TO MY DEAREST JAN

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NOTES ON THE SYNTHESIS OF FORM

6 / THE PROGRAM

Here is the problem. We wish to design clearly conceived forms which are well adapted to some given context. We have seen that for this to be feasible, the adaptation must take place independently within independent subsystems of variables. In the unselfconscious situation this occurs automatically, because the individual craftsman has too little control over the process to upset the pattern of adaptation implicit in the ensemble. Unfortunately this situation no longer exists; the number of variables has increased, the information confronting us is profuse and confusing, and our attempts to duplicate the natural organization of the unselfconscious process selfconsciously are thwarted, because the very thoughts we have, as we try to help ourselves, distort the problem and make it too unclear to solve.

The dilemma is simple. As time goes on the designer gets more and more control over the process of design. But as he does so, his efforts to deal with the increasing cognitive burden actually make it harder and harder for the real causal structure of the problem to express itself in this process.

What can we do to overcome this difficulty? On the face of it, it is hard to see how any systematic theory can ease it much. There are certain kinds of problems, like some of those that occur in economics, checkers, logic, or administration, which can be clarified and solved mechanically.[1] They can be solved mechanically, because they are well enough understood for us to turn them into selection problems.[2]

To solve a problem by selection, two things are necessary.

1. It must be possible to generate a wide enough range of possible alternative solutions symbolically.
2. It must be possible to express all the criteria for solution in terms of the same symbolism.

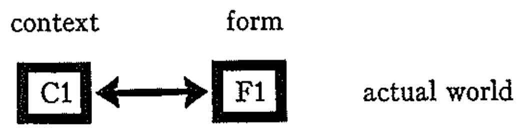
Whenever these two conditions are met, we may compare symbolically generated alternatives with one another by testing them against the criteria, until we find one which is satisfactory, or the one which is the best. It is at once obvious that wherever this kind of process is possible, we do not need to "design" a solution. Indeed, we might almost claim that a problem only calls for design (in the widest sense of that word) when selection cannot be used to solve it. Whether we accept this or not, the converse anyway is true. Those problems of creating form that are traditionally called "design problems" all demand invention.

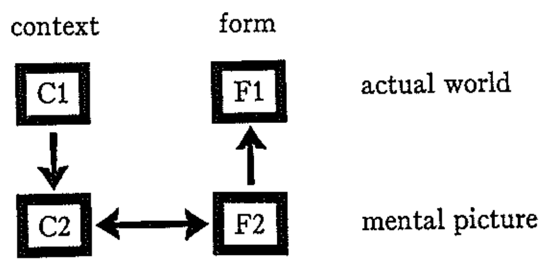
Let us see why this is so. First of all, for physical forms, we know no general symbolic way of generating new alternatives — or rather, those alternatives which we can generate by varying the existing types do not exhibit the radically new organization that solutions to new design problems demand. These can only be created by invention. Second, what is perhaps more important, we do not know how to express the criteria for success in terms of any symbolic description of a form. In other words, given a new design, there is often no

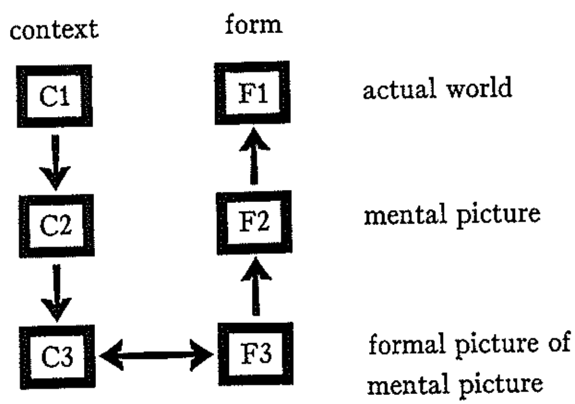
mechanical way of telling, purely from the drawings which describe it, whether or not it meets its requirements. Either we must put the real thing in the actual world, and see whether it works or not, or we must use our imagination and experience of the world to predict from the drawings whether it will work or not. But there is no general symbolic connection between the requirements and the form's description which provide criteria; and so there is no way of testing the form symbolically.[3] Third, even if these first two objections could be overcome somehow, there is a much more conclusive difficulty. This is the same difficulty, precisely, that we come across in trying to construct scientific hypotheses from a given body of data. The data alone are not enough to define a hypothesis; the construction of hypotheses demands the further introduction of principles like simplicity (Occam's razor), non-arbitrariness, and clear organization.[4] The construction of form, too, requires these principles. There is at present no prospect of introducing these principles mechanically, either into science or into design. Again, they require invention.

It is therefore not possible to replace the actions of a trained designer by mechanically computed decisions. Yet at the same time the individual designer's inventive capacity is too limited for him to solve design problems successfully entirely by himself. If theory cannot be expected to invent form, how is it likely to be useful to a designer?

Let us begin by stating rather more explicitly just what part the designer does play in the process of design. I shall contrast three possible kinds of design process, schematically.







