MACHINE DREAMS

BY WILLIAM MARLING

AT CASE WESTERN RESERVE UNIVERSITY, A TEAM OF COMPUTER WIZARDS DEVELOPS ROBOTIC SYSTEMS THAT MAY SOMEDAY PERFORM LASER SURGERY, COMPOSE SYMPHONIES…OR ENGAGE IN WARFARE.

PHOTOGRAPHY BY RIVERBED PHOTOGRAPHY STUDIO

"I don't want to be the hero of this story," says Yoh-han Pao, blinking behind rimless glasses. "Tell about my people – the students and faculty doing the research."

It's a tall order. Yoh-han Pao – born in China's Yangtze valley, resistance fighter against the Japanese, scientist at Du Pont, Bell Labs and NATO – is clearly the force behind the Center for Automation and Intelligent Systems Research (CAISR) at Cleveland's Case Western Reserve University, a one-year-old artificial-intelligence research group that observers such as Jerry Sussman, a professor of computer science at the Massachusetts Institute of Technology, rank among the best in the United States.

Computer wizard John McCarthy coined the term "artificial intelligence," or "AI," as it was quickly dubbed, twenty-six years ago at MIT. In its simplest sense, AI means getting machines to perform like human beings. Implied in this definition is the duplication of human thought processes. No discussion of AI, therefore, would be complete without mention of the equally young science of cognitive psychology, whose experts study human perception, memory and reasoning – all for the purpose of understanding, in ways that can be defined by mathematical models, exactly how we think. If psychologists can discover ways in which to model these cognitive processes reasonably well, there would appear to be no field in which AI researchers could not create an "expert system": a computer program based on the knowledge of a human expert but applied with greater consistency and accuracy. But there is considerable debate among programmers, cognitive psychologists and philosophers about whether or not AI will be able to do these things.

AI's champions contend that eventually computers and robots will do everything man does, even write symphonies. They point to CADUCEUS, a system that diagnoses over 700 diseases, and to PROSPECTOR, which in 1982 located molybdenum deposits in eastern Washington that had been sought for sixty years. The Kurtzweil Reader, they note, has been reading books aloud to the blind for years, and Yoh-han Pao's own group has designed a wheelchair for paraplegics that is controlled by biofeedback.

Among the disenchanted is Roger Shank, a Yale University professor and researcher in cognitive psychology. Shank spent several years developing a program that can organize in order of importance the "news" in newspapers. But even Shank admits that "expert systems are horribly misnamed, since there is very little about them that is expert." Shank charges that most AI projects have neither the ability to learn nor the versatility of the human mind – in short, that AI is oversold. And, according to Shank, "AI is in chaos. It's hard to get good researchers to work on the fundamental problems because the companies are snapping them all up. Theory has stagnated, and we have lost our momentum."

William Marling has written about science for *Fortune* magazine, and is an assistant professor of English at Case Western Reserve University.

