Computers and the Creative Process

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In this paper the role of the computer in the creative process is discussed. The main focus is the investigation of whether computers can be regarded as candidates for sharing or participating in a task that has been attached almost exclusively to humans: that of creativity.

The Machine as a Reflection of the Human Mind

According to Negroponte, "computers are intellectual machines that allow us to simulate human behavior." (Negroponte, 1970) In developing computer programs, one is forced to question how people think and how mental processes develop. In other words, computers must be acknowledged not only as machines for imitating what is understood, but also as vehicles for exploring what is not understood. The entire sequence of specifying computer operations is similar to that of human thinking. When designing software for natural language understanding, knowledge representation, inference, or learning, one is actually transferring processes of human thinking to a machine. The computer becomes a mirror of the human mind, and as such, reflects its thinking. In that sense, if computers are encoded with the basic principles of human logic, taught ways to acquire their own knowledge, and given ways to import and export information from the real world, then they can probably behave in ways similar, if not more advanced, to that of humans.

Furthermore, thinking can be explored as a mental process not only by observing human behavior, but also by observing the machine's behavior. To do this, it is necessary to perform individual operations with substantial independence. The entire sequence of operations must be such that there is no human intervention from the time data is entered until the time results are obtained. The decision-making mechanisms must be built into the machine itself. This does not mean that a "computer-thinker" is to be created. Rather, it suggests the attainment of independence in solving particular problems. Thus, the human-thinker can observe via the computer his/her decision-making process and compare it with that of others.

Limitations of the Machine

According to Sapir and Whorf, "a world view of a culture is limited by the structure of the language which that culture uses." Maybe this applies to the world of computers. To understand the way computers work, one must know and understand their technical structure and the logic of their language. In the same way that a poet or an author is bounded by language, context, or culture, a "computer-thinker" may also be bound by issues of technology, language, or algorithmic complexity.

At present, machines have denatured language-codes. Databases must extend beyond mere geometric and non-geometric codicil information to employ computers more effectively in the creative process. They must also include the meaning of that

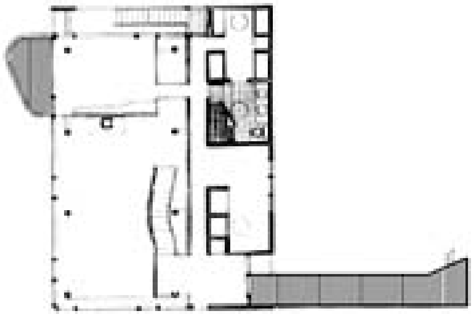


Figure 1 (left). A plan (far left) and a re-arrangement of the plan (left).

information. For example, in graphics design, software should allow recognition of a square regardless of its size and orientation. Or an object, such as a statue, should be understood both as a form and for what it represents. Today one can begin to see systems that allow one to perform a large number of calculations and which move towards larger databases that permit human interpretation. In the future, databases may include information on the meaning of objects, events, and relationships. If and when that happens, computer can move closer to the creative process.

Games and Design

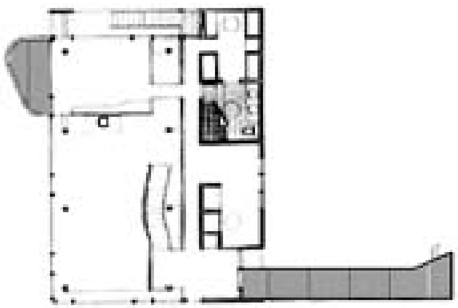
Lets concentrate on design as a creative process. According to Norbert Wienner, computers are able to play games in as much as they are able to follow rules, tactics, and strategies. "It is not very difficult to make machines that will play chess of a sort. The mere obedience to the laws of the game, so that only legal moves are made, is easy within the power of quite simple computing machines." (Wiener, 1947)

