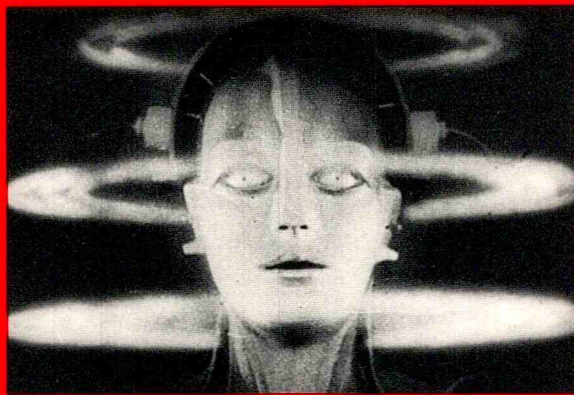
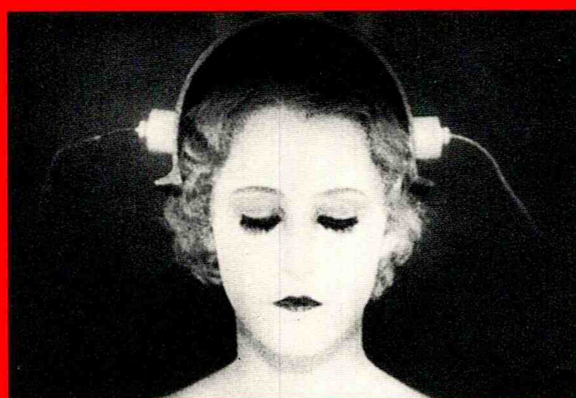
Robots





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**I, too, first brought beneath the yoke
great beasts to serve the plow,
to toil in mortals' stead. . . .**

Aeschylus, *Prometheus Bound,* ca 450 BC

**Technology is the replacement
of natural sources of power
by created power beyond all
past artistic imagination.**

Daniel Bell, *The Winding Passage,* 1980

Editor's Notes

Since the earliest myths of human creation there have been parallel tales of variously constituted synthetic creatures, now all lumped together in the public consciousness under the generic category "robot." While we were growing up these "amazing marvels" were the stuff of the comics, of the Saturday matinee. And even now they are at the center of the proliferating sci-fi market. Of interest to *Design Quarterly* is the fact that the so-called "mechanical man" (they're most often referred to as male) is no longer intriguing fiction, but an actor in life's daily drama. As the robot becomes more visible, more acceptable to us emotionally, we will no doubt raise more penetrating questions about its appearance—its physical presence. Should its form follow its function, or should we continue to enclose its mechanism in a semi-human skin? Will we learn to interact with these inevitably intelligent machines—at this time they are by definition reprogrammable, but they will soon become self-programmable—only if they come in an androgynous skin?

To prepare us for things to come Michael Webb provides a history of the robot through myth, literature and film: he defines the essential terms of robotics and outlines the evolution of robot imagery. He then follows with a description of current applications of the science of robotics to industry and medicine. Webb's essentially literary view is followed by the more immediately practical one of Arthur Harkins, who describes currently available "personal robots" (PRs) and their future in society. He also discusses emerging forms of smart machines and the apparently limitless potential for interaction between ourselves and our future robot pals.

Sometimes men build robots, sometimes robots build men. What does it matter, really, whether one thinks with metal or with protoplasm? As for myself, I can assume whatever substance and shape I choose—rather used to assume—for we no longer indulge in such trifles.
Stanislaw Lem, *The Cyberiad,* 1967

Lem's "fables for a cybernetic age" casually embrace the idea that humans will some day be indistinguishable from robots. In a similar vein, Harkins points to the paradox of mechanical parts replacing organic ones in humans from such relatively routine examples as steel hip joints to the sophistication of Barney Clark's heroic mechanical heart.

Evolving robot imagery arouses the continuing interest and participation of the art world. From the earliest descriptions of anthropomorphic machines—the Golem, Frankenstein, to Ernest Trova's *Falling Man*—our hostility to and fear of these heartless creatures has been reflected in their physical manifestations. Not until 1940 did we have a "good guy" robot, Isaac Asimov's Robbie. Only recently, as our relationship to the computer and its offspring has become more intimate, has it been possible to create genuinely lovable robots, such as George Lucas's R2-D2 and C-3PO. It may be significant that the more comfortable we become with *them,* the less humanoid they will need to be.

With the advent of the personal robot it may be that our attitude toward the physicality of these potentially intelligent companions will allow us to change the way they look. We may no longer need to provide them with human trappings. Based on our experience with children and computers, coming generations will relate fearlessly and equally to artificial intelligences whether they come on a microchip or in the guise of an android.

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Robots

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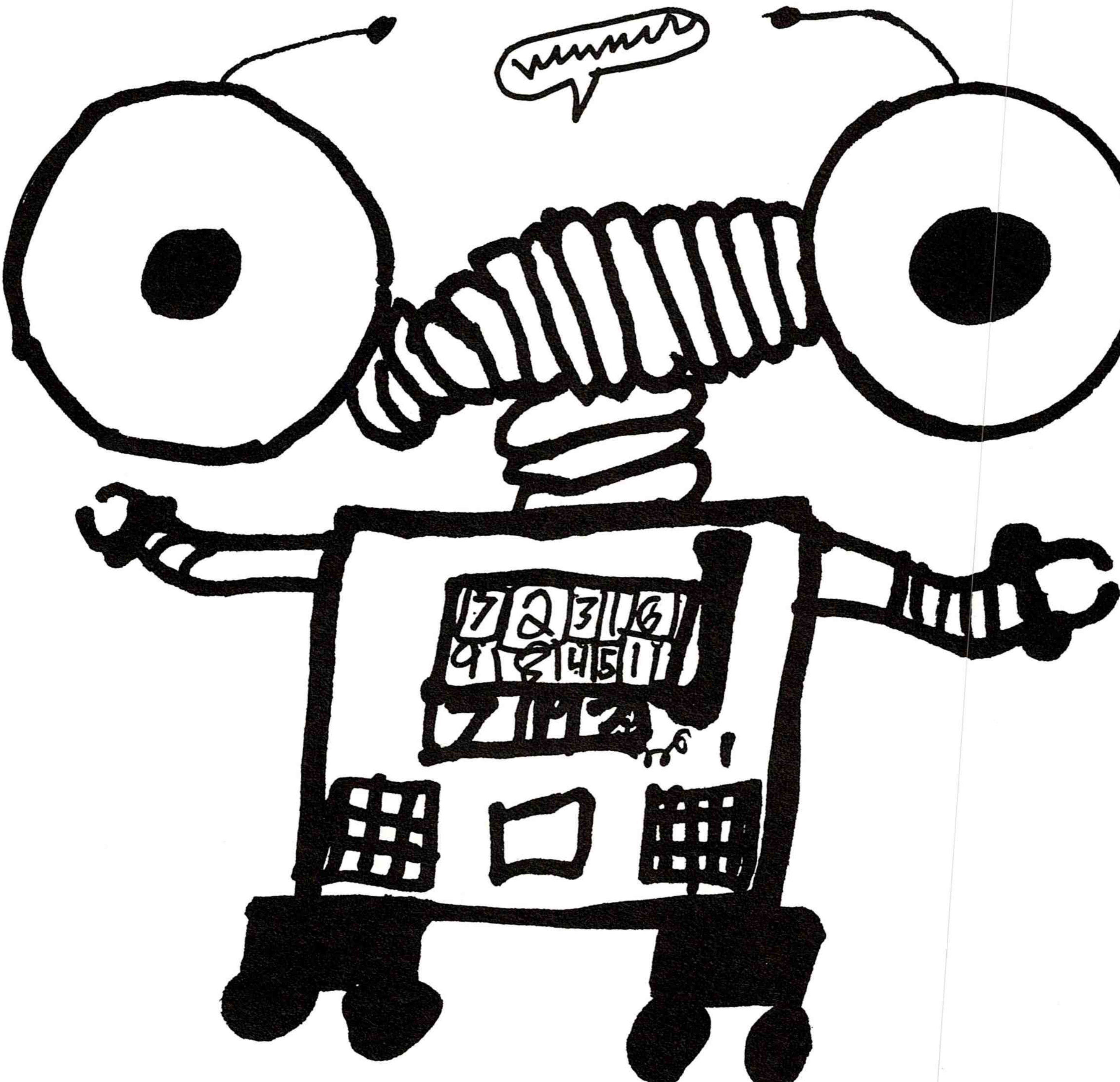


It is expected that the robot will not . . . "run amok." If the computer malfunctions . . . the robot's technology is intended to allow it to shut down within seconds.
Denning Systems, Inc., 1982

I am incapable of making an error.
Hal, in Stanley Kubrick and Arthur C. Clarke's *2001: A Space Odyssey,* 1968

The Robots Are Here! The Robots Are Here!

Michael Webb

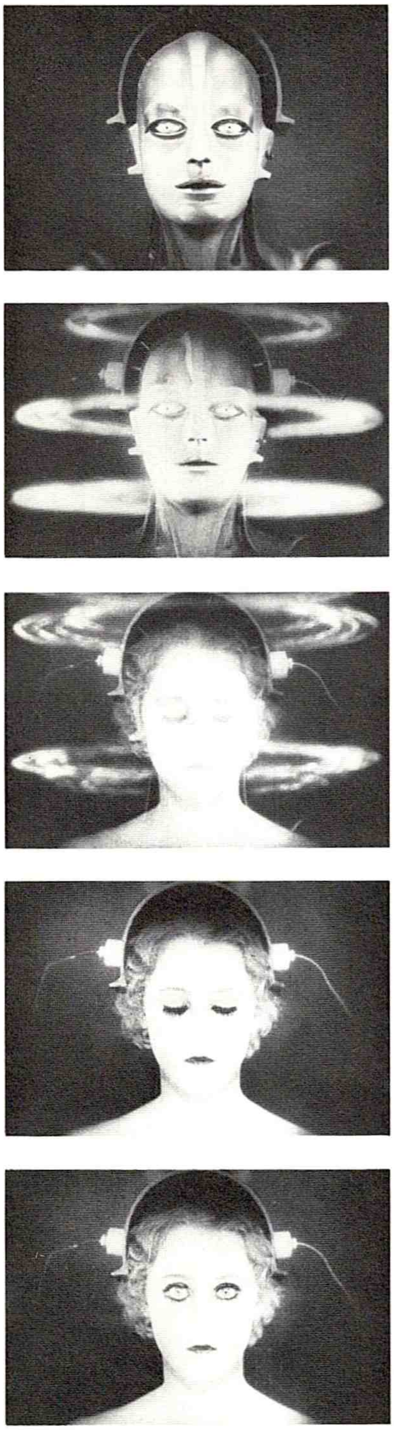
True robots are a product of computer technology, but the robot idea has been scaring and inspiring us since the dawn of civilization. Legend and scientific predictions, literature, art and the movies have long colored our perception of robots' appearance, capability and potential.

Bradley Northrup, a pragmatic eight-year-old, describes a robot as a talking machine. His kinetic interpretation reflects his youth, for it describes a lively creature, but one that is somewhat less than humanoid. The more traditional popular view of the robot, still held by the vast majority of people, is of a machine-man that possesses super-human capabilities and functions in a technological sphere somewhere between people and machines.

The Robot Institute of America defines a robot as "a reprogrammable multi-functional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks." The key word here is reprogrammable; the indispensable component is the computer. Most so-called robots—in theme parks or factories—are, by this definition, mere automatons. They are programmed to perform one set of functions and lack the capability to vary this predictable routine.

It is a crucial difference, but, superficially, the automaton may be indistinguishable from a robot. The mythology of robots has been enriched over the centuries by a marvelous collection of imagined machines and monsters, whose capabilities often exceed anything we have today. Myths of human creation have been interwoven with legends of artificial life. In the Bible, God created Adam from dust; in Jewish legend, Rabbi Loew animated the Golem (a formless mass of clay) to protect the Jews of Prague. Pygmalion fell in love with a sculpture of the goddess Aphrodite; he prayed to the goddess to bring him a wife like the statue, and she brought it to life as Galatea. St. Thomas Aquinas is reputed to have smashed a life-size automaton servant, denouncing it as the work of the Devil.

