Manufacturing Automation

Robotics in Manufacturing

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Robotics in Manufacturing

An **industrial robot** is defined as *"an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications."*

MOTIVATIONAL FACTORS/ECONOMIC JUSTIFICATION TO USE ROBOTS IN INDUSTRIES

Hazardous work for humans

When the work and the environment in which it is performed are hazardous, unsafe, unhealthful, uncomfortable, or otherwise unpleasant for humans, an industrial robot should be considered for the task. In addition to die casting, there are many other work situations that are hazardous or unpleasant for humans, including spray painting, arc welding, and spot welding. Industrial robots are applied in all of these processes.

Repetitive work cycle

A second characteristic that tends to promote the use of robotics is a repetitive work cycle. If the sequence of motion elements in the work cycle is the same, or nearly the same, a robot is usually capable of performing the cycle with greater consistency and repeatability than a human worker.

Difficult handling for humans

If the task involves the handling of parts or tools that are heavy or otherwise difficult to manipulate, an industrial robot may be available that can perform the operation.

Multi-shift operation

In manual operations requiring second and third shifts, substitution of a robot provides a much faster financial payback than a single shift operation. Instead of replacing one worker, the robot replaces two or three workers.

Infrequent changeovers

Most batch or job shop operations require a changeover of the physical workplace between one job and the next. The time required to make the changeover is non-productive time because parts are not being made. Consequently, robots have traditionally been easier to justify for relatively long production runs where changeovers are infrequent.

APPLICATION OF ROBOTS IN INDUSTRIES

Material Transfer

These applications are ones in which the primary purpose of the robot is to move parts from one location to another. The basic application in this category is called a pick-and-place operation, in which the robot picks up a part and deposits it at a new location. Transferring parts from one conveyor to another is an example. Only two or three joints are required for many of the applications, and pneumatically powered robots are often used.

A more complex example of material transfer is palletizing, in which the robot retrieves parts, cartons, or other objects from one location and deposits them onto a pallet or other container at multiple positions on the pallet.

Other applications similar to palletizing include depalletizing, which consists of removing parts from an ordered arrangement in a pallet and placing them at another location (e.g., onto a moving conveyor); stacking operations, which involve placing flat parts on top of each other; and insertion operations, in which the robot inserts parts into the compartments of a divided carton.

Machine Loading and/or Unloading

In machine loading and/or unloading applications, the robot transfers parts into and/or from a production machine.

The three possible cases are

- machine loading, in which the robot loads parts into the production machine, but the parts are unloaded from the machine by some other means;
- machine unloading, in which the raw materials are fed into the machine without using the robot, and the robot unloads the finished parts; and
- machine loading and unloading, which involves both loading of the raw work part and unloading of the finished part by the robot.

Industrial robot applications of machine loading and/or unloading include the following processes:

- **Die casting.** The robot unloads parts from the die casting machine. Peripheral operations sometimes performed by the robot include dipping the parts into a water bath for cooling.
- **Plastic molding.** Plastic molding is similar to die casting. The robot unloads moulded parts from the injection molding machine.
- **Metal machining operations**. The robot loads raw blanks into the machine tool and unloads finished parts from the machine.
- **Forging**. The robot typically loads the raw hot billet into the die. holds it during the forging strikes, and removes it from the forge hammer.
- **Press working**. Human operators work at considerable risk in sheet metal press working operations because of the action of the press. Robots are used to substitute for the workers to reduce the danger. In the simplest applications, the robot loads the blank into the press, then the stamping operation is performed, and the part falls out of the machine into a container.
- **Heat-treating**. These are often simple operations in which the robot loads and/or unloads parts from a furnace.

Spot welding

Robots used for spot welding are usually large, with sufficient payload capacity to wield the heavy welding gun. Five or six axes are generally required to achieve the position and orientation of the welding gun. Playback robots with point-to-point control are used. Jointed-arm robots are common in automobile spot-welding lines, which may consist of several dozen robots.

Arc welding

Industrial robots can also be used to automate the arc welding process. The cell consists of the robot, the welding apparatus (power unit, controller, welding tool, and wire feed mechanism), and a fixture that positions the components for the robot. The fixture might be mechanized with one or two axes so that it can present different portions of the work to the robot for welding (the term positioner is used for this type of fixture). The robot used in arc welding must be capable of continuous path control. Jointed arm robots consisting of six joints are frequently used.

Spray coating

Robot applications include spray coating of automobile car bodies, appliances, engines, and other parts; spray staining of wood products; and spraying of porcelain coatings on bathroom fixtures. The robot must be capable of continuous path control to accomplish the smooth motion sequences required in spray coating.

