. Unfortunately, we can't just make up for the individual's lack of capacity by substituting a team. The "Architects Collaborative" at Cambridge is an organization started with very noble intentions by Walter Gropius, but the collaboration quickly became nominal, and now design goes on there very much as it does in any other architect's office. Why did this happen?

We have all suffered from the lack of communication in committees and conferences. For a team to work as effectively as an individual, the communication within the team must be quite exceptional. To put it rather fancifully, this communication really needs to reach the same order as the neurological communication which takes place within an individual designer's brain. It is only then that the members of the team can achieve the level of coordination necessary to solve the problem in the integrated way that an individual designer manages. However, there can be no communication until it is clear

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what the communication is to be about. At present we don't even know that. And this makes it clear, if nothing else does, that the process of design must be given explicit organization before the modern complexity of requirements and conflicts can be overcome, because teams will not be able to carry out communal design work properly until this happens.

The second kind of complexity we deal with concerns information. The information which bears on design problems is enormously complicated, very diffuse, more and more specialized every day. It is not all in one place: you can't find out what you want to know, because usually you don't know where to look, and often you don't even know whom to ask.

To sum this up, when you have a problem and you want information which bears on it, ideally you would like to have all the available information relevant to your problem, and none of the information irrelevant to it. Unfortunately, we rarely achieve this. Most often we search through a great deal of irrelevant information, and come out of it with just a little bit that is relevant. And, of course, the more scattered and specialized the information the more difficult it is to get the facts you want.

What is more, processes of design are themselves so lacking in order today that designers are hard put to it even to say what kind of information is relevant to their purposes. This doesn't mean that they can't make a crude distinction between information which is important and that which is not, but relevance is more than importance. Relevance presupposes use. And, since the part which information is to play in the process of design (the way it is to be put to use) has never been defined, it is hardly surprising that relevance is a rather tricky subject.

Thus, we have two problems:

1) How do you organize a design process so that it has explicit enough shape, as a process, to provide the basis for communication in a design team?

2) How do you store your information so that you can always lay your hands on what you want?

In a way, these are both problems of relevance. We must define what we mean by "relevant information" before we can organize the library. And, we have to know which aspects of a problem are most relevant to its solution before we can organize a design process. Ideally, these two questions of relevance should be answered simultaneously. In both cases, relevance depends on the structure of the problem you are trying to solve. Let me try to explain this by going at it backwards.

What is it about the way we usually try to handle complex problems that makes them hard to solve? To make a complex problem manageable, we classify its various aspects. A typical example of such a classificatory term (and a quite recent one) is the word "acoustics." "Acoustics" is a classificatory heading in the technical section of the Massachusetts Institute of Technology's design library, but that does not solve the problem. The whole problem of classifying library material is, in a way, the same as the problem of building up a process of design. In other words, the use of the classificatory term "acoustics" in the library is coupled with the fact that whole books are devoted to this one subject; that there is an Acoustical Society of America; that there are firms of consultants who specialize in solving acoustic problems; that there are moments in the designing of any building when the designers sit back and say, "Now, what about the acoustics?"

All this suggests that the acoustic problems of design can somehow be isolated from the rest of the problem; in fact, acoustical engineers will tell you with amazement that some designers don't consult acoustical experts until after their buildings are designed, or even (in some unfortunate cases) completely built.

This is not to imply that problems of design must be seen as wholes, that you cannot possibly break them apart without interfering with the unity of the creative process. In fact, this would be a very romantic kind of idealism. What we know about cognitive processes and the brain suggests strongly that human beings always tackle complicated problems in pieces, even when they experience the strongest illusions of creative unity[1]. * All I am quarrelling with is the arbitrary nature of the subdivisions. The presence of the word "acoustics" in the English language is to some rather considerable extent a linguistic accident, but, after all, the language which generates the word is only most distantly related to the problems we are trying to solve. What I have been working on for some years is the possibility of breaking a problem into pieces which are more intimately connected with its structure than arbitrary classifications like "acoustics[2]."

Let us consider an example. The basic elements of a problem are the specific requirements which are to be met. Thus, acoustics is really just a name for a set of specific requirements—all those which have to do with noise. We do not want to hear the neighbors' radio; husbands do not want to hear the children squalling; wives want to hear the children in case anything is wrong; I want to hear my hi-fi to the best advantage, and to have parties at late hours without waking other people; I don't like the bathroom and garbage disposal units to make too much noise, or the planes flying overhead to disturb me.

