GRIPPERS

The end of the manipulator is the part the user or robot uses to affect something in the environment. For this reason it is commonly called an end-effector, but it is also called a gripper since that is a very common task for it to perform when mounted on a robot. It is often used to pick up dangerous or suspicious items for the robot to carry, some can turn doorknobs, and others are designed to carry only very specific things like beer cans. Closing too tightly on an object and crushing it is a major problem with autonomous grippers. There must be some way to tell how hard is enough to hold the object without dropping it or crushing it. Even for semi-autonomous robots where a human controls the manipulator, using the gripper effectively is often difficult. For these reasons, gripper design requires as much knowledge as possible of the range of items the gripper will be expected to handle. Their mass, size, shape, and strength, etc. all must be taken into account. Some objects require grippers that have many jaws, but in most cases, grippers have only two jaws and those will be shown here.

There are several basic types of gripper geometries. The most basic type has two simple jaws geared together so that turning the base of one

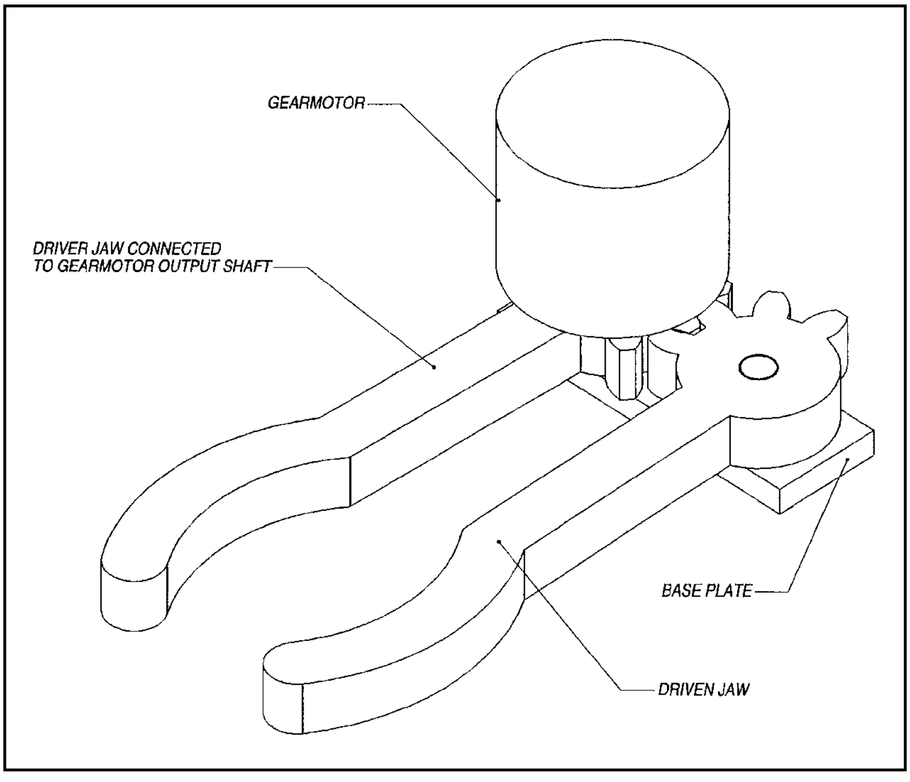

Figure 10-16 Simple direct drive swinging jaw

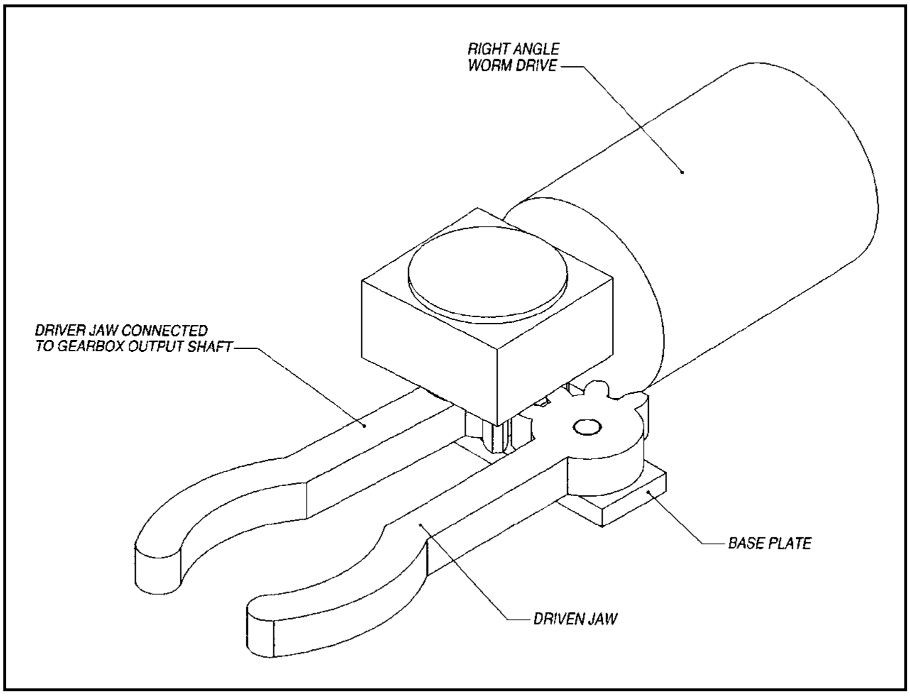

Figure 10-17 Simple direct drive through right angle worm drive gearmotor

turns the other. This pulls the two jaws together. The jaws can be moved through a linear actuator or can be directly mounted on a motor gearbox's output shaft (Figure 10-16), or driven through a right angle drive (Figure 10-17) which places the drive motor further out of the way of the gripper. This and similar designs have the drawback that the jaws are always at an angle to each other which tends to push the thing being grabbed out of the jaws.