The first scheme represents the unselfconscious situation described in Chapter 4. Here the process which shapes the form is a complex two-directional interaction between the context C1 and the form F1, in the world itself. The human being is only present as an agent in this process. He reacts to misfits by changing them; but is unlikely to impose any "designed" conception on the form.

The second scheme represents the selfconscious situation described in Chapter 5. Here the design process is remote from the ensemble itself; form is shaped not by interaction between the actual context's demands and the actual inadequacies of the form, but by a conceptual interaction between the conceptual picture of the context which the designer has learned and invented, on the one hand, and ideas and diagrams and drawings which stand for forms, on the other. This interaction contains both the probing in which the designer searches the problem for its major "issues," and the development of forms which satisfy them; but its exact nature is unclear.[5] In present design practice, this critical step, during which the problem is prepared and translated into design, always depends on some kind of intuition. Though design is by nature imaginative and intuitive, and we could easily trust it if the designer's intuition were reliable, as it is it inspires very little confidence.

In the unselfconscious process there is no possibility of misconstruing the situation: nobody makes a picture of the context, so the picture cannot be wrong. But the selfconscious designer works entirely from the picture in his mind, and this picture is almost always wrong.

The way to improve this is to make a further abstract picture of our first picture of the problem, which eradicates its bias and retains only its abstract structural features; this second picture may then be examined according to precisely defined operations, in a way not subject to the bias of language and experience.[6] The third scheme in the diagram represents a third process, based on the use of such a picture. The vague and unsatisfactory picture of the context's demands, C2, which first develops in the designer's mind, is followed by this mathematical picture, C3. Similarly, but in reverse, the design F2 is preceded by an orderly complex of diagrams F3. The derivation of these diagrams F3 from C3, though still intuitive, may be clearly understood. The form is actually shaped now by a process at the third level, remote from C2 or F2. It is out in the open, and therefore under control.

This third picture, C3, is built out of mathematical entities called "sets." A set, just as its name suggests, is any collection of things whatever, without regard to common properties, and has no internal structure until it is given one.[7] A collection of riddles in a book forms a set, a lemon and an orange and an apple form a set of three fruits, a collection of relationships like fatherhood, motherhood, brotherhood, sisterhood, forms a set (in this case a set of four elements). The elements of a set can be as abstract or as concrete as you like. It must only be possible to identify them uniquely, and to distinguish them from one another.[8]

The principal ideas of set theory are these:

1. An element x of a set S, is said to belong to that set. This is written $x \in S$. A set is uniquely defined by identifying its elements.
2. One set S_1 is said to be a subset of another set S_2, if and only if every element of S_1 belongs to S_2. This

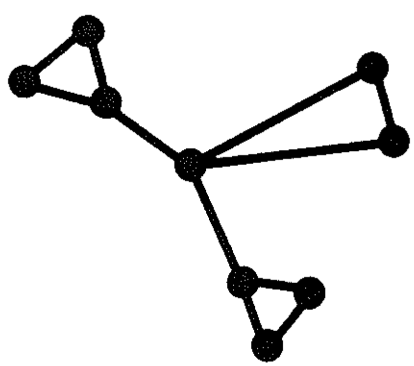
is written $S_1 \sqsubset S_2$. If S_2 also contains elements which are not elements of S_1, so that S_2 is "larger" than S_1, then S_1 is called a proper subset of S_2, and we write $S_1 \subset S_2$.
3. The union of two sets S_1 and S_2 is the set of those elements which belong to either S_1 or S_2 (or both, in the case where S_1 and S_2 have elements in common). We write it as $S_1 \cup S_2$.
4. The intersection of two sets S_1 and S_2 is the set of those elements which belong to both S_1 and S_2. We write it $S_1 \cap S_2$. If S_1 and S_2 have no elements in common, this intersection is empty, and we call the sets disjoint.

Let us be specific about the use of set theory to picture design problems. We already know, from Chapter 2, what the designer's conception of a problem looks like. The problem presents itself as a task of avoiding a number of specific potential misfits between the form and some given context. Let us suppose that there are m such misfit variables: $x_1 \cdots x_m$. These misfit variables form a set. We call the set of these m misfits M, so that we may write $x_i \in M$ (for all i, $i = 1 \cdots m$).[9]

The great power and beauty of the set, as an analytical tool for design problems, is that its elements can be as various as they need be, and do not have to be restricted only to requirements which can be expressed in quantifiable form. Thus in the design of a house, the set M may contain the need for individual solitude, the need for rapid construction, the need for family comfort, the need for easy maintenance, as well as such easily quantifiable requirements as the need for low capital cost and efficiency of operation. Indeed, M may contain any requirement at all.

These requirements are the individual conditions which must be met at the form-context boundary, in order to prevent misfit. The field structure of this form-context boundary, in so far as the designer is aware of it, is also not hard to describe. He knows that some of the misfits interfere with one another, as he tries to solve them, or conflict; that others have common physical implications, or concur; and that still others do not interact at all. It is the presence and absence of these interactions which give the set M the system character already referred to in Chapters 3, 4, and 5.[10] We represent the interactions by associating with M a second set L, of non-directed, signed, one-dimensional elements called links, where each link joins two elements of M, and contains no other elements of M. As we shall see in Chapter 8, the links bear a negative sign if they indicate conflict, and a positive sign if they indicate concurrence, and may also be weighted to indicate strength of interaction.

