How is design possible?

BILL HILLIER AND ADRIAN LEAMAN

This paper approaches the question 'how is design possible?' by suggesting that design is a relatively simple set of operations carried out on highly complex structures, which are themselves simplified by 'theories' and modes of representation. The analysis strongly suggests that if design method is to be improved then it is more important to study the environment itself than how designers design.

INTRODUCTION

It has been observed that the art of mathematical proof lies in finding a framework in which what one wants to say becomes nearly obvious. Improbable as it sounds, the search for theories in science is often similar. What has to be 'said' is the observable evidence and its manifest relationships. A theory is an abstract model which predicts that such observables and such relations will occur. A 'good' theory renders data 'obvious' which a 'bad' theory renders contradictory or disconnected.

The theories of design developed over the past decade in connection with 'systematic design', 'design method' and subsequently 'computer-aided design' do not in general have the merit of rendering the evidence about design 'nearly obvious'. On the contrary, they make it appear mysterious. For example, the syncretic generation of outline solutions in the earliest stages of design is made to appear illegitimate and undesirable on the grounds that any 'rational' approach to design must seek to generate the solution as far as possible from an analysis and synthesis of problem information and constraints. The penalty of not following this 'rational' procedure is that bad old imagistic methods of design will be perpetuated. 'Rationality' in design was virtually equated with purging the mind of preconceptions, to make way for a problem-solving method which linked a procedure to a field of information.

The sources of this conception of rational design were analysed in a previous paper, in which it was also argued that the designer's 'prestructures' were not at all an undesirable epiphenomenon, but the very basis of design.[1] Without prestructures of a fairly comprehensive order, it is not possible to identify the existence of a problem let alone solve it. The task now is to find a scientific framework in which such a formulation would become 'nearly obvious', and this will be equivalent to a theory of how design is possible. In general, it will be argued that design is possible for roughly the same reasons as speech is possible. Methodologists have not been able to characterize speech because they have tried to look at it independently of a much larger structure analogous to language. Too small a system has been considered.

GENOTYPES AND PHENOTYPES

Consider an example. An army marches all day. . nightfall a halt is called and unpacking begins. Wit a short time a structured environment appears. T of various kinds and sizes are placed in certain de finite relations; kitchens, sentry posts, flags, fences and other paraphernalia are erected. A complete environment is, as it were, 'unfolded'.

The army experiences this as a simple, repetitive procedure. But looked at scientifically in terms of the structures which must exist for such a simple 'unfolding' to be possible, it is both complex and illuminating. First, the observable environment which is unfolded is based on a set of instructions in the army manual or in standing orders. Secondl these abstract instructions and relations are 'embedded' in the items the army carries about with it to manufacture this environment, which may be cal its 'instrumental set'. Third, and most important, i will be noted that any series of camps unfolded by army will exhibit both similarities and differences In this simplified and artificially deterministic example, the source of similarity is the set of instruc tions as embedded in the instrumental set, and the source of differences is the local constraints and contingency, which will include personal and enviro mental factors, strategic considerations and so on.

This example has the curious attribute of resembli a theory in reverse. Just as scientists try to make abstract invariant models which 'generate' and the by explain a variety of observable phenomena, so i this case the abstract model is the starting point a the observable phenomena are generated. One can speculate on a Martian anthropologist's theories a to how the similarities and differences of series o such camps are to be explained. One can imagine, for example, the difficulties that a purely 'environmentalist' theory would encounter in explaining the observable phenomena.

Although an extreme example, this structure does illuminate certain pervasive properties of cultural forms. In many situations, sets of basic instructio which are variably unfolded are not written down o genetically programmed, but embedded in the artifi cial systems which we call 'cultures'. Deep cultur structures may be transmitted unchanged through several generations, yet produce great variety at t observable level. Such underlying stable structure corresponds to what biologists call 'genotypes', as compared to a 'phenotype' which is a variably developed observable form. In the army example, the genotype is the information carried in the instructions and embedded in the instrumental set; the phenotype is the observed layout and activity of the camp. In most cultural areas the structured sets of instructions, the genotypes, change and evolve much faster than biological genotypes, and may even be able to alter themselves by self-reference, but the overall logical form is the same. In order to avoid confusion with the more closed and stable genotypes of biology, these looser cultural genotypes and phenotypes may be referred to as g-models and p-models.

