ROBOT APPLICATIONS

By Prof. S.K. Saha, IIT Delhi

Structure

3.1 Introduction

Objectives

3.2 Industrial Applications

3.2.1 Material Handling

3.2.2 Welding

3.2.3 Spray Painting

3.2.4 Assembling

3.2.5 Machining

3.3 Other Applications

3.3.1 Medical

3.3.2 Mining

3.3.3 Space

3.3.4 Underwater

3.3.5 Defence

3.4 Robot Economics and Safety

3.4.1 Robot Economics

3.4.2 Robot Safety

3.5 Summary

3.6 Key Words

3.7 Answers to SAQs

3.1 INTRODUCTION

As studied in the previous units, a robot is a reprogrammable, multifunctional machine designed to manipulate materials, parts, tools, or specialized devices, through variable programmed motions for the performance of a variety of task. It can conveniently be used for variety of industrial tasks. Today 90% of all robots used are found in factories and they are referred to as industrial robots. Robots are slowly finding their way into warehouses, laboratories, research and exploration sites, power plants, hospitals, undersea, and even outer space. Few of the advantages for which the robots are attractive in industrial uses are as follows :

- Robots never get sick or need to rest, so they can work 24 hours a day, 7 days a week.
- When the task required would be dangerous for a person, they can be do the work instead.
- Robots do not get bored. So the work that is repetitive and unrewarding is of no problem for a robot.

Objectives

After studying this unit you should be able to

- know the various industrial applications of robots,

- various advantages and disadvantages of using robots under a given condition,
- decide whether a particular job is suitable for robots or against it, and
- what are the economical considerations of using robot, and
- relevant safety issues.

3.2 INDUSTRIAL APPLICATIONS

There are certain industrial tasks robots do very well like material transfer, machine loading, spot welding, continuous arc welding, spray coating, material removal, cutting operations, assembling operations, part inspection, part sorting, part cleaning, part polishing, and a dozen more specialized tasks. In this section, some of these applications will be elaborated.

3.2.1 Material Handling

During the sixties and the seventies automation has primarily affected the manufacturing process and too control but not the auxiliary functions such as handling, setup, loading, and unloading. The time spent to transfer a workpiece from one station to the next is still high. Up to 95 percent of the time involved in manufacturing a part is composed of transfer and waiting time, and only about 5 percent of the total time is the part in the actual processing time. Whereas the processing time has been reduced considerably by automation, much less progress has been made in handling and loading. The fully automatic systems that were developed for mass production (e.g., transfer lines in the automobile industry) are rigid (hard automation) and not suitable for batch production (in the order of 50 to 100,000 parts annually). A more flexible automation technology which takes into account frequent changes in production is needed for this category of industrial production, which accounts for about 75 percent of the manufactured parts. Hence, with the development of industrial robots a new solution is offered to the handling and machine tool loading of small and medium series of parts. Actually, loading and unloading machine tools are the major applications of robots. Robots are utilised to load and unload machine tools in two basic configurations :

(a) a robot tending a single machine, and

(b) a robot serving several machines.

The first configuration is applied when typical machining times per part are short, and second system, when a chain of operations must be executed to complete a part. This category includes a wide variety of applications. The items being handled by robots may weigh anything from a few grams to some tonnes. Obviously the type of robot applied will also vary considerably, from lightweight non-servo-controlled pneumatic robots, through medium sized electric types, to massive hydraulic manipulators. For many applications the cylindrical, polar and articulated types are equally suitable, and for some light duty work in restricted areas rectangular types may be used. For material handling applications point to point control is necessary. The controller should be able to store a large number of points and have the facility to easily program horizontal and vertical increments. Thus, by defining only the start point the robot arm can be programmed to pick or place components at equal steps along the X, Y and Z axes by simply defining the length, direction and number of steps.