Other processing operations where robots are used

- Drilling, routing, and other machining processes
- Grinding, wire brushing, and similar operations
- Waterjet cutting
- Laser cutting

Assembly

Assembly involves the combining of two or more parts to form a new entity, called a subassembly or assembly. The most appealing application of industrial robots for assembly involves situations in which a mix of similar models are produced in the same work cell or assembly line. Examples of these kinds of products include electric motors, small appliances, and various other small mechanical and electrical products.

Inspection

Inspections accomplish the following functions:

- making sure that a given process has been completed,
- ensuring that parts have been assembled as specified, and
- identifying flaws in raw materials and finished parts.

Inspection tasks performed by robots can be divided into the following two cases:

- The robot performs loading and unloading to support an inspection or testing machine.
- The robot manipulates an inspection device, such as a mechanical probe or vision sensor, to inspect the product.

Collaborative Robots

These applications involve robots and humans working together to perform a task. They collaborate, synergistically leveraging the strengths of the robot (accuracy, repeatability, speed, lifting capability, and tirelessness) with the strengths of the human worker (intelligence, adaptability, and problem solving ability).

ADVANTAGES OF INDUSTRIAL ROBOTS

Better quality and consistency

Industrial robots are able to provide better production quality and more precise and reliable processes. Added benefits also include reduced cycle times and real-time monitoring to improve preventive maintenance practices.

Maximum productivity and throughput

An industrial robot increases speed for manufacturing processes, in part by operating 24/7. Robots don’t need breaks or shift changes. The speed and dependability of robots ultimately reduces cycle time and maximizes throughput.

Greater safety

Using robots for repetitive tasks means fewer risks of injury for workers, especially when manufacturing has to take place under hostile conditions. In addition, supervisors can oversee the process online or from a remote location.

Reduced direct labour costs

The cost of having a person handle many manufacturing operations is often more expensive than robot. This can also free up workers so their skills and expertise can be used in other business areas, such as engineering, programming and maintenance.

Prestige

You set yourself at the cutting edge of your industry and wow your customers when they come to see you. As a marketing tool robots are fantastic, boost your brand image, and have often been used simply for the PR even if they don’t offer many benefits over a bespoke non-robotic system.

DISADVANTAGES OF INDUSTRIAL ROBOTS

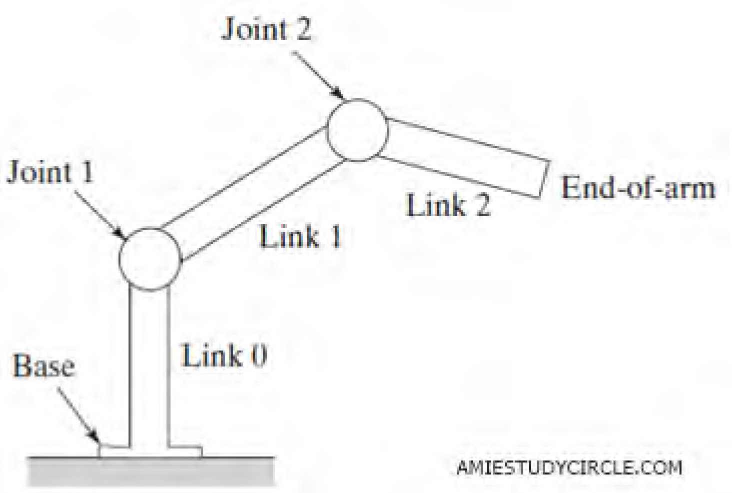
- The use of robots can create economic problems if they replace human jobs
- Robots can only do what they are told to do – they can’t improvise This means that safety procedures are needed to protect humans and other robots

- Although robots can be superior to humans in some ways, they are less dextrous than humans, they don't have such powerful brains, and cannot compete with a human's ability to understand what they can see.
- Often robots are very costly – in terms of the initial cost, maintenance, the need for extra components and the need to be programmed to do the task.

JOINTS AND LINKS

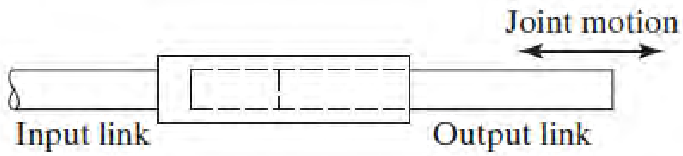
- A robot's joint, or axis as it is also called in robotics, is similar to a joint in the human body: It provides relative motion between two parts of the body.
- Robots are often classified according to the total number of axes they possess.
- Connected to each joint are two links, an input link and an output link. Links are the rigid components of the robot manipulator.
- The purpose of the joint is to provide controlled movement of the output link relative to the input link.