An important property of g-models is that they become unconscious or autonomic. Moreover they operate not only as a basis for creative action, but also as a basis for understanding and interpretation. They act, literally, as theories of the artificial systems they interpret. In all human societies such theory-like structures are evolved to mediate the artificial, natural and social universes. Language, for example, uses an unconscious, autonomic, syntactic and semantic g-model as the basis for speech. It is this that makes Chomsky's 'rule governed creativity' possible. In general the richness and variety of intelligible cultural existence is founded on the existence of such models. But it is only as scientists (or artists like Marcel Duchamp) that we attempt to bring them into the light of day.

Such theory-like models are no less necessary in design. But the fact that they are autonomic may lead the designer into a curious illusion when he tries to explain the nature of his own activity. It might appear to him that the phenotypical choices he makes in relation to his analysis of the constraints of a particular design problem could or should account for the entire solution, that is for its similarities to the g-model as well as its p-model differences and variability. This is exactly the illusion conjured up by 'scientific' approaches to design. As would be predicted, it is the source of the solution itself which cannot be described in terms of the methodologies, and it therefore appears extra-rational. Because the g-model is both the structure by which the designer analyses and identifies as well as solves his problem, it has become invisible to him. Nevertheless, in any analysis of how design is formally possible such structures are of the utmost importance. To ignore them in representing design as a decision procedure is like assuming that a speaker re-invents semantic and syntactic structures which he depends on knowing in advance in order to use and understand the language. Most of the fallacies of behaviourism, as well as design methodology, can be derived from this extension of the domain of scientific interest.

A simple general theoretical framework may therefore be suggested within which the everyday evidence about design becomes 'nearly obvious': design is the search for the appropriate transformation or unfolding of prestructures (however rapidly these may be evolving) in relation to the constraints imposed by the environment of the problem. Design is therefore both the transmission (g-models) and transformation (p-models) of prestructures, a process of elaboration and discovery, within which every solution may be unique. Referring obliquely to H.A. Simon, it may be argued that design is simple, only its environment is complex.[2]

The prestructures on which design depends are synchronous—they are not arranged in a time sequence. But design obviously occupies time, and contains certain sequences of events. The decision procedure approach to design method ignored the importance of the synchronous plane in structuring the design process. On the other hand, a prestructure that is not subject to operations, cannot be transformed into a unique p-model. The problematic of design method studies is therefore twofold: to characterize the autonomic prestructures by which the designer interprets his problem and which also act as a 'solution field'; and to characterize the operations which may be performed with and upon such structures in a more or less complex problem environment to produce unique and effective solutions. The first is a problem of synchronic analysis, the second, diachronic.

This analysis will suggest that design is a relatively simple set of operations carried out on highly complex structures which are themselves simplified by 'theories' and modes of representation. It suggests strongly that if design method is to be improved, then it is more important to study the environment itself than how designers design, since in the last analysis the designer's understanding and how the total g-model constructs his understanding is the most important factor influencing design. Insofar as design should be studied, it should be in terms of how the designers' internal models transform environmental reality, and what conventional simplifications and distortions are introduced by the use of methods of representation and selection of problem variables.

THE STRUCTURE OF A SOLUTION FIELD

Understanding the structure of solution fields, or at least their organizing principles, is therefore a major problem in design theory. If no models yet exist, comfort may be taken from the great generality of this type of problem. Most man-made systems on which our daily lives depend combine the paradoxical properties of being 'known' in the sense that we are able to use them without mistakes to convey intersubjective 'meaning', but being at the same time inaccessible to scientific explanation. Languages, cities, fashions, economies, societies and even theories all fall into this category. We have 'sciences of the artificial' to enable us to 'understand' what we already 'know'. In all such cases, it is likely that intelligibility at the everyday level is due to autonomic underlying models; lack of intelligibility at the scientific level is due to our not having adequate scientific models for such models. Recent research in linguistics, artificial intelligence and mathematics suggests lines which research might follow.[3] It may at least be shown that certain types of structure must be inherent in such fields in order for them to work in the way they do.

It is useful to make an initial subdivision of the problem into three. First, understanding how the solution field is organized formally; secondly, understanding how it is organized semantically, that is, understanding the 'theory' or 'bundles' of theories and g-models on which it is based; thirdly, understanding how it is represented, and how these representations may be acted on so as to produce effective transformations. In certain senses it will be seen that all three are the same problem.

Most artificial systems exhibit a duality between a morphology based on entities which are manipulated—words, walls, coins, mathematical symbols—with a formal or logical structure which relates such entities to other entities of the same type, and also to other dissimilar entities like 'meanings' or 'values', by which social signification is achieved. In general, formal structures, like grammars, for example, are autonomic while morphologies make up a consciously manipulable set.

