Send This Computer to Kindergarten

A childlike machine that observes, imagines and then creates designs may someday come to the aid of architects

By IVARS PETERSON

A young boy sits at a little kindergarten table that is covered by a grid of inscribed lines. Across this small field, he sends armies of shapes—smooth, brightly colored cardboard squares, circles and triangles and maple-wood cubes, spheres and tetrahedra. His fingers shift, stack and arrange the forms to create pleasing, playful designs.

One child who went through this kind of experience was Frank Lloyd Wright. Later in life, Wright, who became one of the most influential architects of the early 20th century, wrote: "On this simple unit-system ruled on the low table-top all these forms were combined by the child into imaginative pattern. Design was recreation! ... The virtue of all this lay in the awakening of the child-mind to rhythmic structure in Nature — giving the child a sense of innate cause-and-effect otherwise far beyond child-comprehension."

Now, imagine a machine, instead of a child, playing in a kindergarten environment. Suppose the machine studies this simple world of basic shapes and straightforward rules and conceives plans to begin altering this small world by creating artificial objects. If the machine makes something that we recognize as being playful and creative, something that we would expect a young child to make in such surroundings, then it would also be showing imagination and may be on its way to becoming an architect.

So argues Lionel J. March, an architect and mathematician at the Royal College of Art in London. He suggests that imagination is not necessarily a peculiarly human quality. Modern mathematical concepts now being developed, March contends, may help bridge the gap between the arts and the sciences and between human and machine imagination.

"What I would like to do over the next 20 years is to build one of these machines and get it into a kindergarten," says March. "It would look out on the world and make sense of it. It would have language and may have some theories to try out. It would act on this world and create things in it."

The idea of an "architecture machine" is not a new one. More than a decade ago, Nicholas Negroponte and his architecture machine group at the Massachusetts Institute of Technology (MIT) designed and studied sophisticated computer systems for intelligent computer-aided design. Their aim was to make machines that would create designs responsive to context and able to cope with missing information.

The MIT researchers decided that among the important qualities required by an intelligent architecture machine were an ability to learn from experience and the capacity to make creative jumps. "Tools like intuition (sharpened by experience) are valuable and are often responsible for the major joys in architecture, and we should strive to bestow such devices on machines," wrote Negroponte in "The Architecture Machine" (MIT Press, 1970). "My position is that machines, like humans, will have to evolve these mechanisms by developing in time and with experience, each machine being as different from the next as you are from me." Because public taste and needs also keep changing, the architect, whether human or machine, must be able to adapt.

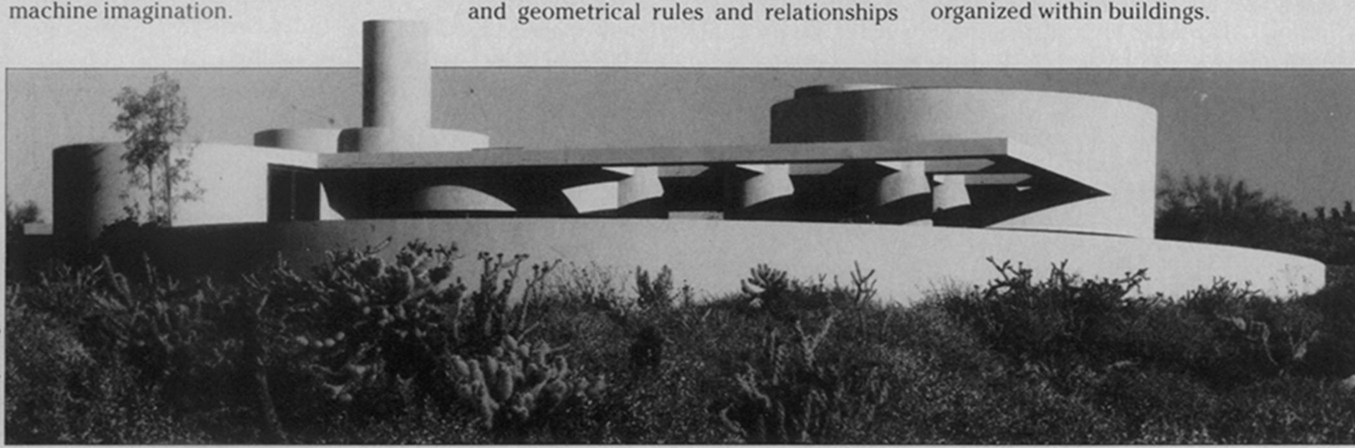
But the idea of an architecture machine, in at least one sense, goes back centuries — to the attempts by classical Greek and Roman designers, and later, Renaissance artists, to come up with "laws of beauty" and geometrical rules and relationships that would automatically translate into aesthetically pleasing structures.

