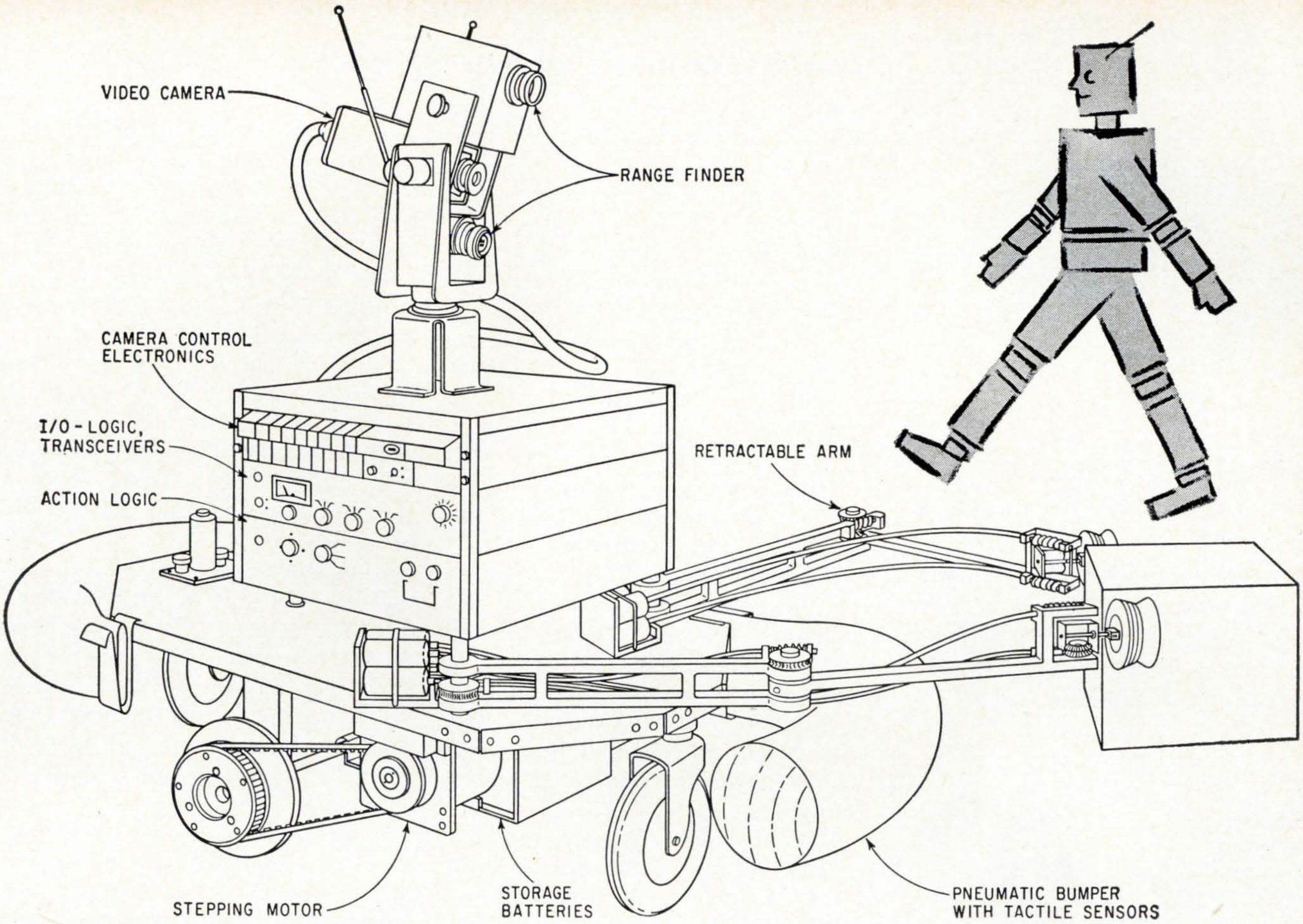

A far cry. Like the other prototype systems in the field, Stanford Research Institute's buggy-mounted intelligent automaton, scheduled for completion later this year, differs markedly from the public's conception of a robot.