The key to understanding how such structures combine into effective artificial systems must tell us about the nature of the morphological 'units', the building rules of the overall logic, and how the two combine together in a 'natural' way. The thesis here is that the elementary units of the morphology are not 'units' at all in the usual sense, but are already structures. Moreover, their structure, as opposed to their phenomenal form, is as autonomic as the overall formalism. The understanding of all such systems lies in discovering how the internal autonomic structure of the 'simplest structures' of the morphology already contains the rules which govern aggregation into higher logical forms. The failure of general system theory to progress beyond an elementary level in characterizing how such systems work is because this elementary principle of the dynamics of artificial systems cannot be formulated within a definition of a system as 'elements and their relations'. There simply are no elements.

This abstract argument may be made intuitively accessible by considering a simple example, that of a coin. Consider what it is that makes a coin more than a piece of metal. A coin depends on entities and formal structures which are both absent physically, and which may be entirely abstract. The 'meaning' of a coin depends on the existence of logically similar entities with which the coin may be compared (coins of other values); a set of dissimilar entities to which it may be systematically related (loaves of bread, a day's work); and a set of rules for making transitions between and within these two domains. The coin 'carries' with it at least so much structure which gives this 'simplest structure' the form of an H, with the left vertical representing the similar domain, the right vertical the dissimilar domain, and the bar the mapping structure (Figure 1).[4] The H shape is given for reasons of intuitive

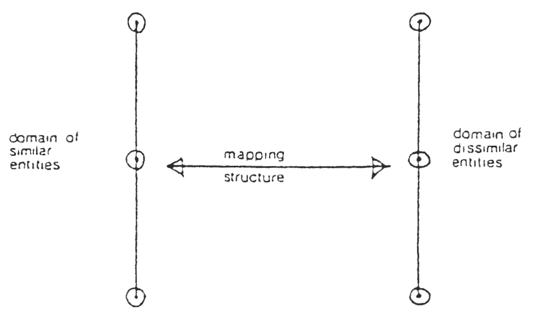

Figure 1 Illustration of 'simplest structure'.

accessibility, but from a formal point of view, the simplest structure should be represented as a commutative square (Figure 2) since transformations in one domain carry with them transformations in the other if 'meaning' is to be retained. Such commutative squares, which appear to be general simplest structures in artificial systems, are fundamental to modern algebra and category theory, and offer a simple formal representation of the concept of 'meaning' (i.e. a transformation in both domains such that the mappings are commutative).

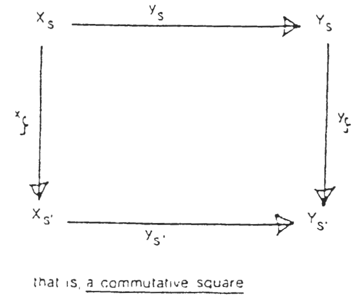

Figure 2 Simplest structure: algebraic form.

This example provides an illustration of the gener: dependence of 'parts' on the 'whole' in such system In a sense, the internal structure of the 'simplest structure' is the same as the structure of the whol system. In architecture the 'simplest structures' are even more complex, but have the same general form. Consider, for example, a wall. A wall appear a simple object, but considered logically it turns ou to be complex, even more complex, in fact, than the coin. In the first place, a wall, by reason of its purposeful existence, distinguishes at least two types of space. The reason for building the wall is to dra such a distinction. The same applies to the invisibl 'walls' which are pervasive in artifactual forms. Moreover, if the wall is perforated or not, then it also defines a relation between the two types of space. This is the simplest phenomenal form equiv lent to the coin. To this must be added the relation t a similar domain of such structures, and dissimilar domains of usage and semantics to give the 'simple. structure' of architectural form. This may also be called a 'minimum meaning unit' (Figures 3 and 4).

The pattern of dissimilar domains of entities, with mapping structures between them, one domain of which constitutes the normal 'manipulable set', are

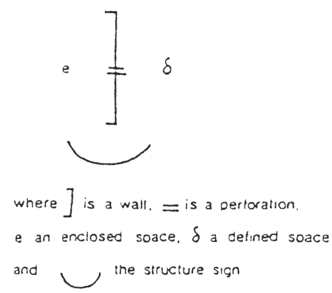

Figure 3 Architecture: simplest phenomenal form

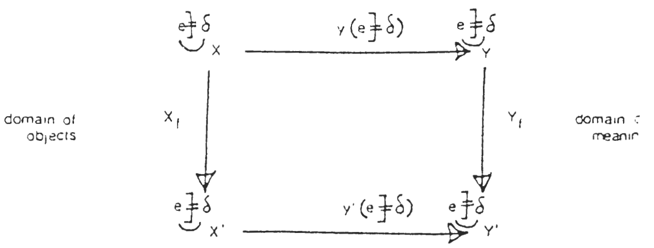

Figure 4 Architecture: simplest structure.

