ASPECTS OF RULES AND LANGUAGE IN DESIGN DECISIONS

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ABSTRACT

This paper is a report of a doctoral research seminar conducted during the Winter term, 1987. The interdisciplinary seminar investigated both theoretical and practical aspects of how design decisions are made. Participants in the seminar represented diverse interests ranging from human science to computer-aided design. The paper focuses on two of several decision making issues that emerged from this seminar: design rules and design languages. These issues are explored from a theoretical context and illustrated through design experiments and discussions that were conducted as part of the seminar. The paper concludes with several suggestions for the development of computer-aided design software.

INTRODUCTION

As both hardware and software continue to evolve, questions continue to be asked about the appropriate role of the computer in design decision making. Many of us that have tried to experiment with computers in an actual design process have had mixed results. In some cases we have abandoned the computer in favor of more traditional techniques — at least until we understood more about the problem we were working on. Perhaps, as Norman (1986) has suggested, the creative phase of design is largely an individual, intuitive process—not capable of being given a rational basis.

However, the design professions are moving towards design scenarios characterized by inter-disciplinary design teams that deal with large, complex building design problems requiring multiple sources of information and increasingly being asked to take into account a wide variety of behavioral, energy, economic, engineering, and user specific performance criteria. The image of the master designer working in creative isolation at the drafting board does not fit the reality of today’s problems. This design complexity requires the joint decision making collaboration of a large number of design participants. Organizing the creative energies of all design participants into an integrated decision process is an issue that has not been resolved in the organizational fragmentation of the construction industry. Nor has it been resolved in the traditional architectural school design studio.

If we want to improve the quality of design, we need to understand more about how creative design decisions are made and the context within which they are made. Through this understanding we may be able to better define the appropriate role of computers in this process. This paper is a partial summary of a doctoral research seminar conducted during the Winter Term, 1987 whose purpose was to begin to explore issues of design decision making. The seminar was multi-disciplinary in that it involved students whose interests ranged from hermeneutics to computer-aided design. The summary presented in this paper deals with two of the many decision making issues that emerged from this seminar: design rules and design languages. The role of these issues in
design and computer-aided design are discussed from a theoretical perspective followed by a summary of seminar experiments and discussions. The purpose of the seminar, and therefore this paper, was not to propose solutions, but rather to help to understand and clarify the problems of design decision making. During the process of preparing this paper, it became apparent that "decision making" may not be a good descriptor for the breadth of issues addressed during the seminar. Decision making implies a choice between alternatives. We were interested in not only how one selects alternatives, but how those alternatives were generated and modified during design activity.

The Organization of the Seminar

The objectives of the seminar were to explore some theoretical approaches to decision making and to overlay that understanding on actual design decision processes. A variety of design experiments and discussions were performed during the course of the seminar. Two design experiments have been selected to illustrate various concepts in this paper. The first experiment was the redesign of an existing office in the College. The second experiment was the redesign of an apartment unit in another country. Both problems were kept small so that they could be completed in a few hours.

There seem to be two major approaches that are helpful in understanding this decision making process. First, how we think, what we think about, how we internalize events into our thoughts and how we communicate those thoughts to others may help us to understand the design process. This first approach may be categorized as a language approach. Design is viewed as a form of language, and one cannot think of design without using its language(s). Second, our inherent ability to make decisions, judgements and to act creatively in the face of uncertainty has its base in understanding our internal cognitive system. Much of recent research in cognitive psychology has speculated that the mechanism underlying our decision making behavior is strongly related to our ability to internalize past events, knowledge and experiences into rules, principles and beliefs. The remainder of the paper will discuss these two issues and their implications for computer-aided architectural design.

DESIGN AS THE MANIPULATION OF RULES

Rules appear to be one of the major mechanisms we use to make everyday decisions in the face of uncertainty and ambiguity. It would not be possible for human beings to conduct a detailed analysis of every event of the day prior to taking some action. Instead, we abstract and classify past knowledge and experiences in such a way that facilitates our decision to act quickly and decisively. This behavior is understandable when we are faced with a situation that draws upon our knowledge of a similar prior experience. "Education" is often thought of as the process of learning the "rules" that are relevant to a chosen discipline. Similarly, the use of expert systems can be thought of as organizing previously learned knowledge. However, some of the most creative individuals seem to have developed a facility for breaking existing rules or creating new rules. A goal of this investigation, therefore, was to develop a better understanding of how rules are used in decision making and design. This investigation was developed from both a theoretical perspective and through discussions and design experiments conducted as part of the seminar.

