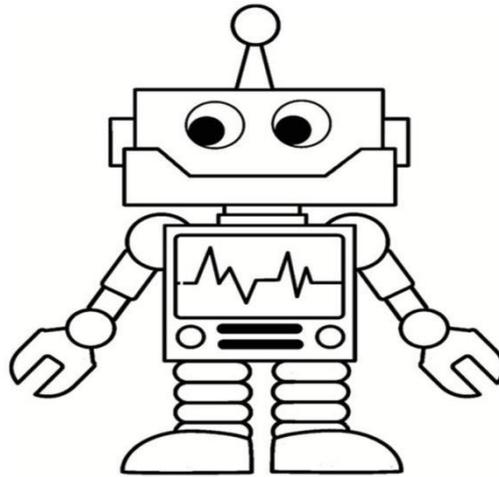


INDUSTRIAL ROBOTICS & AUTOMATION



DEPARTMENT OF MECHANICAL ENGINEERING

6TH SEMESTER

KIIT POLYTECHNIC, BHUBANESWAR

ODISHA- 751024

CHAPTERS

Fundamentals of Robotics:

- 1.1 Definition; Robot anatomy (parts) and its working.
- 1.2 Robot Components: Manipulator, End effectors; Construction of links, Types of joints.
- 1.3 Classification of robots; Cartesian, Cylindrical, Spherical, SCARA, Vertical articulated.
- 1.4 Structural Characteristics of robots; Mechanical rigidity; Effects of structure on control work envelope and work Volume.
- 1.5 Robot work Volumes, comparison.
- 1.6 Advantages and disadvantages of robots.

Robotic Drive System and Controller:

- 2.1 Actuators; Hydraulic, Pneumatic and Electrical drives; linear actuator; Rotary drives.
- 2.2 AC servo motor; DC servo motors and Stepper motors; Conversion between linear and rotary motion.
- 2.3 Feedback devices; Potentiometers; Optical encoders; DC tachometers.
- 2.4 Robot controller; Level of Controller; Open loop and Closed loop controller.
- 2.5 Microprocessor based control system; Robot path control: Point to point, Continuous path control and Sensor based path control; Controller programming.

Sensors:

- 3.1 Requirements of a sensor.
- 3.2 Principles and Applications of the following types of sensors: Position sensors (Encoders, Resolvers, Piezo Electric); Range sensors (Triangulation Principle, Structured lighting approach). 3.3 Proximity sensing; Force and torque sensing.

Introduction to Machine Vision:

- 4.1 Robot vision system (scanning and digitizing image data); Image processing and analysis.
- 4.2 Cameras (Acquisition of images); Videocon camera (Working principle & construction).
- 4.3 Applications of Robot vision system: Inspection, Identification, Navigation & serving

Robot kinematics and Robot Programming:

- 5.1 Forward Kinematics; Inverse Kinematics and Differences.
- 5.2 Forward Kinematics and Reverse Kinematics of Manipulators with Two Degrees of Freedom (In 2 Dimensional); Deviations and Problems.
- 5.3 Teach Pendant Programming; Lead through programming; Robot programming Languages; VAL Programming.
- 5.4 Motion Commands; Sensor Commands; End effector commands; and Simple programs.

Automation & Industrial Applications:

- 6.1 Basic elements of automated system, advanced automation functions, levels of automation. 6.2 Application of robots in machining; welding; assembly and material handling.

FUNDAMENTALS OF ROBOTICS

INTRODUCTION:

- ❖ An industrial robot is a general purpose programmable machine, processing creation anthropomorphic characteristics.
- ❖ Some of the quality that make industrial robot commercially and technologically important are listed:
 1. Robots can be substituted for human in hazardous or uncomfortable work environments.
 2. A performed its work cycle with a consistency and reputability that can't be attained by humans.
 3. Robots can be reprogrammed, when the production run of the current task is complicated.
 4. Robots are controlled by computers and can there for connected to other computer system to achieve CIM.
- ❖ **“A Robot is a programmable, multi-functional manipulator designed to move material, parts, tools, or special devices through variable programmed motions for the performed of a variety of tasks.”**

OBJECTS USING INDUSTRIAL ROBOT:

- ❖ To increased productivity.
- ❖ To raise the quality level of products.
- ❖ To maintain the labor requirements.
- ❖ To reduce production time.
- ❖ To improve existing manufacturing process.
- ❖ To enhance the life production machines.
- ❖ To increase the safety level of the labor.
- ❖ Thus to minimize the loss of man hours on account of accident and diseases.