There are large numbers of such requirements (of many different types, of course, not just acoustic ones). The reason it is difficult to meet them all at once is that many of them conflict with one another, and it is these conflicts which give the problem a structure. We can picture this structure by means of a mathematical entity called a linear graph or topological one-complex[3] (Fig. 1). In this diagrammatic example, the points stand for requirements, the links for conflicts. Of course, a real problem is still more muddled and intricate. What we do in a process of design is to look at various incomplete sets of requirements in turn, decide what their implications are, possibly make diagrams of these implications, and then fuse the diagrams into more complex diagrams, until finally we have a complete design.

The sets of requirements we ought to look at are those which correspond to the subsystems of the problem, as they are indicated in Figure 2. What I mean by saying that acoustics is an arbitrary concept, unrelated to the structure of any specific problem, is that in most problems it turns out to be the name of a set that looks like Figure 3, rather than like those in Figure 2. In other words, the various specific requirements which deal with noise problems, though they have a common linguistic bond, do not really make a functional subunit of the problem[4]. I can't explain here precisely how to carry out the analysis which defines these subsystems properly. It depends on a formal, mathematical way of picking out the same entities which we can see by eye in very simple cases[5].

*Raised figures in parentheses refer to List of References at end of paper.

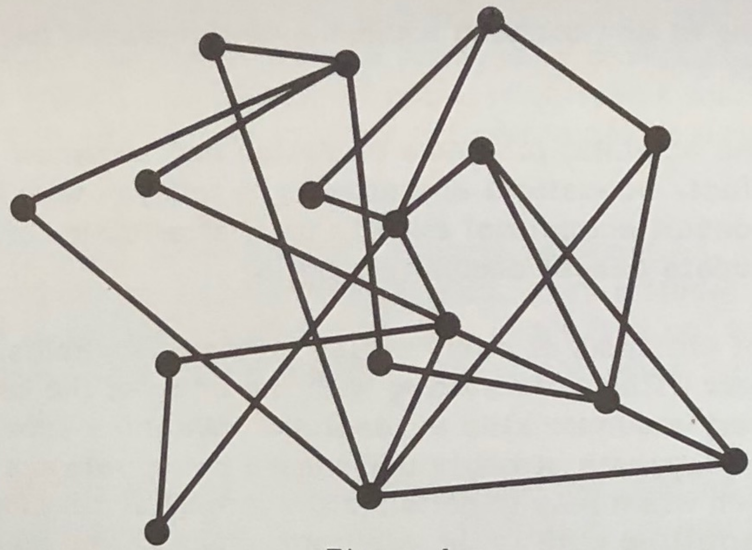

Figure 1

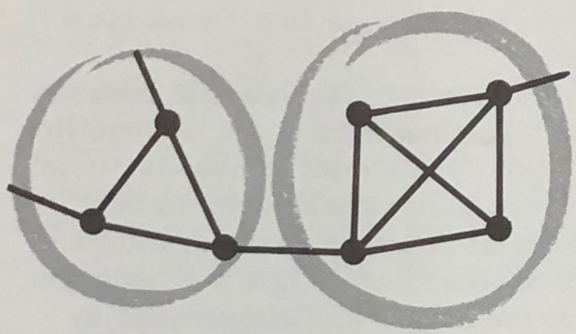

Figure 2

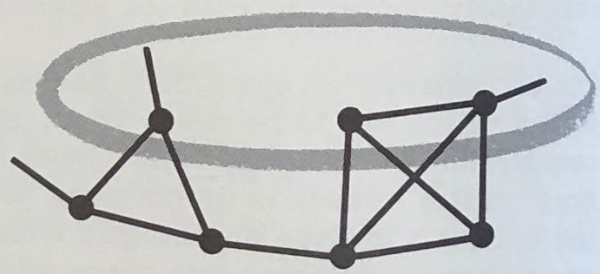

Figure 3

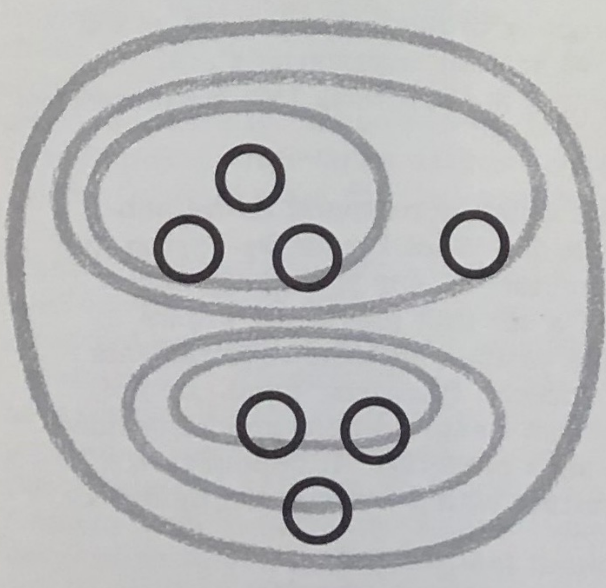

Figure 4

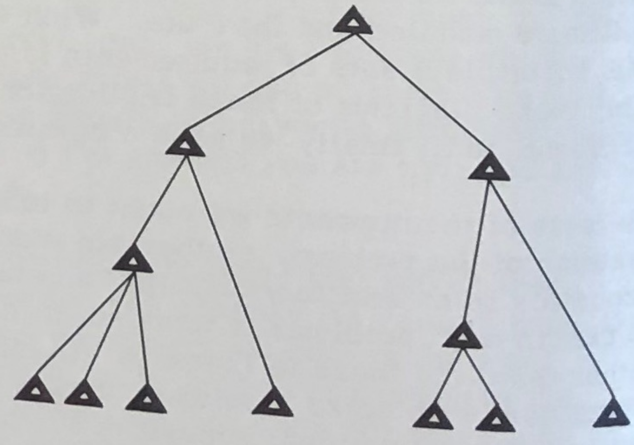

Figure 5

If we do a complete analysis of a problem's graph, we get something that looks like Figure 4, a nested system of systems within systems. Each system consists of a densely connected set of requirements. Thus, imagine that the smallest circles in Figure 4 contain the same sort of thing as the circles in Figure 2. This nest of systems clearly has a hierarchical character. We can make another picture of the same structure which brings out its hierarchical form more obviously, and looks like a tree (Fig. 5). This tree really prescribes the process of design. You start at the bottom, solving the simplest systems of requirements, and work your way to the top[6].

What we want now, naturally, as we conduct the process of design, is to be able to get our hands on the information relevant to these different subsystems as we solve them one by one. If there were only one problem we wanted to solve, we could obviously do this by using that problem's hierarchy as the basis for classification in the library. That is, each item of information that came into the library could be classified according to the subsystem to which it was most relevant, so that the library's organization would also be based on this same hierarchy. The Universal Decimal Classification system is based on a single hierarchy of concepts in very much this way.