3.2.2 Welding

Welding is a manufacturing process in which two pieces of metal are joined usually by heating and fusing. The welding operations performed by robots are thermal processes in which the metals are joined by melting or fusing their contacting surfaces. These processes can be grouped under two classes, by namely, where no filler material is added to the joint interface, and in which a filler material of the same type as the parent metal is added. Accordingly, there are two types of welding operations performed by the robots :

spot welding and arc welding. Spot welding falls in the first category which the two pieces of metal are joined only *at certain points*. The required heat is generated by the passage of an electric current through the metals at the point where they are to be joined. Spot welding is frequently used in the automative industry to join thin sheet metals. Arc welding falls in the second category in which the two metals are joined *along a continuous path*. The required heat is provided by an electric arc generated between the electrode and the metals. Arc welding is needed, for example, in sealing a container against leakage. Each of these welding operations requires a different type of equipment and a different control system for the robot arm.

Spot-welding Robots

A spot-welding robot has to carry the welding gun, which consists of the electrodes, the cables which are required to conduct the high current, and sometimes a water-cooling system for the electrodes. The welding gun is relatively heavy (10 to 80 kg), and many DC motor driven robots cannot handle such heavy loads. Therefore, most of the spot-welding robots are hydraulically powered. The control system for spot-welding robots is of a point to point (PTP) type. The desired positional accuracy is usually not high, and a positional repeatability of ± 1 mm is sufficient. This repeatability is much better than that obtained by human welders. Further, the operation of robotised spot welding is very fast. When the distance between spot welds is 25-50 mm, several spot welds can be made per second – faster than human welders. Positioning of the welds is more accurate, resulting in more uniform quality.

Spot-welding generates sparks which might be detected by the robot controller as feedback pulses. Therefore, robots operating in a spot-welding environment may require isolation transformers or special screening and filtering devices for their controllers to protect them from the electrical noise and ensure reliable positioning. Another special feature is an arm that enclosed and thereby protects the cables from sparks. Spot-welding robots are used in fabrication of structural metal products, domestic appliances, metal furniture, containers which do not require liquid-tight joints, etc. However, nowhere have spot-welding robots affected industry operation more than in car body assembly. The first spot-welding robots were installed in 1969 at a General Motors plant for welding car bodies. Since then spot-welding robots have proved to be very profitable. Moreover, parts of the robots can be suspended from the ceiling, which saves expensive floor space. Several robots can operate simultaneously on the same car body, which increases the efficiency of the assembly line. Better efficiency is also obtained by specifying fewer welds for robot welding than with human welders. A human operator might miss a weld or make it in an incorrect location, and therefore many times extra welds are added at the design stage. With robot operation the work is consistent and all the welds are placed in the right location and therefore the required body strength can be achieved by specifying fewer welds.

A typical assembly line produces between 50 to 90 cars per hour, and the work is performed while the car bodies are continuously moving on conveyors, which means that the weld locations specified by the task programs should be synchronised with the velocity of the assembly line. Since the velocity of the assembly line is constant, the positional compensation is inserted off line into the task programs, and consequently those programs are appropriate only for one specific line velocity.

Arc Welding Robots

While most robotic arc welding uses a consumable wire electrode (i.e., in MIG welding) with an automatic wire feeder, welding with non-consumable tungsten electrodes with shielding gas (i.e., in TIG welding) is also in use.

In arc welding the robot uses the welding gun as a tool. The mechanism is demonstrated in Figure 3.1. The consumable electrode, which provides the filler material, is in the form of a wire (coiled on a drum) of the same composition as the material to be welded. Wire diameters of 0.8 to 4.8 mm are commonly used. The wire is automatically fed by a motor with adjustable speed at a preset rate that is determined by the arc voltage. The wire feed increases with an increase in the voltage applied between the work and the electrode. This voltage can be monitored and used to maintain a constant arc length by varying the speed of the motor which feeds the wire. In order to keep the electrode cooler and permit higher currents to be used, the shielding gas flows in a tube along the electrode. The tube is terminated in a nozzle at the end of the gun from which the gas flows into the arc region. Welding robotic systems sometimes use water-cooler guns.