very general indeed in human cultures. It might not be fanciful to define man as a structure who knows how to effect a large number of mappings between dissimilar domains which may be expressed as commutative squares. Languages have this form, with mappings between an abstract domain of 'meaning' and a concrete domain of phonetic sounds. The architecture of architecture is equally based on such structures which include, for example, the mapping between human behaviour and its spatial containment, or between psycho-physiology and the environmental filter. In design the mapping structures are used as autonomic devices to solve problems. In research these mapping devices are studied in order to understand and improve them.

These arguments show in principle why it is possible for action on simple 'manipulable sets' to carry with it a high degree of morphological and logical complexity, often without our being aware of it. The encapsulation of the complex in the simple seeming object provides an initial tool for understanding the structure of a solution field. But this is already insufficient for design, since design is not carried out on objects but on representations of objects, whether on paper or in the head. It is necessary to understand how, formally speaking, this complicates matters, but again the complexity provides a key to how the system works.

It has been known since the Stoics that the 'sign' is only a sign by virtue of being connected to two dissimilar types of entity: the lecton or conceptual referent; and the real or phenomenal referent. Figure 5 represents these relations. This 'simplest structure' may be married to those already described to

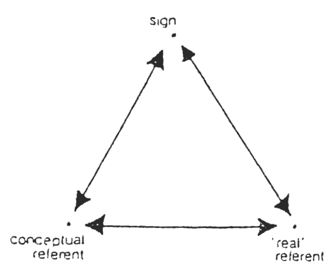

Figure 5 Sign: simplest structure.

produce illuminating results. For example, 'signs' in the normal sense constitute a manipulable set. Insofar as they form a system in themselves, they do so by virtue of being based on some semantic model, or bundle of theories, about reality. There is of course no universal language in which every property of the world as it is can be equally and 'objectively' represented. Language is more like a theory of reality than a copy of it, as philosophers have argued. Languages act selectively on the world and at the same time systemically, and this is as true of mathematics as of natural language. In order to inaugurate the modern era in mathematical physics, Gallileo purified the world of all properties that could not be represented in the evolving mathematical language, calling them 'secondary' because they were concerned with the perception of the subject rather than the measurable properties of the thing. This is still generally true of science. In classical physics, for example, the operations which may be performed on the calculus serve as models within sign systems for external realities, and thereby constitute the means by which phenomena may be said to be 'understood' scientifically. The recent advent of new mathematical formalisms like catastrophe theory[5] demonstrates how closely related the understanding of the universe is with the forms implied in mathematical systems. Modern theoretical physics accepts a basic duality in its research: on the one hand it investigates formalisms; on the other, it investigates the physical universe itself, making models in the former which satisfy the appearances of the latter. The movement known as structuralism proposes an exactly similar strategy in the 'sciences of the artificial'.[6]

All sign systems have this duality. At the same time as constructing a permissible universe out of the maze of undifferentiated phenomena, they also systematically interpret it. This pervasive form of connectivity in the artificial universe is often overlooked. A term is needed and the notion of manifold may serve the purpose (Figure 6). Manifold structures

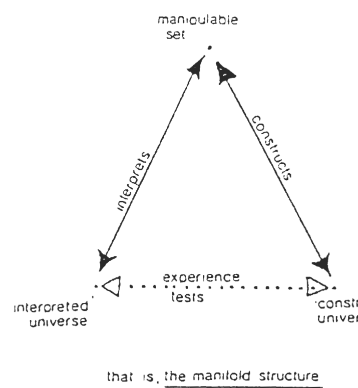

Figure 6 Sign system: simplest structure.

are very general indeed. Consider a machine, for example. A machine constructs a permissible universe from which it can accept certain types of input. It then carries out a structured conversion on the input, and outputs an interpretation, which we call a product. An algorithm is similar. The algorithm constructs its permissible universe, performs a structured conversion on what is 'selected' within the domain so constructed, and outputs an 'interpretation'. Like the previous examples discussed, the manifold form of connectivity (manifoldness) is one of the structures which makes everyday life possible. The form of connectivity of the manifold is such that when part of the manifold is activated, the whole necessarily also is.