A Theoretical Framework for the Investigation of Design Rules

For the purpose of this discussion, our definition of a rule will conform to that of a condition-action rule. Knowledge is represented as a collection of these condition-action rules that take the form:

\[
\text{IF} \ (\text{condition}_1, \text{condition}_2, \cdots) \quad \text{THEN} \quad (\text{action}_1, \text{action}_2, \cdots)
\]
These rules underlie much of the important work in artificial intelligence, including problem solvers (Newell and Simon, 1972) and expert systems. They also appear in the work of Alexander (1968), Hanson and Radford (1986), Coyne and Gero, (1986), and Archea (1986) as a mechanism to help guide and explain design decisions.

How can knowledge and experience (represented as rules) be organized so that an individual has some basis for action, even in unfamiliar situations? One theoretical approach to answering this question has been proposed by Holland (1986) in his concept of mental models as rule systems. In his developing an understanding of the basic processes involved in induction, he describes these models as consisting of basic building blocks defined as condition-action rules. "These rules are divided into three types: empirical rules, inferential rules, and system operating principles."

There are two categories of empirical rules. Synchronic rules are atemporal, providing associations between categories and individuals at a single point in time. Diachronic rules specify how the environment is expected to change over time either autonomously (predictor) or because of specific actions (effectors). An example of an associative synchronic rule is "If an object is a house, then activate the 'family' concept." These rules may be generated informally from past personal experiences or they may be generated from formal education. "Personal" rules may be idiosyncratic and relevant only to individuals. For example, the family concept activated in the synchronic example may well be "my family" and it may be difficult for me to understand your concept of family because of cultural or other personal differences.

If the function of empirical rules is to model the world, then the main task of inferential rules is to develop better empirical rules. In general, people appear to possess a number of abstract, domain independent inferential rules that provide the mechanism for everyday pragmatic reasoning. For example, Tversky and Kahneman (1981) have shown that people rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations. Their research has also suggested that at least some of these simpler operations frequently result in systematic biases. An example of an inferential rule is the Specialization Rule, which states that if a prediction on a strong rule fails, then one will create a more specialized rule which includes the properties that caused the failure as well as the observed unexpected outcome.

Unlike empirical and inferential rules, system operating principles are neither learnable nor teachable. They may be thought of as "meta-rules" in that they provide the basic means by which other rules are selected as well as operators to carry out generalization of new rules. Examples include rules that serve to "call up" the relevant empirical rules and rules that make predictions about future realities.

How Rules are Organized and Used

Holland suggests that these three rule types are organized into higher order knowledge structures called rule clusters. These rule clusters are further organized into default hierarchies which provide a set of expectations that are considered true as long as they are not contradicted. These default expectations provide the best available sketch of the current situation. However, the core of induction is understanding how knowledge structures are created and modified. Two mechanisms are involved in this process: revising parameters (such as strength) of existing rules and mechanisms for generating potentially useful new rules. New rules are generated through triggering conditions, which are best understood as a response to the failure or success of current rule predictions. Failure triggers a revision of old rules and development of a new mental model with new predictions. In short, "new ideas arise from recombination of the old." (Holland, 1986, p 22)
The Strength of Personalized Rules in Design Decisions

The realization of a rule based design system requires some mechanism for selecting among competing rules. In the design of the office, one solution reflected primarily the intentions of the designer rather than the occupant of the office. She planned the space as if it were her personal office. "...I wanted to personalize it. I added plants. I wanted my tape recorder, my coffee pot. These things are very important to me." It is interesting to note that this transference of personal rules occurred even though the office was clearly being designed for another individual. We believe that many architects similarly design from their own experience primarily because it is difficult to do otherwise. It is inevitable that the selection of rule clusters is conditioned strongly by an individual's personal background and experiences. Another example: in the redesign of the existing apartment unit, all of the participants agreed that the living zone was problematic, but did not agree on why:

"To one, the problem was the inability of the space to accommodate the activity which it was designed to fulfill; another saw the problem as related to the violation of cultural demands of not having a dining room and an entrance lobby; still another saw the problem in the lack of privacy; and finally another saw that the living space lacks the theoretical concepts and ideas which are supposed to show how the space should be planned. Therefore, even though the problem was identified by all, the motivational relevance of the same problem ... was completely different." -- seminar participant

The strength of personalized rules helps to explain why designing for others is so difficult. There appear to be constraints to rule selection and generation, where strong rules are preferred to weak rules. Strong rules are most likely to come from one's own background and experiences. Design actions, therefore, tend to reflect the personal intentions of the designer even when these intentions may not be appropriate for a given context. Intentionality is concerned with the self formation of meaning through the individual subjective perception of reality. It is always present in designing and thinking, and is part of the context that influences design judgements. Concepts of intentionality (Koche, 1973) may help to explain how people "frame" a design problem thereby restricting possible solutions sets.