The chief figure responsible for laying down the rules for art and architecture in 15th century Italy was Leon Battista Alberti. An inventive man, attuned to the regular forms hidden within nature, Alberti based his rules on geometrical concepts of proportion and ratio. Within a building design, for example, a certain proportion would be repeated over and over again on varying scales. Large arches would sweep over smaller but still perfectly proportioned arches and so on down to the finest details.

For Alberti, design was governed by rules derived from a vocabulary of elements combined with a set of relationships between these elements. This design structure provided a kind of "grammar" within which the designer worked. Later artists, like Leonardo da Vinci, incorporated and refined these ideas in their own works.

Renaissance architects, thus, had a list of architectural features and procedures to choose from, and out of this list came a rich array of what many critics consider some of the most beautiful designs ever created. March comments, "It was difficult to follow those particular procedures and not end up with something that was reasonable." The goal now, he says, is to get that kind of list or grammar into an architecture machine.

The application of modern mathematics to architecture is like shifting from "the alchemy to the chemistry of design," says March. New mathematical concepts like set theory, group theory and symmetry, graph theory and networks, mappings and transformations and others make it easier to describe and understand how shape is organized within buildings.



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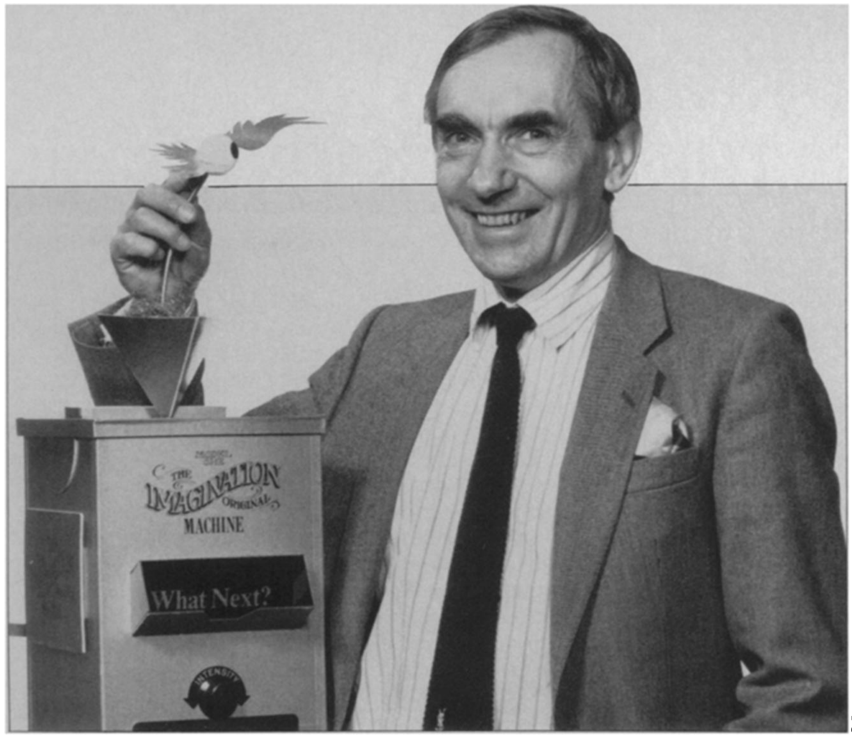

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Lionel March poses beside a whimsical model designed to advertise a recent lecture on "artificial imagination" that he presented at the National Bureau of Standards.