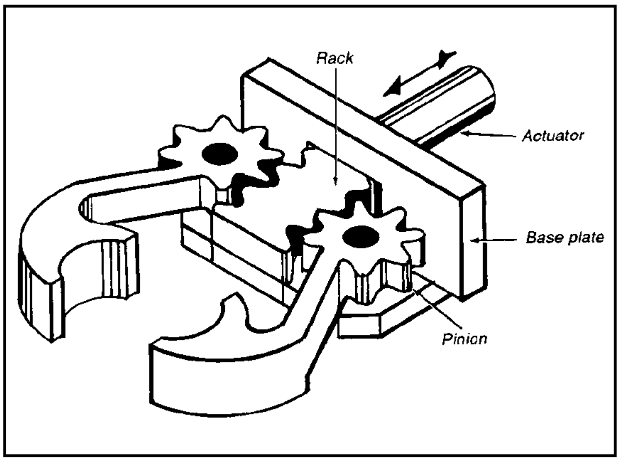

Figure 10-18 Rack and pinion drive gripper

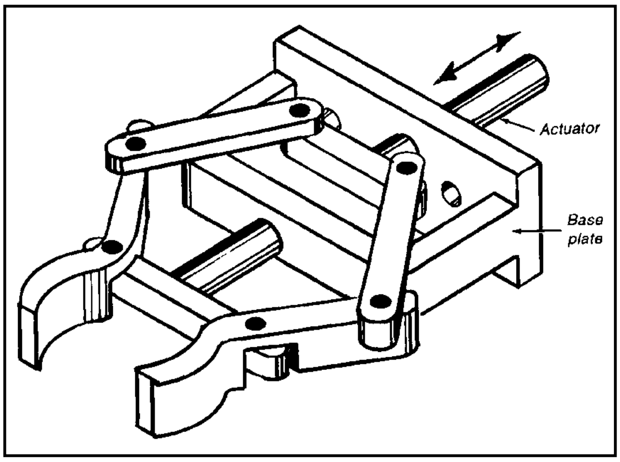

Figure 10-19 Reciprocating lever gripper

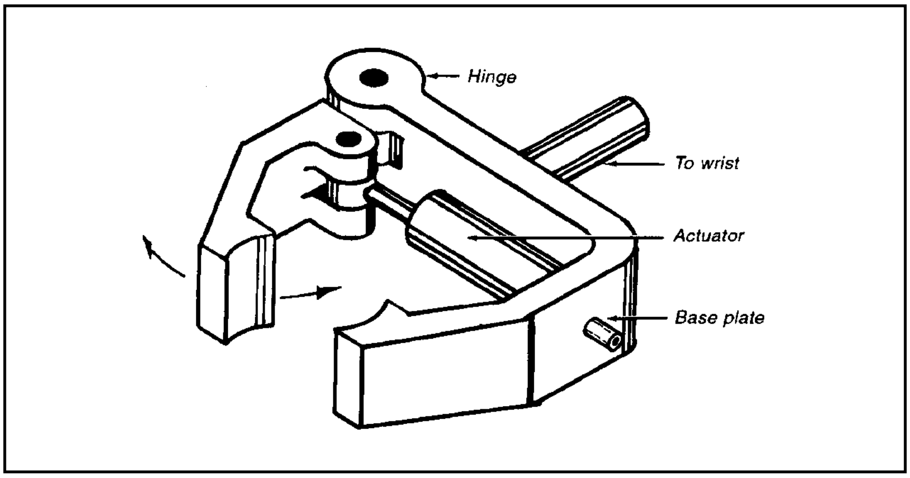

Figure 10-20 Linear actuator direct drive gripper

A more effective jaw layout is the parallel jaw gripper. One possible layout adds a few more links to the basic two fingers to form a four-bar linkage which holds the jaws parallel to each other easing the sometimes very difficult task of keeping the thing being grabbed in the gripper until it closes. Another way to get parallel motion is to use a linear actuator to move one or both jaws directly towards and away from each other. These layouts are shown in Figures 10-21, 10-22, and 10-23.