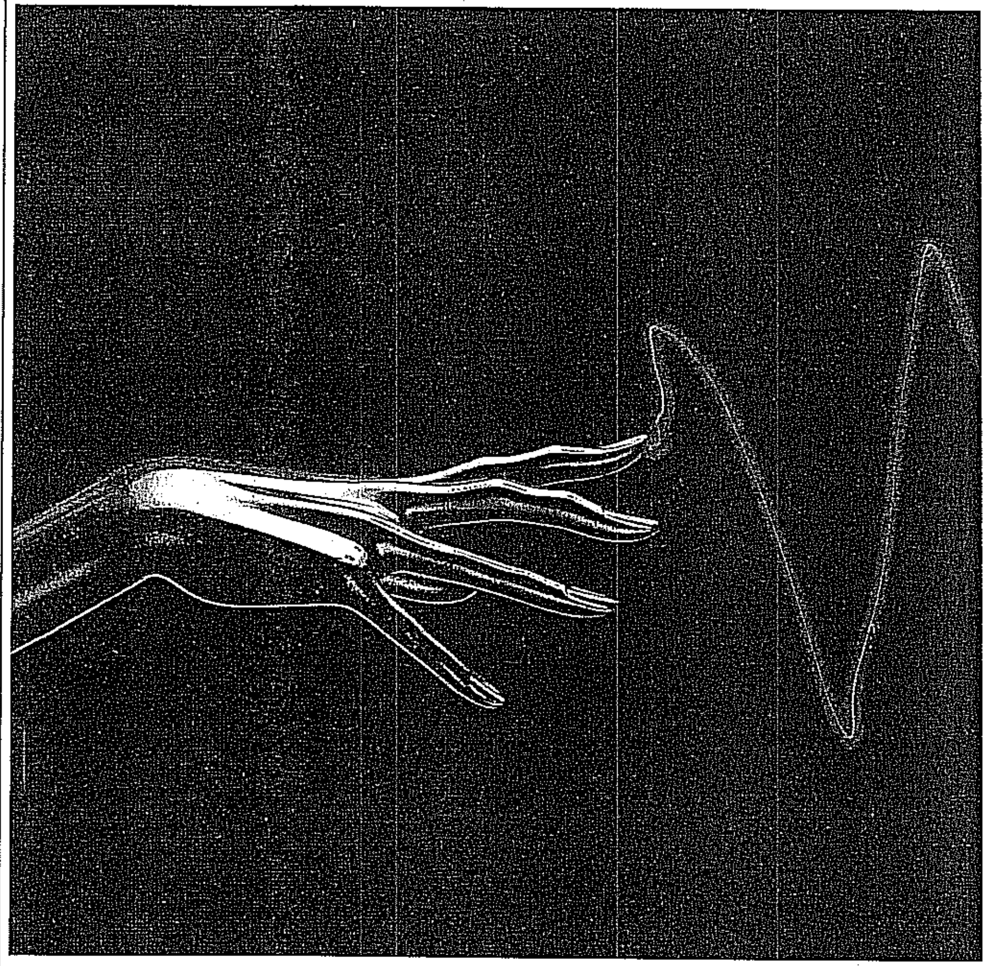
Yoh-han Pao foresaw five years ago the problems Shank describes. The CAISR group is not worried about selling its products immediately; rather, it is attacking the versatility problem. "Our focus," says Pao, "is the integration of computer-based technologies—machine vision, tactile sensing, control of manipulators, and voice recognition—with an understanding of the learning process."

CAISR draws its energy from a core of ten professors and twenty-five graduate students in engineering. It dominates the third floor of the Glennan Building, an eight-story cement monolith that overlooks East Boulevard and an RTA station from the southwest corner of the CWRU campus. Inside the center, the air is cool and filtered, the conversation subdued. In the half devoted to machine vision and robotics, two students are flying an F-18 fighter simulator on an IRIS color-graphics terminal. A large robotic arm slumbers in one corner, and a group of people clusters around a small robot, ready to videotape an experiment. In the wood-paneled computer work area, researchers sit before huge video terminals, called VAXstation 100s, that cost $25,000 each. Behind them beats the center's heart: a VAX 11/782 computer from Digital Equipment Corporation worth $200,000. When the VAX chews on a problem, it makes 1.4 million decisions a second. Its power makes possible the quests of Pao's people for new knowledge about machine vision, sensing devices and computer languages.

Hsianglung Wu, a researcher in machine vision, is having trouble with his Coca-Cola can. Line by line, the can appears in red-and-white glory on an IRIS computer terminal, with a resolution four times as fine as that of a home television screen. The bottom of the can, however, disappears in a diaphanous glow. "No, no," says Wu, a twenty-seven-year-old Taiwanese graduate student, "this no good."

Why doesn't he adjust the contrast, as he could if he were looking at an image on a television screen? Unfortunately, it's not that easy. Television cameras produce analog data: Light coming into the camera excites a photosensitive cell, which emits a stream of electrons that excites another cell in the screen. The flow is smooth and continuous, like a placid river. Wu takes this data and breaks it into units that he stores in the computer as digits—the irreducible symbols of computer language. In effect, he freezes the river of data, cuts it up and stacks the twenty thousand pieces so that he can retrieve any section of the image in a microsecond. Having reduced the Coke can to digits, he can "massage" it with Sobel operators, mathematically weighted grids that tell whether the data makes an arc, angle or straight line. By overlaying and linking the Sobel operators, he rebuilds the Coke can.

The problem is that white glow at the bottom of the screen. A person looking at the Coke can could squint to discern the bottom edge, or infer it from past experience—that is, from his or her memories of all the other Coke cans he or she had seen. But cameras can't squint, and computers have no "experience." Wu must understand human vision and how the eye comprehends the whole of an object even when sight is impaired by glare, and then he must write a program



that will give a computer perception identical to human vision. After he has mastered this particular task, he plans to install a camera on a robot that moves on wheels. "So I want him to get me a soft drink," he says. "He will look around and find Coca-Cola. Good, huh?"