Eight-year-old Bradley Northrup views the robot as an impersonal talking machine. His drawing combines the attributes of the ubiquitous, pushbutton telephone with those of an industrial robot—pincer hands, antennae, unwavering eyes and casters in place of the more traditional metal legs we've come to associate with robots.



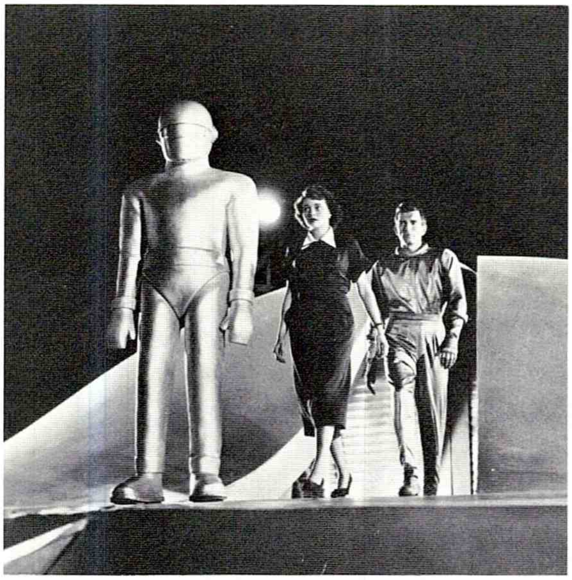
In this sequence of stills from Fritz Lang's 1926 masterpiece, *Metropolis*, Rotwang says to the girl Maria, "Come, I am going to make the robot look like you."

The Industrial Revolution introduced us to a secular devil that still haunts us: the machine as a destructive force, escaping our control and enslaving the human race. Faith in science and progress, as expressed by Darwin, Huxley and Wells, was challenged by such doomsayers as Samuel Butler, who wrote: "Day by day the machines are gaining ground upon us; day by day we are becoming more subservient to them. . . . Our opinion is that war to the death should be instantly proclaimed against them. Every machine of every sort should be destroyed. . . ." To justify this chauvinism, he contrasted the slow evolution of our species with the dizzying progress of the mechanical arts.

Fifty years later, in 1921, Karel Čapek's play *RUR* put the word robot, derived from the Czech *robota* (forced labor), into the English language. In this "comedy about truth and science," robots have been marketed worldwide to take over almost every task. "The human machine was terribly imperfect," remarks one of the scientists, "it had to be removed sooner or later. God hasn't the least notion of modern engineering." All goes well until the scientists give the robots emotions. Then, resentful of their subordinate status, they rise in destructive rebellion.

Fritz Lang's 1926 film *Metropolis* develops a comparable theme. The inventor Rotwang creates a clone of the human Maria to provoke a rebellion among the workers of the underground city as a pretext for destroying them. "I have created a machine in the image of man that never tires or makes a mistake," he declares. "Now we have no further use for living workers." The workers—though cowed to robot-like submission—destroy his invention and save themselves.

Early movies—notably a haunting group of German silents—explored the theme of artificial life. In *Homunculus, The Golem, Alraune,* and Hollywood's *Frankenstein,* a monstrous creation is driven to violence by a realization of its lack of humanity, or by the cruelty of man, its maker. These creatures belong to the Gothic-Romantic tradition; their message is anti-scientific: "There are things man was not meant to know." In recent years, such monsters have threatened nothing but the nerves of teenagers watching exploitation movies, but the theme of artificial life was given intelligent treatment in Ridley Scott's *Blade Runner,* an adaptation of Philip Dick's *Do Androids Dream of Electric Sheep?* In a future world, man has created replicants that are visually identical to himself, but stronger and more intelligent. The moral issue is that of *RUR*: do we have the right to create superior creatures and then abuse them and deny them emotions?



The Day the Earth Stood Still, **1951**
Twentieth Century Fox
Film Corporation

Post-war science fiction movies have borrowed heavily from the pulps, in which robots zapped our troops with heat rays, and carried off our women. There were a few intelligent exceptions. In *The Day the Earth Stood Still,* an alien arrived in Washington, D.C. to advocate a nuclear freeze. Concerned that he might have problems delivering this message (in the Eisenhower years the military always shot first) he brought along Gort to run interference. Gort was your all-purpose impregnable man of steel (actually the doorman of Grauman's Chinese Theater—the tallest man in Hollywood—wearing a metal-sprayed rubber suit).

But the clanking monster is a thing of the past. Technology no longer breaks down doors, it infiltrates, or worse, *it* is all around us, invisible and malevolent. The monsters in *Forbidden Planet* and the Soviet film *Solaris* were figments of human imagination. In *2001: A Space Odyssey,* the entire spaceship is a robot that is animated by HAL 9000, its computer brain. When Hal announces that he is incapable of error and decides he knows better than the crew how to run the ship, they are compelled to perform a lobotomy in order to save themselves. The computer in *Demon Seed* decides to reproduce and, in the spirit of "reach out and touch someone," it impregnates the scientist's wife with the aid of a robot arm.

Nothing like this happens in the stories of Isaac Asimov. As his 21st-century scientist, Susan Calvin, declares: "To you, a robot is a robot. Gears and metal, electricity and positrons.—Mind and iron! Human-made! if necessary, human-destroyed! But you haven't worked with them, so you don't know them. They're a cleaner better breed than we are." Asimov's robots are programmed with three laws to guarantee their good behavior:

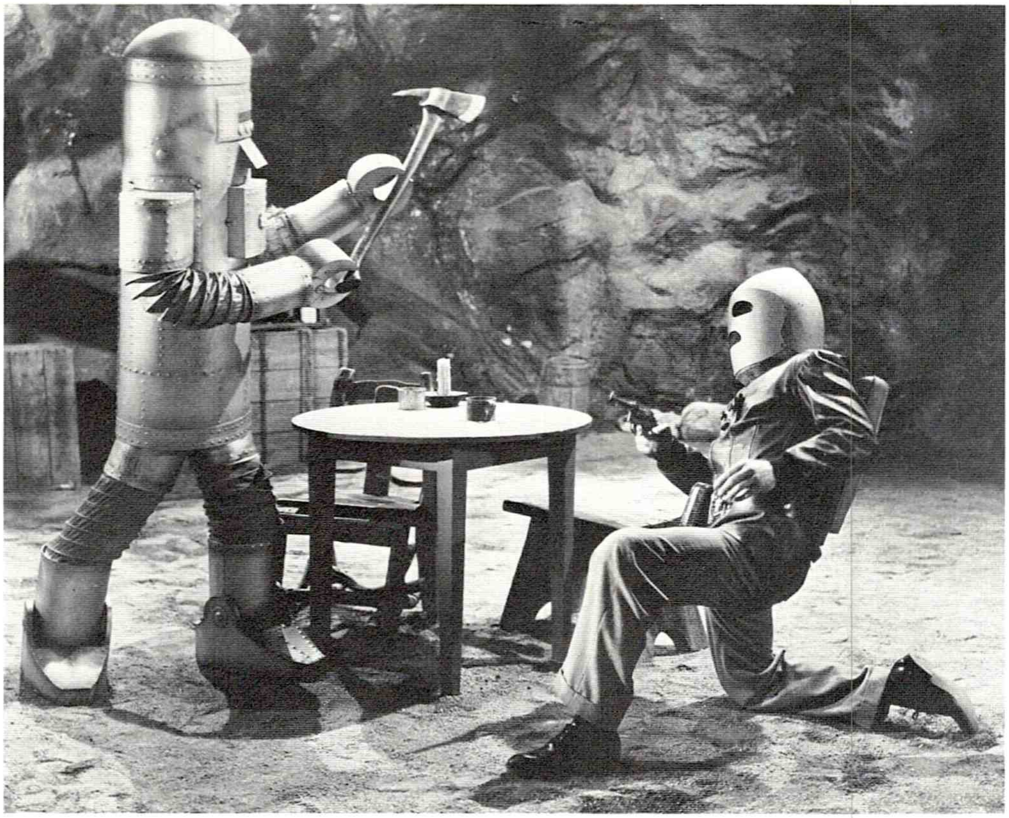
1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

2. A robot must obey the orders given it by human beings, except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Asimov explores the philosophical relationship between man and robot and the limitations of machine intelligence. The best science fiction writing is more thoughtful than all but a handful of movies.

Hollywood has treated the robot theme in a variety of films from adult features such as Columbia's recent *Blade Runner* (5), 1982, to such long-forgotten mega-bombs as *Zombies of the Stratosphere* (1), a 1952 Republic Pictures Corporation twelve-part serial. A production still from *Dancing Lady* (2), 1933, a Joan Crawford musical, includes a scene with a band of metallic men. Other amusing robot-like characters appear in *Forbidden Planet* (3), 1956, Metro-Goldwyn-Mayer's space-age homage to Shakespeare's *The Tempest;* and the immensely popular *Sleeper* (4), 1973, a comedy of contemporary manners written and directed by Woody Allen.



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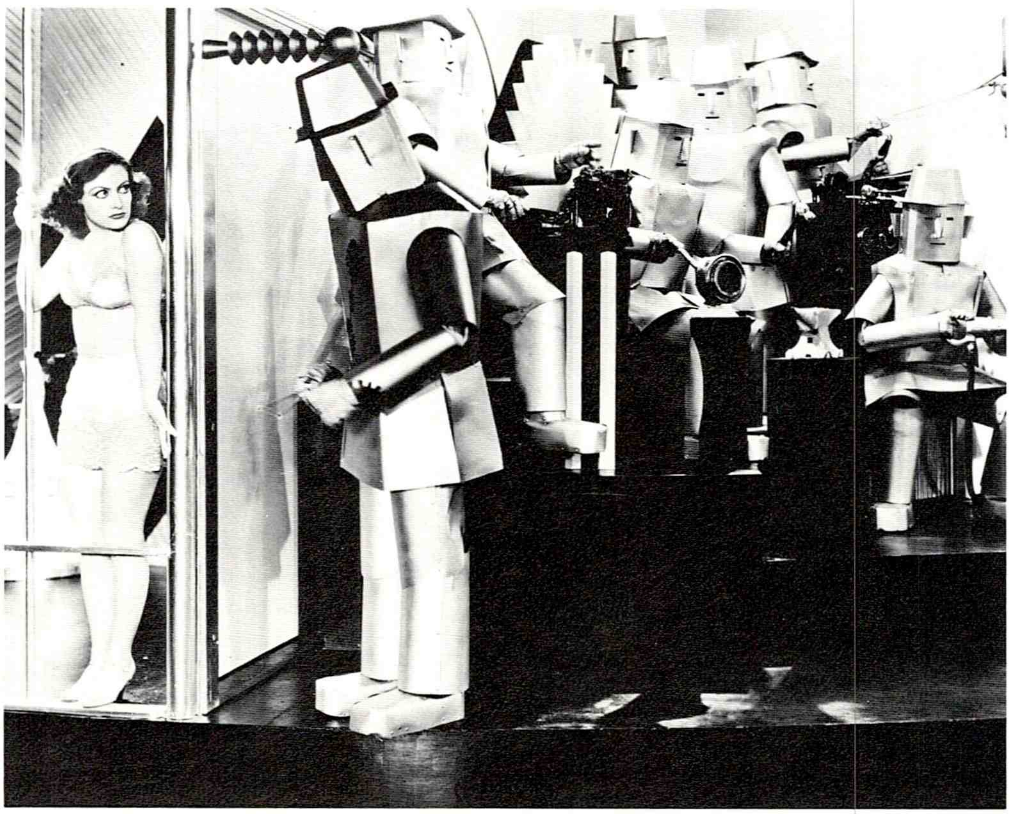