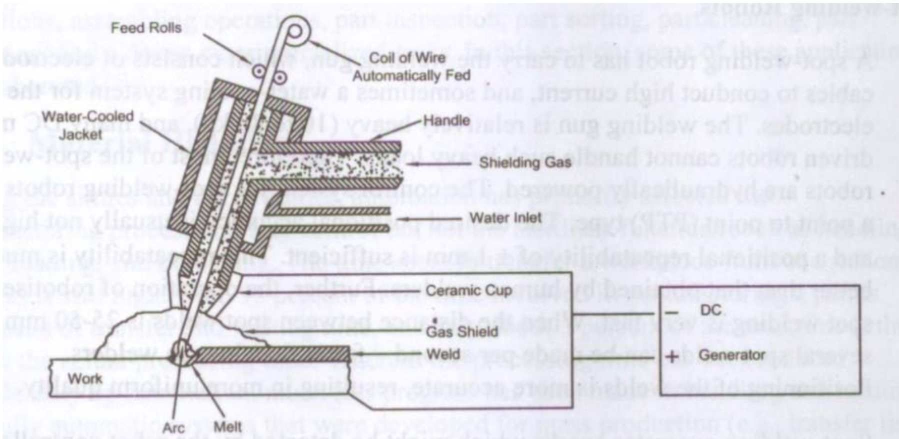

Figure 3.1 : Insert Gas Shielded Arc Welding with a Continuous Wire Fed as Electrode

The weight of the welding gun is usually not heavy (unless the water-cooled type is used) and therefore DC servomotor-driven robots are typically used in arc welding, although hydraulically drive robot are also sometimes used. Welding speeds range from about 10 to over 120 in/min (0.25 to 3 m/min). The welding current usually ranges between 100 and 300 A, but with the larger electrodes the current may be as high as 1200 A, resulting in a very deep penetration of the weld. The control of both the rate at which the wire electrodes is fed and the welding cycle (i.e., the time during which the inert gas flows) are performed by the standard welding equipment. The task of the robot is to lead the welding gun along the programmed trajectory. The control system for robots in arc welding is usually of a continuous path (CP) type. Nevertheless, PTP control systems are also used. In point to point (PTP) programming the required trajectory is divided into a large number of small (e.g., 1 cm) and equal segments. In all cases the control computer of the robot is interfaced with the control unit of the welding equipment in order to synchronise the start and termination of the robot motions with the cycle of the welding equipment.

3.2.3 Spray Painting

The unhealthy and unpleasant environment of the painting booth in industry made this process an ideal candidate for the application of robots. The solvent materials that are used in spray painting are toxic, and therefore the operators must be protected by masks and be provided with fresh-air ventilation. The painting area must be dust-free and temperature-controlled, and consequently the painting booth is small in size and inconvenient for the operators. Furthermore, the noise arising from the air discharge through the painting nozzles can cause irreversible damage to the ears. For all these reasons, spray painting became one of the first applications of robots. The requirement for robots in spray painting are different from those of other robot applications, and therefore many robot manufacturers offer a robot dedicated to this one application. The spray painting robots are of CP capability and have the following characteristics :

(a) high level of manipulator dexterity,

(b) large working volume for small-base manipulator,

(c) compact writs,

(d) small payload, and

(e) low accuracy and repeatability.

The painting robot must be able to carry any type of spray gun. Spray guns, however, are light in weight and therefore painting robots are designed for small payloads (e.g., 1 kg).

Finally, the requirements for repeatability and resolution are the least severe in painting robots. The exact location of end points is not critical, and in many jobs can be even outside the painted surface. Therefore, a repeatability of 2 mm throughout the working volume is regarded as sufficient for spray-painting robots.

3.2.4 Assembling

Assembling with industrial robots are mainly used for small products such as electrical switches and small motors. Robotised assembly systems are programmable and therefore provided a cost-effective solution for the assembly of small batch sizes and for batches containing different products. Although industrial robots require the same fixtures, feeders, and other equipment for positioning the parts as conventional assembly machines, simpler workpiece feeder and fixtures may be used because of robots' programmability feature. Furthermore, tactile or optical sensors may be added to the assembly robot to tackle more complex assembly tasks. Some assembly tasks require the participation of more than one robot. In order to reduce the cost per arm, there are systems in which several cartesian arms can use the same base and share the same controller. Assembly robots can be designed in any coordinate system, cartesian, cylindrical, spherical, or articulated. However, many tasks require only vertical assembly motions, such as the assembly of printed circuit boards. For these applications the four-six robot shown in Figure 3.2 can be adequate. Its arm has two articulated motions, and the wrist has two axes of motion : a linear vertical displacement and a roll movement. This robot can pick up parts located on the horizontal plane, bring them to the assembly location, orient them with the roll motion of the wrist, and finally insert them in a vertical motion.