Most robots are mounted on a stationary base on the floor. Let this base and its connection to the first joint be referred to as link 0. It is the input link to joint 1, the first in the series of joints used in the construction of the robot. The output link of joint 1 is link 1. Link 1 is the input link to joint 2, whose output link is link 2, and so forth. This joint-link numbering scheme is illustrated in following figure.

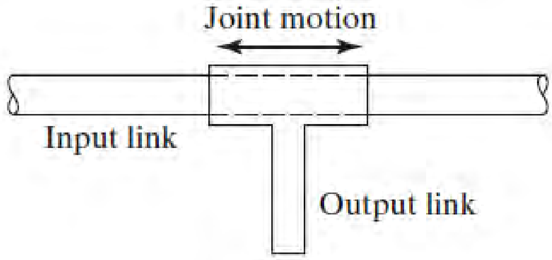


Types of joints

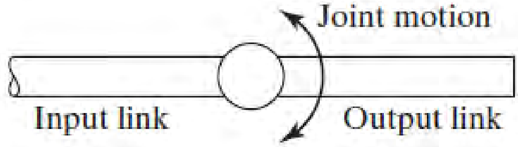
- **Linear joint (type L joint).** The relative movement between the input link and the output link is a translational telescoping motion, with the axes of the two links being parallel.



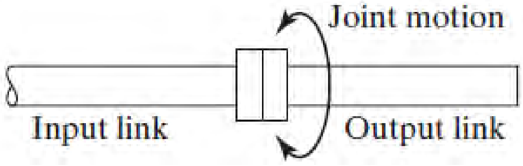
- **Orthogonal joint (type O joint).** This is also a translational sliding motion, but the input and output links are perpendicular to each other.



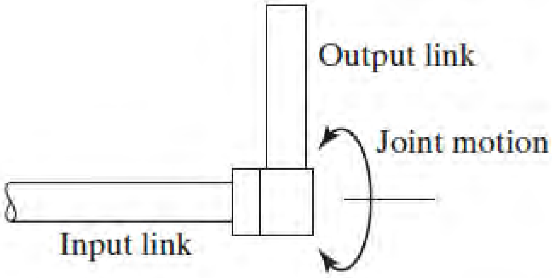
- **Rotational joint (type R joint).** This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.



- **Twisting joint (type T joint).** This joint also involves rotary motion, but the axis of rotation is parallel to the axes of the two links.



- **Revolving joint** (type V joint, V from the "v" in revolving). In this joint type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.



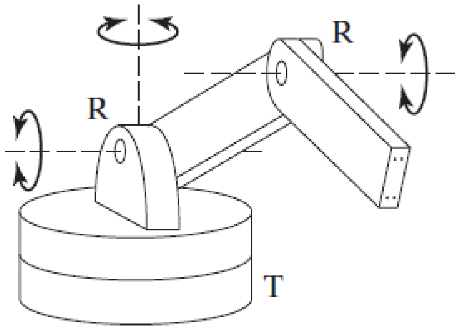
BODY-AND-ARM CONFIGURATIONS

Given the five types of joints defined earlier, there are 5 x 5 x 5 = 125 possible combinations of joints that could be used to design the body-and-arm assembly for a three-axis manipulator. In addition, there are design variations within the individual joint types (e.g., physical size of the joint and range of motion).

Configurations are given below.

Articulated robot

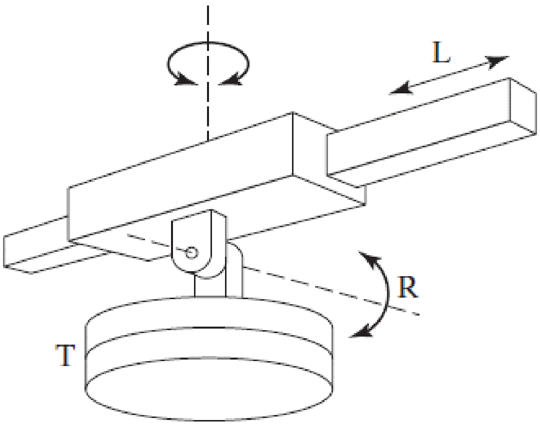
Also known as a **jointed-arm robot** (see figure), it has the general configuration of a human shoulder and arm.



It consists of an upright body that swivels about the base using a T joint. At the top of the body is a shoulder joint (shown as an R joint in the figure), whose output link connects to an elbow joint (another R joint).