Graph theory, the mathematical study of how points can be joined by lines (SN: 5/5/84, p. 278), provides a useful way of representing floor plans when the designer wants to know how rooms should be arranged and where doors should go so that the rooms are connected in a reasonable way. The same idea also applies to things like the arrangement of hallways in a large building or the pattern of streets in a city.

As a result of this mathematical study, March says, "we're already in a position to know, in a sense, how many fundamental floor plans there are." It's impossible to conceive of a building that doesn't include one of these plans. However, although there are a limited number of such plans, the architect still has considerable freedom to "ornament" his designs in a "vast variety of ways," March says. He cites the example of three Wright houses that "all look remarkably different in geometry but turn out to have the same connectivity."

Wright's work also showed frequent use of designs that began with a single fundamental unit that was then repeated to generate larger entities, going from a house to a large apartment building to a great complex of towers. Although his procedure was very mathematical, relying on symmetry and the concept of "cyclic groups" to produce the designs, the resulting structures were breathtakingly different.

Wright designed "one building after another that startled the world," says March. "But he was not just a dreamer. It was using the mind and the intellect very powerfully to drive the imagination into new modes."

"Mathematically, we are beginning to learn how these things work," says March. "There's no reason why we shouldn't use this knowledge in the design process, and if we can use it, so can machines use it."

While it is possible to see how useful and fruitful mathematical ideas can be in the design process and how this may be mechanized, the second half of the creative equation — imagination — is much more elusive. What is imagination? How do human beings take their stored, observation-based representations of the world, modify them to create something that doesn't yet exist out there and then, when possible, act on the world to make the dream come true?

Some philosophers have contended that it is the existence of language that leads to imagination because it provides a shorthand way of reworking representations of the world. Without language as an intermediary between the world sensed and the world effected, it becomes simply a matter of stimulus and response — a matter of instinct. On the other hand, words and plans allow one to modify a response. Often, however, only a few of these creations can actually be implemented.

It's this idea that March and others see as a possible way toward building a machine that shows imagination. The machine's designer must provide it with a language (including a grammar) for design, just as Alberti formulated his rules for architecture. "Given that we have provided it with language, this machine, I believe, will have an artist's imagination," says March. "That's no worse than the case of Alberti, who believed [the language] was provided by the angels."

Attempts have already been made to formulate sample architectural grammars by studying in detail the work of particular architects. A few years ago, two architecture students, working under George Stiny at the University of California in Los Angeles, managed to extract the essence of Frank Lloyd Wright, and their computer generated new Wright house designs that experts insisted were authentic. "These [designs] had all kinds of quirks, peculiarities that one tends to associate with a real Frank Lloyd Wright house," comments March, "and that was entirely generated through the use of this very vast grammar."

March admits that an architecture machine won't be able to do the whole design process by itself. "Right at the core of the thing is the language which we have to more or less implant into the machine initially," says March. He sees a future role for architects as language designers. "It puts designers on a new level...in which we are designing languages for design," March says, "and then we get our servant, the machine, to figure out how to effect a certain design."

Russell A. Kirsch, a researcher in the field of artificial intelligence at the National Bureau of Standards in Gaithersburg, Md., says March and his students are "showing that some of the tools that have grown up around computer science are reasonable candidates for achieving some kind of synthesis between the arts and humanities on the one hand and technology on the other."

March says, "I personally believe that by trying to mechanize we actually begin to understand more and more about what we do as human beings." At the same time, although the prospects of achieving "artificial imagination" still seem remote, work on a "science of design" is moving along rapidly. March's optimism is reflected in the spirit of Alberti's favorite Latin motto: "Quid Tum," or simply "What next?" □

This Frank Lloyd Wright house (left) in Scottsdale, Ariz., was based on one of three designs that looked strikingly different but mathematically had the same underlying structural pattern.

Natl. Gallery of Art

Medallion honoring Leon Battista Alberti.