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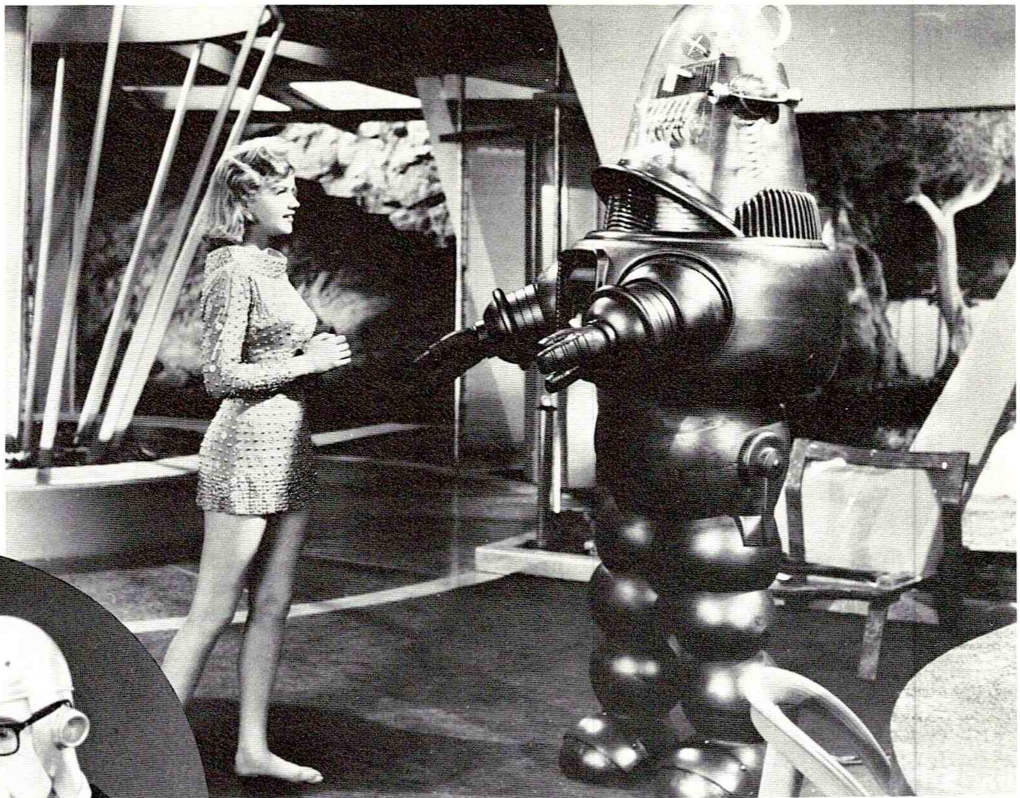

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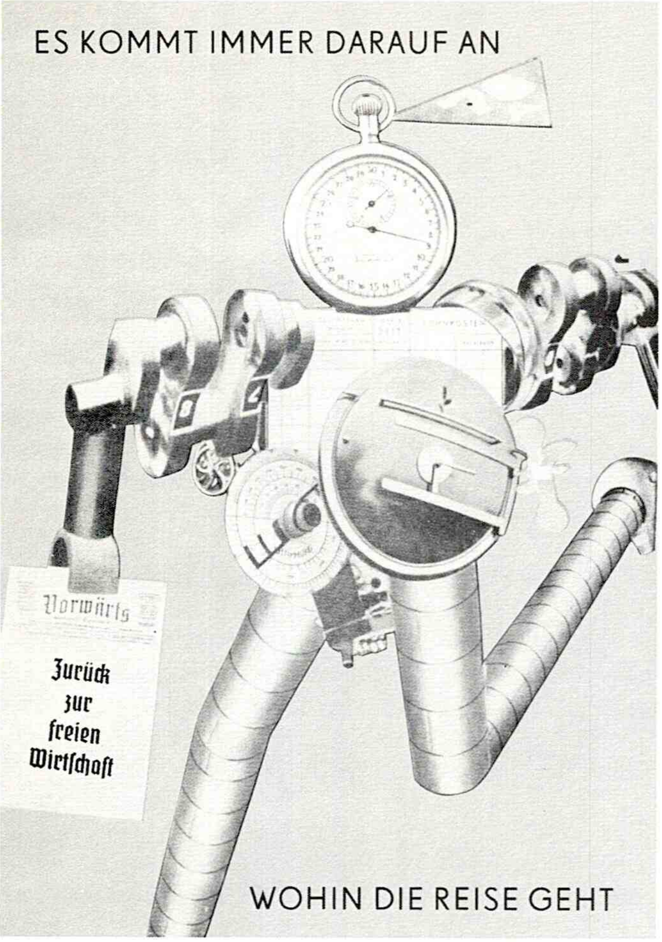
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zur
freien
Wirtschaft
WOHIN DIE REISE GEHT

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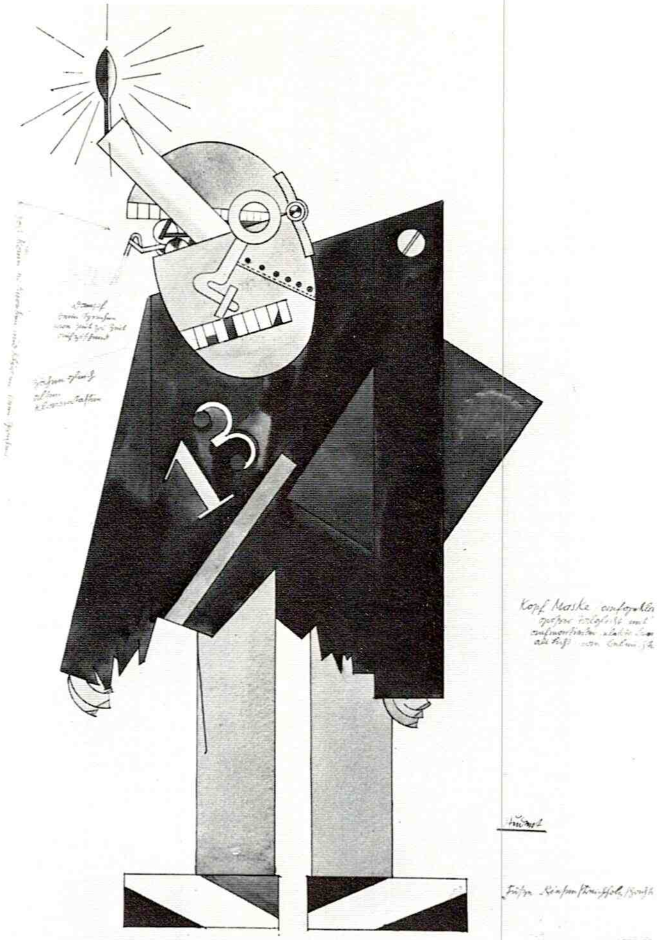

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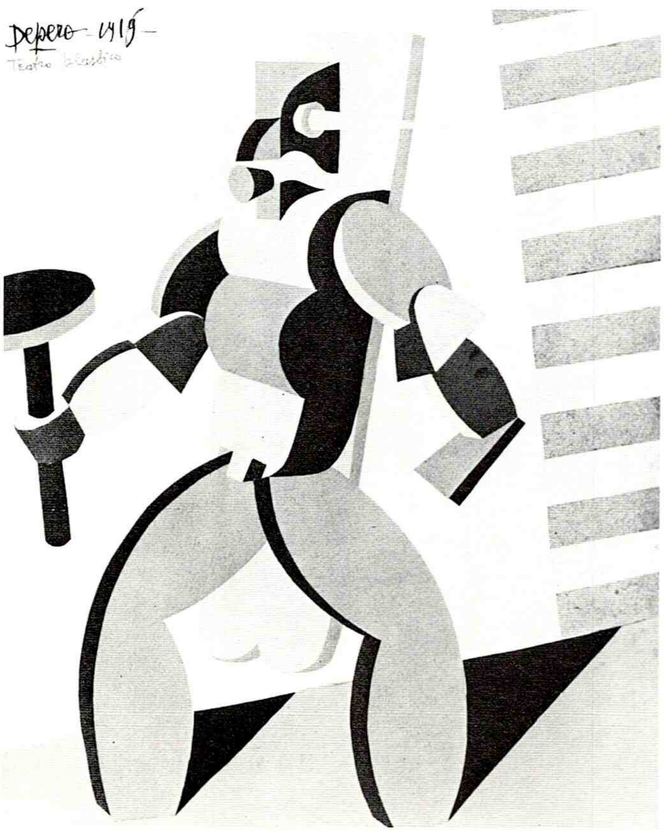
Depero - 1919 -
Teatro plastico

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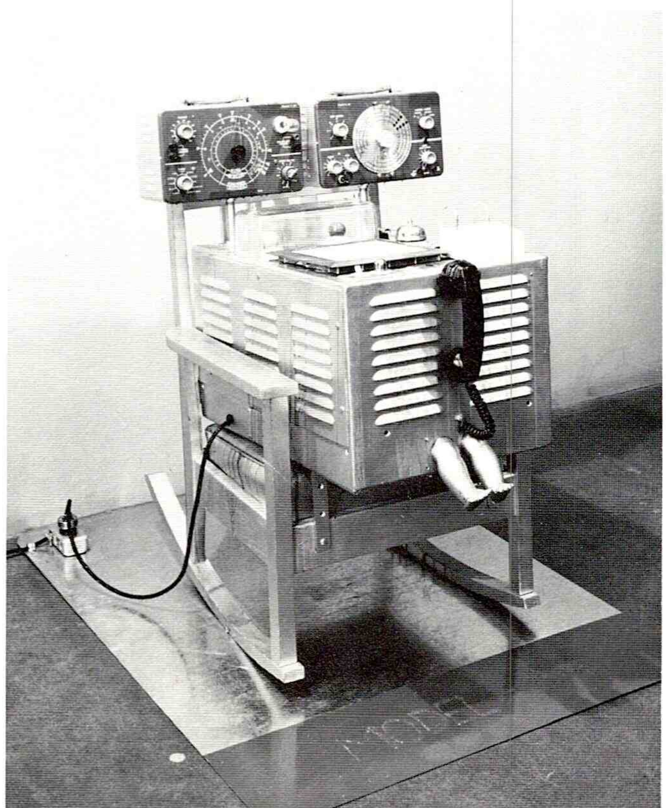

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1. John Heartfield
It all depends where the trip is going . . .
It's going back to free enterprise.
Cover design for Malik Publishing Company's 1923–24 yearbook.

2. George Grosz
Design for a theatrical dummy in Iwan Goll's *Methusalem. The Eternal Bourgeois,* 1922

3. Fortunato Depero
***Costume per Teatro Plastico,* 1916**

4. Edward Kienholz
***The Friendly Grey Computer-Star Gauge Model no. 54,* 1955**
motor-driven assemblage
Collection The Museum of Modern Art, New York
Gift of Jean and Howard Lipman

Artists have used robot imagery to comment on society. The futurists celebrated the machine with unrestrained enthusiasm—as in Fortunato Depero's 1916 designs for the theater that portray people as robot-like creatures. But the objects of the futurists' affection were curiously old-fashioned. At heart they remained 19th-century romantics, looking forward to a brave new world, unaware of the technological changes that surrounded them. Their contemporaries—George Grosz, John Heartfield and Raoul Hausmann—took a pessimistic view of the world. Their photomontages are intended to satirize an impersonal society tumbling towards destruction, like a machine that is out of control.

Robot imagery has also been a rich source of inspiration for sculptors. The absurdist machines of Jean Tinguely and Nam June Paik are at the opposite pole from Ernest Trova's sleek metallic figures, yet all three are unmistakably robotic. One of Edward Kienholz's constructions, *The Friendly Grey Computer,* is accompanied by a text that reads in part: "Computers sometimes get fatigued and have nervous breakdowns, hence the chair for it to rest in. If you know your computer well, you can tell when it's tired and sort of blue and in a funky mood . . . remember that if you treat your computer well it will treat you well." The ironic tone, and the distinctly unheroic guise of the chair-bound computer is a far cry from the futurists' worship of the machine as a secular god.

Robby the Robot, the star of *Forbidden Planet,* could cook, drive, speak 188 languages, and was as friendly as a puppy. In another movie, *Silent Running,* three small robots named Huey, Dewey and Louie, maintained an extra-terrestrial nature reserve and played a mean game of poker. Like C-3PO of *Star Wars,* they embody a popular fantasy: of the uncomplaining slave that never breaks down, brings us breakfast in bed, washes up afterwards and then performs tricks.

Such marvels have been realized on a limited scale. An 18th-century Japanese inventor perfected a mechanical doll that would walk to a neighboring sake store and not return until its container had been filled. Some years later, a mechanical chess player remained a popular attraction even after someone had detected the diminutive human player hidden in the base. Even so practical a man as Joseph Engelberger, President of Unimation, plans to build a robot servant to welcome his guests and serve drinks. You can buy automatons that (the manufacturers claim) will walk your dog, vacuum your carpet and cook your dinner. The *Consumer Guide* has yet to test them, but the best warning is provided in *RUR,* in which the scientists prefer to do their own cooking because the robots that are programmed to cook do it very badly.