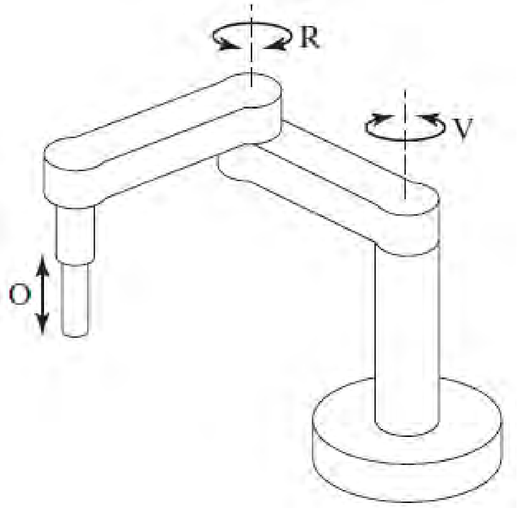
Polar configuration

This configuration consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and a horizontal axis (R joint).



SCARA

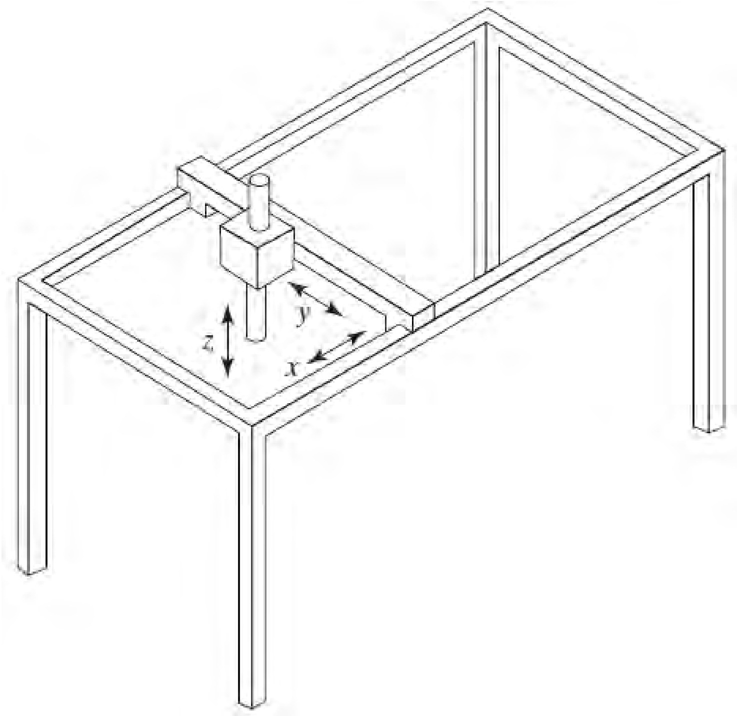
SCARA is an acronym for Selectively Compliant Arm for Robotic Assembly. This configuration is similar to the jointed-arm robot except that the shoulder and elbow rotational axes are vertical, which means that the arm is very rigid in the vertical direction but compliant in the horizontal direction. This permits the robot to perform insertion tasks (for assembly) in a vertical direction, where some side-to-side alignment may be needed to mate the two parts properly.



the SCARA configuration typically does not have a separate wrist assembly. As indicated in the description, it is used for insertion-type assembly operations in which the insertion is made from above. Accordingly, orientation requirements are minimal, and the wrist is not needed

Cartesian coordinate robot

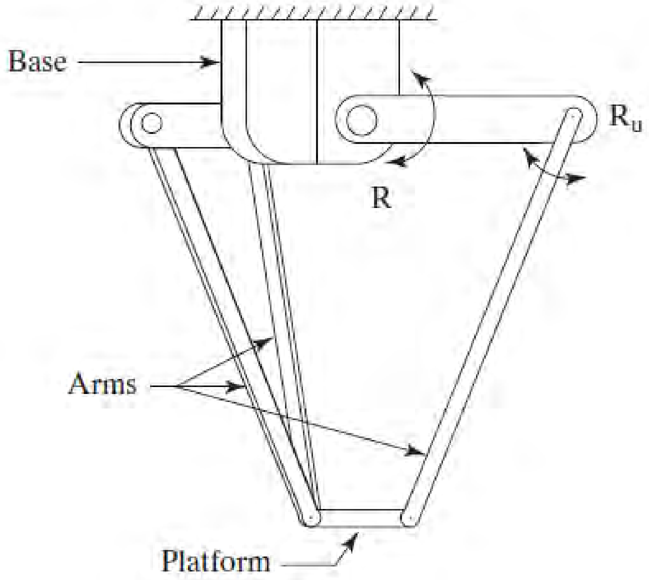
Other names for this configuration include gantry robot, rectilinear robot, and x–y–z robot. As shown in following figure, it consists of three orthogonal joints (type O) to achieve linear motions in a three-dimensional rectangular work space. It is commonly used for overhead access to load and unload production machines.



The usual Cartesian coordinate robot is suspended from a gantry structure. The first and second axes permit x–y movement over a rectangular area above the floor. The third axis permits movement in the z direction to reach downward. Depending on the application requirements, a wrist assembly can be attached to the end of the arm.