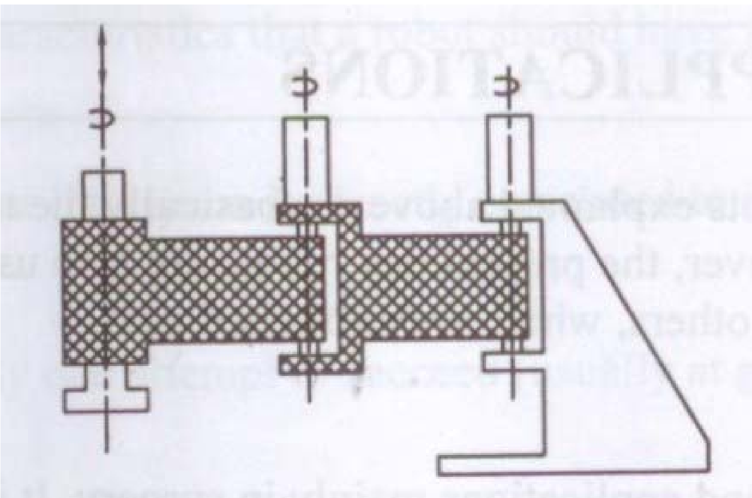

Figure 3.2 : SCARA-type Robot for Assembly in the Vertical Direction

This class of robot is known as the *selective-compliance-assembly robot-arm* (SCARA) type robot, and was developed in Japan.

3.2.4 Machining

There are five basic types of machine tools to perform machining : drilling machine, lathe or turning machine, milling machine, shaper, and grinder. Out of all these machining operations, only drilling is being successfully done with robots, and mainly in the aircraft industry. Another application related to machining which is performed by robots is deburring metal parts. Most metal parts made by machining operations (either by machine tools or by mass production machines) contain burrs, that is, rough edges or ridges left on the machined surfaces. The removal of these burrs can be done by robots.

Drilling

Robots can replace the manual operators if the template hole is provided with a chamfered guide. The gripper of the robot holds a portable pneumatic drill and guides from hole to hole. At each hole, a fixed drill cycle is performed, and then the robot moves the drill to the next hole. Programming the robot to perform the task is quite simple. Since drilling is PTP operation, the manual teaching method is appropriate. The programming and control methods are much more complicated when CP machining operations
(e.g. deburring) are applied.

Deburring

Burrs are generated almost always when machining is performed on metal parts. Burrs are generated between a machined surface and a raw surface, or at the intersection between two machined surfaces. The removal of these burrs is an expensive operation. Most deburring is performed manually by workers equipped with appropriate tools. By closely following the manual method, the industrial robot can solve most deburring problems.

There are two basic way to perform robotised deburring. If the part is relatively lightweight, it can be picked up by the robot and brought to the dubrring tool. If the part is heavy, then the robot holds the tool. The support of the tool is very important, whether it is held by the robot or mounted on the work table. In both cases the relative motion between the tool and the part is of a CP type with high repeatability (approximately 0.2 mm) and highly controlled speed. Therefore, deburring is one of the most difficult tasks for robots.

SAQ 1

(a) In what type of welding robots are used?

(b) What are the characteristics of spray painting robots?

3.3 OTHER APPLICATIONS

The applications of robots explained above are basically the tasks previously performed by human beings. However, the present day robots are also used in medical surgery, space explorations, and others, which are explained next.