Historically, the main function of automatons has been to entertain. Chinese emperors and Renaissance princes delighted in such toys. Leonardo da Vinci created a mechanical lion; the 18th-century Swiss inventor Pierre Jaquet-Droz built a boy-automaton that dipped its pen into an inkwell and wrote a letter in copper-plate script. There are over twenty restaurant chains in the U.S. that offer a mechanical cabaret as a lure to children of all ages. The pioneer in this field, Pizza Time Theatre, presents Dolli Dimples, the performing hippo, and a lion ("The King") that sings Elvis's greatest hits with convincing thrusts of the pelvis. At Disney's EPCOT Center, you can hear a squeaky-clean version of American history from the lips of the latest "Audio-Animatronics," a lifelike Ben Franklin and a suitably droll Mark Twain.

The most ambitious—and curious—enterprise to date is the cloning of Andy Warhol. The task was given to Alvaro Villa, who developed animated figures for Disney, then established his own company, AVG Productions, to create the *Battlestar Galactica* and *Dracula's Castle* shows for Universal Studios Tour. AVG looks like a cross between Santa's workshop and a research laboratory. Amid the singing alligators and dancing frogs that are destined for theme restaurants, is the incredibly complex mechanism that will become a lifelike Warhol. The artist, whose wish that he were a machine is about to be fulfilled, was photographed, measured and videotaped to capture every nuance of his notoriously inexpressive face and body. The body comprises eighty pneumatic pistons that animate thousands of mechanical joints. The face is of molded rubber and will have eighteen separate gestures, including a subtle twitch of the lips and a characteristic nod of the head. Villa explains that a special computer had to be designed and programmed from the client's script. The mystery, soon to be solved, is what "Warhol" will do on tour. It would be appropriate if it were to appear on talk shows promoting a book that had been written by a computer: a labor-saving arrangement that should appeal to every best-selling author.

You may be wondering if these digressions have anything to do with robotics. Samuel Johnson had the answer. He declared that: "The movements that put into action machines of no use but to raise the wonder of ignorance, may be used to drain fens, manufacture metals, assist the architect or preserve the sailor." Scientists are scrambling to realize this blueprint. Theirs is a two-step process: turn dreams into reality; improve the prototype to assure dependable performance.

For every breakthrough, there are many setbacks. In fiction, robots step out as surefootedly as any human. In fact, a six-legged robot has forty-million possible movements. The fewer its legs, the more critical is the problem of balance. Some years ago, General Electric developed a prototype Cybernetic Anthropomorphic Machine (CAM) for the Army.

Automatons lack one important characteristic that is the key to robotics: reprogrammability. But from articulated Egyptian statues, to mechanical clocks, to Jaquet-Droz's 1774 boy writer, to today's singing "Cyberamics" such as Pizza Time Theatre's rock 'n' roll lion, these amusing and often intricately designed entertainments have captivated generations of curiosity seekers. They have also served to pave the way for their cybernetic descendants.

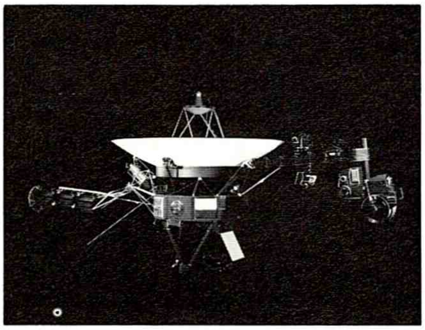
Its four six-foot-long legs were controlled by a human driver through force feedback (that is, the amplification of the operator's own bodily movements). GE has successfully applied the principle in its Man-Mate Industrial Manipulator, which can lift up to seven thousand pounds. But the CAM stumbled and was abandoned. Now, Carnegie-Mellon University's Institute of Robotics is about to test a six-legged model that is being funded by the Department of Defense. Each leg has sensors to tell it when it has stepped into a hole and how to get out.

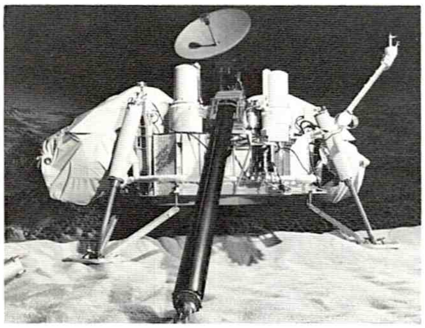
Two other major areas of research are touch and vision. Both MIT and Stanford are experimenting with robot finger joints that are precisely controlled by cable or tape muscles, and whose fingertips have a sensitivity comparable to those of a human. Such a device, if perfected, would have immediate value to amputees. However, a related problem has then to be solved: how to reduce the size of the power packs that are needed to amplify nerve and muscle impulses, and thus activate the hand as an extension of the human arm. In industry, the hand could be connected to a massive robot arm, and the problem would not arise.

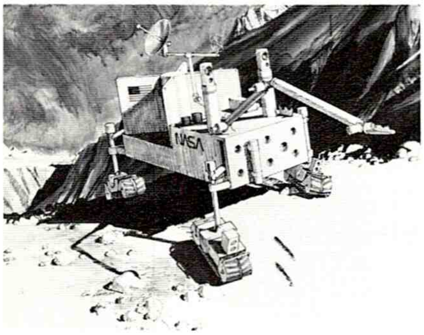
A group of researchers at the University of Minnesota, including mechanical engineer Max Donath, is experimenting with a three-fingered robotic hand that will be more sophisticated than existing industrial grippers. Constructed of hollow aluminum tubes, the fingers are designed to be lightweight and are driven by motors on the forearm of the robot via cables. The "hand" will carry out a wide diversity of tasks rather than the single or limited capability of current industrial robot "end-effecters."

We can also progress beyond nature. Ichiro Kato, Professor of Robotics at Japan's Waseda University, has created a twenty-five-fingered hand to diagnose breast cancer. Not only does the device have a highly developed tactile sense, but its lack of human emotions reportedly permits a completely objective diagnosis.

An equally challenging task is to simulate vision. Robots now in production can, by computer analysis of video pictures, discern the outline of an object. To do this, the picture is broken down into a series of spots that are graded by brightness like a half-tone photo. By increasing the contrast, the object is defined as a silhouette. For many industrial jobs that is sufficient, but experimental models in corporate and university research departments have greater capability. The Japanese have employed a seeing robot to detect impurities in ampuls of a potentially dangerous drug. The human inspectors claimed that their eyesight was being impaired by the need for unremitting concentration. The robot eye never tires, but it has to be precisely calibrated to achieve an acceptable level of judgment.







NASA is responsible for our most sophisticated robotic technology. The space agency has applied its research to a series of partially autonomous space probes from Voyager 1 in 1977 to the Viking Lander and now the Rover, projected to land on Mars in 1984.

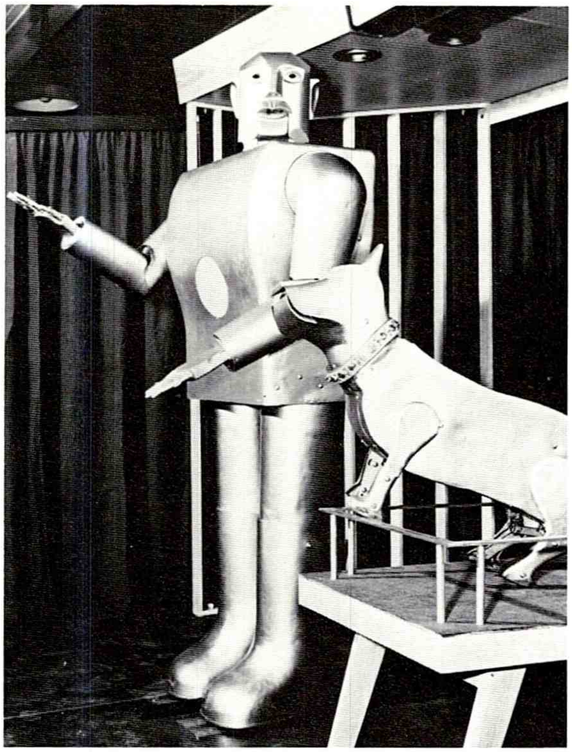
Many factors determine the degree of sophistication that can or needs to be achieved. The Mars Rover, designed by Cal Tech/Jet Propulsion Laboratory for NASA, comes close to the limits of available technology. Cost and bulk allowances are generous, but the vehicle has to deliver extraordinary performance over an extended period of time, in hostile conditions and with no possibility of maintenance. The proposed vehicle has tracked feet to carry it over rough or soft ground, and sonar devices to trigger its hands. It would be able to judge the size, shape and distance of objects through computer analysis of information from a laser beam and twin video cameras. If it were unable to surmount an obstacle, it would stop and await further instructions from earth.

The Rover exists only on paper; NASA's Voyager space probes have performed in spectacular fashion for over five years, changing trajectory and sending back pictures under the direction of on-board computers and signals from a billion miles away. The Voyager, like the Mars Rover, needs to be partially autonomous. Instructions from earth take too long to arrive for it to depend upon outside guidance. Its programs are designed to anticipate a variety of scenarios and allow for corrective action or a temporary shutdown: a fail-safe mechanism that prevents self-damage.

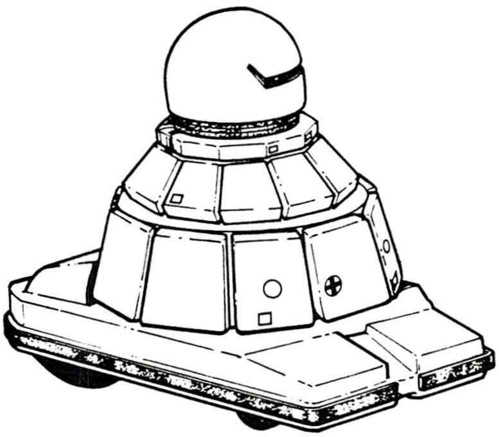
Thus a productive partnership is established between man and machine; the human controllers intervening only in case of emergency or when they need to change the program. Carl Sagan cites an added advantage of reprogrammability: a robot explorer could be instructed to switch from biology to geology far more readily than could a specialized human astronaut.

Today's robots have begun to deal with the unexpected. For automatons, that could be a fatal hazard. At the 1939 New York World's Fair, Westinghouse exhibited two automatons: Elektro and Sparko, "the wonder dog." Sparko had sensors that picked up on light and heat. It won applause for following visitors around. One night, the door of the pavilion was left open. Sparko ran out, attracted by a passing car and, as the driver swerved, it homed in on the lights and was crushed.

Back in the 1950s, researchers in England and at Bell Labs in America developed tiny robots that learned from their mistakes and, like a laboratory mouse, were able to negotiate an obstacle course. Only this year has such a device reached the market: a sentry robot manufactured by Denning Systems Incorporated. This two-hundred-pound, bulletproof guard will wheel around a property using ultrasonic range finders of the kind developed for Polaroid's automatic focusing cameras. Two microprocessors will analyze and store this information so that the sentry can compile a map of its territory, much as a blind person remembers spaces he cannot see.



Westinghouse introduced Elektro, a seven-foot-high automaton, that performed at the 1939 New York World's Fair with Sparko, "the wonder dog."



This year a robot watchman, equipped with infrared sensors and microwave radar, was marketed by Denning Systems Incorporated.

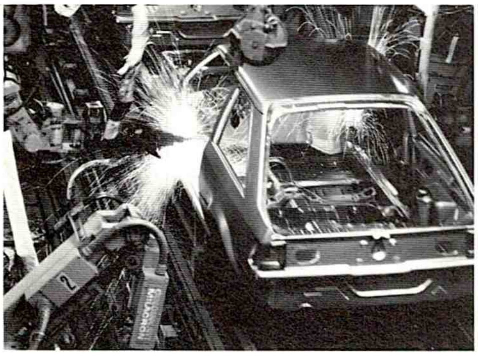
The sentry has several advantages over a human night watchman. It will never get sleepy or steal; it is almost invulnerable to attack; it is too heavy to carry off; and it can "see" in the dark and through walls, using infrared sensors and microwave radar. Talos, the bronze giant that guarded ancient Crete, reacted to intruders by turning red hot and hugging them to death. Denning's sentry is more humane. It merely sounds an alarm, which is just as well, since it is unable to distinguish between a thief and the plant manager.