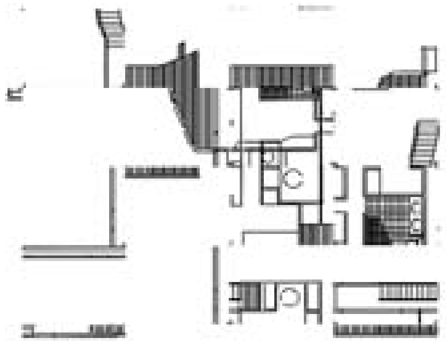
There is a theory of games (Von Neumann, 1945) which establishes a way to describe and analyze them and their strategies by working from the end of a game rather from its beginning. In the last move of the game, a player strives to make a winning move if possible, or, if not, at least a drawing move. When the entire strategy is known, this is manifestly the best strategy for playing the game. However, in design, available knowledge is not sufficient to permit the formulation of a complete strategy of this sort. In design, strategies can only be approximated. Such a strategy would rely on the relation of local actions to global intents these attitudes not always justified. For example, the local moves embodied in construction procedures are characterized by specificity. In contrast, global goals can be quite ambiguous. Given that the global intentions of design are, at best, ambiguous it is not necessary to question whether it is possible to construct a game-playing machine which will generate an optimum solution by following rules in Von Neumann's sense. On the contrary, it is unquestionably possible to construct systems that undertake local actions irrespective of the final goal. The real problem is to construct a computer system, which will offer opportunities for interesting and challenging dialogue with a designer. Such a system would be capable of learning by experience. This would enable it to improve its knowledge of the strategy and rules of design. The point of departure for this learning would be a set of rules derived statistically from design precedent.

The Machine as an Assistant Designer

In the 1960s the role of computers in design was to replicate human endeavors and to take the place of humans in the design process. In the 1970s the role was to create systems that would be intelligent assistants to designers, relieving them from the need to perform the more trivial tasks and augmenting their decision-making capabilities. "The aim has been to

Figure 2 (right). A plan (right) and a random re-arrangement of the plan (far right).





leave the value judgement to the user and have the system do all the procedural and tedious work which will check the feasibility of the user's propositions " (Yessios, 1973). Today, computers are increasingly involved in the design process. Their roles vary from drafting and modeling to intelligent knowledge-based processing of architectural information. While the future of computers appears to include a variety of possible roles, it is worth exploring these roles in the context provided by the question: "Who designs?" If one takes the position that designing is not exclusively a human activity and that ideas exist independently of human beings, it then would be possible to design a computer mechanism which relates ideas.

Visual Thinking

It can be argued that designers construct their drawings in a very precise way. We, as viewers, can recognize that the compositions are not random, perceiving the presence of a relational structure even if the construction itself evades us. In most paintings, drawings, or sketches we distinguish certain visual relationships that makes us believe that this must be a "meaningful" composition. Let's take an example: in the architectural plans of Richard Meier one may notice that the vocabulary of building elements — such as walls, columns, curvy walls etc.— are repeated over and over in his plans. The plan in the figure below (left) corresponds to an actual house. The plan on the left is a re-arrangement of the same elements found in the first plan but in a different order.

The difference between the two buildings (or rather between the two compositions) is not the number of elements — since no parts are added or subtracted. The difference lays in the relationships of the parts within the plan. There are infinite ways that these elements can be arranged on a white piece of paper. Only a few would be seen as architectural plans, and even fewer would be seen as those of Meier. The composition in figure 2 is a complete random generated composition of pieces taken from the plan.

But then, what is that which makes a plan to look like a plan, a map to look like a map or a poem to look like a poem? Two answers seem possible: first, since constructed objects show a high degree of interrelationship, we can conclude that "coherence" is something that we have the intrinsic capacity to discern and which we value, since it helps us distinguish between randomness and order. We can speculate that we respond to forms as groups of relations, or rules. Second, it appears that sometimes the relationships, which hold together the elements of a composition, are stronger than the vocabulary of elements. This can be expressed by representing the structure of a composition as opposed to its content. In other words, what makes a Meyer plan look like a Meyer plan relies strongly on the formal relationships.

Along with the increased sophistication of Computer-Aided Design (CAD), it has been increasingly necessary and desirable for a computer to recognize visual compositions. The recognition process can be used not only as means to input information into computer, but also as a vehicle to investigate how we as human see, recognize, and appreciate visual information. Methods exist for inputting and recognizing engineering drawings and diagrams. This is primarily because they are drawn to conform to specific standards. In contrast, graphic or architectural designs are not always prepared in accordance to existing standards.