Some prankster has named it "the little robot that could." The RHINO XR1 robot extends a short aluminum arm toward a pile of erasers, picks up one and moves toward its destination, another pile two and a half feet away. Suddenly Dave Noeth shoves a book into its path. The robot advances until it touches the book. Mechanical sensors signal it to halt. The arm rises until it clears the book, adds ten centimeters for good measure, advances and deposits the eraser on the second pile.

Noeth, a twenty-four-year-old from Pepper Pike who graduated from CWRU in 1983 with a Master of Science in Electrical Engineering degree, is pleased. As manager of CAISR's sensors and manipulators laboratory, his mission is to develop tactile sensors and machine vision that can give immediate feedback to robotic manipulators.

Today's robots can perform only rigidly defined tasks, with no margin for unexpected variations. If a car body comes down an assembly line in the wrong position, for example, the robots on the line will weld in the wrong places. Noeth wants to develop robots that can see and feel the car body so that they can correct misalignments and avoid costly welding errors. He has developed a set of rules and a control hierarchy for combining machine vision and tactile sensors, which he is testing on "obstacle avoidance"—the eraser-and-book experiment being one example of his testing.

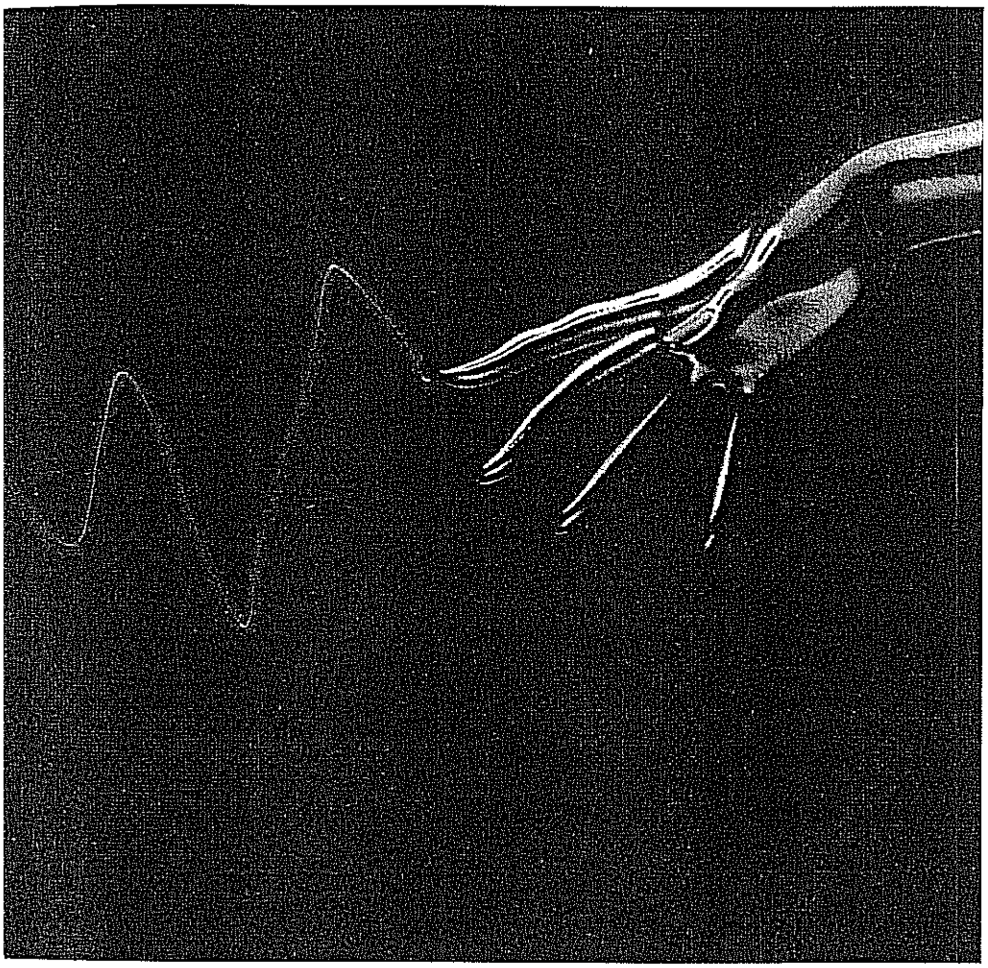
Now that their robots can detect and avoid objects, CAISR researchers want the sensors to make "educated guesses" about the items in their grasp. This information will be combined with that yielded by Hsianglung Wu's research in machine vision to give robots the senses of sight and touch and allow them to perform precise operations. Ultimately, Yoh-han Pao says, robots will do most hazardous jobs, such as fighting fires, welding on oil platforms on the ocean floor and handling nuclear fuels. As their controls grow finer, experts predict, robots will perform laser operations on the human eye and assist doctors with brain surgery.