Though primitive, the sentry is a step beyond those mechanized trolleys that deliver mail or industrial parts by following an electronic track. "Mobile robotics is a crucial field . . . inherent in the concept is autonomous control," says Michael Brady, senior researcher in artificial intelligence at MIT. A Carnegie-Mellon scientist, Hans Moravec, goes further: "In the evolutionary process, mobility led to intelligence." It may have a similar effect in robotics.

Thus, each advance—mobility, vision, touch and learning capability—fosters another, and every specialist has some influence on his peers. As the size and cost of computers shrinks, as servo-mechanisms become more capable, as more companies and researchers enter the field, the potential expands.

In addition to his previously described diagnostic hand, Ichiro Kato is working on a robot that will be able to walk, talk and have the intelligence of a five-year-old. That claim is greeted with scepticism by those who believe that there will be no such dramatic advance in robotics until we have perfected a new breed of computer. And debate rages over the feasibility of developing a "thinking" computer. Researchers, including a large team of Japanese scientists, are dedicated to creating artificial intelligence; the results thus far are inconclusive.

Computers can solve complex mathematical problems, and deal with such structured situations as playing chess, diagnosing a disease and predicting the outcome of legal cases. They do so by mechanical analysis of human expertise that has been fed into their memory banks. Yet even the most powerful among them has no ability to learn, or to proceed, as humans do, by analogy. Hubert Dreyfuss, a University of California philosopher who has studied the subject for twenty years, argues that they never will. He believes that computers are nothing more than fancy calculating machines; that they are structurally incapable of dealing with real-life problems. "You can't put in the shared understanding of human concerns and the purposes that embody society," he says.



General Motors began using working robots on the assembly line in the 1960s. Industrial applications, slowed only by the current recession, will certainly dominate our production processes by the close of this century.

Just as space flight was impossible until we had developed rockets, so with computers: we have to come up with a new system that can learn without relying on humans to teach it. To grasp the magnitude of the problem, consider an everyday function like getting up from a chair and the complexity of the movements that are required. Then consider the vastly greater subtleties of mastering a language and employing it with clarity and feeling.

Those who believe, as Arthur C. Clarke does, that we are in the process of creating our successors—that computers will eventually match or excel every aspect of human intelligence—argue that humans are also products of engineering, genetically programmed by the DNA code. They maintain that a human would be as helpless as a computer in unfamiliar situations without exposure to the world, and that this exposure can be artificially simulated. And they point out that computers are a mere thirty years old, as primitive in their development as were aircraft engines in the 1930s.

Meanwhile, the deployment of working robots proceeds apace. Their greatest concentration is in the factory. Unimation, the first and still the largest robot manufacturer in the world, installed its first robot at General Motors in 1961. Unimation did not turn a profit until 1975. During those years only a few large companies employed robots, and then only on a man-for-machine replacement basis—to do the dirty work of welding, assembling parts and tending die-casting machines.

Only now is a boom (held back by the current recession) in sight. Unimation, and its closest competitor, Cincinnati Milacron, offer a wide range of robots, from monsters that can handle the heaviest loads, to the nimble PUMA and T3 models that were designed to work in confined spaces and alongside humans. The largest U.S. corporations are gearing up for the production and use, not just of individual robots, but of computer-controlled factories. Computer-assisted design and manufacture (CAD/CAM) are the new buzz words. The sale of advanced manufacturing systems is expected to grow from one to twenty-nine billion dollars in this decade! American companies still lead in technology, notably in software. But, across the Pacific . . .

Marilyn Monroe as a singing "Cybot," was created by Shunichi Mizuno.

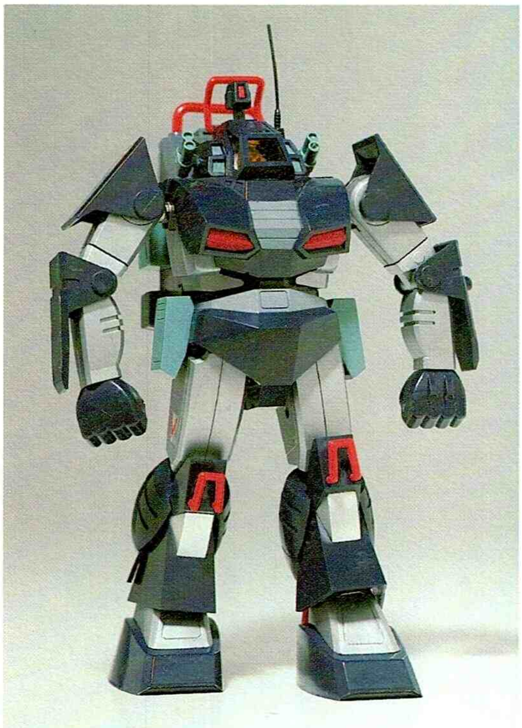
The Japanese run with technological innovation and implement it with aplomb. We tend to agonize, and so are likely to be upstaged.
Joseph Engelberger, President of Unimation

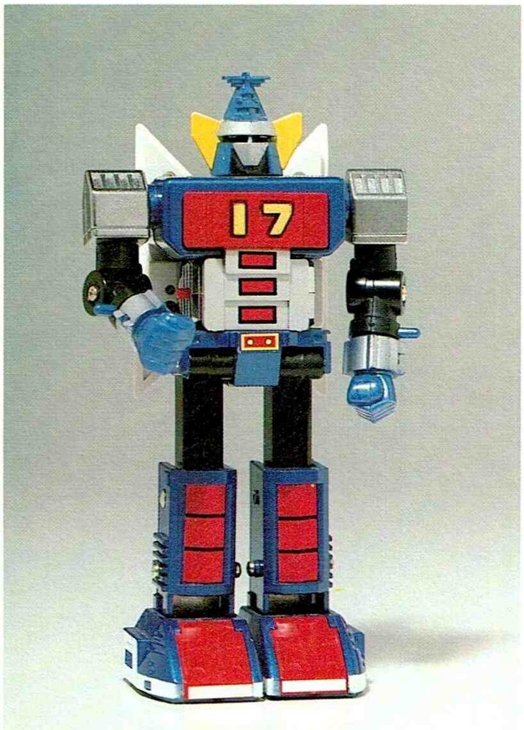
Japan has, in a single decade, outstripped America and Europe in its application of robotics to all aspects of industry. One explanation for this is attitude. *The New York Times* correspondent, Henry Scott Stokes, notes that ". . . the Japanese have a love affair with robots . . . a unique, intensely personal reaction, with roots in Buddhist values." The Japanese have always had an emotional attachment to tools, which they regard almost as friends. For years they decorated tools on the New Year, a practice now extended to robots. They even ascribe feelings to them.

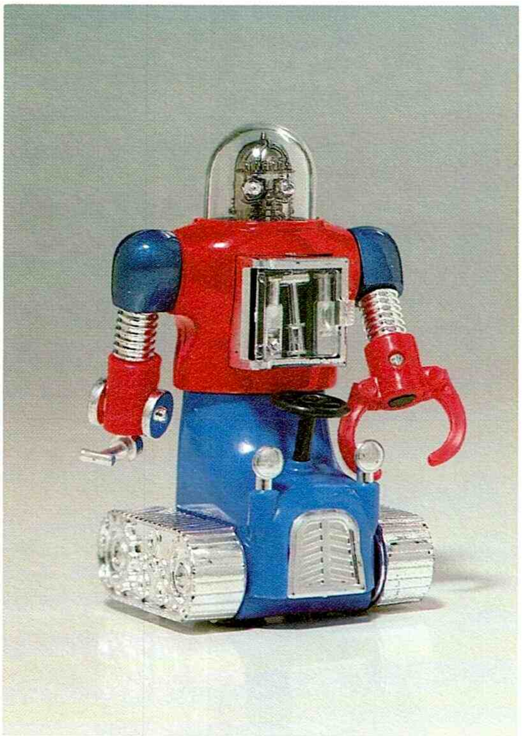
In Japan, children watch television cartoons with robot heroes and villains. Their robot toys are a remarkable blend of childhood fantasy and sophisticated engineering. One of these, the God Marz, is described in the promotional flier as "Ruler of all the Robots, a combination of the gods of the past joining strength with the gods of modern technology. . . . When pulled apart, God Marz becomes six powerful rulers, each with weapons and accessories, ready to maintain harmony throughout the universe."

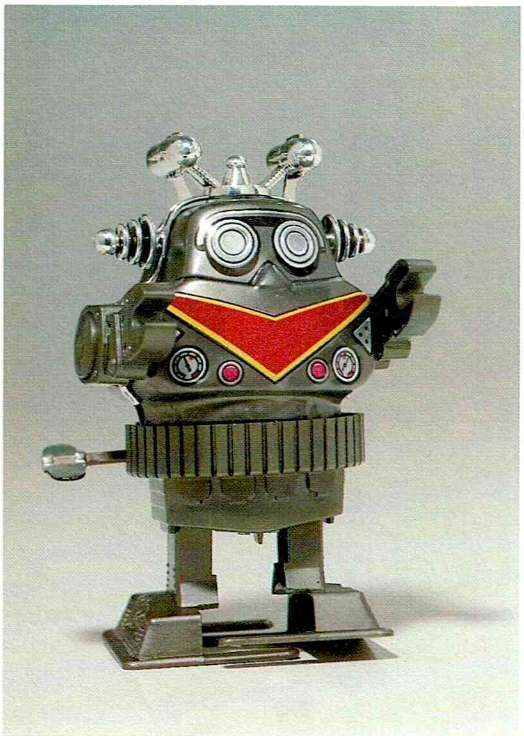
Japanese families pack department stores to watch the performances of automatons dressed as princesses, samurai and a Marilyn Monroe look-alike. Marilyn, the creation of Shunichi Mizuno, is computer-programmed to sing *River of No Return,* play a guitar, wiggle and wink. Others in the Mizuno family include Thomas Edison and John F. Kennedy. Architect Arata Isozaki designed a giant robot for the Cybernetic Environment of the 1970 Osaka World's Fair. Its primary task was to assemble blocks to form a stage, but it could also walk and dance, emit light, sound and fog. Japan has even begun to automate the near-mystical process of making sushi. There are now 450 robots that mold rice balls, a craft that normally requires a five-year apprenticeship.

Japan's greatest success has been in integrating robots into the production process. Fifteen years ago Japan had almost no robots; today it employs more than all other countries combined—a total of 14,000. By the year 2000 it is expected to have a million in operation. In 1967, it began to build the American Unimate under license; today, GE, IBM and Westinghouse are recovering from their late entry into the market by manufacturing Japanese designs.