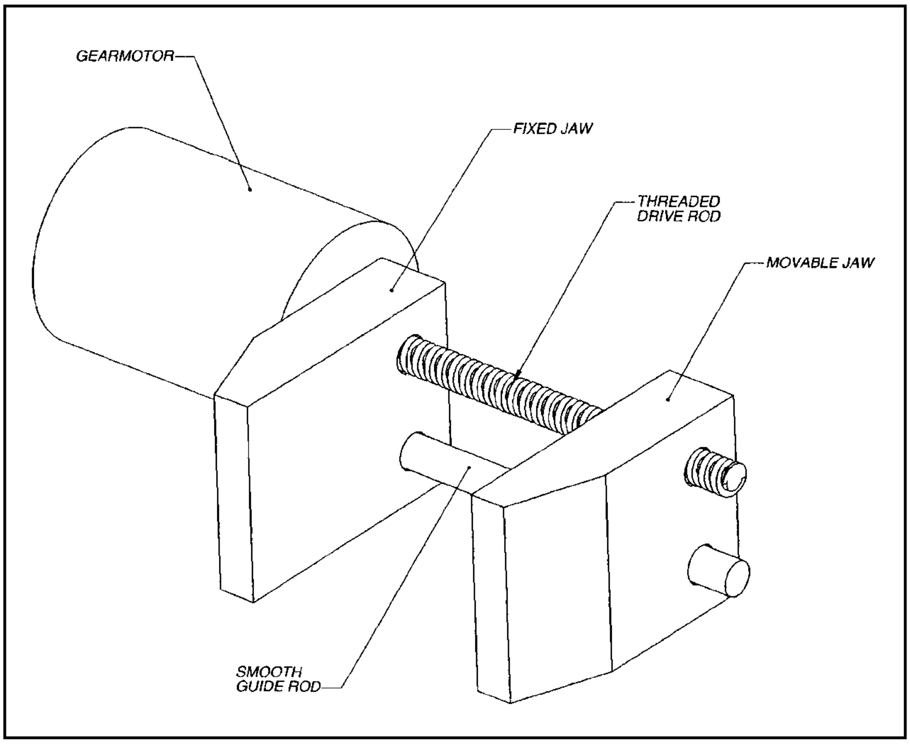

Figure 10-21 Parallel jaw on linear slides

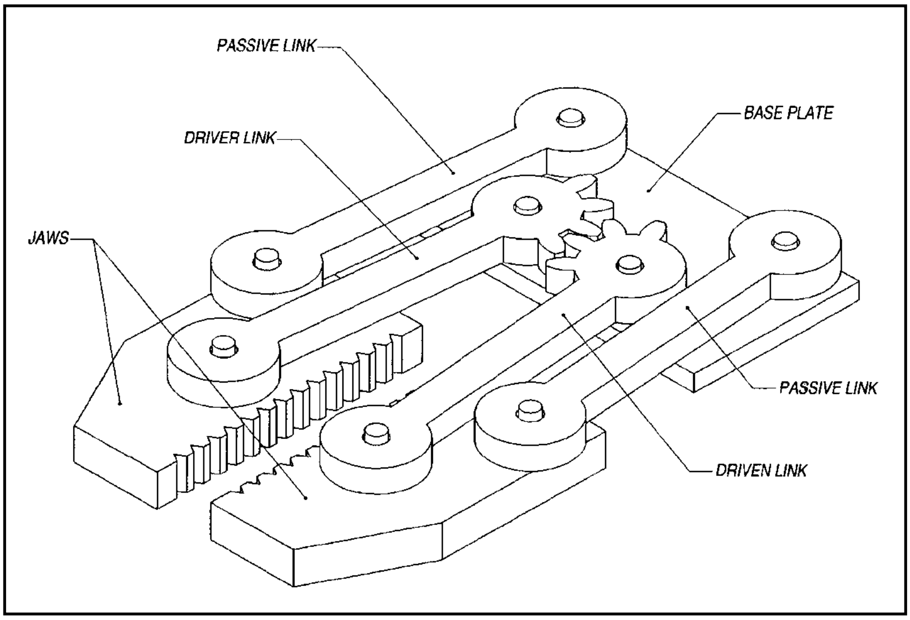

Figure 10-22 Parallel jaw using four-bar linkage

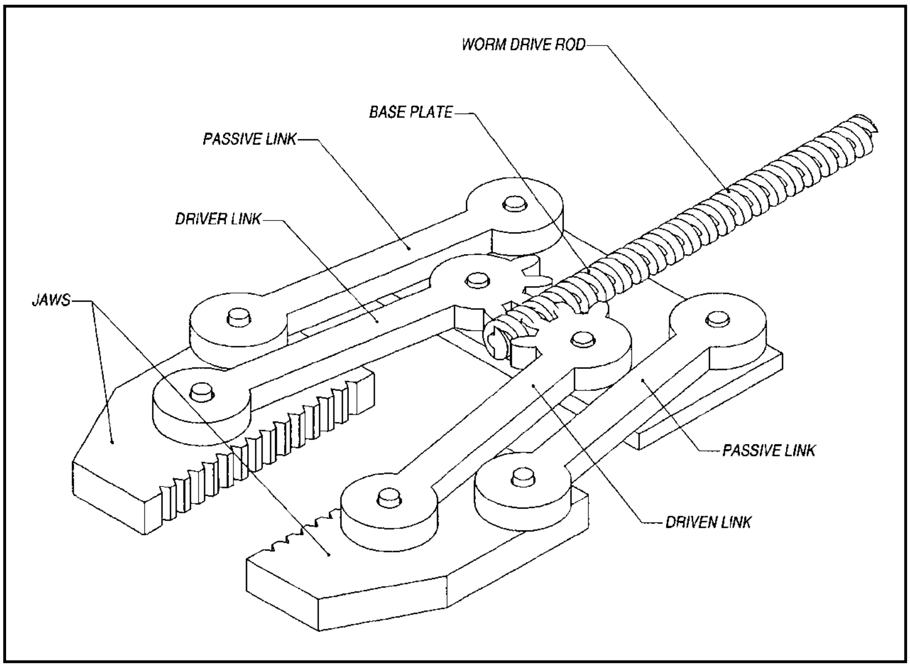

Figure 10-23 Parallel jaw using four-bar linkage and linear actuator

PASSIVE PARALLEL JAW USING CROSS TIE

Twin four-bar linkages are the key components in this long mechanism that can grip with a constant weight-to-grip force ratio any object that fits

