How Will A Robot Change Your Life?

An Exciting Future in Which Robots Will Become the Helpers that Humans Have Always Imagined Is Just Over the Horizon

by JAMES G. KERAMAS

Will robots continue to be used successfully as brain surgeons, window washers, and lab technicians? Can you look forward to an automatic cook, maid, butler, or gardener? Is the robot going to evolve to the point where it can be viewed as a new life form?

In some ways, the state of the art of robot applications is paralleling the development of digital computers. In the 1960s, people feared computers would reduce the number of white-collar workers, such as accounting clerks and secretaries. Instead, the computer has increased the number of jobs by creating new requirements for computer operators, computer programmers, and systems analysts.

Now as we begin the new millennium, we fear robots will reduce the number of blue-collar jobs. However, it is more likely that robots will increase jobs, some of which may be white-collar jobs. New human jobs such as robot supervisor, robot setup person, robot trainer, and robot repairperson are sure to emerge from the widespread use of robots in industry. Right now, new types of manipulator joints, actuators, and grippers are under development. Japanese researchers are experimenting with shape-memory alloy wire, composed of nickel and titanium, and MIT is experimenting with artificial joints and muscles based on the human sense of kinesthesia to develop a new sensor or actuator for humanlike hands. Fig. 1 illustrates such a haptic device from MIT.

Presently, industrial robots use mechanical, electrical, electronic, and hydraulic devices to obtain feedback information. Such devices are called closed-loop and servo-controlled systems. The navigational computers and sensors necessary for getting around safely in city traffic already exist and use this type of device, but the advancement of the robot to the state shown in such films as *Star Wars*, *Star Trek*, and *Buck Rogers* must await more major technological breakthroughs in the areas of artificial intelligence, voice interfacing, vision, and touch sensors in order to be successfully realized. Considerable research is going on in these areas, and it is only a matter of time before the objects of today's laboratory curiosity become economical enough for use in robots.

Robotic technology would advance much more quickly if future products were needed today. Economics is a major driving force in research and development, as is the government, through its military and space programs. For instance, the government was responsible for much of the development of electronics and computers. Today, the Atomic Energy Commission is sponsoring research in robotics for advanced nuclear reactors. When this comes to pass, robots will have to work in extremes of temperature, humidity, and radiation levels, and be able to climb over obstacles. The future of robots is controlled by events from the past and present and by our imagination. Important products of imagination include art, science fiction, cinema, and children's toys.

Issues

Even in their present state of development, robots are used for more and more jobs. They have already been successfully uti-

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lized as brain surgeons, window washers, and lab technicians. A new use was introduced recently when ABC began employing robots to run the television cameras for its national news broadcasts. This allows the cameras to be operated by a single person from the remote control booth.

The primary driving force behind the research in robots is how to lower their unit cost, increase reliability, and simplify operations.

The automated robot cook, maid, butler, or gardener is still far from becoming a reality. However, a robot chauffeur can be built with today's technology if someone is willing to pay the high cost. As it merges with the electronic computer, the robot is evolving toward the point where it could be viewed as a new life form.

Artificial intelligence has already shown great promise for robots. Work has begun on the development of self-reproducing machines. In an article in *Technology Illustrated*, Freitas [1] talked about the prospects of a self-replicating factory being practical by early in the 21st century, located on the moon and running on solar power. This factory would use the moon's raw materials to reproduce itself and to manufacture additional solar cells, which could then be hauled away to a nearby solar-powered generation-station satellite to be beamed to earth as electrical power. NASA has already proposed programs along these lines.

Robots are currently used in education as teaching tools. The show robot, which has a unique operating platform that allows teaching by position via a graphical user interface (GUI), is very useful for working with abused children whose bad experiences often make it hard for them to trust and talk to adults. It is a user-friendly robot that, with no prior familiarity, enables students to write complex sentences. Safford wrote about the show robot in his *The Complete Handbook of Robotics* [2]. Programmable mobile devices, such as the Big Trak tank (robot), can be used to teach programming, since they deal with motion rather than numbers and are easier to relate to children. Educational robots are also used to teach applications programming for industrial robots.