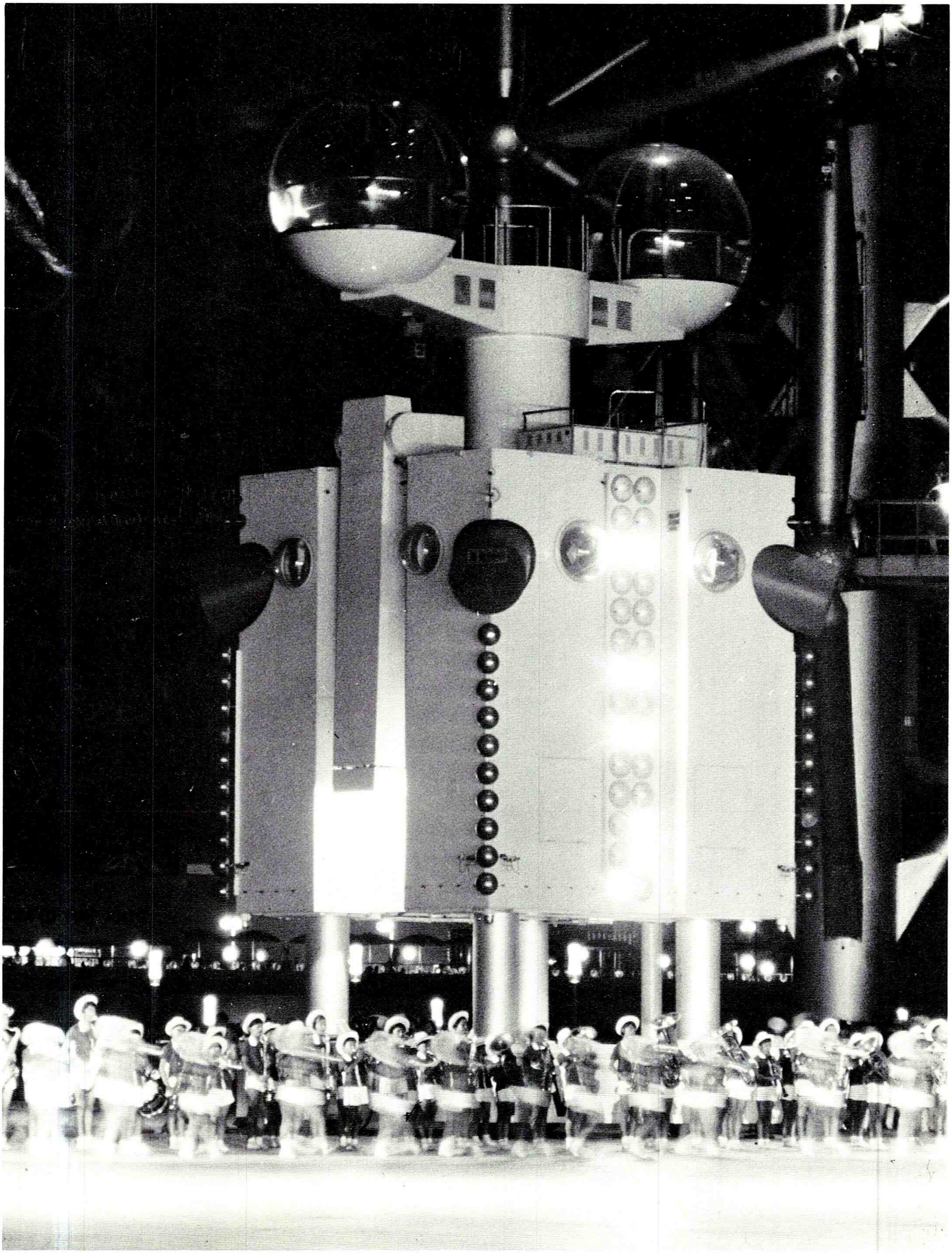


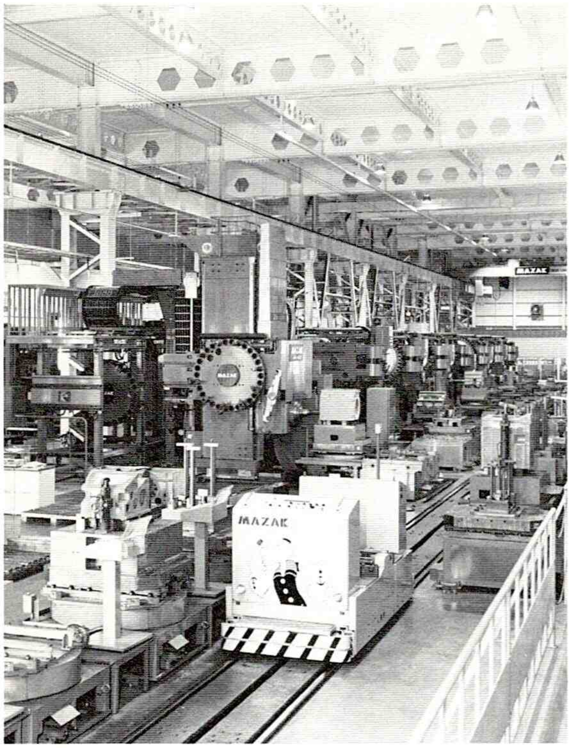




Robot toys are enormously popular in Japan. In many ways they are in the tradition of the ceremonial Kokeshi dolls, lovingly collected and displayed by Japanese children.

Arata Isozaki's two-headed RM performing robot 21 for Expo '70 in Osaka stands at attention as an all-girl marching band passes by.





Yamazaki Machinery Works, Ltd., an entirely robotic factory in Japan, uses MAZAK equipment energized by, of all things, Popeye!

The application of industrial robots in Japan soared in the wake of the 1973 oil crisis and a steep rise in labor costs. Japan has few natural resources: its survival depends upon high productivity. In a few years, the cost of a robot dropped from ten times the average annual wage to a little more than twice as much—at which point most managers were willing to install robots. (So were their American colleagues. GM Chairman Roger Smith declared that ". . . every time the cost of labor goes up one dollar an hour, a thousand more robots become economical.")

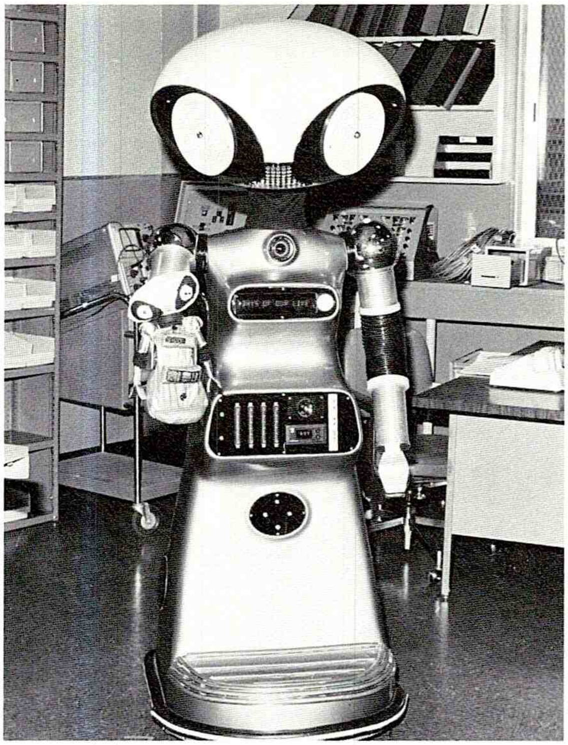
But Japan had additional incentives. Workers were in short supply, and few could be found to do dangerous or dirty jobs. Unions welcomed robots—not only to mechanize, but to humanize factories. Management consulted with labor, and offered displaced workers retraining programs. The use of robots was stimulated by accelerated depreciation benefits, and through leasing programs that made them accessible even to one-man workshops.

In a small factory featured on Japanese television, a Shinto priest conducts a purification ceremony; the company president introduces the new robot to his staff and sets it in motion. Large companies, like Fujitsu Fanuc, have manufactured their own robots and have introduced all-robot factories, in which humans are needed only for cleaning and routine maintenance. Japanese workers say "good morning" to robots, and name them after pop singers and baseball stars. Given lifetime job security, a more pleasant working environment, and a share of increased profits, their enthusiasm is easy to understand.

Are you going to reduce your work force twenty-five percent by putting in robots, or one-hundred percent by going out of business?
Thomas G. Gunn, Arthur D. Little Group

Business Weekly forecasts that, ". . . in the United States, 'steel collar workers' could displace up to seventy-five percent of the factory work force." Other analysts predict major layoffs in service industries. We should remember that similar cries of alarm were sounded two centuries ago. In the early 19th century, Luddites smashed machines, but mechanization proceeded apace. Then, as now, the challenge was to share the new wealth, and create new jobs.

We are in for a painful period of adjustment—a lot rougher than one might suspect from reading Alvin Toffler's *The Third Wave.* Optimists look ahead to a brave new world in which robots, guided by computers, will do all the unpleasant work, leaving to humans "only those tasks that are intrinsically human," in Asimov's phrase. Carl Sagan



Days of Our Lives* robot actor, 1983. The following summary of the soap's plot recently appeared in the *Minneapolis Star and Tribune:

***Days of Our Lives:* The robot is once again programmed to poison. This time Alice Horton is the target. But when Stephano and Alex realize Gretchen is onto their plans, the robot is reprogrammed to poison her. Just before she dies, Gretchen tries to alert everyone that Stephano and Alex are the culprits, but she is unable to. Liz again tells Neil she's not carrying his child.**

believes that "our future depends upon a partnership between human and machine intelligence," and that acceptance is a matter of acclimatization. Or, as the scientist in *RUR* proclaimed: "Man shall be free and supreme, with no other care than to perfect himself."

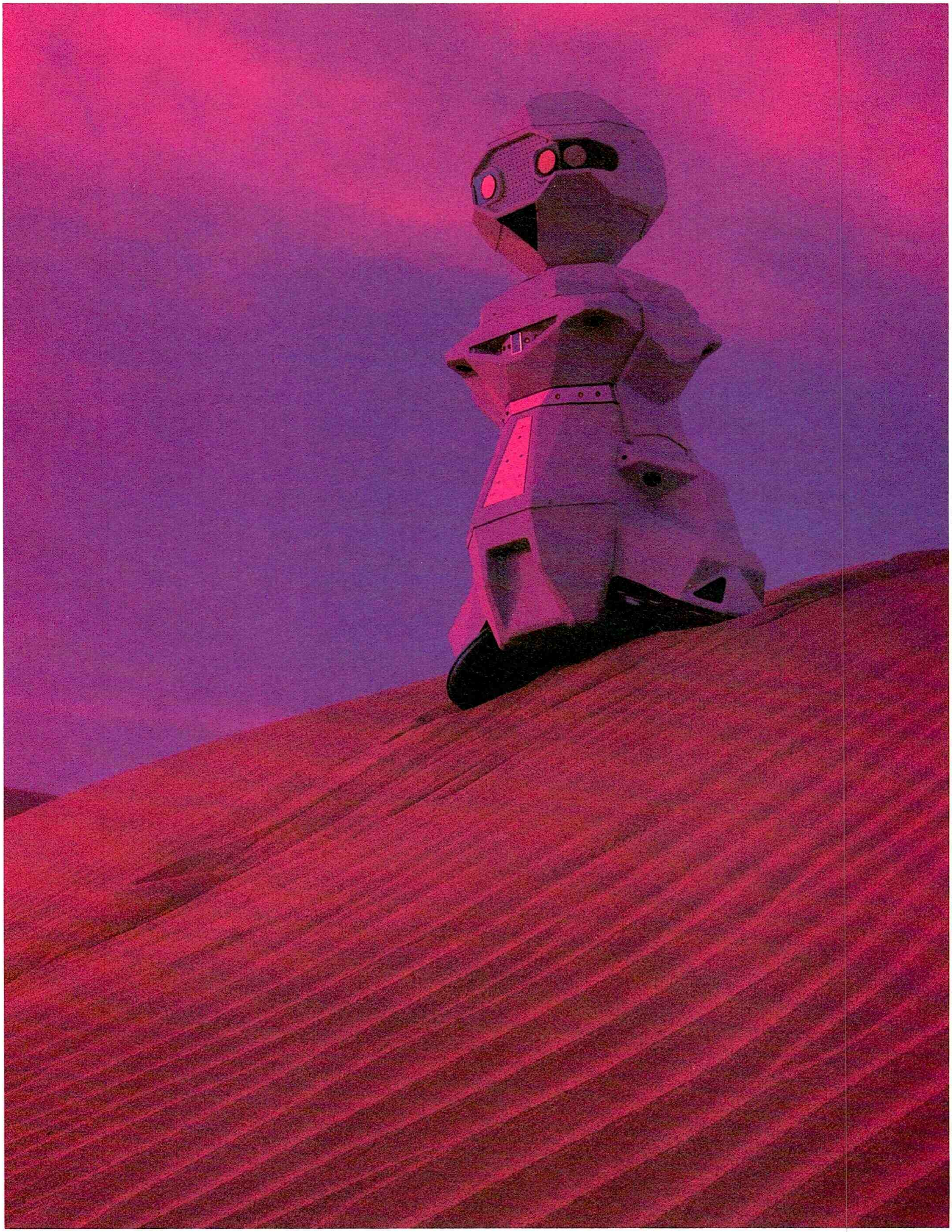
Pessimists (such as Kurt Vonnegut in *Player Piano*) see a society in which a small elite run the machines, and an unemployable majority subsists on handouts in resentful idleness. It sounds like the Roman Empire all over again, with robot slaves and video circuses. Optimists and pessimists must wonder what most people are going to do without the work ethic to spur them, and with such limitless expanses of leisure time to occupy.