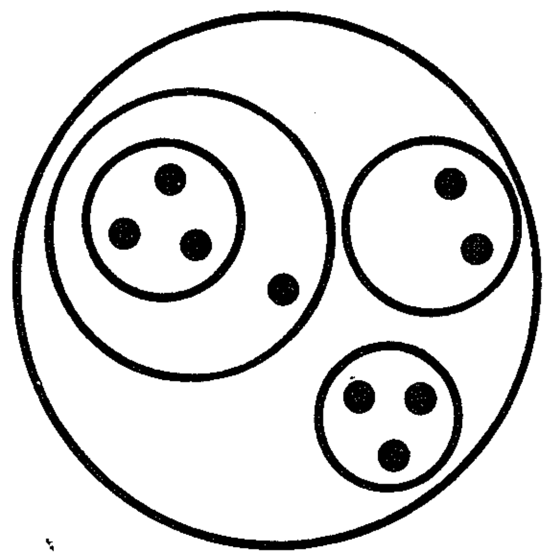
The two sets M and L together define a structure known as a linear graph or topological 1-complex, which we shall refer to as $G(M,L)$, or simply G for short.[11] A typical graph is shown below. Such a graph serves as a picture of a designer's view of



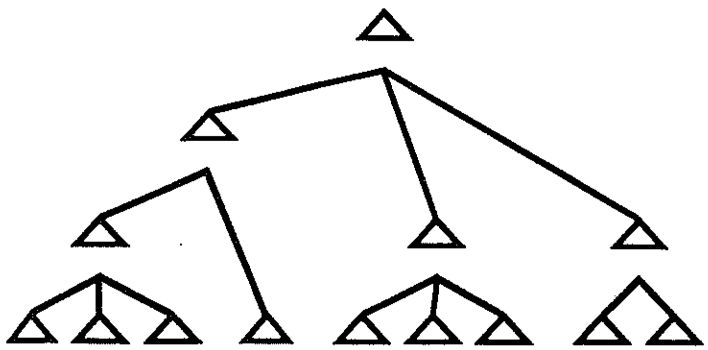
some specific problem. It is a fairly good picture, in the sense that its constituents, the sets M and L, are available to him introspectively without too much trouble; also because it keeps our attention, neatly and abstractly, on the fact that the set of misfits has a structure, or, as we called it in Chapter 2, a field.[12]

We must now explore the structure of this field. The most important and most obvious structural characteristic of any complex entity is its articulation — that is, the relative density or grouping and clustering of its component elements. We will be able to make this precise by means of the concept of a decomposition:

Informally, a decomposition of a set M into its subsidiary or subsystem sets is a hierarchical nesting of sets within sets, as is shown in the first of the two diagrams that follow. A more



usual diagram, which brings out the treelike character of the decomposition, is shown below. It refers to precisely the same structure as the other. Each element of the decomposition is a subset of those sets above it in the hierarchy.



Formally I define a decomposition of a set of misfits M as a tree (or partly ordered set) of sets in which a relation of immediate subordination is defined as follows, and in which the following further conditions hold:[13]

A set S_1 is immediately subordinate to another set S_2 if and only if S_2 properly includes S_1 ($S_1 \subset S_2$), and the tree contains no further set S_3 such that $S_1 \subset S_3 \subset S_2$. Further, the tree must satisfy the following four conditions:

1. If S_i and S_j are two immediate subordinates of a set S, then $S_i \cap S_j = 0$.
2. Every set which has immediate subordinate sets is the union of all these sets.
3. There is just one set which is the immediate subordinate of no other set. This is the set M.
4. There are just m sets which have no immediate subordinates. These are the one-element sets, each of which contains one element of M.

As it stands, such a decomposition deals only with the set M. L, the set of links, plays no part in it. But it is easy to see that the existence of these links makes some of the possible decompositions very much more sensible than others. Any graph of the type $G(M,L)$ tends to pull the elements of M together in natural clusters. Our task in the next chapters is to make this precise, and to decide which decomposition of M makes the most sense, once we have a given set L associated with it. Each subset of the set M which appears in the tree will then define a subproblem of the problem M. Each subproblem will have its own integrity, and be independent of the other subproblems, so that it can be solved independently.

It is very possible, and even likely, that the way the designer initially sees the problem already hinges on a conceptual hierarchy not too much unlike a decomposition in general outline.[14] In trying to show that the links of L favor a particular decomposition, I shall really be trying to show that for every problem there is one decomposition which is especially proper to it, and that this is usually different from the one in the designer's head. For this reason we shall refer to this special decomposition as the *program* for the problem represented by $G(M,L)$. We call it a program because it provides directions or instructions to the designer, as to which subsets of M are its significant "pieces," and so which major aspects of the problem he should apply himself to. This program is a reorganization of the way the designer thinks about the problem.[15]