The Technology of Robots

A robot is a machine constructed as an assemblage of joined links so that they can be articulated into desired positions by a programmable controller and precision actuators to perform a variety of tasks. Robots range from simple devices to very complex and "intelligent" systems by virtue of added sensors, computers, and special features. Figure 2 illustrates the possible components of a robot system.

There are several-hundred types and models of robots. They are available in a wide range of shapes, sizes, speeds, load capacities, and other characteristics. One way to classify them is by their intended application. Care must be taken to select a robot to match the requirements of the tasks to be done. Generally, there are industrial, laboratory, mobile, military, security, service, hobby, home, and personal robots. Figure 3 illustrates the general configuration and operating parameters of an industrial robot.

In the last three decades, the robotics field benefited considerably from the advancement of microelectronics, com-

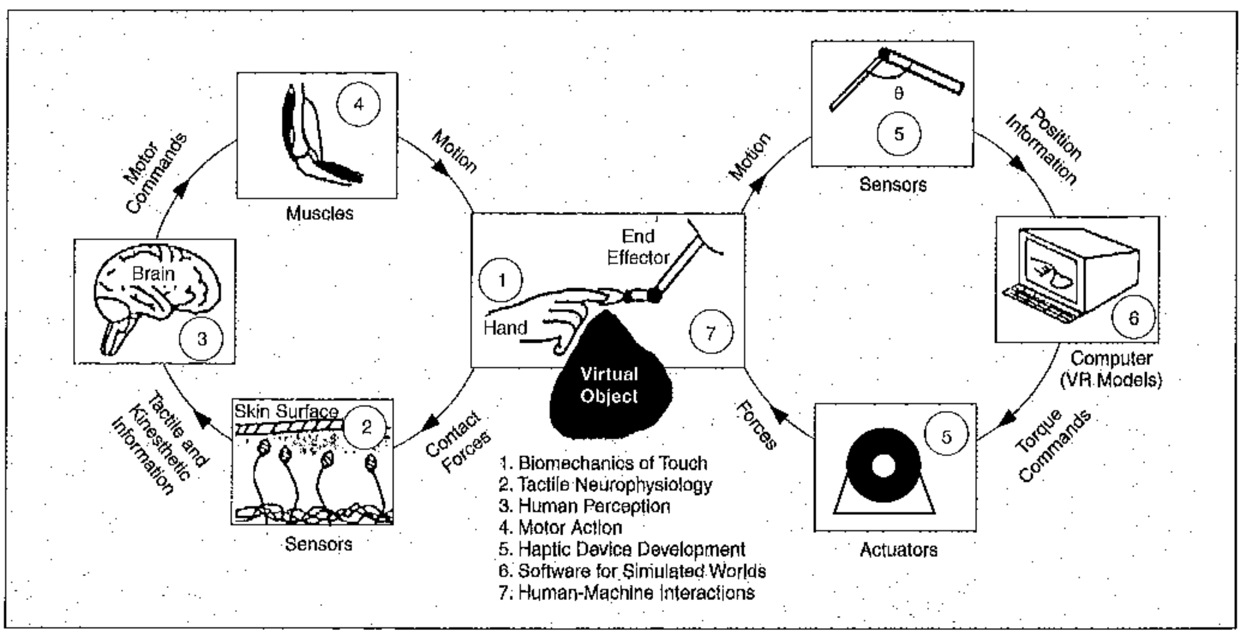

Figure 1. *Haptic perception—human and machine haptics enhance interactions in virtual reality and teleoperator systems, according to the number in the functional block diagrams.*

puter science, and improved design of electrical, electromechanical, and hydromechanical servo systems. Figure 4 illustrates how fuzzy logic controls a robot arm.