Delta robot

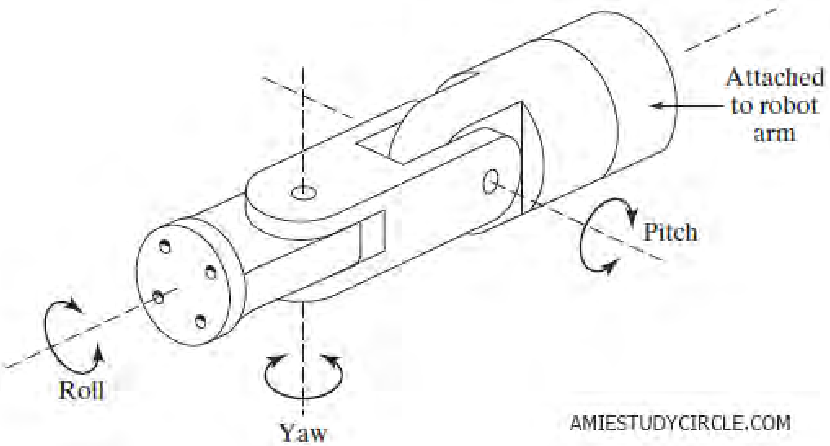
This unusual design, depicted in following figure, consists of three arms attached to an overhead base. Each arm is articulated and consists of two rotational joints (type R), the first of which is powered and the second is unpowered. All three arms are connected to a small platform below, to which the end effector is attached. The platform and end effector can be manipulated in three dimensions. The delta robot is used for high-speed movement of small objects, as in product packaging.



The delta robot is also suspended from an overhead base rather than floor mounted. Its most unique feature is its three articulated arms that are all connected to the platform below. Each arm has one powered joint and one follower joint.

WRIST CONFIGURATIONS

- The robot's wrist is used to establish the orientation of the end effector.
- Robot wrists usually consist of two or three joints that almost always consist of R and T type rotary joints.
- Following figure illustrates one possible configuration for a three-axis wrist assembly.



The three joints are defined as follows:

- **roll**, using a T joint to accomplish rotation about the robot's arm axis;
- **pitch**, which involves up-and-down rotation, typically using an R joint; and
- **yaw**. which involves right-and-left rotation, also accomplished by means of an R-joint.

A two-axis wrist typically includes only roll and pitch joints (T and R joints).

SENSORS IN ROBOTICS

A wide variety of sensors is available for collecting data from the manufacturing process for use in feedback control. A sensor is a transducer, which is a device that converts a physical variable of one form into another form that is more useful for the given application. In particular, a sensor is a device that converts a physical stimulus or variable of interest (such as temperature, force, pressure, or displacement) into a more convenient form (usually an electrical quantity such as voltage) for the purpose of measuring the stimulus.

Sensors used in industrial robotics can be classified into two categories:

- internal and
- external.

Internal sensors

Internal sensors are components of the robot and are used to control the positions and velocities of the robot joints. These sensors form a feedback control loop with the robot controller. Typical sensors used to control the position of the robot arm include potentiometers and optical encoders. Tachometers of various types are used to control the speed of the robot arm.

External sensors

External sensors are external to the robot and are used to coordinate the operation of the robot with other equipment in the cell. They act as interlocks. In many cases, these external sensors are relatively simple devices, such as limit switches that determine whether a part has been positioned properly in a fixture or that a part is ready to be picked up at a conveyor.

ADVANCED SENSOR TECHNOLOGIES

Tactile sensors

These are used to determine whether contact is made between the sensor and another object. Tactile sensors can be divided into two types in robot applications: (1) touch sensors and (2) force sensors. Touch sensors indicate simply that contact has been made with the object. Force sensors indicate the magnitude of the force with the object. This might be useful in a gripper to measure and control the force being applied to grasp a delicate object.

Proximity sensors

These indicate when an object is close to the sensor. When this type of sensor is used to indicate the actual distance of the object, it is called a range sensor.

Optical sensors

Photocells and other photometric devices can be utilized to detect the presence or absence of objects and are often used for proximity detection.

Machine vision

Machine vision is used in robotics for inspection, parts identification. guidance, and other uses. Improvements in programming of vision-guided robot (VGR) systems have made implementations of this technology easier and faster, and machine vision is being implemented as an integral feature in more and more robot installations, especially in the automotive industry.

GRIPPERS

Grippers are end effectors (An end effector is usually attached to the robot's wrist) used to grasp and manipulate objects during the work cycle. The objects are usually work parts that are moved from one location to another in the cell. Machine loading and unloading applications fall into this category.