For better or worse, robots will certainly play an ever-expanding role in our lives. At this time they are used mainly as tools, or as substitutes for things we already have. A teacher in the Bronx had her husband make a teaching robot that she could program to assist backward pupils. A smaller, more sophisticated version is now being produced, but it is no longer necessary. Children have, through their exposure to television and video games, become so accustomed to the small screen that they can interact with a computer terminal as readily as with a humanoid robot.

A robot named George suffers a heart attack several times each day so that pre-med students can recognize and respond to the symptoms. Psychiatrists at Bellevue Hospital program a robot to deal with unstable patients—who seem less hostile towards a machine than to doctors. A robot named Silent Sam plays flagman, tirelessly slowing traffic beside a construction site. The special effects in films like *Blade Runner* and *Star Wars* are generated by computer-controlled cameras making multiple passes over miniatures of space vehicles and futuristic model cities.

In time, robots may be used to test new cars, dispose of bombs and radioactive waste and perform on voice command for the sick and handicapped. A surgeon may conduct operations by remote force feedback, working through a slave robot in an inaccessible location. Robots may drill on the ocean floor or repair a crippled ship, remaining in place indefinitely without food or air; they may be used to assemble solar collectors in space, to mine and refine ore on remote planets and to ship it back to earth.

All of these projects are on the drawing board. To reach beyond them we have only to use our imaginations, or delve into the work of writers and illustrators, whose fantasies are unconfined by practical limitations. Meanwhile, there is an encouraging sign that we may be losing our fear of robots and achieving harmony between ourselves and our machines: a robot has recently joined the cast of *Days of Our Lives.* Where the soaps lead, America is sure to follow.



A robot is infinitely more to be trusted than a human nursemaid. Robbie was constructed for only one purpose really—to be the companion of a little child . . . He just can't help being faithful and loving and kind. He's a machine—*made so.* That's more than you can say for humans.
Isaac Asimov, "Strange Playfellow," 1940

The Computer, the Robot and the Sheep Dog

Arthur Harkins

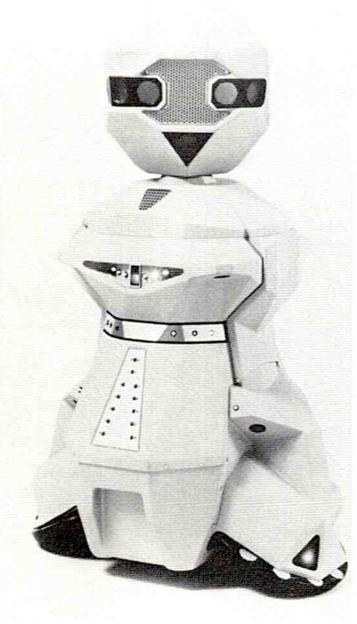
In the first few days of 1983 two major manufacturers announced the marketing of relatively cheap robots aimed at home and institutional markets. One of these, the Androbot (Androbot, Inc.) is expected to be sold to over one hundred thousand people in 1983. The Androbot is among the first of what promises to be a long line of inexpensive personal robots (PRs). It is the analogue of the Apple personal computer.

Current interest in robots is justified for we are undoubtedly going to see as much fascination with robots as we now have with microcomputers. There will likely be less fear of robots than many people displayed toward computers before they became available in the department stores. PRs ironically are another setting for the ubiquitous chips that make up the brains of computers, and Androbot BOB (for brains-on-board) will provide yet another avenue for the computer to reach into our lives.

Androbot BOB is something of a shocker. Home-and-hobby robots with such features as on-board reprogrammable computers, infrared and sonic sensing, voice input/output, and the potential for autonomous action weren't supposed to be on the market until several years from now. Androbot BOB has all of these features and will cost a fraction of the cheapest assembly-line robot. If the evolution of PRs continues with the pace set by Androbot BOB, we will see a variety of institutional uses for these machines during the 1980s, including hospital robots (currently under development in Japan), robot playmates (two varieties—one for children and one for adults), tree-trimming and line-working robots, and a whole variety of robot appliances for the kitchen, for wheelchair applications and for hundreds of other uses.

Androbot BOB is one of the first personal robots to be marketed in the U.S. Poised here on the crest of a purple dune, BOB is seen by his manufacturer not as a "worker" robot but rather as a social being—a friend.

There is cause for ethical concern in some of these applications, and for psychological or sociological concerns in others. What if a child's playmate robot wins affection away from the parents, or engenders a preference in the child for machines rather than for other children? What if an adult's playmate robot becomes the partner of choice in sexual relations, leaving a spouse or lover out in the cold?



Androbot President Tom Frisina and friend, BOB.

BOB's Vital Statistics
Full name: Androbot BOB
Date of birth: 1983 (The Year 1 A.B.)
Place of birth: Androbot, Inc., Sunnyvale, CA
Citizenship: International
Ht: 3'
Intelligence: Artificial
Computers on board: 3 Intel 8088 microprocessors
Memory: Exceeds 3 megabytes, (3 million bytes of information). Expandable.
Function lights: To indicate ultrasonic sensors active, infrared sensors active, human companion targeted, forward, backward, left and right directions.
Infrared sensors: Reading out at all times. To detect human body heat.
Ultrasonic devices: To determine the range and position of objects. Accuracy to 1/10th of a foot.
Moving speed: 2 ft. per second (may vary depending on surface conditions).
Wheels: Two, independently motor-driven.
Motors: Two. High torque.
Batteries: Three: Gel electrolyte, sealed, rechargeable. Long life. Industrial grade. LED indicates if batteries need recharging.

Japanese children have an easy relationship with robots that undoubtedly reflects the positive attitudes of their parents toward developing technologies.

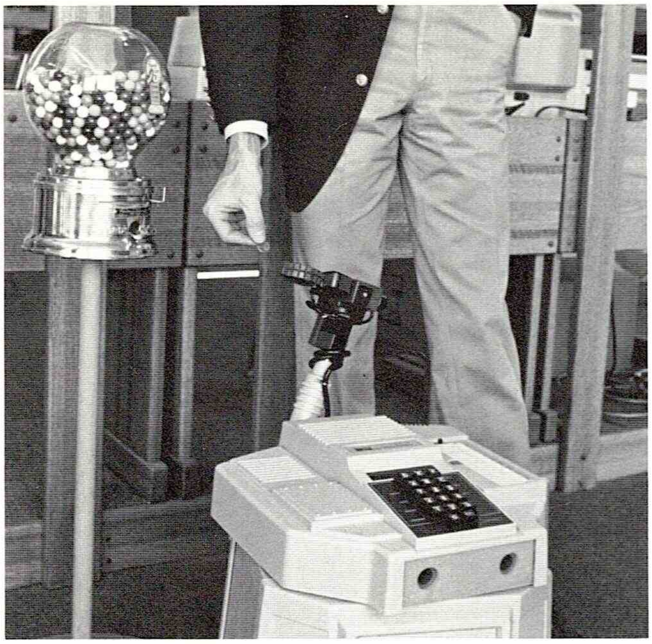
And what if robots are made with emotional programs in their chips, and feel themselves subjected to cruelty, even torture, by their human masters?

Such concerns can't be taken lightly. Indeed, the Hawaii Judiciary and the political science department at the University of Hawaii have undertaken a joint research program on the social rights of robots. This study points to the eventual use of emotion circuits in robots and calls our attention to the concept of sensitive machines. Such projects build upon the historical emergence of laws preventing cruelty to 1) animals, and 2) children, enacted in the United States in that order.

The concept of sensitive machines is tied to our beliefs about human nature, or that which is alleged to be immutably human, put there by common genetic heritage: sharing of emotions. Something that will pass for emotion will be present in early sensitive robot appliances. It is interesting that many people do not regard superior intellect as a distinctively human characteristic. A large and probably growing number of people attribute equal or greater intellectual power to computers, a mistake based upon a confusion about what brain circuits and current computer circuits have and do not have in common.

As Michael Webb points out, the Japanese are developing cultural and social acceptance of robots by treating them as partners in the work place. The sociable robot will have an easy time of it in Japan, where the concept of the intelligent robot (the grand old robot, equivalent in some ways to a venerated older person) is already being shaped. The Japanese are especially able to prepare for the future of machine intelligence as they routinely show positive emotions—and respect—toward robots already working on the assembly line.

Machine intelligence applied to robots moves us beyond the appliance robot, no matter how convivial the latter may be. While appliance robots may cut the lawn, share your bed, bring a meal to the ill, engage in limited but satisfying conversation and become a valued part of family life, they are still going to be sophisticated appliances, much like an aircraft with an automatic pilot. But robots with machine intelligence will force us to a new level of technical sophistication and confront us with our possible successors. Intelligent robots will have life expectancies tied to the information in their computers. This information will move at light speed to a safer location if the robot finds itself in danger. The information also will be transferable to later model robot bodies when these become available. What one robot learns may be sent to all other friendly robots at the speed of light, anywhere. The implications of this development are vividly expressed in Arthur C. Clarke's recent book *2010: Space Odyssey Two* in which Hal, the computer from the earlier *2001,* is portrayed as possessing a humanity so powerful it is able to convince its human programmer of its ability to think and feel.



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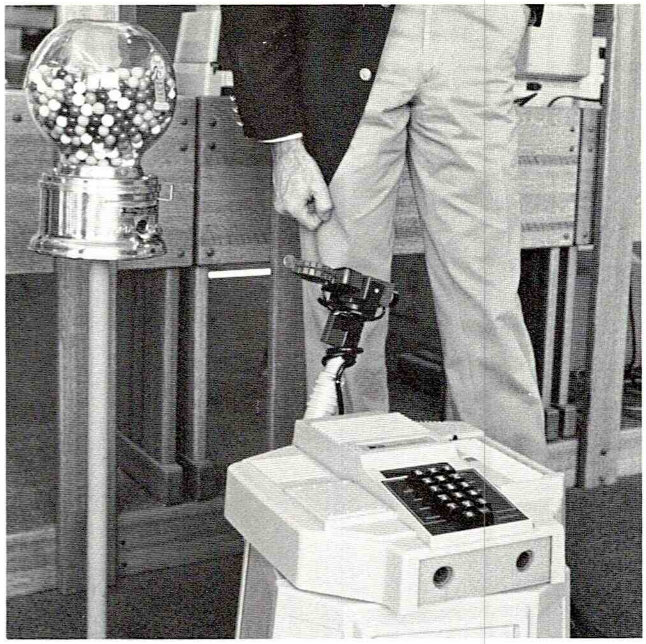

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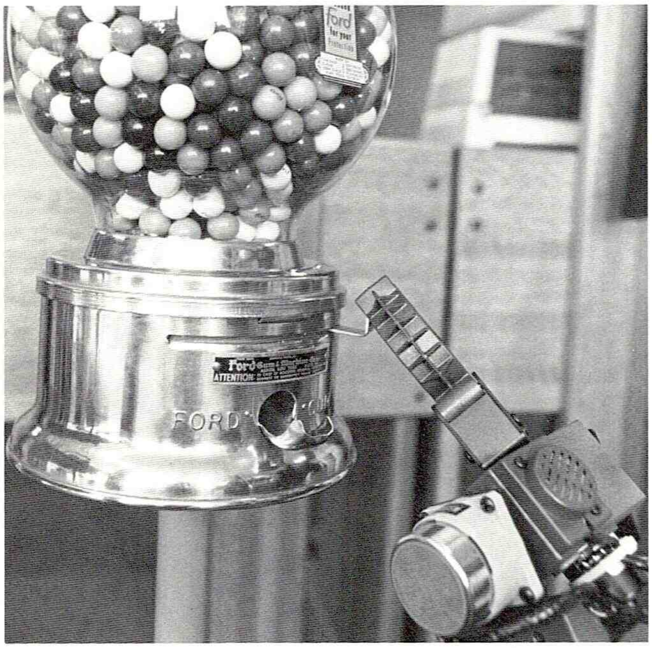

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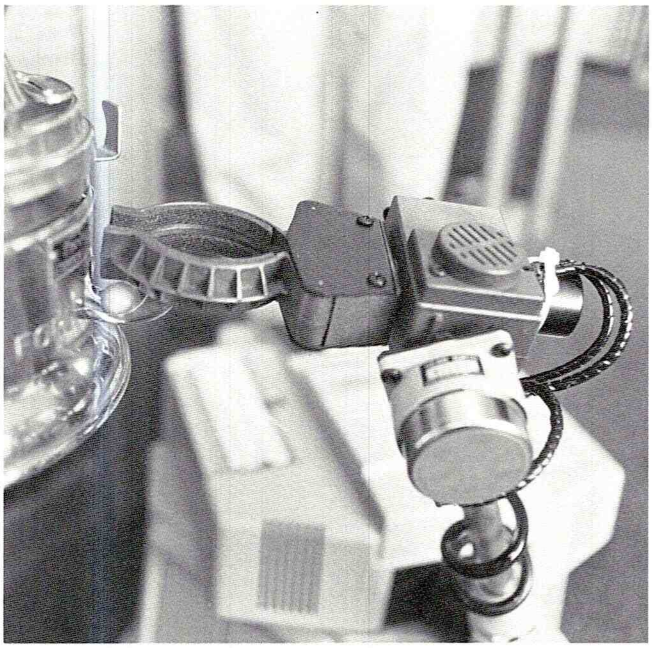

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Heathkit, a producer of do-it-yourself kits for audio systems and other electronic equipment, has recently added HERO, a microprocessor-controlled robot, to its catalogue. This robot can move, see, hear, speak, learn what you teach it and, according to its manufacturer, teach *you* robotics. In this sequence of photographs HERO attempts to buy a gumball. After approaching a nearby human for the necessary funding, he/she/it (?), with penny in "hand," proceeds to its encounter with a mechanical being of a lower order. The gumball machine, obviously envious of HERO's capabilities, decides to be difficult and our robot has some problems. With a skilled and patient operator (HERO is responding to human commands) the robot could probably complete all the steps necessary to buy a penny gumball, but it was obviously designed for higher purposes.