The industry continues to grow and expand. Currently, there are approximately 40 major robot manufacturers in the United States and over 500 worldwide. The annual growth rate of the industry is approximately 35% per year, and continued market expansion is expected. The Robotic Industries Association (RIA) estimates that annual sales volumes for the year 2001 will be about $7 billion. Spot-welding still remains the largest application area for robots today.

Competitive forces are beginning to segment the market with many manufacturers focusing on specific industries or applications. This specialization approach will speed technological advancements and enhance robot capabilities in specific areas. Lately, manufacturers are paying greater attention to sensor integration, as explained by Annaswamy and Srinivasan [3]. More robots today are sold with optional capabilities, such as vision and tactile sensors and even fuzzy-logic controls. Robots that are more intelligent will be the result of efforts such as what Srinivasan and Dandekar [4] described in their two-dimensional models. Robot manufacturers will continue to quickly implement the computer-industry improvements and expanded capabilities to raise the "IQ" of robots to handle more data and process it faster, as Popoff explained in his *Psychology Today* article [5].

The move is well under way to utilize more AC electric servo systems to power robot motions. It is expected that this trend will continue along with CAD/CAM integration, which is a logical direction for users of robotic technology.

Computer-graphics technology is also rapidly advancing to provide us with "simulation" capabilities to analyze manufacturing approaches and methods prior to implementation. "Off-line" programming, a necessary component to realize full CAD/CAM capability benefits, is now being offered. The "universal robot controller" finally emerged into the market in 1999 to eliminate those nuisance programming languages that are fixed for each robot model. All factory controllers will be replaced with this new universal controller to reduce the unnecessary programming, as Keramas explained in *Robot Technology Fundamentals* [6].

Mobility will also allow robots the necessary freedom of movement, so that users can more fully appreciate and utilize the robots' inherent flexibility throughout a manufacturing facility.

Economic Aspects and Growth

A dramatic decrease in the cost of robots can be expected in the near future if the following conditions exist:

- Fewer manufacturers supplying robots to a larger market.
- Mass-production methods with advanced technologies applied to the manufacturing of robots.

In 1987, there were approximately 17,000 industrial robots in the United States. By the end of 1998, RIA forecasted 90,000 robots were in operation in US factories, placing the United States second only to Japan. According to Dave Lavery, manager of the robotics program at NASA, there are about 650,000 robots at work today worldwide.

Over the past decade, highly selective applications for robots resulted in so-called "islands" of automation. With the development of more sophisticated automation concepts, such as computer-integrated manufacturing (CIM) and flexible manufacturing systems (FMS), users learned that industrial operations are usually best automated through the integration of robots with machines, which are referred to as a workcell. This integration, which causes the need for knowledge about robots, has become very important in automated manufacturing today.

Future robots are likely to have greater sensory capabilities, more intelligence, higher levels of manual dexterity, and adequate mobility as compared to humans.