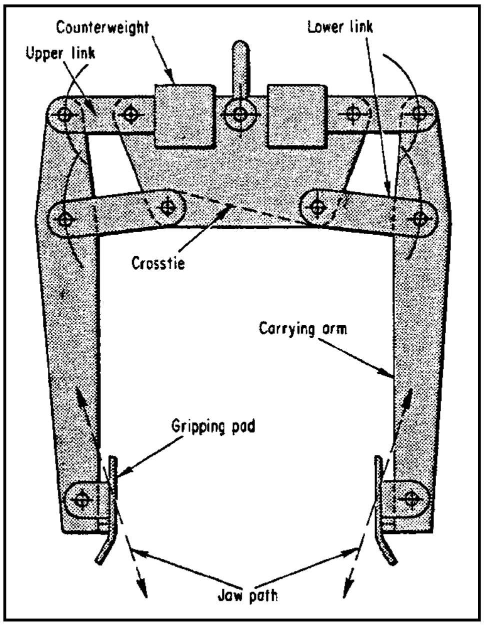

Figure 10-24 Passive parallel jaw using cross tie

within its grip range. The long mechanism relies on a cross-tie between the two sets of linkages to produce equal and opposite linkage movement. The vertical links have extensions with grip pads mounted at their ends, while the horizontal links are so proportioned that their pads move in an inclined straight-line path. The weight of the load being lifted, therefore, wedges the pads against the load with a force that is proportional to the object's weight and independent of its size.

Some robots are designed to do one specific task, to carry one specific object, or even to latch onto some specific thing. Installing a dedicated knob or ball end on the object simplifies the gripping task using this mating one-way connector. In many cases, a joint like this can be used independently of any manipulator.

PASSIVE CAPTURE JOINT WITH THREE DEGREES OF FREEDOM

New joint allows quick connection between any two structural elements where rotation in all three axes is desired.

Marshall Space Flight Center, Alabama

A new joint, proposed for use on an attachable debris shield for the International Space Station Service Module, has potential for commer-

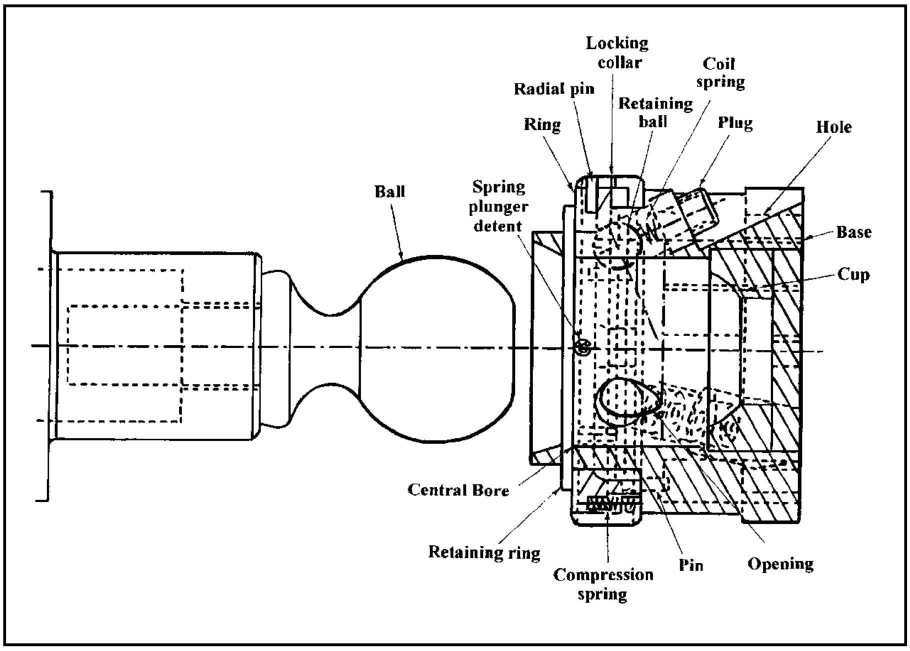

Figure 10-25 The three-degrees-of-freedom capability of the passive capture joint provides for quick connect and disconnect operations.

cial use in situations where hardware must be assembled and disassembled on a regular basis.

This joint can be useful in a variety of applications, including replacing the joints commonly used on trailer-hitch tongues and temporary structures, such as crane booms and rigging. Other uses for this joint include assembly of structures where simple rapid deployment is essential, such as in space, undersea, and in military structures.

This new joint allows for quick connection between any two structural elements where it is desirable to have rotation in all three axes. The joint can be fastened by moving the two halves into position. The joint is then connected by inserting the ball into the bore of the base. When the joint ball is fully inserted, the joint will lock with full strength. Release of this joint involves only a simple movement and rotation of one part. The joint can then be easily separated.