Industrial electronics

Intelligent robots: slow learners

But a handful of pioneering researchers are working toward the day their laboratory curiosities will perform useful and complex tasks

By H. Thomas Maguire, Boston regional editor
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What may well be the most exclusive fraternity of research scientists in the U.S. is exploring the staggering complexities of artificial-intelligence systems at universities on the East and West Coasts. The researchers' goal is the creation of automatons capable of performing useful tasks.

Artificial-intelligence systems differ markedly from working industrial robots in that they are designed to learn and to discriminate. Industrial machines are strictly materials handlers and lack the capacity to make decisions affecting their own actions [Electronics, March 20, p. 165].

At the Massachusetts Institute of Technology in Cambridge, Mass., Marvin L. Minsky, a professor of electrical engineering, is working on what he likes to call a visually controlled manipulator. In common with the handful of other pioneers in the field, Minsky generally avoids using the word "robot" because of its sensational science-fiction implications.

At the Stanford Research Institute in Menlo Park, Calif., Charles A. Rosen and Nils J. Nilsson are building a free-wheeling research platform that integrates available information-processing techniques into a single system with artificial intelligence. Next door in Palo Alto, John McCarthy, a professor in Stanford University's computer science department, is assembling hardware for an intelligent automaton. Stanford researchers have been

. . . the whole system is built around confidence levels for hypotheses . . .

working in this field since 1963.

These are the only known U. S. projects along this line, but sources suggest there is a good deal of work being done "under commercial cover" on behalf of Government and military agencies. The National Aeronautics and Space Administration, for one, is said to be interested in intelligent automatons.

I. Working model

Minsky's work, a part of MIT's project MAC (Machine-Aided Cognition), is underwritten by the Advanced Research Project Agency of the Defense Department. His machine combines an electronic eye, a computer, and a mechanical arm. Minsky describes it simply as a project "to build a robot that can orient itself to the physical world and do something about things it sees."

But the only activity his machine can yet perform, he says, is stacking identical blocks. The machine's eye sees the blocks, distinguishes them from their background, and tells the computer where they are. The computer-directed mechanical arm then picks them up and erects a tower-like pile.

Next on the agenda is the use of curved blocks of different sizes so the robot can construct a house-like structure with an arched roof. To accomplish this, the machine will have to consider and answer the question: Will this block fit in this spot?

Cyclops. In its present form, there is nothing about the robot to suggest a human appearance. Its eye, an image-dissector tube with 1,000 x 1,000 photosensitive points, selectively measures the amount of light in various parts of its field of view.

The eye Minsky now uses is exposed until a predetermined photocurrent level is reached. At that point, the eye tells the computer how long this exposure lasted, and the computer calculates the light level at the relevant spot. But a new eye, to be delivered soon, will have a programable signal-to-noise ratio and a dark-current cutoff, "so it won't spend a lot of time looking at a hole," explains Minsky.

The mechanical arm now used on Minsky's robot is rather primitive. It can move in three axes and has a two-finger grip. Engineers at Minsky's laboratory are working on a new model with greater maneuverability.

Also entering a new phase is the computer portion of the project. To supplement his Digital Equipment Corp. PDP-6 machine, Minsky is adding a core memory with a capacity of more than 260,000 40-bit words.

Line drawing. Minsky concedes that his robot "is minimal in many respects." The system is programed to watch for line gradients. When it detects an intersection, it puts this fact into its memory and searches for another line until it constructs a picture of a shape in its memory.

A new approach now being programed begins with a coarse scan based on simple statistics, local color combinations, textures, and the like. "It makes a simple topological analysis," says Minsky. "It finds boundaries and has checks and balances to stop it from going down blind alleys."