Types of grippers

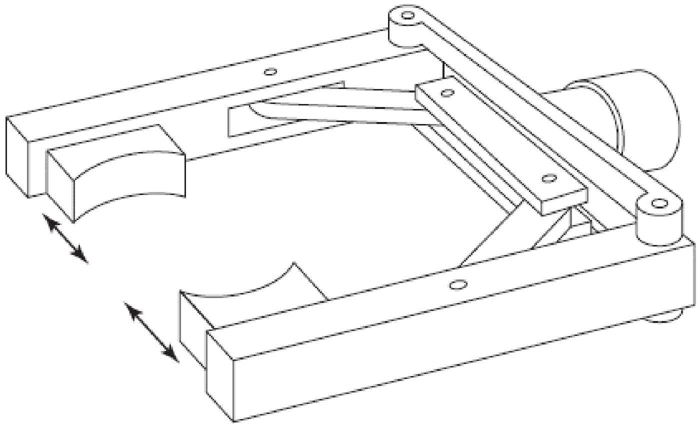
- **Mechanical grippers**, consisting of two or more fingers that can be actuated by the robot controller to open and close on the work part (Figure 8.10 shows a two-finger gripper)
- **Vacuum grippers**, in which suction cups are used to hold flat objects
- **Magnetized devices**, for holding ferrous parts
- **Adhesive devices**, which use an adhesive substance to hold a flexible material such as a fabric
- **Simple mechanical devices**, such as hooks and scoops.

Mechanical grippers

Mechanical grippers are the most common gripper type.

Some of the innovations and advances in mechanical gripper technology include:

- **Dual grippers, consisting of two gripper devices** in one end effector for machine loading and unloading. With a single gripper, the robot must reach into the production machine twice, once to unload the finished part and position it in a location external to the machine and the second time to pick up the next part and load it into the machine. With a dual gripper, the robot picks up the next work part while the machine is still processing the previous part. When the machine cycle is finished, the robot reaches into the machine only once: to remove the finished part and load the next part. This reduces the cycle time per part.



Robot mechanical gripper

- **Interchangeable fingers** that can be used on one gripper mechanism. To accommodate different parts, different fingers are attached to the gripper.
- **Sensory feedback in the fingers** that provide the gripper with capabilities such as (1) sensing the presence of the part or (2) applying a specified limited force to the part during gripping (for fragile work parts).
- **Multiple-fingered grippers** that possess the general anatomy of a human hand.
- **Standard gripper products** that are commercially available, thus reducing the need to custom-design a gripper for each separate robot application.

ROBOT ACCURACY AND REPEATABILITY

Accuracy

Accuracy is the robot's ability to position the end of its wrist at a desired location in the work volume. For a single axis, using the same reasoning as in NC,

$$Ac = \frac{CR}{2} + 3\sigma$$

where CR = control resolution.

Repeatability

Repeatability is a measure of the robot's ability to position its end-of-wrist at a previously taught point in the work volume. Each time the robot attempts to return to the programmed point it will return to a slightly different position. Repeatability variations have as their principal source the mechanical errors previously mentioned. Therefore, as in NC, for a single joint-link mechanism,

$$\mathrm{Re} = \pm 3\sigma$$

where σ = standard deviation of the error distribution.

Example (Winter 2019, 4 marks)

One of the joints of an industrial robot has a type R joint with a range of 90°. The bit storage capacity of the robot controller is 10 bits for this joint. The mechanical errors form a normally distributed random variable about a given taught point. The mean of the distribution is zero and the standard deviation is 0.05°. (a) Determine the control resolution CR_2, accuracy, and repeatability for this robot joint. (b) Also, if the output link has a length of 0.75 m, determine the linear distance corresponding to CR_2, accuracy, and repeatability at the end of the link.

Solution

$$CR_2 = \frac{R}{2^B - 1} = \frac{90}{1024 - 1} = 0.088^0$$

$$Ac = \frac{0.088}{2} + 3(0.05) = 0.194^0$$

$$\text{Re} = 3x0.05 = 0.15^0$$

COMPUTER VISION AND MACHINE INTELLIGENCE

- **Definition of Robot vision** : Robot vision may be defined as the process of extracting, characterizing and interpreting information from images of a three dimensional world.
- Here, robot vision is divided into three fundamental tasks : **Image transformation, image analysis and image understanding.**
- Robot vision, also known as computer vision or machine vision is an important sensor technology with potential applications in many industrial operations.
- Computer vision has become a very important part of an "intelligent" robotics system.
- Vision provides a robot with a sophisticated sensing mechanism that allows the machine to respond to its environment in an intelligent and flexible manner. .
- The use of vision and other sensing schemes is motivated by the continuing need to increase the flexibility and scope of applications of robotics systems.
- Although proximity, touch and force sensing play a significant role in the improvement of robot performance, vision is recognized as the most powerful robot sensory capability.