The manifold is also one of the structures which makes design possible. Because the systems of representations on which the designer operates both construct and interpret their universe, and because they integrate the type of connectivity discussed previously, it is hardly surprising that design is largely a syncretic and hypothetico-deductive activity. The idea of the manifold in particular suggests that current approaches to computer-aided design may be involved in a kind of paradox. Even to name an architectural problem—say, 'design a school'—implies a whole range of solutions which will be more or less immediately activated in some sense through the designer's manifold. The same applies to the definition of space at all levels. To try to relate abstract space to abstract activity overlooks the fact that each has already become an expression of the other. Concepts of space are already social to us, not pure perceptions waiting to be socialized. The designer, whether he is using the language of the brief, the language of concepts, or the language of drawings, is already embedded in a richly connected universe whose connections are those dissimilar domains that must be related in his design—these include activity and space, physiology and climate and so on. Moreover these structures are embedded in all the language the designer uses, and in the instrumental set—the technologies in terms of kits of parts and typical design solutions—to which his systems of representations refer.

Manifolds show why prestructures must dominate design. But there is a further question. What is the relation of the manifold to 'reality'? With a manifold base, design takes an existing technological and environmental situation (kits of parts, solution types) as a necessary starting point. But this does not mean that design somehow works on the environment 'as it really is'. On the contrary, the distance between the 'real' socio-spatial situation and the designer's prestructure which represents it will be subject to at least two types of transformation. The first will be concerned with the designer's 'code'—the structure which he abstracts from and interprets the given situation—personal history, professional education, the office, will all play a part in constructing this code. Secondly, a further transformation will occur through the influence of the method of representation itself which will construct and interpret as any manifold will. This means that the study of design codes and the effects of all methods of representation used in design are essential dimensions of the science of design.

These types of structure tell us in general how design is possible and what should be studied. On the whole, they are properties of all similar manifold systems of the artificial. But at least one other formal structure must be taken into account, which begins to distinguish the properties of architectural design from the general properties of manifolds. In all manifolds the question of how function turns into structure is of central importance. In architectural design this problem may be approached through the four-function model which, although presented elsewhere otherwise, turns out to be a structure in itself.[7]

The four-function model may be interpreted in the following way. Buildings mediate two different kinds of relationship between man and nature and between man and man. In mediating relations between himself and nature, man builds a climate modifier. In mediating relations between himself and other men, man builds a behaviour modifier. These two functions constitute the observable object-level realization of the man-nature/man-man distinction. Each of these is mapped into a higher-order signifying system or, in other words, a general social language and accounting framework for such modifications. On the one hand, the object-level functions are mapped into a general analysis of resources whose language is economics, giving the resource function; this is a generalization of the man-nature relationship. On the other hand, they are mapped into a general language of social signification giving the symbolic function; this is a generalization of the man-man relationship. Both higher-order languages comprise both lower-order systems. This structure is shown in Figure 7.

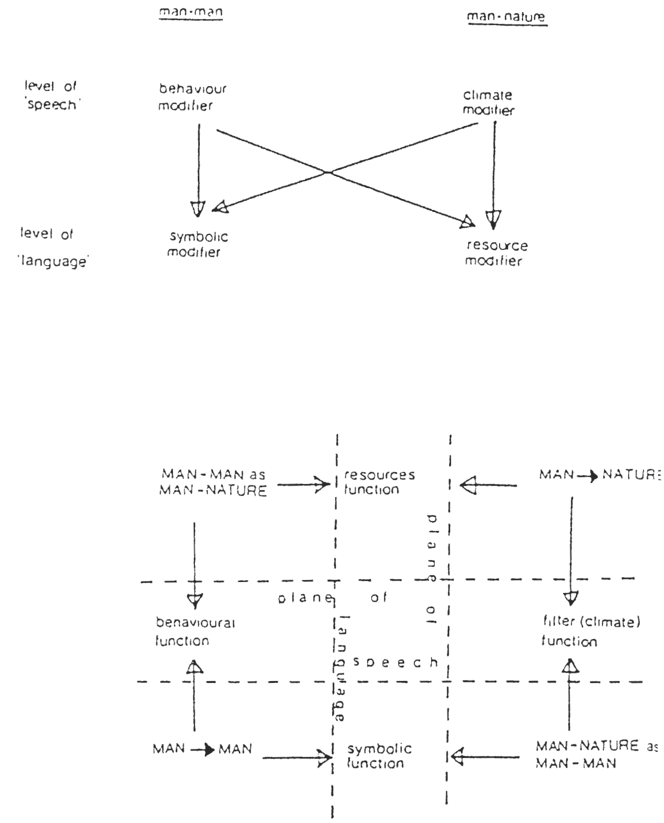

Figure 7 The four-function model as a structure (two versions).