ROBOT CHARACTERISTICS

- ❖ Sensing

First of all your robot would have to be able to sense its surroundings. It would do this in ways that are not similar to the way that you sense your surroundings. Giving your robot sensors like light sensors (eyes), touch and pressure sensors (hands), chemical sensors, hearing sensors, and taste sensors will give your robot awareness of its environment.

- Movement

A robot needs to be able to move around its environment. Whether rolling on wheels, walking on legs or propelling by thrusters a robot needs to be able to move. To count as a robot either the whole robot moves, like the Sojourner or just parts of the robot moves, like the Canada Arm.

- Energy

A robot needs to be able to power itself. A robot might be solar powered, electrically powered, battery powered. The way your robot gets its energy will depend on what your robot needs to do.

- Intelligence

A robot needs some kind of "smarts." This is where programming enters the pictures. A programmer is the person who gives the robot its 'smarts.' The robot will have to have some way to receive the program so that it knows what it is to do.

LAWS OF ROBOTICS

A. First Law

- ❖ A robot must not harm a human being or through inaction, allow one to come to harm.

B. Second Law

- ❖ A robot must always obey human beings unless it is in conflict of 1st law.

C. Third Law

- ❖ A robot must protect itself from harm unless that is in conflict with the 1st / 2nd Law.

APPLICATION OF ROBOT:

- ❖ Material handling, Material transfer.
- ❖ Machine loading and/or unloading.
- ❖ Spot welding, Continuous arc welding, Spray coating.
- ❖ Assembly, Inspection.
- ❖ Robots in Space
- ❖ Robots in Hazardous Environments
- ❖ Medical sector
- ❖ Robots at Home (for entertained, cooking and other house hold work)
- ❖ In military service.