Unfortunately, while we have just a single library, we have many different problems to solve, each with its own characteristic hierarchy of subsystems. This means that the organization of the library must be independent of any one problem, and cannot be dependent on any single hierarchy of concepts. To achieve this greater library flexibility, a number of methods have been suggested in recent years. The central criticism implicit in each of these suggestions is directed against the use of inflexible and arbitrarily chosen categories, very much as my criticism of current design procedures has been. Recent progress in this field has produced the method known variously as multiple indexing, coordinate indexing, and concept coordination. With this method, a set of classificatory terms or key-words are used in place of the old, fixed classificatory headings. Each item, as it comes into the library, instead of being classified under some one heading, is indexed by all those terms which are pertinent to the information it contains[7].

If now you wish to get information out of such a library, you express the question you wish to ask as a combination of classificatory terms. Each item of information which has been indexed with the combination you have indicated is then selected. For instance, suppose we have a library dealing with space technology, and such index terms as "atmosphere," "orbit," "drag," "rocket," "satellite," "jet-stream," "wind," "radar," "velocity."[8] You might then ask for all the items of information classified under both "wind" and "velocity," or for all the items under either "wind" or "jet-stream," and "drag," or for those under "rocket," and then either "jet-stream" or both "wind" and "velocity." In each case what you have actually done is to express an inquiry as a Boolean or logical function of certain terms. Thus, the three inquiries given as examples have the following functional forms:

$$A \cap B, \quad A \cup (C \cap D), \quad E \cap (C \cup (A \cap B))$$

Such functions, in this context, are called retrieval functions. The retrieval function defines a set of items. They may or may not be the ones you want. In fact, we may now press the relevance issue very sharply. To get all the information relevant to any inquiry, we have to find an appropriate retrieval function which does in fact include all the items of wanted information, and exclude all those not wanted.

We have already taken a step towards the problem of finding the relevant information in a design process, because we have succeeded in delineating the process as a hierarchy of subsystems of requirements. We now face a very specific research task. It is this: Given a library organized according to the kind of multiple indexing method described, and given some specific problem whose hierarchical structure we know as the result of mathematical analysis, what kind of logical retrieval functions will select the items of information which are relevant to each step in the hierarchy?