Failure Triggers the Formation of New Design Rules

As was mentioned earlier, one explanation of creativity (induction) is that it is the result of the failure or success of an existing mental model. In the case of design, the failure of a trial design may serve to trigger a recombination of other rules to result in something "new." Two examples serve to illustrate this point. First, one experience from the office design experiment illustrated how failure can trigger the development of a new solution. In this case the designer felt that dealing with a more efficient arrangement of books did not yield a satisfactory design solution. He "...became a little frustrated, sketched a few small scale isometrics and began to sketch another perspective. During this process (he) began to think of the possibility of a stand-up work area, and sketched a quick section of what one would look like." (see Figure 1) "The failure of the first design solution triggered the recategorization of the problem from "book storage" to "work activity areas."

As another example, the architect Murcutt (Hanson and Radford, 1986, p 202) broke all his rules in the design of a particular house "...because other factors (the lie of the land and big rock shelves) meant he had to use different solutions." This definition of induction is consistent with the common expression: "Necessity is the mother of invention."
Generating New Design Rules

A critical component in design decision making is understanding how new design rules are generated. Previous references on the use of rule-based systems in design generally presume the existence of a set of rules and have little to say about the process of creating new rules. According to the mental model theory, there are two types of rules that could be created: empirical rules and rules of inference. Further, the theory speculates that new rules are created either by the modification of existing rules or by the actual generation of new rules. There are several processes by which rules are modified and new rules are generated. Here we will only discuss the role of analogy in this process.

Analogy plays a central role in knowledge creation. It imports experience from one domain to less familiar domains. Higher level abstractions of problem representations facilitate inter-domain transference largely because they are better able to illuminate similarities between sometimes radically different problem types. There are many documented examples of the use of analogies by creative thinkers. One example is Darwin's use of a tree diagram (Figure 2) as a mechanism to understand evolution. "Over the years Darwin drew a number of tree diagrams both trying to perfect it and penetrate it — to learn what his own imagery would tell him." (Crutin, 1980, p215). The essence of these thought notations seems to be the way the thinker reclassifies these cluster
of thoughts (rules) into a symbolic form only to find that “unpacking the symbol is a promising and demanding task.” (John-Steiner, p215).

Figure 2

The use of abstraction and metaphor is also found within the creative and intuitive phase of the design process. Design drawing notations are frequently performed in such a high level of abstraction that it is difficult for an outsider to discern their meaning. The work of internationally known designers is full of pattern notations that appear to have little direct relevance to a building (Figure 3). Schön (1983) also has examples of the use of metaphors imbedded within his description of the language game.

Figure 3

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However, there appear to be constraints imposed on the “unpacking” or recategorization of these abstract notations into new rules or rule clusters. This has to do with the fact the people’s propensity to generalize new rules is based largely on their prior knowledge and experience. New rules are not likely to displace older, "strong" rules. Instead, rules that are not found satisfactory are gradually eliminated while newly generated rules gradually replace weak rules. New rules get their chance in situations where none or few of the high strength rules have their conditions satisfied. This may help to explain why it is often difficult to generate radically different design alternatives for the same project. The rules used to generate the first alternative become "strong" rules that are difficult to break.

DESIGN AS A LANGUAGE GAME

As was previously mentioned, how we think and how we communicate those thoughts may help us understand some aspects of the design decision process. Most communication is performed through the use of language. However, language is more than just an instrument of communication; it is the medium for human existence and interaction in the world. In this section we will expand beyond the limited definition of language as a tool that consists of words and sentences governed by syntax and grammar. Instead we will consider that through language we shape a world picture that becomes a living reality. Design may also be thought of as a language that helps shape reality. I talk, I think, I design; they are all on the same level. The goal of this section is to explore some of the aspects of the language of design and its influence on design decisions.

A Theoretical Framework for the Investigation of Design Language

We used a broad conceptual framework described by Prak (1968) as a “three-termed relation” for this investigation. These three terms are: 1) Symbol, 2) Denotatum, and 3) Interpreter. All three elements are necessary for the understanding of language and how it is used. As an example, I (3) can recognize a photograph (1) as the portrait of Lincoln (2). Put in still another way, language can be thought of as symbols to which meaning has been assigned. These symbols (1) must exist within a certain context (2) in order to be meaningfully interpreted (3).