3.3.1 Medical

Medical robots have found applications mainly in surgery. It is a highly interactive process and many surgical decisions are made in the operating room. The goal of surgical robots is not to replace the surgeon with a robot, but to provide the surgeon with a new set of very versatile tools that extend his or her ability to treat patients. Hence, medical robotic systems are *surgical assistants* that work cooperatively with surgeons. A special subclass of these systems is often used for remote surgery. Currently, there are two main varieties of surgical assistant robot are available. The first variety, *surgeon extender*, is controlled directly by the surgeons. They augment or supplement the surgeon's ability to manipulate surgical instruments during surgery. The promise of these systems is that they can give even average surgeons superhuman capabilities such as elimination of hand tremor or ability to perform dexterous operations inside the patient's body, etc. As a result, casualty rates are reduced, and operative times are shortened. The second variety, *auxiliary surgical support*, generally works side-by-side with the surgeon and perform such functions as endoscope holding or retraction. These systems typically provide one or more direct control interfaces such as joysticks, head trackers, voice control, or the like. However, the surgeon should be attentive during their use, e.g., while using robot vision to keep the endoscope aimed at an anatomic target.

Note that initial surgical robotic systems in the 1980s employed general-purpose industrial manipulators, either directly or with minor modifications. Industrial robots are still being used today as research and validation tools where immediate clinical use is not contemplated or specialised kinematic design is not essential. Surgical robots must be compatible with the operating theatre. The robot must have sufficient strength, accuracy, and dexterity for its intended use. It must be placed where it can work on the patient while also allowing access by clinical staff. Usually, this is done by mounting the robot to the operating table or placing it on the floor beside the patient. However, ceiling mounts and attachment to the patient are occasionally used.

3.3.2 Mining

In order to enhance productivity, access unworkable mineral seams, and reduce human exposure to the inhospitable environment of dust, noise, gas, water, moving equipment and robots are used. In coal mining room-and-pillar mining is accomplished by repetition of a well-defined cycle of cutting coal, removing coal, and supporting the roof. When a robot is used the ability to maneuver it in highly constrained corridor-like environments, and to accurately cutting coal is required. Data from the laser range scanner can be used to model the environment and to compute the position of the robot.

3.3.3 Space

Explorations of the planets, moons and other near bodies in space are a clear goal for the international space science community. A robotic approach to explore these bodies has the benefit of being able to achieve many of the things a human could do but at lower cost without endangering human life. To be effective, such robotic systems must be versatile and robust with cost reduction becoming increasingly important. There are a variety of tasks that the robots can do in space including space manipulation (servicing equipment in space), surface mobility (planetary exploration), and robotic colonies (outposts that are either self-sustaining, or preparatory for human colonies). In addition, robots may perform scientific experiments that include sample and return of planetary atmosphere or terrain, manipulating the environment (moving rocks, drilling, etc.), testing the composition of the atmosphere and other tests using arbitrary scientific equipment. There are three characteristics that a robot should have for space missions :

Compactness and Lightness

The cost of sending robot into space is directly correlated to its size and weight.

Robustness

Missions often have only one attempt to succeed (usually at great cost).

Versatility and Adaptability

In exploration where the environments are inherently unknown, adaptability must be high to increases the chance of success.

3.3.4 Underwater

Underwater applications of robots involve prospecting for minerals on the floor of the ocean (e.g., nodules of manganese), salvaging of sunken vessels, and the repair of ships either at sea or in dry dock. In the latter case, a prototype version of a mobile robot that is used to clean barnacles from the sides of ships has been built and tested in France by a ship-building company. This rather remarkable tripod is capable of moving in either air (i.e., above the waterline) or in water. It grips the ships sides with both vacuum and magnetic feet, a technique that has proven to be reliable. The scrubbing action is produced by a rotating brush mounted on the end of a rotary axis arm.

3.3.5 Defence

The defence people, namely, the air force and navy, are both interested in mobile fire fighters. These devices would be equipped with infrared sensors and could react more quickly than people in an emergency and in extremely hazardous situations. Other defence applications of robots will be on the battlefield itself. Although it is not inconceivable that robots might someday be used to fight other robots, more realistic short-term applications from the defence's point of view would be in the areas of surveillance (e.g., guard and sentry duty), mine sweeping, and artillery-loading devices.