The problem of finding these retrieval functions must then be divided into two further steps. The first step is to express the items relevant to each requirement, as a function of the library's classificatory terms. This is an ad hoc problem with no great theoretical interest. Once it is done, since each item of information is then defined as relevant to certain requirements and not relevant to the others, we in effect re-indexed the library, using the requirements as indexing terms. Each requirement has associated with it a set of items, which I shall call the requirement-set.

The second step is to express the set of items relevant to each subsystem of the hierarchy as a function of its component requirement-sets. This is a significant theoretical problem. Referring to the picture of these subsystems in Figure 2, one possible retrieval function would be the union of all the requirement-sets in the system $R_1 \cup R_2 \cup \ldots \cup R_i$. That is, you take every item which is indexed under at least one of the requirements in the system. Usually, this will be much too large a set, and will contain much information you don't want. Another possible retrieval function would be the intersection of all the requirement-sets, $R_1 \cap R_2 \cap \ldots \cap R_i$; that is, just those information items which are indexed under every requirement in the subsystem. Usually, this set will not contain a wide enough selection of information.

Some function in between these two is needed. To see what kind of function might be adequate, we must reconsider the purpose of the design process. The crux of the design problem is to resolve the conflicts between requirements, so the information necessary is that information which bears on the resolution of these conflicts. In the simplest subsystems, we might take the union of certain pair-wise intersections; for instance, $(R_1 \cap R_2) \cup (R_1 \cap R_3) \cup \ldots \cup (R_i \cap R_j)$, taken over the linked pairs ij. That is, all the items indexed under both requirements of any pair which are in conflict, and hence linked in the graph.

What about the next level of the hierarchy? You don't want all the information you've obtained so far. Not only have you used it already but, as you move up the tree, it mounts up in volume and becomes impossible to handle. What you really want now are those items which are relevant to the conflicts you are about to resolve, but not to those you have already resolved; that is, some function of the subsystem based on the links between its own subsystems. (In Figure 2, for instance, there is just one link of this kind between the two circles.) The crucial point is that these functions should be based on the structure of the conflicts in the problem.

To sum up this discussion: If a design process is to make optimum use of the information available, it must be possible to set up temporary isomorphisms between the library's organization and the cognitive organization of the process. In both cases you have the task of finding relevant classifications. In one case you are trying to classify requirements, in the other you are trying to classify items of information. To tie the two together, you must find some logical or mathematical relation between the two classification systems. I propose using the topological structure of the problem as the source of this relation.

To find out which kinds of retrieval functions will really have the properties we want, we shall have to make experiments with various functions in real actual work situations. One possible, practical research program might be set up as follows:

GENERAL PROCEDURE

A suitable test problem is the design of an urban residential community which overcomes the contemporary difficulties of noise, privacy, and technical production, one of the most urgent problems in contemporary architecture(9). In view of the failure of existing cities in these respects, any successful solution will have to be radically different from the developments now being built, and therefore affords good opportunity for gauging the progress of the experiment.

PERSONNEL

The design analyses so far undertaken (at Harvard and M. I. T. respectively) make it clear that an experiment with the degree of sophistication required to get results should be carried out in much finer detail, with more highly differentiated personnel, and cover a period of at least three years.

The minimum pilot organization capable of carrying out the proposed experiment should consist of four professionals and secretary:

1) Program Coordinator— Trained mathematician and architect. Principal functions: to state the problem, analyze it, define and supervise the design program.

2) Information storage and retrieval specialist— Trained librarian with computer experience. Principal function: information collection and organization.

3) Communication designer— Trained designer with knowledge of architecture, experienced in graphic means of communication. Principal function: information reduction and presentation.

4) Architectural designer— Trained architect with office experience, familiar with special problems of the building industry. Principal function: use of reduced information in design.

5) Secretary.

DETAILED PROCEDURE

Phase One (6 Months)

Program coordinator and architectural designer together define the problem in graph-theoretic terms.

Information specialist prepares and indexes an information store of relevant material according to some multiple indexing principle. It should contain between 1,000 and 10,000 items.

Phase Two (6 Months)

Program coordinator makes the topological analysis of the problem and defines the design program as a hierarchy of subsidiary problems to be solved.

Information specialist defines requirement-sets as ad hoc-determined functions of the indexing terms, and sets up a computer simulation.

Communication designer and architectural designer work out a graphic language for condensing and abstracting packets of items from the information store.