Thus we have the following scenario for robot development during the next fifteen to twenty years: Androbot BOB will be a hit and will spawn successors in tens, if not hundreds, of companies in the U.S., Japan, West Germany, France and Italy. Mass production of such robots will be done cheaply in these countries and in Taiwan, South Korea and perhaps China. People the world over will find uses for such robots, many more than we can now imagine. Late 1980s versions of Androbot BOB will be able to carry on relatively simple conversations in English and other languages. Around 1990 to 1995 new robots with machine intelligence will begin to appear in research and development programs in Japan and America. Regarding these machines as appliances will be difficult, because, consistent with 1) the type of programming they are provided, and 2) the degree of their own self-learning, they will qualify as "humans." Intelligent machines are by definition able to teach themselves new things. Societies of such intelligent robots could engage in mutual teaching and learning at a rate roughly tens of thousands of times faster than humans, for whom a generation is often required to allow new knowledge to take hold.

The best way to understand all of this—exciting, mystifying or frightening as it may be—is to consider the lowly sheep dog and its place in the development of automation. The sheep dog is actually an example of a convivial biomachine, "manufactured" by selective breeding and training over a long period of time. The result of such "natural" manufacturing is an animal capable of doing work for human beings and also capable of affecting the ways in which humans, particularly shepherds, behave. The sheep dog is a kind of early robot, constructed of carbon, hydrogen, oxygen and nitrogen and a number of other elements. Like a modern robot, the dog even has a gripper—its jaw. And of course each sheep dog is somewhat unique from every other because of its differing characteristics and experiences.

Modern reprogrammable robots are like sheep dogs, except that they are less smart and made out of different materials. They will not be less smart for long. Modern robots and the affectionate and intelligent ones to follow build upon human experience with sheep dogs, horses, oxen, trained bears, domesticated plants and even with humans themselves. Our social and cultural systems are examples of the process of domestication, or bending the living entities around us to our will and needs. We may understand the evolution of the robot as another series of steps in the automation of selected parts of the environment in the direction of domestication. Even the rearing of a human child offers us a recapitulation of the automation/domestication of a selected part of the environment.

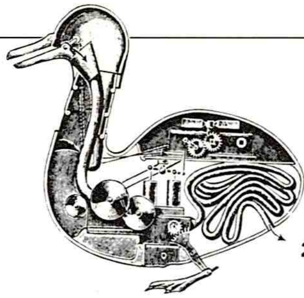
A steel-collared "significant other" as depicted in Jean-Claude Forest's comic strip, *Barbarella.*

Now here is the rub. The smarter the sheep dog or the more intelligent the human baby, the more likely is the automation/domestication process to produce unplanned variations. In other words, the product affects the manufacturer. In this general way computers have already vastly changed many aspects of education, business, manufacturing and even the arts. When will there be a troupe of performing robots? When someone decides to create them. What will a troupe of performing robots do to our concept of acting, of staging? Will there be a Jessica Shebot and a Hume Hebot? Probably, sooner or later. But remember, there is nothing really new about this if you consider the precedent of chimps, monkeys and orangutans on stage today. But no one can predict the outcome of such changes when the robot substitutes for the chimp.

Chances are excellent that you will have a robot friend in your lifetime, so you may as well prepare. Indeed, before your time is out you may have some robot hardware implanted within your own body, perhaps to replace a defective heart or lost limb. Even your brain may be augmented by implanted chips, some of which allow you and your robot friend to communicate with a kind of silent radio telepathy. As robots develop more human characteristics, such as language and conviviality, humans begin to take on certain physical attributes of robots, such as steel hip joints and electronic spinal cord repairs.

We should end our tour of emerging robots with a genuinely fascinating possibility: marriage between humans and robots (as projected in the film *Blade Runner).* Is this idea intriguing, boring, disgusting? Most people this author has talked with find using robot appliances for intimate intellectual and social purposes no problem at all. After all, you can always tell the robot appliance exactly what to do. It is when machine intelligence is introduced to the robot that many people have second thoughts. Why have a machine with a mind of its own who can say "No!"? People in general prefer the appliance robot. They have had enough of human contrariness. Liberated robots would simply be too much. Yet a small number admit that the relationships they currently enjoy most are with people who have minds of their own, adding that independent robots in their lives would be a source of new variety, wonder and joy. Let us hope that there will be some robots who agree with them.

A Brief Chronology of Robotics



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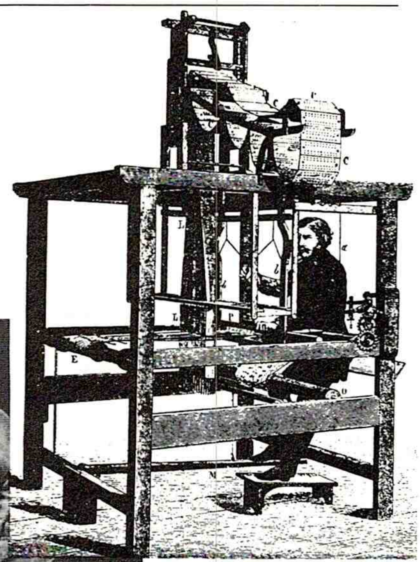

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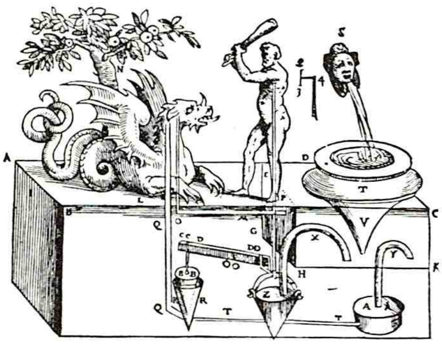

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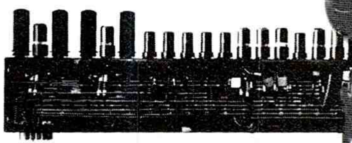
	100 BC	1300 AD	1600	1800
Fact	1598 wooden reconstruction of the Alexandrian Hero's hydraulically operated vignette depicting Hercules striking a dragon, ca. 100 BC **1**	mechanical clocks Europe, ca. 1300 AD	mechanical calculator Gottfried von Leibniz, Germany, 1694 mechanical duck Jacques de Vaucanson France, 1738 **2**	automatic loom Joseph Jacquard, France, 1801 **4** Analytical Engine (never constructed) Charles Babbage, Great Britain, ca. 1825 first computer programmer Ada, Countess of Lovelace, Great Britain, ca. 1825 electric tabulating machine using punch cards Herman Hollerith, USA, 1890
Fiction		Golem mythical monster, medieval Europe **3**		Frankenstein's monster (reanimated human) from a novel by Mary Shelley, Great Britain, 1818



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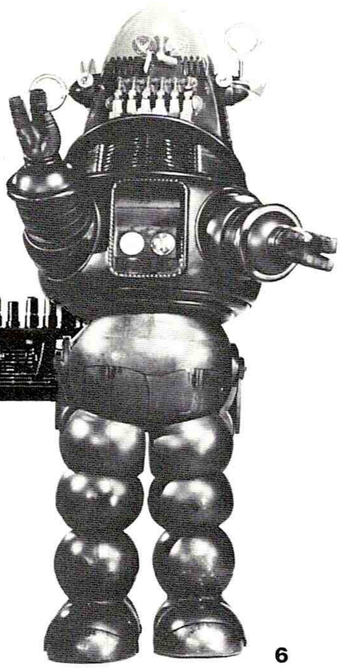

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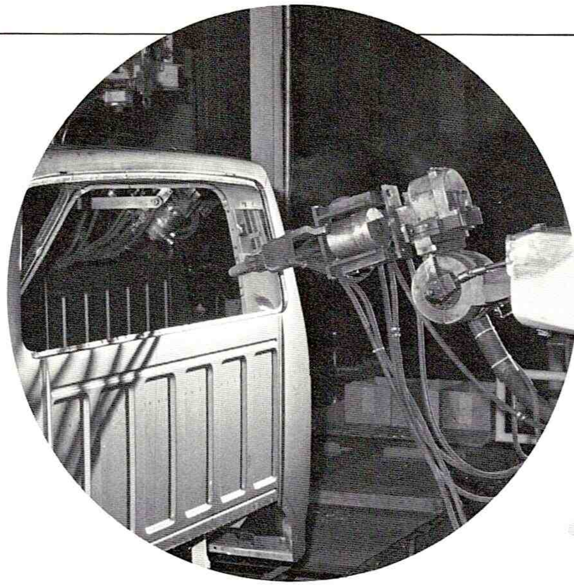

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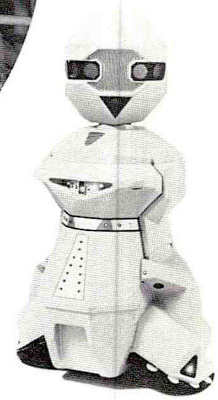

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1940

cybernetics
Norbert Wiener, USA, 1940s

ENIAC-electronic numerical integrator and computer
J. Eckert, J.W. Mauchly, USA, 1946
5

transistor
Bell Telephone Labs, USA, 1948

1950

first commercial computer
Univac, USA, 1951

artificial intelligence research
USA, 1950s

assembly line robot
General Motors, USA, 1960s
7

microcomputer (single silicon chip)
University of Illinois, USA, 1971

1980

robot speech recognition
USA, 1981

robot vision
USA, 1982

affordable personal robot
Androbot, Inc., USA, 1983
8

Rossum's Universal Robots (R.U.R.)
a play by Karel Čapek, Czechoslovakia, 1921

Robbie, first "good guy" robot from Isaac Asimov's short story, "Strange Playfellow," USA, 1940 (film adaptation, *Forbidden Planet,* 1956).
6

Hal (malevolent computer) from *2001: A Space Odyssey,* a film by Arthur Clarke and Stanley Kubrick, Great Britain, 1968

2010: Odyssey Two, 1982. Arthur Clarke's sequel to *2001.*

Assumptions

three-dimensional vision
1983–87

complete robot mobility
1983–87

domestic help robot
1990–2000

companion robot (e.g. seeing-eye dog)
1990–2000

intelligent self-reprogrammable robot
2000–

self-reproducing robot
2000–

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HERO (pp 26, 27) was assembled by Doug Broehm.

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Anderson Open School, Minneapolis and John Donais, teacher: p 4
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Glenn Halvorson: cover, pp 26, 27
Arata Isozaki: p 19
The Museum of Modern Art/Film Stills Archive: pp 7–9
Collection the Museum of Modern Art, New York; Gift of Jean and Howard Lipman: p 10 (bottom, right)
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