The application of robots for surveillance and guard duty can be in power generating plants, oil refineries, and other large civilian facilities that are potential targets of the terrorist groups. The robots for these applications would probably be mobile (running on wheels, treads, or tracks), equipped with some form of vision system and other types of sensors (e.g., infrared), and even have defensive and/or offensive capability. In fact, several police forces (e.g., those in New York City and in London) have already employed prototypes of this class of robots for bomb disposal.

3.4 ROBOT ECONOMICS AND SAFETY

In this section, economics and safety issues associated with robot usages are explained.

3.4.1 Robot Economics

The success of any commercial undertaking has to be measured in terms of financial performance. The most brilliant technical innovation is a failure if it results in money lost by the entrepreneur or his shareholders. Robots are no exception to this rule. No matter what the social benefits are, no matter how clever the technology, no matter how pretty the robot is to watch, every proposed investment in robotics has to pass the test of a critical financial appraisal. The following headings provide a framework for management to analyse the costs and benefits of the robotics installation.

Purchase Price of the Robot

The purchase price of a robot is highly variable, particularly, if one definition of robot includes simple pick and place devices with few articulations. The range might extend from Rs. 10 lakhs to Rs. 50 lakhs depending upon the number of articulations, operating area, weight handling capacity and control sophistication. Generally speaking the higher priced robots are capable of more demanding jobs and their control sophistication assures that they can be adapted to new jobs when original assignments are completed. So the more expensive and more sophisticated robot will normally require less special tooling and lower installation cost.

Special Tooling

Special tooling for a robot may include an indexing conveyor, weld guns, transformers, clamps and a supervisory computer for a complex task of robots, e.g., in the spot welding of car bodies. For assembly automation, the special parts may cost well in excess of the robot equipment costs.

Installation

Installation cost is sometimes charged fully to a robot project, but is often carried as overhead because plant layout changes. As a model change there are usually installation costs to be absorbed even if equipment is to be manually operated. There is no logic to penalising the robot installation for any more than a differential cost which is inherent in the robotising process.

Maintenance and Periodic Overhaul

To keep a robot functioning properly, there is a need for regular maintenance, a periodic need for more sweeping overhaul and a random need to correct unscheduled downtime incidents. A rule of thumb for well-designed production equipment operated for two shifts continually is a total annual cost of 10% of the purchase price. This has been borne out for thousands of Unimates many of which have enjoyed several overhauls whilst accumulating as much as 10,000 hours of field usage each. There is variability, of course, depending upon the demands of the job and the environment. Maintenance costs in a foundry are greater than those experienced in plastic moulding.

Operating Power

Operating power is easily calculated as the product of average power drain and the hours worked. Even with increasing energy costs, this is not a major robot cost.

Finance

In some cost justification formulae one takes into account the current cost of money. In others one uses an expected return on investment to establish economic viability.

Depreciation

Robots, like any other equipment will exhibit a useful life and it is ordinary practice to depreciate the investment over this useful life. Since a robot tends to be general purpose equipment, there is ample evidence that an 8 to 10 year life running multi-shift is a conservative treatment.

The following observations are also made on potential benefits.

Increased Productivity

The prime issue in justifying a robot is increased productivity. Industries are interested in shielding workers from hazardous working conditions, but the key motivator is the increased productivity by introducing a robot that can operate for more than one shift continuously and thereby multiply the production rate.

Quality Improvement

If a job is in a hazardous environment, or is physically demanding, or is simply mind-numbing, there is a good chance that product quality will suffer according to the mood of a human worker. A robot may well be more consistent on the job and therefore it may produce a higher quality output.

Increase in Throughput

Higher quality naturally means more net output when robot woks fast enough to just match a human workers' output. However, there often are circumstances where a robot can work faster to increase gross output as well. The increased throughput is valuable in its own right.

3.4.2 Robot Safety

It is said that robots take over the hazardous jobs, but at the same time new risks are involved. One thing that must be kept in mind is that a robot is a type of automatic machine – a very sophisticated one, but a machine nevertheless. It has to be treated with respect like any other piece of equipment. Accidents involving robots can happen just as with other machinery. The robot workplace must be watched to prevent operators from hurting themselves through carelessness, exactly as it is done with other automated machines. Robots, however, may need more attention, since their workspace is much larger than the occupied floor space, and people may not be aware of the danger of the moving manipulator. Some of the possible ways the accidents can happen are as follows :

(a) The arm of a robot suddenly shot up as the oil-pressure source was cut off after the robot ended work.