Elements of Design Language

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<th>SYMBOL</th>
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<tr>
<td>Symbol</td>
<td>Denotatum</td>
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<tr>
<td>Designed Objects</td>
<td>Design Content</td>
<td>Design Meanings</td>
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<td>Design Grammar</td>
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<td>Spatial Organization</td>
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Symbol. In natural language, symbols are the linguistic building blocks of sentences. Languages have generally accepted and understood rules (grammar) for how these symbols are to be strung together. However, it is possible to obey all the rules and still end up with ambiguous and meaningless sentences. Symbols play a similar role in design through design grammars. Design grammars can be defined (for example, see Stiny and Mitchell, 1985) as the formal (syntactic) representation of a design language consisting of decision making principles, the definition and interrelationship of spatial form, and the rules of engagement for the design activity. As with natural language, the selection, use and understanding of design language rules depends heavily on the context within which design occurs.
Context. Context refers to the specific situation within which meanings are assigned to the symbol. The basic assumption of contextualization is that any symbol denotes a name, an activity or a rule and connotes an idea or a meaning. This denotation-connotation relationship is a fundamental principle in analyzing the language(s) of design. In natural language, denote is used to indicate the object’s name, and connote to indicate our association with the object. In design language, spatial organization denotes the function of the place and connotes our expectations of behavior or other meaning derived from past experience (Scruton, 1979, p.165). Unlike the case of natural language where syntax and semantics are intertwined, design language lacks a clear association between architectural syntax and architectural semantics. That is to say, the conjunction between symbols and meanings represented in contextual analysis is missing. Understanding a design is a matter of re-capturing from the architectural symbol the various meanings which it incorporates taking into consideration the multiple facets of the context. These multiple facets include physio-psychological, economic-social, political, formalistic, etc.

Meaning. In natural language processing, the meaning of a sentence is dependent not only on the form of the sentence, but also on the context. This context is rarely explicit, and "...the full understanding of any given speech act is always enmeshed in the unarticulated background expectations of the speaker and the hearer" (Winograd, 1984, p 144). The language of design also has implicit and explicit meanings as well as multiple layers of meanings. For example, professional terminologies usually are explicit while an individual’s personal meaning of space can be difficult to express. These personal meanings are often embedded in the unique time and place within which design occurs.

Interpersonal Dialog and Design Decision Making

The design process can be seen simply as three levels of conversation: Interpersonal dialog, Inner dialog and Internsubjective dialog. Interpersonal dialog takes place among individuals, and includes all means of communication necessary to reach a "congruence of meaning." This dialogue is composed of both words and visual images. The participants are all parties interested in the development of the final design and may range from a single client to an entire community. All are trying to understand and interpret each others meanings. This process of interpretation and reinterpretation creates what has been termed a "language game" (first introduced by Ludwig Wittgenstein, 1945). The notion of a language game suggests that language owes its form primarily to the use people make of it. It also implies that while the rules of the language are explicit, the rules of the game are implicit and in constant change.

An example of interpersonal dialog and language game can be seen in the apartment redesign experiment. After the problem was introduced, the designers asked many questions about the locality of the project, the users, construction constraints and any economic limitations. One participant asked many questions about the social and cultural context in an effort to discover implicit cultural meanings. The fact that this housing was built for middle income residents was perceived differently by this person because of his different cultural background. The subsequent process of questioning, answering, and discussing enabled this individual to partly uncover the denotations and connotations of various design decisions. It was through this interpersonal dialog that this participant gained better understanding of implicit cultural rules.

Inner Dialog and Design Decision Making

Inner dialog concerns itself with the language of thinking. "The inner language of thought differs from language used for communicative exchanges in its rapidity, in its condensed form, and in its functions." (John-Steiner, 1985, p.139) While language is a highly standardized form of expression, memory images are much harder to define, with some people seeming to prefer verbal images
while others have a preference for thinking in visual images. An example of these inner images can be found in Darwin's tree diagram (Figure 2). These images tend to be highly metaphorical and convey many levels of meaning to the individual. "Inner speech is to to a large extent thinking in pure meanings. Is is a dynamic, shifting, unstable thing." (Vygotsky, 1962)

In design, it is probable that the inner language of design is largely visual in character. The design process gives meaning reality through the mental manipulation of images. The act of projecting those mental images onto paper through drawing is similar to speaking and writing. The characteristics of rapidity and condensed form are apparent from an examination of idea generative sketches (Figures 1 and 3). This inner language might be thought of as the manipulation and generation of new design rules.