LOCAL AND EVOLUTIONARY TIME

Attention has so far been confined to the synchronous organization of the solution field as a searchable structure and as a formal structure of relationships based on a general theory of environmental reality, through which problems may be both defined and solved, the same structure governing both definition and solution. As was previously argued, design may be seen as both the transmission of the abstract 'genotype' structure as a whole, and its transformation to realize a particular 'phenotype'. To understand how transformation occurs, the operations which are performable on the genotype structure must be understood. This in effect is equivalent to asking what time structures are relevant to an understanding of how design is possible.

Time is vital to an understanding of design at two levels. The first may be called the level of evolutionary time, where the cultural genotypes of architectural and urban form mutate gradually or are suddenly altered. This normally appears in the history book under the heading of the history of style, but it is clear that, from the point of view of the built environment as a whole, much more profound mutations in the relations of changes in society to changes in its spatial form occur. Evolutionary time is concerned with the gradual unfolding of a socio-spatial morphology, which includes the development and stabilization of technologies, social processes of environmental control and all constructions of the mapping from social into spatial form. The second level is that of local time, in which the genotype is elaborated into a phenotype appropriate for a particular set of local conditions, through the activity of designers, users and others.

Design has usually been represented as a decision process in local time. The concepts of prestructure, solution field and so on, suggest that this is too small a part of the story to render the whole process intelligible. But since design does involve sequences of operations, in which time order is critical, then these must be elaborated. First, a general consideration. Time structures in design must be considered in relation to a ubiquitous property of manifolds—when part of the manifold is activated the whole also is. Consider, for example, in carrying out a conversation, the whole language structure is in action both in order to interpret what others say, as well as to plan one's own.[8] The demonstrable dependence of the part on the whole requires this formulation. No part of the manifold may be used without having the whole at the ready. The manipulable set cannot be used without holding the rules as an autonomic generative structure.

Four types of local time structure may be distinguished in design. The first three have been dealt with at length elsewhere[9], so the fourth—arguably the most important—will be the subject of attention here. First, a process of increasing specification, in, for example, a sequence of more precise drawings, continuously increases the range of excluded solutions and converges on a unique solution which will be built. This is the process of variety reduction. Secondly, the process of conjecture-test provides a basic unit of design activity by which activated parts of the manifold are simulated as solutions and tested against the problem constraints which will influence the form of the phenotype. Thirdly, a time structure which is the product of the complex of social relations in which design is embedded. This leads to the sequential production of communications of various kinds, sequences of consultation, and so on, all of which have to be distinguished from the underlying cognitive processes in the designer's mind, however much they may influence the result.

The fourth type of time structure is a generalization of the conjecture-test molecule of cognitive activity to the overall level of the process in local time. It is here that the language analogy may be made most precise, and the language-speech distinction used to clarify what happens in design. What a speaker can say at any point in time depends initially on his competence which is described by his grasp of the syntactic, semantic and functional structural abstractions which make up the language as a whole. He requires a systematic structure for mapping between meaning and verbal production. The limitations on this intervening structure will limit both what can occur in the domain of meaning and in the domain of sounds. The speaker, like the designer, starts from a prestructure in which the most important entity is the abstract structure by which mapping between dissimilar domains may be effected. In all such cases there is a manipulable set. In the case of language, the manipulable set is words and phrases; in the case of the designer, it is the representations of the instrumental set. Without the mapping structures these are virtually useless and only meaningless sounds or arbitrary artifacts could be generated.

What happens between meaning and speech happens in two stages, not one. First, a set of semantic units, known in principle to be sayable, is conjectured in the speaker's mind. This may be thought of as a transition from the domain of structured, combinable meanings, through the semantic structure, into a general set of proposals for speech which are as yet unspoken. These units are realized in the form of speech by passing them through a second mapping structure which constructs word orders, phrase forms, sentence forms and so on, out of conjectured, but unrealized assemblages of units. This is illustrated in Figure 8. The first of these mappings operates between dissimilar domains (conjectural meaning units in verbal form), the second within one domain (general verbal structure, precise verbal structure).