Most passive capture devices allow only axial rotation when fastened—if any movement is allowed at all. Manually- or power-actuated active joints require an additional action, or power and control signal, as well as a more complex mechanism.

The design for this new joint is relatively simple. It consists of two halves, a ball mounted on a stem (such as those on a common trailer-hitch ball) and a socket. The socket contains all the moving parts and is the important part of this invention. The socket also has a base, which contains a large central cylindrical bore ending in a spherical cup.

This work was done by Bruce Weddendorf and Richard A. Cloyd of the **Marshall Space Flight Center**.

INDUSTRIAL ROBOTS

The programmability of the industrial industrial robot using computer software makes it both flexible in the way it works and versatile in the range of tasks it can accomplish. The most generally accepted definition of an industrial robot is a reprogrammable, multi-function manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions to perform a variety of tasks. Industrial robots can be floor-standing, benchtop, or mobile.

Industrial robots are classified in ways that relate to the characteristics of their control systems, manipulator or arm geometry, and modes of operation. There is no common agreement on or standardizations of these designations in the literature or among industrial robot specialists around the world.

A basic industrial robot classification relates to overall performance and distinguishes between limited and unlimited sequence control. Four classes are generally recognized: limited sequence and three forms of unlimited sequence—point-to-point, continuous path, and controlled path. These designations refer to the path taken by the end effector, or tool, at the end of the industrial robot arm as it moves between operations.

Another classification related to control is *nonservoed* versus *servoed*. Nonservoed implies open-loop control, or no closed-loop feedback, in the system. By contrast, servoed means that some form of closed-loop feedback is used in the system, typically based on sensing velocity, position, or both. Limited sequence also implies nonservoed control while unlimited sequence can be achieved with point-to-point, continuous-path, or controlled-path modes of operation.

Industrial robots are powered by electric, hydraulic, or pneumatic motors or actuators. Electric motor power is most popular for the major axes of floor-standing industrial industrial robots today. Hydraulic-drive industrial robots are generally assigned to heavy-duty lifting applications. Some electric and hydraulic industrial robots are equipped with pneumatic-controlled tools or end effectors.

The number of degrees of freedom is equal to the number of axes of an industrial robot, and is an important indicator of its capability. Limited-sequence industrial robots typically have only two or three degrees of freedom, but point-to-point, continuous-path, and controlled-path industrial robots typically have five or six. Two or three of those may be in the wrist or end effector.

Most heavy-duty industrial robots are floor-standing. Others in the same size range are powered by hydraulic motors. The console contains a digital computer that has been programmed with an operating system and applications software so that it can perform the tasks assigned to it.

Some industrial robot systems also include training pendants—handheld pushbutton panels connected by cable to the console that permit direct control of the industrial robot .

The operator or programmer can control the movements of the industrial robot arm or manipulator with pushbuttons or other data input devices so that it is run manually through its complete task sequence to program it. At this time adjustments can be made to prevent any part of the industrial robot from colliding with nearby objects.

There are also many different kinds of light-duty assembly or pick-and-place industrial robots that can be located on a bench. Some of these are programmed with electromechanical relays, and others are programmed by setting mechanical stops on pneumatic motors.

Industrial Robot Advantages

The industrial robot can be programmed to perform a wider range of tasks than dedicated automatic machines, even those that can accept a wide selection of different tools. However, the full benefits of an industrial robot can be realized only if it is properly integrated with the other machines human operators, and processes. It must be evaluated in terms of cost-effectiveness of the performance or arduous, repetitious, or dangerous tasks, particularly in hostile environments. These might include high temperatures, high humidity, the presence of noxious or toxic fumes, and proximity to molten metals, welding arcs, flames, or high-voltage sources.

The modern industrial robot is the product of developments made in many different engineering and scientific disciplines, with an emphasis on mechanical, electrical, and electronic technology as well as computer science. Other technical specialties that have contributed to industrial robot development include servomechanisms, hydraulics, and machine design. The latest and most advanced industrial robots include dedicated digital computers.

The largest number of industrial robots in the world are limited-sequence machines, but the trend has been toward the electric-motor powered, servo-controlled industrial robots that typically are floor-standing machines. Those industrial robots have proved to be the most cost-effective because they are the most versatile.