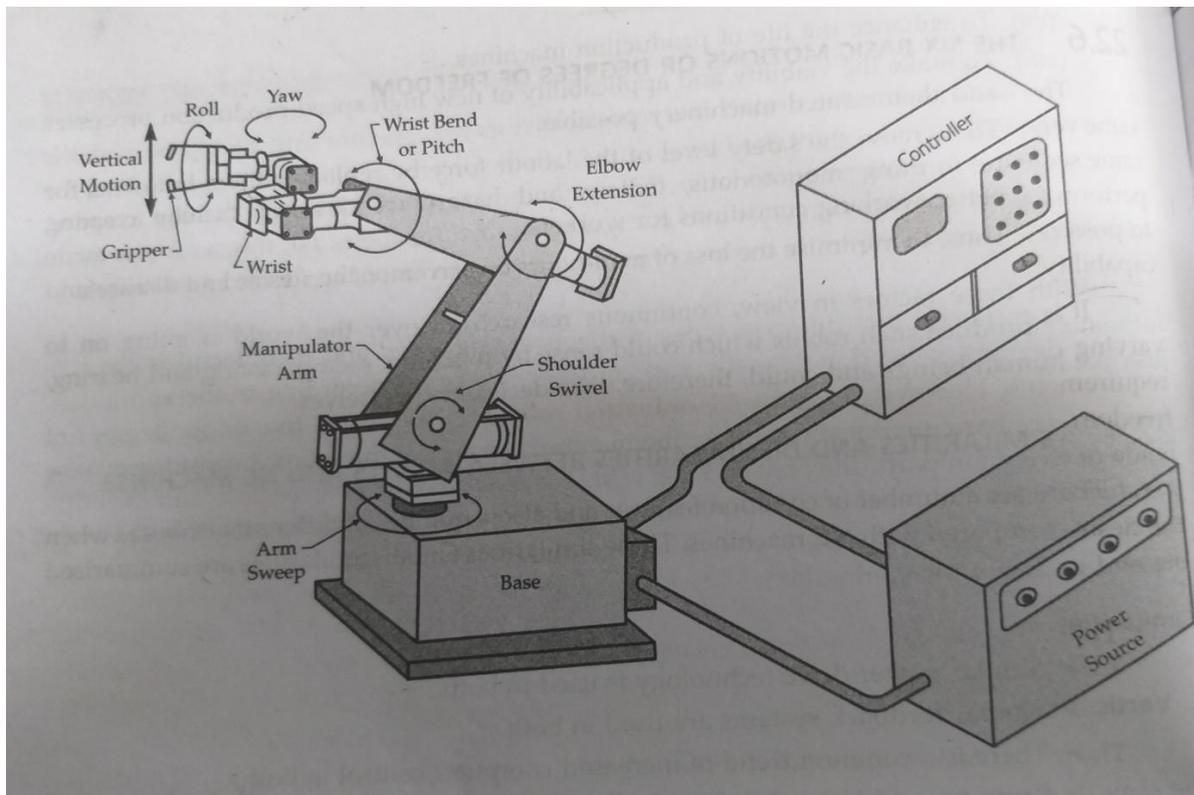
ADVANTAGES OF ROBOT

- ❑ Robots increase productivity, safety, efficiency, quality, and consistency of products.
- ❑ Robots can work in hazardous environments without the need.
- ❑ Robots need no environmental comfort.
- ❑ Robots work continuously without experiencing fatigue of problem.
- ❑ Robots have repeatable precision at all times.
- ❑ Robots can be much more accurate than human.
- ❑ Robots can process multiple stimuli or tasks simultaneously.

DISADVANTAGES OF ROBOT

- ❖ High initial cost.
- ❖ Need extra space and new technologies.
- ❖ They need constant power.
- ❖ They lead humans to lose their jobs.
- ❖ Perform relatively few tasks.
- ❖ Need high skilled engineers, programmers.
- ❖ They impacts human interaction
- ❖ Only programmer understands its function.

BASIC COMPONENTS OF A ROBOT:



❖ A Robot carries a large number of components of which the main components are the following:

I. Base:

This may be moveable or fixed. Base is the component where the whole assemble of robot will stand.

II. Manipulator arm:

A manipulator arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot.

III. Gripper and end effectors:

It is used for holding a piece of tool, depending upon the application of robot. The gripper or end effectors are the portion by which robot can able to hold a job rigidly and replace it one place to another.

IV. Drives:

Also knows as actuators, they move the manipulator arm and end effectors to the required position in space.

V. Controller:

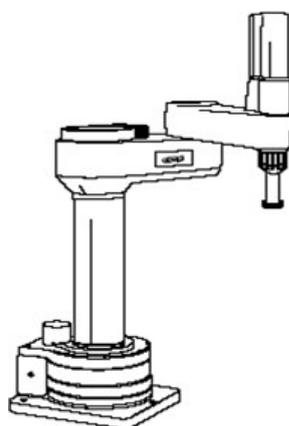
It delivers commands to the actuators with the help of hardware and software supports.

VI. Sensors:

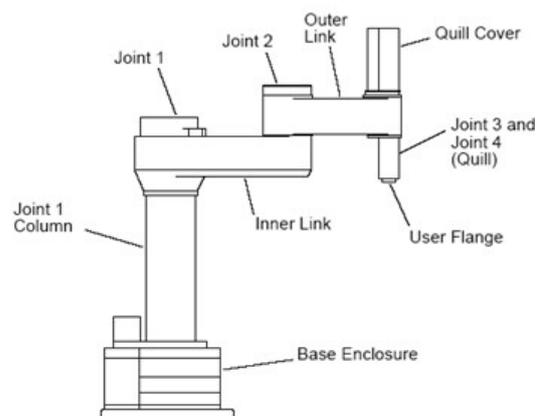
They performed dual functions

- 1) To act as feedback devices to direct further actions of the manipulator arm and the end effectors (gripper).
- 2) To interact with the robots working environment.