In line for Minsky's robot is a program treating objects in the abstract and recognizing partly obscured objects as human beings do. But in no case will the system match or compare an object with a known description or picture in its memory. "This would be disastrous in the case of occluded objects," says Minsky.

The robot starts with an abstract description of its environment, and the relations of objects to make hypotheses. "The hypothesis laid down has to be either confirmed or the machine must come up with a good excuse why it cannot be confirmed," says Minsky. "The whole system is built around confidence levels for hypotheses."

"We aren't doing parallel processing," he states. "Rather it is sequential analysis based on hypotheses." In solving problems, the system inspects the entire structure, recognizes things from small clues, and sets up hypotheses.

"Our project doesn't depend on

the machine seeing the whole object, anymore than a human being does," Minsky says. "We do visual analysis. The machine makes a hypothesis, looks at the scene for a while, and tries first one and then another alternative. It runs up and down through different levels of analysis."

Human processes aren't consciously imitated, the scientist notes, because "virtually nothing is known about human vision and visual analysis."

II. Perambulator

Working under a joint contract from the Air Force's Rome Air Development Center and ARPA, SRI's Rosen and Nilsson are building a "buggy"-mounted automaton. Affixed to the self-propelled vehicle will be a television camera, an optical range finder, touch sensors, and, eventually, retractable arms. The buggy will be connected either by cord or radio signal to a Scientific Data Systems 940 real-time computer.

Two independently driven wheels, using electrical stepping motors with feedback control, will power the buggy. Similar units will actuate the television camera's pan, tilt, and focus functions as well as provide the rudimentary arms with several degrees of freedom. Completion of the buggy is scheduled for later this year.

By any other name. Rosen cautions, "Our main purpose is to make machines that do intelligent things, not to replace humans, who also do intelligent things and some unintelligent things."

What SRI is after immediately is a "somewhat autonomous" machine that "trots around and does simple tasks," Rosen says. But programing has proved difficult. The project will try to combine previous computer experiments in intelligence, including chess and checkers playing, modeling of equations on computers, pattern recognition, and computer learning programs.

Experimentation will begin on a laboratory floor where simple geometric shapes will be placed. The buggy's task will be to map the floor; as it goes around the area and detects objects, the computer would figure out what it saw from models in memory. To go from one place to another it would use another reference.

Where's my basket? Rosen is not sure when, but the SRI researchers would like to bring the buggy into the "real world" of the building hallway. Here they could command it to go to room K-20, pick up a waste basket, and carry it to room K-60. The next command might be the same with changed room numbers. Recognition of the specific rooms or objects would not be a programed function of the machine. It would have to find them itself. "Can a dog do as well?" Rosen jokes. "We could replace the mail boy, but it would be expensive."

Rosen stresses that these would be advanced tasks for a simple automaton. "We're getting into areas we don't know well," he says. "Nobody really knows today how to make a computer representation of the real world." To program individual objects would "use too much computer memory," he says.

III. Pattern recognition

To handle pattern recognition, an automaton's computer must deal in abstractions. While a human conceives a chair without a detailed "program" of its structure and shape, "we barely know how to begin line drawings of things now," Rosen says. He hopes automaton memories will eventually include an array of pattern-recognition programs covering exploration, analysis, and tactics. "It's difficult interleave these into a hierarchy," Rosen says. "Humans do it unconsciously. You don't decide to walk in a series of commands, but with a computer it has to be planned sequentially."

The work of Stanford's McCarthy is also being underwritten by ARPA. Still in a formative stage, his automaton project will eventually integrate a computer, an arm, and a television camera.

McCarthy believes it's possible to program abstractions with 64,000-word memories. He will not, however, elaborate on this theory. Although computers "think" sequentially, he notes, they still react faster than a human mind. Furthermore, if the researchers ever need a faster-reacting computer, they'll build a parallel simultaneous system, he says. "The problem isn't the computers' doing things slowly, but doing them at all."