(b) A robot made a motion that was not part of its program.

(c) A robot started moving as soon as its power source was switched on, although its interlock conditions were still not ready.

(d) When operating alone, a robot destroyed the work it was to weld because of a mistake in program instruction.

(e) During hot summer weather, the arm of a robot sprang up, although it had otherwise been working normally.

The most common causes of malfunctions are reported to be electrical noise, oil-pressure valve troubles, encoder-related problems, electronic malfunctions, and mistakes by human workers. Safety measures for using robots must be imposed for the following reasons :

(a) For programming, humans must enter the workspace of robots.

(b) Monitoring, tool changing, inspection, and other operations involving robots or their peripheral equipment are still done by humans.

(c) To correct problems with peripheral equipment, it is necessary to enter the workspace of robots.

(d) Since each robot installation is different, each presents unique application problems.

(e) In programmed or accidental halt, the operator might enter the workspace to inspect the work or investigate the trouble.

To take care of the issues arising out of the above reasons, the following three aspects must be looked into :

(a) the design of a reliable control system to prevent malfunctions,

(b) the design of the workstation layout, and

(c) training of plant personnel (programmers, operators, and maintenance staff).

While the first aspect depends on the robot manufacturer, the other two must be taken care of in the plant itself. The following guidelines can help to remove hazardous situations to robot personnel, factory workers, visitors, and to the robot itself :

(a) The robot working area should be closed by permanent barriers (e.g., fences, rolls, and chains) to prevent people from entering the area while the robot is working. The robot's each envelope diagram should be used in planning the barriers. The advantage of fence-type barrier is that is also capable of stopping a part which might be released by robot's gripper while in motion.

(b) Access gates to the closed working area of the robot should be interlocked with the robot control. Once such a gate is opened, it automatically shuts down the robot system.

(c) An illuminated working sign, stating "robot at work," should be automatically turned on when the robot is switched on. This lighted sign warns visitors not to enter into the closed area when the robot is switched no, even if it does not move.

(d) Emergency stop buttons must be provided in easily accessible locations as well as on the robot's teach box and control console. Hitting the emergency button stops power to the motors and causes the brakes on each joint to be applied.

(e) Pressure-sensitive pads can be put on the floor around the robot that, when stepped on, turn the robot controller off.

(f) Emphasise safety practices during robot maintenance. In addition, the arm can be blocked up on a specially built holding device before any service work is started.

(g) Great care must be taken during programming with the manual reaching mode. The reach box must be designed so that the robot can move as long as a switch is pressed by the operator's finger. Removing the finger must cease all robot motions.

(h) The robot's electrical and hydraulic installation should meet proper standards. This includes efficient grounding of the robot body. Electric cables must be located where they cannot be damaged by the movements of the robot. This is especially important when the robot carries electrical tools such as a spot-welding gun.

(i) Power cables and signal wires must not create hazards if they are accidentally cut during the operation of the robot.

(j) If a robot works in cooperation with an operator, for example, when a robot forwards parts to a human assembler, the robot must be programmed to extend its arm to the maximum when forwarding the parts so that the worker can stand beyond the reach of the arm.

(k) Mechanical stoppers, interlocks, and sensors can be added to limit the robot's reach envelope when the maximum range is not required. If a wall or a piece of machinery not served by the robot is located inside the reach envelope, the robot can be prevented from entering into this area by adding photoelectric devices, stoppers, or interlock switches in the appropriate spots. There are robots supplied when adjustable mechanical stoppers for this purpose.

Another approach states that only robots themselves are able to detect the approach of humans. Therefore, the solution to the safety problem is to provide sensor system that can detect intruders entering the robot area while it is in motion. The American National Bureau of Standards (NBS) divides the sensor systems into three levels :

Level I : Perimeter penetration detection around the workstation

Level I systems provide perimeter penetration detection around the robot workstation. These systems provide an indication of an intruder crossing the workstation boundary, but they do not necessarily provide any information regarding the location of the intruder within the workstation. The simplest safety strategy approach might be to use the level I system to alert personnel that they are entering a robot workstation and that they should exercise extreme caution or to provide a preliminary signal to the robot control system to check the status of other safety sensors.