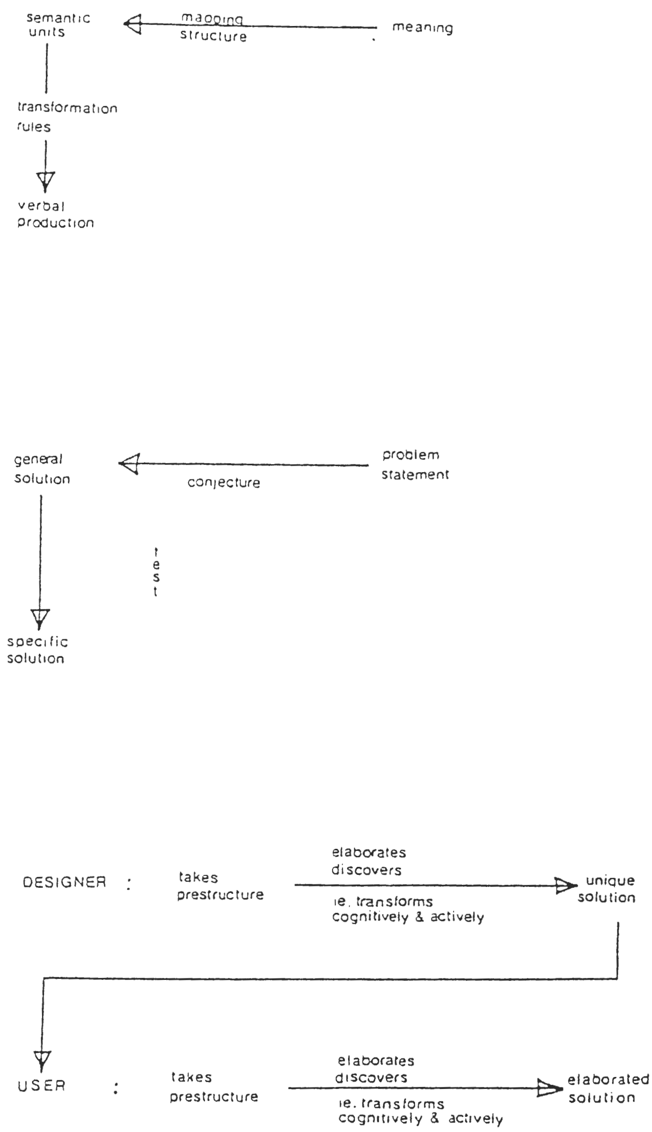

Figure 8 The L-shaped theory of language.

In design, two similar stages are detectable (Figure 9). As in language each is representable as a mapping, in the one case between dissimilar domains, in the other within a single domain. The first mapping, made possible by the abstract prestructures, goes from a statement of the problem into a general solution. The second maps from a general solution to a particular solution. The language analogy confirms that the distinction suggested by Alex Gordon between strategic and tactical design is not simply a useful approximation, but a basic attribute of all processes which involve the use of some prestructured code in an open-ended situation.

A further useful point may be derived by examining this simple basic structure more closely. First, in language as well as design, the mapping from the general solution (semantic units) to the specific solution (speech production) constitutes a test of the realizability or sayability of the conjectured set. Thus this two stage process is formally equivalent to the conjecture-test sequence previously hypothesized. Since it is now widely agreed that such a sequence also underlies science, it appears that this simple idea can unify speech, design and science as being transforms of the same basic cognitive activity. In design, the normal way of testing a conjectured solution is to try to specify it more precisely (thus fitting the conjecture-test sequence into the overall programme of variety reduction) and ultimately by building it.

Within this structure two different strategies exist, although both are variants on the conjecture-test form. The analogy of a detective who has a crime, a set of clues, and a set of possible villains may be used. The crime and the villain may be imagined as the end point of a chain, the links of which are the clues in a deductive sequence. The detective may either conjecture a villain and attempt to construct the clues in such a way that they lead to him. Or he may try to build the chain of clues from the crime 'outwards', in the hope that they will lead to a unique villain. Both are conjecture-test, or trial-and-error strategies, and both construct particular actions in terms of the overall logical structure. The same alternative exists for a primitive man who has sticks, flints, slings, spears and twine but who does not yet have a bow and arrow. Whichever way the designer operates, his dependence on the given overall structure and the undiscovered potential of the situation is apparent.

These events in local time are in general of less significance in the overall design of the artificial environment than events that take place, less obviously, in evolutionary time. These changes have the effect of altering the general form of the prestructures which designers bring to bear on individual problems of phenotype production, effectively acting as a framework of autonomic assumptions within which they operate. At all stages it is the designer's assumptions, the unconscious givens, that provide clues to changes in the morphology of social space. The present time is as good an illustration as any. Our societies are currently evolving new spatial forms which, in ways which are not understood, seem intimately connected to a parallel social evolution. To designers these changes appear as arbitrary acts of choice. But they will not appear so to anthropologists in the future, any more than the evolution of the structurally stable town form many thousands of years ago appears to us now as the result of arbitrary choices. If design is to be understood beyond the mistaken slight phenotype modification for the continuous recreation of a genotype, then observers must become something like 'archaeologists of the present', attempting to uncover the elementary forms by which our societies are being mapped into new spatial structures. The question 'how does artifactual environment influence the behaviour of society?' is a manager's question, not the first scientific question. The first question for a theoretical science of the environment is 'what social behaviours determine the environment?'. When research legitimizes the second question, and not until then, will environmental science evolve in a non-trivial way. This will not happen while, for example, the application of mathematics to urban structures remains at its current level of aggregating and relating observable collections of arbitrarily selected objects for immediately instrume[ntal] aims. Only a model which aims at the generation [of] socio-spatial form can begin to give the understa[nd]ing of ourselves that must form the basis of an en[vironmental] science.