Image transformation

- Image transformation is the process of electronically digitizing light images using image devices.
- An image device is the front end of a vision system, which acts as an image transducer to convert light energy to electrical energy.
- Compare this with humans, where the image device is the eye.
- In a vision system, the image device is a camera, photodiode array, Charge-Coupled Device (CCD) array or Charge-Injection Device (CID) array.
- The output of an image device is a continuous analog signal that is proportional to the amount of light reflected from an image.

- In order to analyse the image with a computer, the analog signals must be converted and stored in digital form.
- To this end, a rectangular image array is divided into small regions called picture elements or pixels.
- With photodiodes or CCD arrays, the number of pixels equals the number of photodiodes or CCD devices.
- The pixel arrangement provides a sampling grid for an analog-to-digital (A/D) converter.
- At each pixel, the analog signal is sampled and converted to a botic digital value.
- With an 8-bit A/D converter, the converted pixel value will range from 0 for white to 255 for black.
- Different shades of grey are represented by values between these two extremes.
- This is the reason why the term grey level is often used in conjunction with the converted values.
- As the pixels are converted, the respective grey-level values are stored in a memory matrix, which is called a picture matrix.

Image analysis

- A computer needs to locate the edges of an object in order to construct drawings of the object within a scene.
- The line drawings provide a basis for image understanding, as they define the shapes of objects that make up a scene.
- Thus, the basic reason for edge detection is that edges lead to line drawings, which lead to shapes, which lead to image understanding.
- Edge detection
- The edges are usually represented by the points that exhibit the greatest difference in grey-level values within a smoothed picture matrix.
- From calculus, it should be known that the slope of a step edge approaches infinity.
- Using this idea, all we have to do is to calculate the first derivative between adjacent grey-scale values, which is usually called the gradient.
- The technique is called pixel differentiation.

Thresholding

- Lines might then be identified from the binary matrix that is thresholded.
- Some popular techniques for finding lines from an edge-point matrix are model matching, tracking and template matching.
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Image understanding

- The final task of robot vision is to interpret the information obtained during the image-analysis
- This is called image understanding or machine perception.
- Most of the image-understanding research is centered around the 'blocks world".
- The blocks world assumes that real-world images can be broken down and described by 2-D rectangular and triangular solids.
- Several A} based image understanding programs, which can interpret real-world images, have been successfully written under this blocks-world assumption.

Types of Vision systems

1D Robotic Vision (Low level vision)

1D vision systems involve the use of one-dimensional cameras to analyse the digital signal of a single group of lines at a time and compare variations between previous and current line groups. Robots with 1D cameras are typically used to inspect the surface of parts manufactured in a continuous process. 1D vision systems are the least common type in robotics since many manufacturers are looking to automate more complex processes.

2D Robotic Vision (Medium level vision)

2D vision systems are the most common type of robotic vision. 2D systems can provide views of objects on both X and Y planes. There are two types of 2D vision systems, area scans and line scans. Area scans provide a 2D snapshot of an object but are limited when it comes to capturing rounded parts. Line scan vision builds a 2D image by capturing each line of a part and piecing them together to form it as a whole, similar to how a document scanner works. Line scans are often used in tight spaces, for cylindrical parts, and to capture continuously moving objects in high resolution.

3D Robotic Vision (High level vision)

3D vision systems have been gaining popularity in the robot world in recent years. 3D systems provide imagery feedback to robots on all six degrees of freedom of an object, similar to viewing an object in real life. Robotic 3D vision has advanced the depth of robot applications. With 3D vision systems robots have the autonomy to recognize and determine how to adjust to variations in part types, locations, orientation, environment, and applications while operating. These vision systems can be used for assembly, pick and place, part transfer, palletizing, and even welding applications. Integrating 3D vision with the ABB IRB 2600 gives it the ability to automate complex assemblies due to enhanced visual guidance.

Application of robot vision system

The use of machine vision in robotics application are divided into three categories as follows :

- Inspection
- Identification
- Navigation

Inspection

- Inspection process is carried out by the vision system and the robot is used in a secondary role to support the application.
- The objectives of vision inspection include for checking surface defects, verification of presence of components in assembly, measuring for dimensional accuracy and checking the presence hole and other features in part.

Identification

- Identification is concerned with applications in which the purpose is to recognize and classify an object rather than to inspect it.
- Inspection implies that the part must be either accepted or rejected.

Navigation

- In navigation control, the purpose is to direct the actions of the robot and other devices in the robot cell based on visual input.
- An example is to control the trajectory of the robots end effector. towards an object in the workspace.