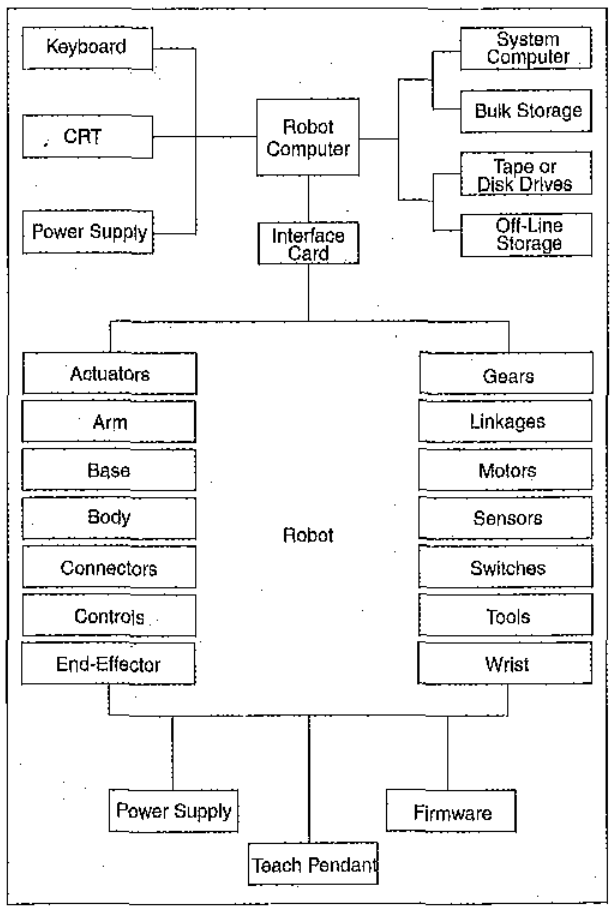

Figure 2. *Schematic of a robot system.*

Robots can be used in any industry providing work and services, and they can also be adapted easily to numerous job functions with uncanny skill and unmatched endurance. These factors and many others, such as reducing production cost, improving quality, and increasing productivity, just to name a few, have contributed to the growth in the use of robots and will continue to impact their evolution, both in pace and direction.

The fully automated factory has been under development in Japan for some time and should be completed within the next few years.

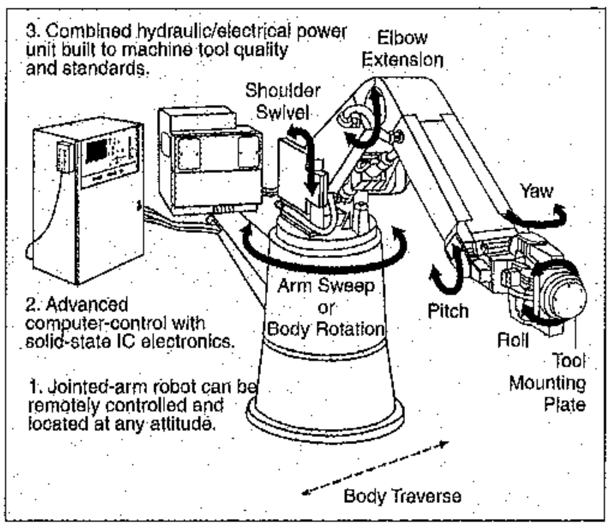

Figure 3. *The general configuration and operated parameters of an industrial robot.*

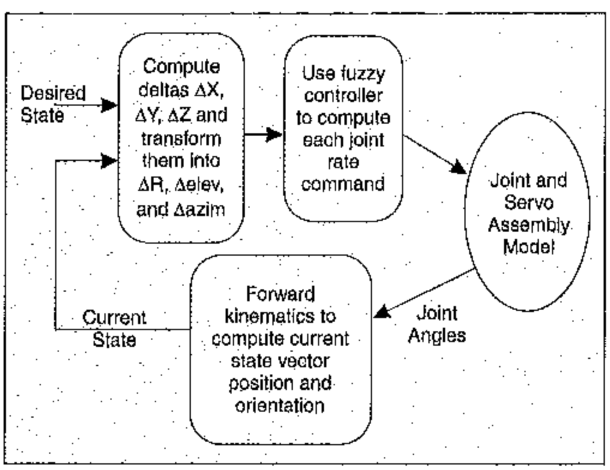

Figure 4. *Remote manipulator system simulates flow-forward kinematics and fuzzy-logic control to operate a robot arm.*

Robot application areas as a percentage of total robot population are shown in Fig. 5. Robot shipments from US-based companies for the period 1994-1998 are shown in Fig. 6. The two reasons for selecting a robot to operate in a production line are (1) to reduce labor costs and (2) to perform repetitive work that is boring, unpleasant, or hazardous for human beings.