ROBOT ANATOMY:



(a)

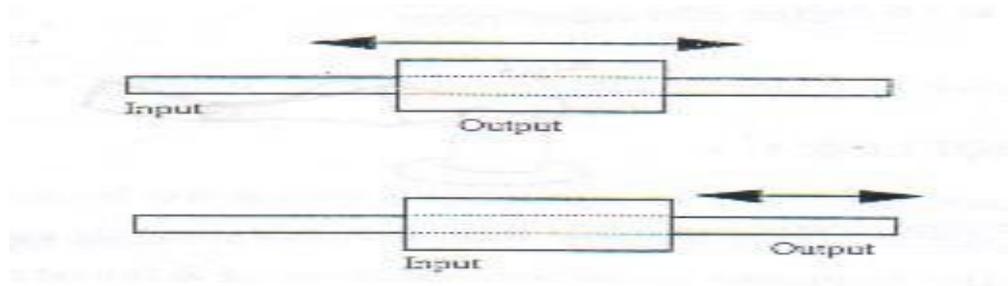


(b)

- ❖ A joint of an industrial robot is similar to a joint in the human body. It provides relative motion between two parts of the body. Each joint and axis as it is sometimes called provides the robot with so called degree of freedom of motion.
- ❖ Normally all industrial robots have mechanical joints that can be classified into one of the five types. Two types that provide translational motion and three types that provides rotating motions.

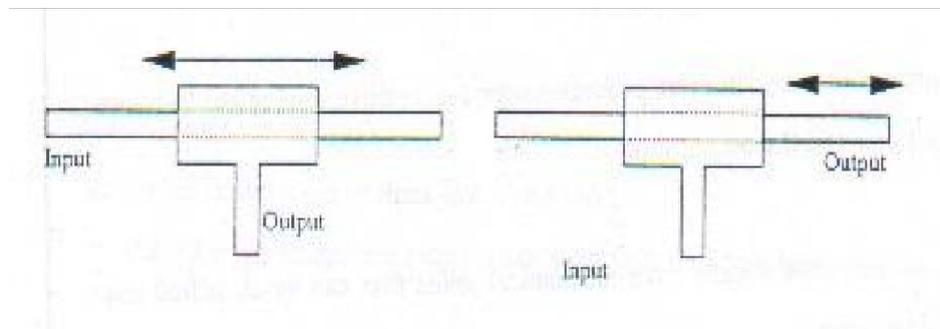
Linear joint (type L joint):

- ❖ The relative movement between the input link and the output link is a translational sliding motion, with the axes of the two links parallel.



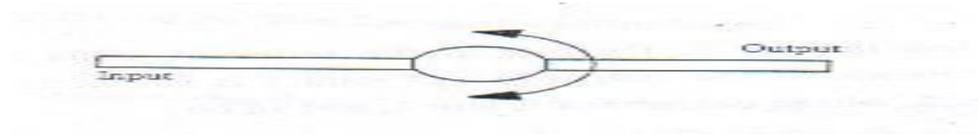
Orthogonal joint (type O joint):

- ❖ This is also a translational sliding motion but the input and output links are perpendicular to each other during the move.



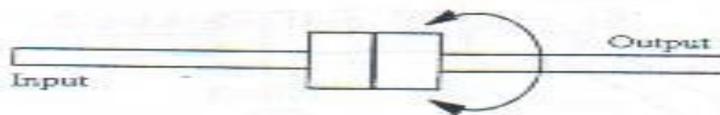
Rotational joint (type R joint):

- ❖ This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.



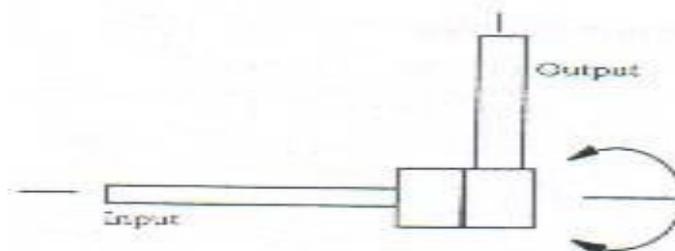
Twisting joint (type T joint):

- ❖ This joint is also involves rotary motions, but the axis of rotation is parallel to the axes of the two links.



Revolving joint (type V joint):

- ❖ 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 rotations.