Randy Beer's is a name heard often around the center. A tall, intense twenty-three-year-old from Mansfield with a 1985 Bachelor of Science degree in engineering from CWRU, Beer would resemble a young Dashiell Hammett if his dress did not tend to Levis and jogging shoes. He works in a basic area of artificial intelligence – its computer language – and is so proficient that Yoh-han Pao has bestowed the rare honor of making him a research associate.

Beer is an innovator in adapting a computer language called LISP (short for "List Processing"), which MIT's John McCarthy invented in the 1960s for artificial-intelligence work. LISP operates in a way resembling that of the human mind. For example, a LISP computer could be programmed to understand the command "Read the magazine article," and it would instantly relate the activity it was being asked to perform with the object of the activity. Computers programmed in conventional languages would find this command incomprehensible and would require it to be broken into two parts, the first giving the instruction "Read" and the second defining what was to be read.

Usually researchers run LISP on specially designed $200,000 computers, but Beer has adapted LISP to the common VAX, a mainstay of industrial computing. Beer's ability is reflected in the fact that Computer Thought Corporation of Texas recently tried to put a language comparable to LISP on the VAX. After four years and $3.5 million of venture capital, Computer Thought admitted failure last summer and chucked the project.

Pao took Beer to Boston recently so that Beer could explain his COMMON LISP Toolkit to executives of Digital Equipment Corporation. Beer talked about his invention, which is the computer equivalent of a set of saws, hammers and screwdrivers. Ordinarily, a LISP user can employ one tool at a time; with Beer's Toolkit, it is possible to use five or more tools simultaneously to carpenter a LISP program.



"I would offer you a job on the spot," said DEC's manager for external research after the presentation, "but I've been told we shouldn't eat our seed corn. So I won't offer you a job. But are you planning to stay at CWRU?"

Beer is staying. "My interest doesn't run to the DEC or IBM sort of thing," he says. "I'm into AI and cognitive psychology."

Conquering the mind-boggling LISP language, he admits, "does seem to take more time than mastering other computer languages." But he is close to a marketable product. He has turned the VAX and its powerful terminals into a workshop in which several different jobs can be done at once. Each of his tools is represented on the computer's video terminal as a "window," a small rectangular area in which one follows the work. Looking at a terminal running Beer's Toolkit, one sees windows laid over each other like sheets of paper. In each window a separate program, or tool, is at work. Beer can edit a program on one work table, compile it on a second, run it on a third and compare it to previous versions on a fourth. Other programmers – Beer's primary market – will design their own workshops, beginning with the windows and adding other features. Beer's Toolkit, he insists, offers more windows than any programmer can possibly use.

Where next? Beer is intrigued by the work of CWRU philosophy professors David Helman and Ray Nelson on AI and the philosophical foundations of knowledge. "Current artificial intelligence approaches aren't going to get us to a theory of the mind," he says. "I have a few ideas about why that might be so and how we get around the roadblocks."

CAISR is playing for enormous stakes in dollars available for AI research, and also for the chance to make a strong impact on Northern Ohio's rust-belt economy. Arthur D. Little, the Cambridge, Massachusetts, think tank, predicts that $1.25 billion a year will be spent on expert systems of "thinking" software by 1990. Leading the way will be the U.S. Department of Defense, which is actively pursuing development of robotic reconnaissance vehicles, expert systems to fight naval battles, and silicon pilots for jet fighters. Research in expert systems for medical diagnoses and for automobile manufacturing will be extensive, Pao calculates. Much of this activity can be expected to take place in the Midwest, which boasts a high concentration of first-class hospital facilities and is expected to remain the national center for the manufacture of cars, two presences that can be expected to make up a healthy market for the products of Pao's and others' labor.

The companies that build these expert systems will station themselves close to universities in order to retain employees. "Managers worry whether there is a university such as CWRU close by," says Pao. "Engineers want to know that they can get M.A.'s and Ph.D.'s."