Intersubjective Dialog and Design Decision Making

Intersubjective dialogue takes place between the designer and the subject of the design. A general example of this dialog is Darwin's continual attempt to "unpack" the many meanings imbedded in the imagery of his tree diagram (Figure 2). A design example of intersubjective dialog is found in "back-talk." (Schön, 1983) As the designer works, alternative representation of a design are created. Because of the complexity of design, some unintended consequences are produced. Reflecting upon these consequences, the designer may obtain a new awareness and appreciation for the situation. This reflects an important characteristic of the language game of design: the nature of the tools used in this game can influence the outcome. A high level of abstraction is characteristic of the creative design decision process and encourages back-talk (see Figures 1, 2 and 3), while model building within most computer aided design systems requires too much specificity and inhibits back-talk (see Figure 4 from the office design experiment).

Figure 4
As another example, in the apartment design experiment, all of the participants developed alternative understandings of the problem. One participant grouped the important aspects of the design into users, clients, and technical/financial aspects. Another participant was perhaps more philosophical, suggesting a radical reorganization of space assuming the relaxation of construction requirements that limited design options. Each participants approach required a reinterpretation of the original context. This circular process of symbolization and decoding is what might be called intersubjective dialogue.

In summary, design can be seen as a language game that is mainly contextual. The rules of the game follow the rules of life from within which design occurred. The language game is possible through dialogue which consists of three parts: interpersonal, inner, and intersubjective. Meanings are intentionally assigned to symbols of design within a specific contextual framework by the designer. The understanding of these meanings allows the designer to select appropriate rules to be used within the design process.

CONCLUSIONS

Our very preliminary conclusion is that design decision making takes place through the combined effect of rules and language. Language is how we communicate; rules are what we communicate; and the process of communication inevitably influences the content of the communication. Language plays a critical and active role, in that it can and does imbue new meanings in the rules that we communicate and it assists in the “spontaneous” generation of new rules through back-talk. The ability to generate new rules flows from an understanding of the unique place/time setting which encourages a design response that fits that unique context. This ability is also constrained by our individual backgrounds and experiences. The process of selecting and generating rules within the three levels of dialog can be thought of as a language game.

We are critical of existing design technologies because they do not adequately reflect the dialogical nature of this language game. It primarily through interpersonal dialog that designers can become aware of the unique time and place considerations that embed meaning in design. It is primarily through inner dialog that we develop abstractions and analogies that enable us to solve difficult design problems. It is through intersubjective dialog (back-talk) that we support our inner thinking. We see the need to pursue the following areas of computer-aided design research:

1. **Interpersonal Dialog Technologies.** Dialog takes place within this three part system. This dialog can be between the computer and the individual designer or enhance interpersonal communication. How we actually design the software is a function of how we view the role of dialog within the design process. If design is conceptualized largely as an individual working in isolation, then we are likely to develop software that is significantly different than if design is viewed as a collaborative enterprise. Our philosophy has been that design is a group act, and that design tools should facilitate group dialog. We see an increased need for the development of and experimentation with decision conferencing and design brainstorming technologies as well as other interpersonal dialog facilitators.

2. **The Role of Machine Knowledge.** Our view is that design is an activity wherein people make decisions about what they want their future to be. The rules that are used within this context vary from explicit, generally accepted “syntactic” rules (e.g., the width of a stair tread) to rules that can only be agreed upon within a particular social context and culture (meaning). We believe that many, if not most, of the major form generators for buildings are imbedded within the unique context of the program and site. Over time, many designers seem develop “rules” (e.g., Murcutt) that facilitate problem recognition and the generation of design solutions. To the extent that these rules are derived from personal background and experience, they do not appear to be purely syntactic. Therefore, we feel that it is important for design technologies to explicitly recognize that
many rules and their interrelationships with other rules must be open for inspection, discussion and possible revision.

3. **Idea Generation Technologies.** While creativity is a very intuitive process, it appears that design tools can be developed to assist this process if they more fully recognize the nature of the process. Idea generative technologies should be able to abstract general principles from specific examples. The library images of Brown and Novitski (1986) have provided some examples as to how this might be done, although these images did not generally deal with inter-domain transfer of analogies. In addition, research has shown that problem solvers may not be able to recognize the relevance of a source analog unless a "teacher" calls attention to the analogy. Perhaps design technologies might be capable of developing libraries of analogies that could be useful in generating design concepts.

4. **Multiple Methods Technologies.** Finally, the development of a design is a complex process. It is unlikely that one technology will be especially suited for all the design processes associated with the "languages of design." We would like to see computer technologies placed within a richer context of multiple decision making tools that can provide for the communication of design ideas on multiple levels. As we develop computer-aided design technology, it seems clear that we are developing a new "language game." What should that game be like and who should play it?

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SELECTED REFERENCES