Level II : Intruder detection within the workstation

Level II systems provide detection in the region between the workstation perimeter and some point on, or just inside, the working volume of the robot. The actual boundaries of this region are dependent upon the workstation layout and the safety strategy being employed for a particular robot design. In some cases, it may be permissible for personnel to be inside the workstation and perhaps even inside a portion of the accessible working volume of the robot while the robot is operating. In others, it may be necessary to slow down to halt all robot movements as soon as an intruder gets within a specified distance of the robot.

Level III : Intruder detection very near the robot (a "safety skin")

Level III systems provide detection within the robot working volume. This type of system, sometimes referred to as a safety skin, is required for cases where personnel must work close to the robot, such as during teach-mode operations. In such cases, the robot must be operational even though someone is within the working volume. The level III system must be capable of sensing and avoiding an imminent collision between the robot and the operator in the event of some unexpected movement. Because the distance between the robot and the operator is much less in this case, the response time of the level III safety system must be much shorter than for the level I or II systems. These smaller separation distances also impose a requirement for finer distance-resolving capabilities in the level III system.

Figure 3.3 illustrates how the transducers are positioned to provide coverage in the workspace area. Since robot installations are not standard and depend on the exact location in the plant, it is difficult to provide guidelines or a design of a sensor safety system which will fit all cases. Therefore, it is wise to have a safety engineer check out the installation before putting the robot to production work.

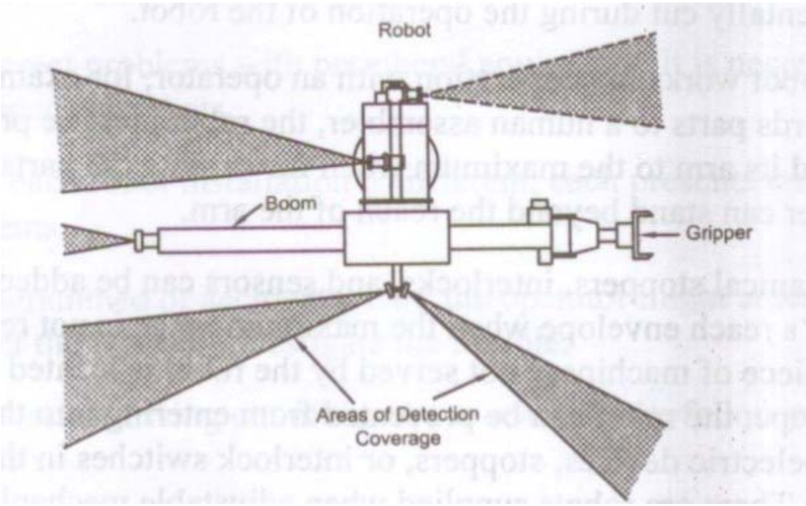

Figure 3.3 : Robot Transducers with Coverage Areas

SAQ 2

(a) Write how the robots can be used in medical surgery?

(b) What are the aspects of robotics a company management would look for?

(c) What are the safety issues in robotics?

.5 SUMMARY

In this unit, industrial and other applications of robots are presented. It is important to decide whether a robot should be used or not for an application. Moreover, robot safety should consider while installing them in a factory setup. These aspects are also explained here.

3.6 KEY WORDS

PTP	**:**	Point to point.
CP	**:**	Continuous path.
Industrial	**:**	Typical activities, e.g. is auto manufacturing and others.

3.7 ANSWERS TO SAQs

Please refer the preceding text for all the Answers to SAQs.

FURTHER READINGS

Koren, Y. (1987), *Robotics for Engineers*, McGraw Hill, New Delhi.

Klafter, R. D., Chmielewski, T. A., and Negin, M. (1994), *Robotic Engineering – An Integrated Approach*, Prentice-Hall India, New Delhi.