Ways Robots Will Affect Our Lives

A decade ago the prediction was that robots would begin to grow in popularity about the year 1998. This was after the general public as well as engineers and scientists had learned to routinely accept robots in their work environments, and that no robot would act or feel like a human being in the foreseeable future. These predictions are still true. Today, the primary driving force behind the research in robots is how to lower their unit cost, increase reliability, and simplify operations.

Future robots are likely to have greater sensory capabilities, more intelligence, higher levels of manual dexterity, and adequate mobility as compared to humans. By the year 2004, there will be more than 250,000 industrial robots in the United States. Sales of military and personal robots will outnumber the industrial robots by that time.

New types of robot actuators will also appear. These might rely on shape-memory alloy wire or other types of artificial muscles. Robots will benefit from more powerful controllers that will allow them to see, learn, and think for themselves. Smart robots will also be able to protect themselves from accidental destruction due to operator error or inattention to some danger to the robot.

Some possible future applications of robots are listed below by industry and special category:

- Aerospace industry
- Agriculture industry
- Construction industry - road construction, paving, and surface finishing procedures
- Health industry - surgery, rehabilitation, biorobotics
- Manufacturing industry
- Nuclear industry
- Service industry
- Textile industry
- Transportation industry
- Utility industry
- Educational field
- Lab automation
- Control and guided vehicles
- Underwater surveying and maintenance activities
- Navigation systems
- Surveillance and guard duty
- Firefighting
- The automated factory of the future
- Household robots

The ability of a robot to carry out surgical, rehabilitation, and biorobotics procedures or examinations will depend on sensor capabilities and real-time computer-processing techniques. Most industrial robots purchased in the next five years will be as parts of larger manufacturing cells rather than individuals. Underwater applications of robots will involve salvaging sunken vessels, ship repairs, and other ocean and sea utilizations.

The military is hoping to make up for its shortage of personnel by using robots to make human forces more efficient. Currently, applications for robots are being sought in a variety of areas. In addition, the US Air Force and Navy are both interested in mobile firefighters and robotic rocket handlers. However, the application of robots for surveillance and guard duty is not restricted only to the military but extends to power-generating plants, oil refineries, and other large civilian facilities that are considered to be potential users.

The fully automated factory has been under development in Japan for some time and should be completed within the next few years. Robots also evolve in space stations, satellites, and planetary exploration. Many space robots and space satellites already draw their power directly from sunlight.

In the next five years, the robot can be expected to find a place in the home. Such devices would need to be small, mobile, sensor-based, easy to program, and autonomous. It will start out as a novelty but grow into a useful servant. This trend has already started with robots that serve as educational toys, and soon it will advance to doing simple tasks around the house. The personal robot will have the same potential of growth as a personal computer.

Finally, the current and future applications of robots are moving in a direction that will provide us with more and more

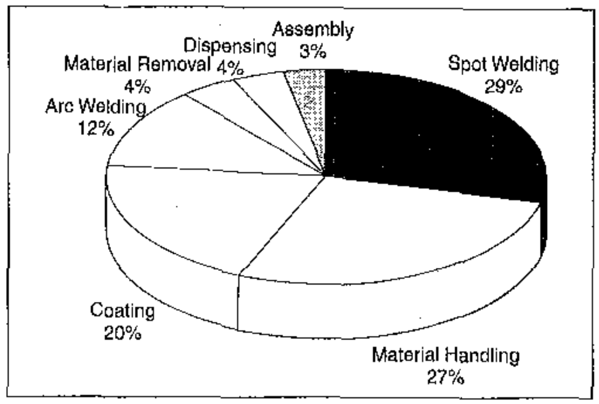

Figure 5. Comparison chart of leading robot applications.