Phase Three (18 Months)

In this phase the research group moves through the full sequence of problems defined by the hierarchy. They spend a great deal of time on each step of the sequence, experimenting with different retrieval functions. A typical hierarchy may contain 50 subsidiary problems.

Information specialist tries different retrieval functions, each time supplying the communicator designer with different packets of information.

Communication designer translates each packet of items into usable graphic form.

Architectural designer uses the graphically condensed information to work out diagrammatic solutions to the step of the problem in hand.

Program coordinator observes and records the effect of different functions and invents new functions according to the progress made.

Phase Four (6 Months)

Preparation and publication of reports and drawings.

SUMMARY OF OBJECTIVES

The primary objective is to find out what effect different logical retrieval functions have on the packets of information they select, and hence on the use which can be made of them. The experiment should make it clear, in particular, how differences in the packet of information affect:

1) The over-all course of the process.

2) The ease of communication between information store, communication designer and architectural designer.

3) The physical form of the design.

COST

Salaries for four professionals, $45,000 per annum Three years	$135,000
Secretary's salary, $3,500 per annum Three years	10,500
Equipment, office supplies, etc.	3,000
Paid consultants, to be used principally during the initial phase	2,500
Books, papers, etc., which can be dissected for use in the information store	5,000
Travel, conferences, contingencies	11,000
Access to computing equipment. (It is hoped that some equipment manufacturer will donate the required machine time.)	-0-
Total (Three years)	$166,000

LIST OF REFERENCES

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4) Chermayeff, S., and Alexander, C., Community and privacy, to be published, Doubleday, 1963.

5) Alexander, C., op. cit.

6) Ibid.

7) Wall, Eugene, A practical system for documenting building research, Documentation of building science literature, National Academy of Sciences—National Research Council, Pub. 791, pp 15-31, Washington, D.C., 1960.

8) Information retrieval, International Business Machines, Inc., 1959.

9) Chermayeff and Alexander, op. cit.

OPEN FORUM DISCUSSION

Henry C. Brown, Armstrong Cork Co.: Are you familiar with the attempts on the part of the Building Research Institute to look into this question of documentation and information retrieval, and if so, do you feel that this is a step in the right direction? Do you think the proposed BRI Documentation Program is the right way for the Institute to approach this?

Mr. Alexander: I only know in a very general way that BRI has set up a trial system which, I believe, is of the multiple-indexing kind that I mentioned. In the first function discussed in my paper, provided you can establish the requirements, you can re-index your library according to the requirements of your program. Then the actual classification in the library is not crucial. I imagine that the BRI library would be perfectly suitable for a test run. I don't know what it contains, but I doubt that it contains a wide enough variety of information to satisfy an architect. Am I correct in this?

Mr. Brown: This project is concerned entirely with the building field. BRI is starting to index building research documents by the coordinate indexing system. The program is in the test stages now. They have so far indexed 10 documents in order to gain some background experience, and now it is proposed that this be expanded to 100. The ultimate aim is to provide at some time in the future a documentation and information retrieval service for BRI members.

Mr. Alexander: Is there some kind of report available which describes what they have done so far?

Mr. Brown: There is no report available yet, but the staff has been working on this program, and I am sure that if you communicate with Mr. Harold Horowitz, he will be glad to bring you up to date on how far it has progressed.

Ben H. Evans, Texas Engineering & Experiment Station: This system of filing documents by concept rather than by book title is a wonderful idea. It makes it possible to retrieve information speedily, and to get what you really want. However, I got the feeling from your paper that you felt the answers were all there, and that all we had to do was find them. I am not convinced that this is true. You can read all the books in a library, and sometimes you still can't get the answer you are looking for. By your process, you diagrammed the problem, and then you found the answer. You implied that there was some mathematical relationship, and all that was necessary was to add or subtract, to arrive at the solution. It seems to me that we still have to exercise a tremendous amount of judgment somewhere in the problem, or perhaps I didn't quite understand the relationship.

Mr. Alexander: The relation between the problem structure and the information store is not the central thing that is going to help you solve the problem. That relation is important only if you must have the information at your fingertips, and must have it in an organized way. The key to aiding the problem solution is the structure of that hierarchy I described, which has nothing to do with its relation to the information store. You are right, it does still require a tremendous amount of judgment, but I can only reiterate that the problems we've tried to solve so far, using this method, have benefited quite extraordinarily from the analyses.

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*Messrs. Gordon, Evans, Brown and Wilson served as chairmen of the four individual sessions of this conference, and as moderators of the ensuing discussions.