Though Pao has worked in AI for fourteen years, CAISR was not founded until the spring of 1984, after the state passed the Thomas Alva Edison Partnership act, which created Advanced Technology Education Centers across Ohio. Before the center's founding, AI research had been scattered among several CWRU academic depart-

Continued on page 99

DREAMS

Continued from page 67

ments; now, CAISR is the keystone of a partnership that includes Cleveland State University and Cuyahoga Community College, with the center performing the basic research, CSU developing applications and CCC training the manpower. "We asked for $7.5 million and received $4.1 million, with encouragement to ask the state again in the second biennium," says Pao. "This is a four-to-one matching-grant program. Our total budget among the three schools is scheduled to be about $27 million over the five years...and I think it will easily be that. Here at CAISR our operating budget is about $1.6 million a year. We are in the midst of a beginning...a very nice beginning." Pao has also recruited corporate "members" for CAISR, including TRW; General Electric Company; White Consolidated Industries, Inc.; Parker-Hannifin Corporation; Allen-Bradley; and Reliance Electric Company, each of which contributes $50,000 a year to share in patent rights and research findings, and to consult with CAISR's talent pool. "Assembly tasks will be nothing in ten years," says Pao. "You will have robots that walk, talk, plan, learn. What you would *like* to have is a robot to which you can say, 'Pick up that white cup,' and it will gracefully pick it up."

Pao enjoys speculating on robotic activities that are, for the most part, still at the outer reaches of AI research. Take the ability of machine vision to distinguish between paintings by Picasso and Braque, for example.

"There are two ways to do it," says Pao. "One way is to ask an art historian, 'How would you distinguish?', and then look for those features. The other way is to show paintings to an *intelligent* machine-vision system and tell it, 'This is Picasso, this is Braque.' It will search for the differences and learn them. The first way, so far, is more reliable. But ultimately you can tell more the other way—by sensing the spectra of the pigments with an infrared or X-ray measurement."

At the other end of the AI spectrum from such discriminating aesthetic judgments is the potential of researchers to build the physical strength and control of an Olympic track star like Carl Lewis into their robots. "That," observes Pao, "is a trivial task, after you have managed to make a walking robot. Right now it's a matter of money, not of intellectual achievement. You want to see a six-million-dollar man? Well, that is what it will cost to have a robot that can jump. That will be a long time coming. By the time you have made a man, you have made artificial intelligence."

Will robots one day be able to compose cogent reviews of tony restaurants?

Pao laughs. "In principle it *could* take a little sample of the meal and chemically analyze it. If you really wanted to devote the resources of the United States to restaurant reviewing, you could do it. The question boils down to this: Are we ever going to be able to reproduce the natural ability we have to produce information in great density? The answer, I think, is yes.

"There is only one level," Pao says, "at which I have qualms about the ability of expert systems to do as well or better than human experts, and that is the level of creativity." The ultimate challenge for AI research, then, will be to factor into expert systems and robotics the capacity for flashes of genius.

From his youth in Shanghai, Pao has seemed destined for the world of artificial intelligence. After taking his bachelor's degree in engineering from Lester Institute, an outpost of London University, he performed what he calls "semi-heroic acts" during the Chinese resistance to Japanese occupation in 1939, as part of a reconnaissance network that supplied weather information to bomber squadrons. After World War II he did master's-degree work at Syracuse University. Having taken a doctorate in material science and applied physics at Penn State in 1952, he worked at E.I. Du Pont de Nemours' experimental laboratories in Wilmington, Delaware, for eight years.

In 1967 he came to CWRU to give four seminars in applied physics. "I saw that my future colleagues were very productive and that the supply of gifted students was very plentiful," he says. "I was in the mood to be a professor."

Pao was the chairperson of CWRU's department of electrical engineering and applied physics for eight years. Along the way he served as a NATO Senior Science Fellow and a division director at the National Science Foundation, became CWRU's George S. Dively Distinguished Professor or Engineering in 1980, and sponsored the Tenth International Machine Intelligence Conference at CWRU in 1981.

Pao's life is a whirl. He teaches three classes a year, directs senior and graduate projects and regularly jets off to Italy and Scotland to present papers. Among the first American scientists invited to China, he has returned leading delegations of computer scientists.

"If I were aggressive," he says, "I would be talking to venture capitalists, because we have things we can move out. But I have to strike a balance between reaping rewards in that manner and encouraging coherent basic research—to avoid being superficial, to increase the depth and strength of our efforts. I am not worried about any present lack of entrepreneurial activity. Students and staff members will do that. Our corporate sponsors will do that. The beauty of CAISR," he concludes, "is that it accommodates the *best* type of fundamental research and has no restrictions whatsoever."□