Such a model is not as inaccessible as might appe[ar] initially.[10] For example, many inconsistencies dis[]appear as soon as the local time of design and its object functions are replaced by consideration of [the] same relationship in its evolutionary time form o[r] higher-order language constructed out of the soci[al] logic of such relations. For example, at the objec[t] level the relation of activity to space appears to r[e]quire some permutation of the concept of 'fit', 'mi[s]fit', 'loose fit' and the like, whereas in the higher-order language the relation requires another type [of] formulation based on concepts of discovery, elabor[a]tion and transformation. In fact, the design model outlined above may be continued through the user who, like the designer, takes a prestructure, elaborates it, discovers it, and cognitively and actively transforms it. This continuous process of transfo[r]mation expressing the relation of behaviour to spa[ce] at all stages is given in Figure 10. Within this mo[del] 'fit' may be assimilated as the efficient elaboratio[n] of a particular pattern of activity in a particular pattern of space. But the opposite end of the spectrum—at the Camden Roundhouse, for example whe[re] a locomotive shed became a theatre—does not appe[ar] as an anomaly, or the result of some quite differen[t] process. The theory based on discovery, the active form of the relationship, contains both within a sing[le] theory.

The principle of elaboration may be used to outline a theoretical approach to space where the fixity of artificial space—the property which confounds the orthodox models—becomes a primary factor. Such a theory begins with the observation that the simplest structures in environmental action are alread[y] complex structures.

Such elementary structures, given that they are ide[n]tifiable, will contain within themselves rules for co[m]bination into the higher-order aggregations which give the spatial structure characteristics of urban and other higher-order spaces, as mappings of soci[al] processes. These will lead, by further elaboration, to different forms of structural stability to which both social and physical factors contribute. Of particular interest are those structurally stable forms whose stability appears as a function of socio-spati[al] denseness. Such a theoretical approach to urban systemness is in many ways similar to that recentl[y] outlined by Rene Thom as a basis for applying the mathematical theory of catastrophes to biological and cultural systems. Difficult and scarcely scienti[]fic as the theory may be at this stage, it is only by such or similar approaches that the broad genotypical changes which construct the individual designer['s] autonomic framework can be identified, and, in the long run, a genuine liberation from the spatial priso[ns] we are currently building for ourselves be envisage[d].

Bill Hillier and Adrian Leaman are members of the RIBA Intelligence Unit.

The authors wish to thank Hara Drakou, Richard Bennett, Tom Reagan and students at University College London who have contributed to the formulation and discussion of many of the ideas in this paper.

REFERENCES

1 Hillier, B., Musgrove, J. and O'Sullivan, P. Knowledge and design, EDRA 3, 1972.

2 Simon, H. A. The sciences of the artificial. Massachusetts, MIT Press, 1969.

3 Michie, D. Machines and the theory of intelligence, Nature, vol. 241, no. 5391, February 1973.

4 de Saussure, F. Course in general linguistics. New York, McGraw-Hill, 1966 (reprinted).

5 Thom, R. Topological models in biology, in Towards a theoretical biology: three: drafts, edited by C. H. Waddington, pp. 89-116. Edinburgh University Press, 1970.
Thom, R. Structuralism and biology, in Towards a theoretical biology: four: essays, edited by C. H. Waddington, pp. 68-82. Edinburgh University Press, 1972.

6 Hillier, B. and Leaman, A. System, structure and transformation, Transactions of the Bartlett Society, vol. 9, 1972/3, pp. 36-77.

7 Hillier, B. and Leaman, A. The idea of architectural research (published under the title, A new approach to architectural research), RIBA Journal, December 1972.

8 Winograd, T. Understanding natural languages. Edinburgh University Press, 1972.

9 Hillier, B., Musgrove, J. and O'Sullivan, P., op. cit.

10 Hillier, B. and Leaman, A. The architecture of architecture. Paper given at conference on Models and Systems in Architecture, Pembroke College, Cambridge, September 1973 (to appear later in book form).