THE BASIC MOTIONS OR DEGREE- OF FREEDOM OF A ROBOT:

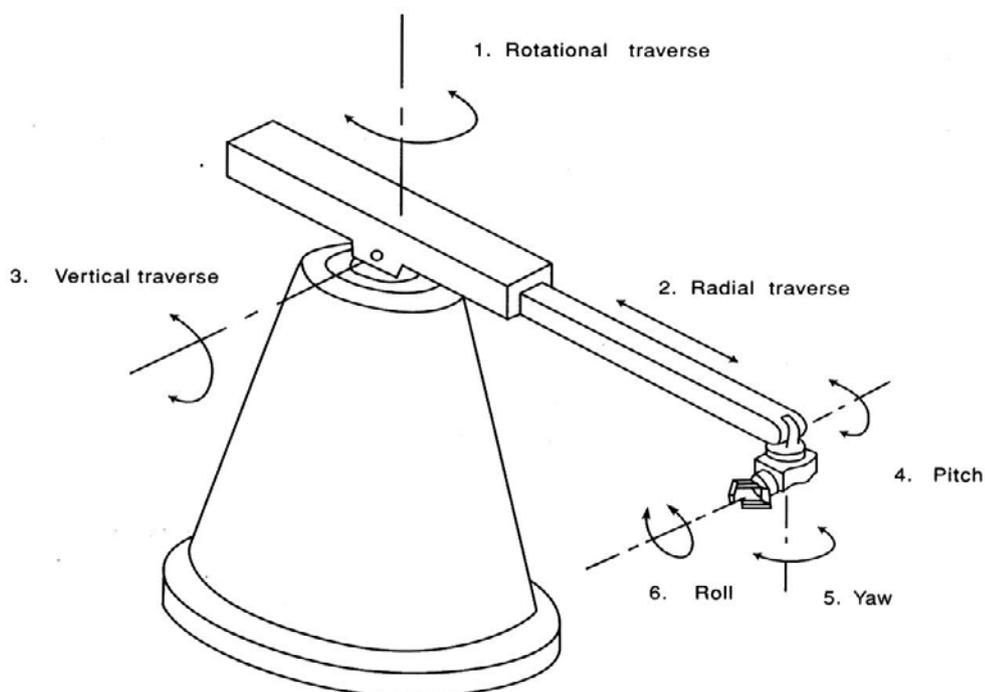


Figure 3.3.2 Six major degrees of freedom of a robotic system

Vertical motions:

- ❖ The entire manipulator arm can be moved up and down vertically either by means of the shoulder swivel i.e. turning it about a horizontal axis or by sliding it in a vertical sliding.

Radial motion:

- ❖ Radial movement i.e. In and out movement of the manipulator arm is providing by elbow extension by extending it and drawing back.

Rotational motion:

- ❖ Clockwise and anticlockwise rotation about the vertical axis to the manipulator arm is provided through arm sweep.

Pitch motion:

- ❖ It enables up and down of the wrist and involves rotational movement as well. it is also called wrist bend. .

Roll motion:

- ❖ Also called wrist swivel, it enable rotations of wrist..

Yaw:

- ❖ Also called wrist yaw, it facilities rightward and leftward swiveling movement of the wrist.

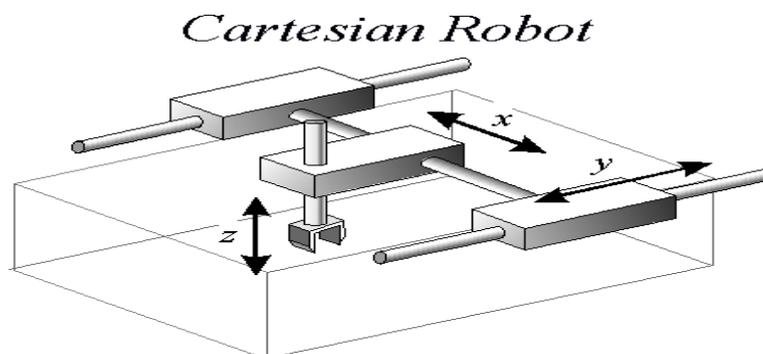
BASIC COORDINATE SYSTEM OF ROBOT CONFIGURATIONS:

- ❖ Industrial robot are designed and built in many different shapes and sizes. They carry different motion system and capable of providing a verity of manipulations arm. But most of the industrial robots are basically designed to carry one of the following coordinate system or configuration.

- ✓ Cartesian coordinate system
- ✓ Polar coordinate system.
- ✓ Cylindrical coordinate system.
- ✓ Revolute coordinate system.