Computer vision is an area of artificial intelligence that investigates into how computers can perform the process of vision. Computer vision systems are designed to capture, analyze, and recognize visual information, create high level descriptions from sensed data, and, then, feed this information to CAD systems for further processing. In general, computer vision systems attempt to recover useful information about the three-dimensional world from image arrays of sensed values. Vision algorithms try to detect relations among image data. These data are numbers representing light intensity or depth range.

It may be possible to assume that vision systems can enhance the conduct of visual interpretation and analysis by allowing the researcher to access information more systematically and efficiently. For example, the automatic extraction of compositional rules from drawings may provide one with insight concerning the designer's form-making approach and intentions. Computer systems are good at dealing with vast amounts of information, sorting, classifying, and analyzing it. In contrast, human experts are good at detecting higher level abstractions. Hence, it is more likely than not that visual analysis can be enhanced substantially by the interaction of humans and machines. Thus, knowledge concerning the visual structure of notable compositions and classes of compositions can be acquired.

Intelligent Process

The process of confronting design as a structured problem has been discussed by many theorists in the area of artificial intelligence and many models have been developed and implemented. The main concern of those theorists is the degree to which design can be rationalized. Simon's thesis (Simon, 1981) is that design is an ill-structured problem, but it can be solved by considering not one, but a spectrum of alternative solutions and choosing the most satisfying one. In order to produce these alternative solutions, design has to be first viewed as a problem-solving process.

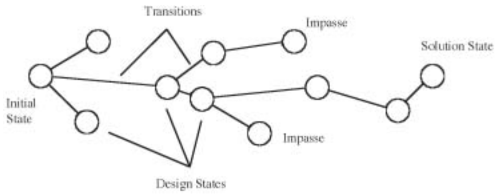


Figure 3 (left). Design as a goal directed search process

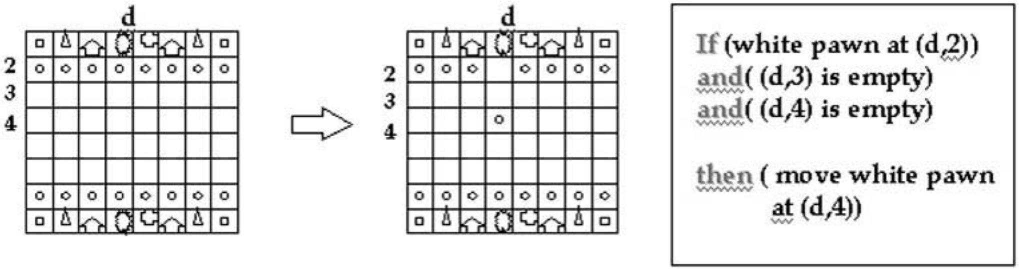
If the design process is viewed as a *problem-solving process*, design may be conceived as a far more systematic and rigorous activity. As defined under a theory formalized by Simon (in collaboration with other researchers like Newell (Newel, 1990)), for every problem a *solution space* exists. That is, a domain exists that includes all the possible solutions to the problem. Problem-solving can then be characterized as the process of identifying and evaluating alternative solutions in this space in order to discover one or several which will meet certain goals and may be considered to be appropriate and desirable.

Game Playing

In game playing, one of the objectives is to make intelligent moves. For example, in chess, there are rules, strategies, and tactics. Every move has to fulfill local and global goals. In design, we can also acknowledge the involvement of rules, strategies, and tactics during the design process. The question, however, is what are the goals in design? What is the local and what is the global goal? One of game playing properties is that although people who do them well are considered to be intelligent, it appears that computers can perform well by simply exploring a large number of solution paths in a short time and then selecting the best. It seems that this process

Figure 4 (top right). A chess move is being codified as a set of logical predictions.