Trends in Industrial Robots

There is evidence that the worldwide demand for industrial robots has yet to reach the numbers predicted by industrial experts and visionaries some twenty years ago. The early industrial robots were expensive and temperamental, and they required a lot of maintenance. Moreover, the software was frequently inadequate for the assigned tasks, and many industrial robots were ill-suited to the tasks assigned them.

Many early industrial customers in the 1970s and 1980s were disappointed because their expectations had been unrealistic; they had underestimated the costs involved in operator training, the preparation of applications software, and the integration of the industrial robots with other machines and processes in the workplace.

By the late 1980s, the decline in orders for industrial robots drove most American companies producing them to go out of business, leaving only a few small, generally unrecognized manufacturers. Such industrial giants as General Motors, Cincinnati Milacron, General Electric, International Business Machines, and Westinghouse entered and left the field. However, the Japanese electrical equipment manufacturer Fanuc Robotics North America and the Swedish-Swiss corporation Asea Brown Boveri (ABB) remain active in the U.S. robotics market today.

However, sales are now booming for less expensive industrial robots that are stronger, faster, and smarter than their predecessors. Industrial robots are now spot-welding car bodies, installing windshields, and doing spray painting on automobile assembly lines. They also place and remove parts from annealing furnaces and punch presses, and they assemble and test electrical and mechanical products. Benchtop industrial robots pick and place electronic components on circuit boards in electronics plants, while mobile industrial robots on tracks store and retrieve merchandise in warehouses.

The dire predictions that industrial robots would replace workers in record numbers have never been realized. It turns out that the most cost-effective industrial robots are those that have replaced human beings in dangerous, monotonous, or strenuous tasks that humans do not want to do. These activities frequently take place in spaces that are poorly ventilated, poorly lighted, or filled with noxious or toxic fumes. They might also take place in areas with high relative humidity or temperatures that are either excessively hot or cold. Such places would include mines, foundries, chemical processing plants, or paint-spray facilities.

Management in factories where industrial robots were purchased and installed for the first time gave many reasons why they did this despite the disappointments of the past twenty years. The most frequent reasons were the decreasing cost of powerful computers as well as the simplification of both the controls and methods for programming the computers. This has been due, in large measure, to the declining costs of more powerful microprocessors, solid-state and disk memory, and applications software.

However, overall system costs have not declined, and there have been no significant changes in the mechanical design of industrial robots during the industrial robot's twenty-year "learning curve" and maturation period.

The shakeout of American industrial robot manufacturers has led to the near domination of the world market for industrial robots by the Japanese manufacturers who have been in the market for most of the past twenty years. However, this has led to de facto standardization in industrial robot geometry and philosophy along the lines established by the Japanese manufacturers. Nevertheless, industrial robots are still available in the same configurations that were available fifteen to twenty years ago, and there have been few changes in the design of the end-use tools that mount on the industrial robot's "hand" for the performance of specific tasks (e.g., parts handling, welding, painting).

Industrial Robot Characteristics

Load-handling capability is one of the most important factors in an industrial robot purchasing decision. Some can now handle payloads of as much as 200 pounds. However, most applications do not require the handling of parts that are as heavy as 200 pounds. High on the list of other requirements are "stiffness"—the ability of the industrial robot to perform the task without flexing or shifting; accuracy—the ability to perform repetitive tasks without deviating from the programmed dimensional tolerances; and high rates of acceleration and deceleration.

The size of the manipulator or arm influences accessibility to the assigned floor space. Movement is a key consideration in choosing an industrial robot. The industrial robot must be able to reach all the parts or tools needed for its application. Thus the industrial robot's working range or envelope is a critical factor in determining industrial robot size.

Most versatile industrial robots are capable of moving in at least five degrees of freedom, which means they have five axes. Although most tasks suitable for industrial robots today can be performed by industrial robots with at least five axes, industrial robots with six axes (or degrees of freedom) are quite common. Rotary base movement and both radial and vertical arm movement are universal. Rotary wrist movement and wrist bend are also widely available. These movements have been designated as roll and pitch by some industrial robot manufacturers. Wrist yaw is another available degree of freedom.

More degrees of freedom or axes can be added externally by installing parts-handling equipment or mounting the industrial robot on tracks or rails so that it can move from place to place. To be most effective, all axes should be servo-driven and controlled by the industrial robot's computer system.