ROBOT PROGRAMMING

To accomplish useful work, a robot must be programmed to perform a motion cycle. A robot program can be defined as a path in space to be followed by the manipulator, combined with peripheral actions that support the work cycle. Examples of peripheral actions include opening and closing a gripper, performing logical decision making, and communicating with other pieces of equipment in the cell. A robot is programmed by entering the programming commands into its controller memory. Different robots use different methods of entering the commands.

Motion Programming

Motion programming with robot languages usually requires a combination of textual statements and lead through techniques. Accordingly, this method of programming is sometimes referred to as on-line/off-line programming. The textual statements are used to describe the motion, and the leadthrough methods are used to define the position and orientation of the robot during and/or at the end of the motion. To illustrate, the basic motion statement is

MOVE Pl

which commands the robot to move from its current position to a position and orientation defined by the variable name Pl.

Interlock and Sensor Commands

The two basic interlock commands (Section 5.3.2) used for industrial robots are WAIT and SIGNAL. The WAIT command is used to implement an input interlock. For example,

WAIT 20. ON

would cause program execution to stop at this statement until the input signal coming into the robot controller at port 20 was in an "on" condition. This might be used in a situation where the robot needed to wait for the completion of an automatic machine cycle in a loading and unloading application.

The SIGNAL statement is used to implement an output interlock. This is used to communicate to some external piece of equipment. For example.

SIGNAL 21. ON

would switch on the signal at output port 21, perhaps to actuate the start of an automatic machine cycle.

Computations and Program Logic

Many of today's robot applications require the use of branches and subroutines in the program. Statements such as

GOTO 150

and

IF (logical expression) GOTO 150

cause the program to branch to some other statement in the program (e.g., to statement number 150 in the above illustrations).

ASSIGNMENT

ROBOTICS

Q.1. (AMIE S20, 7 marks): Define the term robotics, state the advantages and disadvantages of robots.

Q.2. (AMIE W17, 8 marks): Briefly explain the different types of robots.

Q.3. (AMIE W18, 5 marks): Discuss the different application of industrial robot.

Q.4. (AMIE S15, W16, 6 marks): Describe different parts of a robotic system with neat sketches.

Q.5. (AMIE W15, 17, 18, 19, 8 marks): Explain with a neat sketch, different physical configurations of industrial robot. Under what conditions will you recommend a particular type of configuration.

Q.6. (AMIE S15, W16, 6 marks): Distinguish clearly with the help of an example between accuracy and repeatability of a robot.

Q.7. (AMIE S20, 7 marks): List the motivating factors for the introduction of robotic system to the manufacturing units.

Q.8. (AMIE W17, 8 marks): Discuss the various steps to be taken for implementing robots in industry. Write the advantages of using robots in industry.

Q.9. (AMIE W15, 8 marks): Discuss the following robotic joints

(i) linear joint

(ii) rotational joint

(iii) twisting joint

(iv) revolving joint

Q.10. (AMIE S16, 17, 19, 10 marks): What is a robotic gripper? What are the types of grippers used in industrial robots? Discuss in brief.

Q.11. (AMIE W15, 4 marks): Explain how robots with double gripper increase the utilization of machine tools.

Q.12. (AMIE S16, 10 marks): In context with robotic wrist configuration what is roll, pitch and yaw? Enumerate industrial applications of robots?

Q.13. (AMIE S16, 5 marks): Explain the contact and non-contact type robot sensors.

Q.14. (AMIE S17, 19, 7 marks): With the help of a neat sketch explain the working principle of SCARA robot.

Q.15. (AMIE S17, 6 marks): With a neat sketch represent various reference frames of "pick and place" task by a robot manipulator.

Q.16. (AMIE W17, 10 marks): What are the different degree of freedom associated with a robot? Show them with help of a neat sketch. Explain five types of joints used in robots.

Q.17. (AMIE S19, 10 marks): Describe different types of joints used in robot configurations with neat sketch. Discuss about the robot wrist configuration.

Q.18. (AMIE W18, 5 marks): Define prismatic joint and rotational joint with neat sketch.

Q.19. (AMIE W17, 10 marks): Discuss various types of body arm configuration of an industrial robot.

Q.20. (AMIE S20, 6 marks): What is a sensor? List the various sensor used in robotic system.

Q.21. (AMIE W19, 4 marks): Explain interlock and sensor commands in robot programming language in brief.

Q.22. (AMIE S20, 6 marks): Explain the applications of robotics in material handling systems.

Q.23. (AMIE S20, 7 marks): What do you understand by the term robot vision? Differentiate between low level, medium level and high level vision systems.

Q.24. (AMIE W19, 10 marks): What is a machine vision? How is a machine vision system divided into different functions? Explain.

Q.25. (AMIE S20, 7 marks): State the industrial applications of vision controlled robotic systems.

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