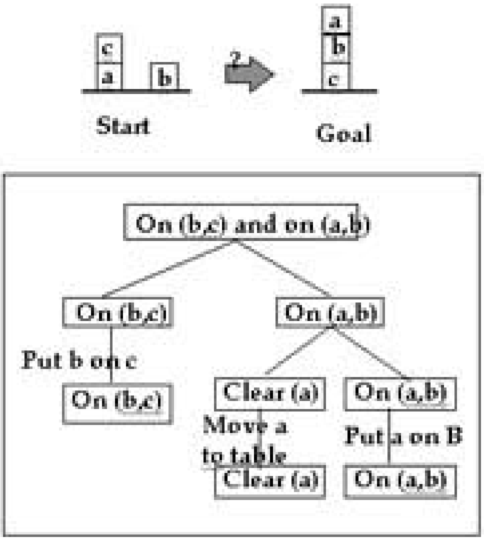
Figure 5 (bottom right). Sorting a set of block involves a series of logical actions.



required little knowledge and could be therefore easily programmed. In other words, computer's involvement in the design process does not have to be that of imitation rather than that of extension.

Problem solving

Problem solving is another area in which AI may be useful in design. It involves a beginning, a goal, and a strategy. Every move has to be analyzed extensively. By considering a set of logical possibilities, a solution strategy may eventually be found. To investigate this kind of reasoning, methods must be developed that incorporate matching, indexing,



heuristics, generate-and-test, hill-climbing, and breadth-first searches. All of these methods are general and aim at solving a problem. The question is what are the problems of design? Can they be defined? What are the goals in design?

Perception

Perception is an area of AI that includes vision and speech. Perception tries to find how do we recognize patterns; how do we see. Perceptual tasks are difficult because they involve analog (rather than digital) signals, the signals. Typically noisy and usually a large number of things (some of which are obstructing others) must be perceived at once. Nonetheless, their contribution to intelligence is extremely significant since perception is our main link with the external world. Perception can contribute not only in the design process but also as a vehicle for understanding, recognizing, and criticizing design solutions. But what are the criteria for evaluating design? Can they be specified?

Natural Language Understanding

The ability to use language to communicate is an important medium that separates people for animals. The understanding spoken language is extremely difficult since it includes the problems of perception. If we restrict the problem to written language it is still very difficult. This problem is also referred to as natural language understanding. In order to understand a sentence, it is not only necessary to incorporate knowledge about the language's structure (vocabulary, grammar, spelling, and syntax) but also

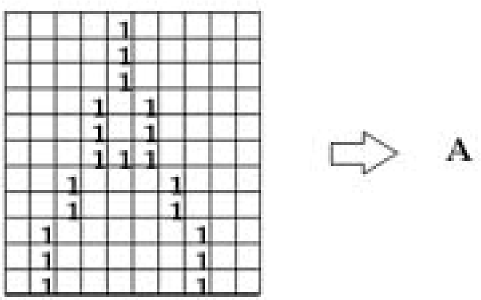


Figure 6 (top left). A letter recognition

Figure 7 (bottom left). Analysis of a sentence

to know about the topic discussed so that implied statement are understood. One of the problems of design is how do designers communicate ideas. This involves not only the actual exchange of straightforward information but the expressions, metaphors, gestures, sketches, etc. involved in conversations between designers. How AI can help designers communicate locally or remotely is an interesting undertaking especially through the use of computer networks. Another area of design where natural language understanding may be useful is in the notion that design is a language of shapes. By analyzing natural languages is it possible to help designers compare and understand their formal languages.

Human-machine Interaction

Human beings are very good in solving complex problems or in artistic creation. Computers are powerful processing devices with enormous memory capacities. What is the power of the machine? What is the power of the humans? It seems that humans are good in processing high-level abstract information. Judgement, interpretation, and creativity are unique characteristics of human thought. On the other hand, humans are very slow in complex number calculations or in memorizing large amounts of information. Computers and humans seem to be superior in different areas of thought. The following diagram shows that humans are good in using many rules and a few tasks. Computers are good in using less rules and performing many tasks. The question that may be posed is whether computers and humans can co-exist and whether they can complement one another? This and other possibilities will be discussed.