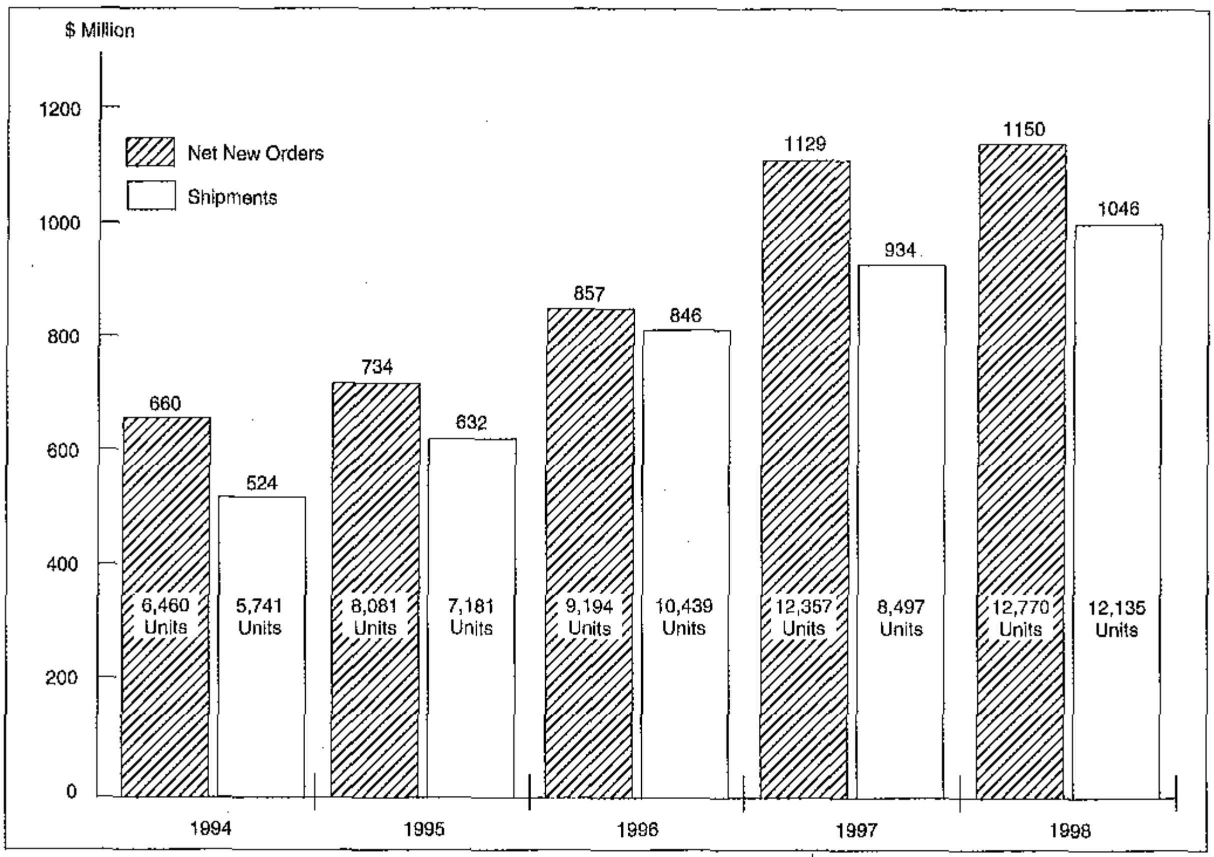

Figure 6. US robot sales for the period 1994-1998.

capabilities like those of humans and that will, undoubtedly change and affect our lives significantly.

Conclusions

Any way you look at it, the robot has an exciting future. Soon, we can expect the robot to move out of the factory and enter the domestic and business worlds. The domestic robot will appear in the home as an electronic pet and soon will develop the ability to perform useful tasks there. The sensory ability of all robots will greatly improve. In the long run, robots will acquire the capabilities they have been described as having in the movies and science-fiction books. Self-reproducing factories may be placed on the moon or on other planets to help meet our growing needs for energy and goods. Inspirational changes are on the way as robots become the helpers that humans have always dreamed of.

Keywords

Robots, technology, education, research, human relations, economic growth

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