As computers become more and more capable of performing many tasks in speeds that surpass by far human performance, it is important to ask what kind of relationship will humans and computers have in the future. In other words, as computer performance increases and their capabilities mimic those of humans, how can AI research relate to humans? What operations make a computer useful to a human? What computer operations are impossible for humans to perform? Three scenarios seem possible. The computer may:

1. Complement the human thinker
2. Extend the process of thinking
3. Replace the human thinker

Scenario A: The computer can assist the designer

According to this scenario, computers provide useful information, advise, appraise, and assist the designer. The goal of Computer-aided Design (CAD) and computer vision systems is to expand in this direction. Computers function mainly as tools for the designer and can help either during the design process or in the early stages of design. Expert systems are also available (an area of AI) whose goal is to assist the designer. Their target is to provide the designer with useful information and function as a consultant during the design process.

Computer can be very useful in helping the

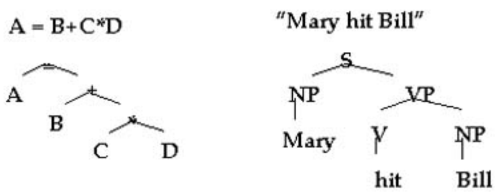
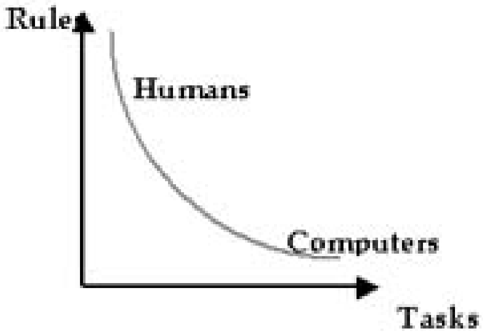


Figure 8 (top right). Human-machine relationship

Figure 9 (bottom right).

Figure 10 (far right).



designer meet the large number of constraints to be simultaneously considered in any design problem. Moreover, the complexity of the design problem can be so great that a designer would be unable to arrive at an appropriate solution unless a computer is used to break down the problem into sub-problems and use a computational approach to solve them (Bernholtz, 1969).

Scenario B: The computer can extend the designer's mind

According to this scenario, the computer functions as a tool that allows the designer to explore alternative possibilities and extrapolate into unknown intellectual territories. Abstract entities such as events, experiences and ideas, can be symbolically represented and transmitted through electronic devices. It is possible to visualize those abstract entities, verify their existence and project their behavior into a once unimaginable world through the use of mathematical models.

The introduction of new electronic media in the last fifty years gave a different twist to the exploration of these mathematical notions. The ideas of mathematical models and simulations were first realized through fast computations and large memory capacities. A new world was *discovered*, the world of *virtual reality*, which is a "make-believe" representation of mathematical models. This world can be projected to the computer screen or animated through real-time computations. Objects, represented through instructions in the computer's memory, were projected to a screen by simple algorithms, then transformed as if they were physically there.

Scenario C: The computer can replace the designer

According to this scenario, the intellectual capabilities of a computer may be far superior to those of the human designer. This scenario suggests a computer program may replace the designer. Since the invention of the digital computer, theorists strive to find ways to relate computers to human thinking. Computers are arithmetic devices, which can perform all basic arithmetic operations, such as addition, subtraction and multiplication. By combining basic operations, computers are also able to perform complex algebraic operations and derive accurate results in shorter time frames. Furthermore, computers have the ability to operate as logical devices, since they can perform logical operations, such as AND, OR and XOR. Given a number of truth tables, computers are able to verify the truth or falsity of a logical sentence and therefore to determine the validity of an argument (Von Neumann, 1945). This latter capability led computer theorists to inquire whether those arguments could be compatible to problems taken from the real world. In other words, is it possible to develop cognitive mechanisms, which would process information from the real world and derive answers or propose solutions as if they were carried out by humans? Some theorists expect to see even more than that. They expect to see computers which would be able to simulate human thinking to a degree such that they would perform tasks which are considered by humans to be "highly intellectual", such as design.

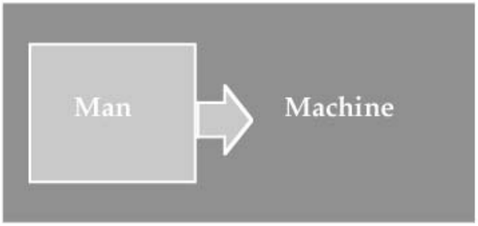


Figure 10 (left).

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