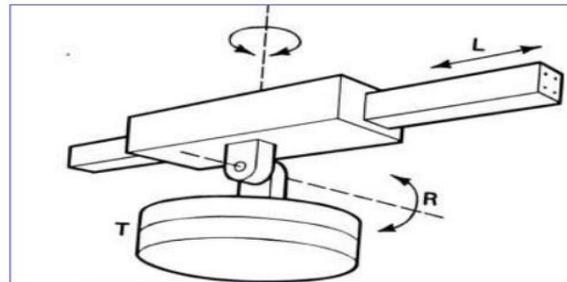
Cartesian coordinate system:

- ❖ This robot with this type of configuration i.e. designed and built with this type of coordinate system has sliding motions along the three standard orthogonal axes x , y , z .
- ❖ The sliding moving along the x -axis enables a right and left motion and that along the y -axis a forward and backward motion and the one along the z -axis an up and down motion.



Polar coordinate system:

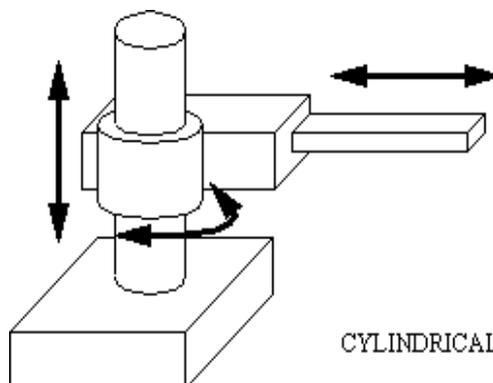
- ❖ It is also called as spherical coordinate system. A robot designed and built around this configuration carries two angular (rotary) motions and one radial (radial) motion.
- ❖ The rotational of this base about a vertical axis provides one regular motion and the 2nd regular motion is provided by the rotation of the arm, about an axis that intersects the vertical axis of the base.
 - ❖ The linear motion is provided by the in and out motion of the telescopic arm



Polar coordinate body-and -arm assembly (TRL).

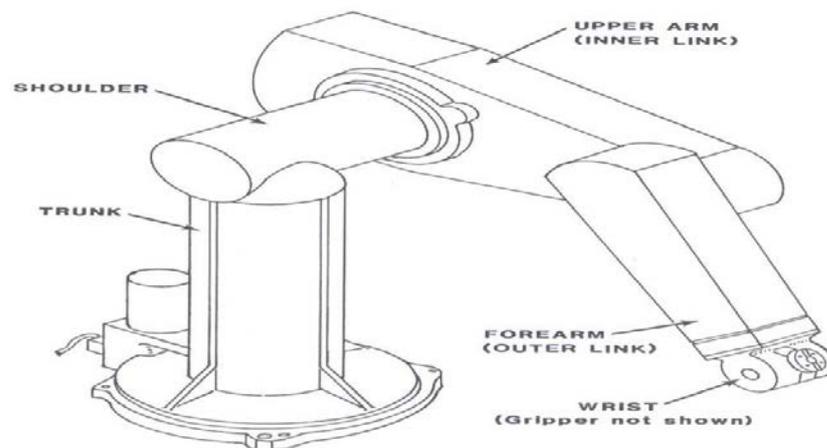
Cylindrical coordinate system:

- ❖ In the cylindrical coordinate configuration the robot carries two linear motions and one rotational motion.
- ❖ The body of robot is a vertical column which can rotate about a vertical column which can rotate about a vertical axis to provide the rotary motion.
- ❖ Also the arm can slide and out to provide the second motion.



Revolute coordinate system:

- ❖ It appearance it very much resembles a human arm, just like the human arm, the robot arm in this configuration comprise a number of straight parts, which are connected together by means of different joints in the same way as the different parts of human arms which carry joints at shoulder, elbows and wrists.
- ❖ The whole arm mounted on the base which can be rotated about vertical z-axis. Also arm can be rotated about horizontal axis provided by elbow joints. This enables the arm to extend and retract.
- ❖ The last link of the arm (wrist) can rotate about a horizontal axis provided by the wrist joint.



ROBOT WORK VOLUME

A space on which a robot can move and operate its wrist end is called as a *work volume*. It is also referred as the *work envelope* and *work space*.

For developing a better work volume, some of the physical characteristics of a robot should be considered such as:

- ❖ The anatomy of various robots
- ❖ The maximum value for moving a robot joint
- ❖ The size of the robot components like wrist, arm, and body

1. Cartesian co-ordinate configuration

- ❖ The Cartesian co-ordinate configuration robot arm will move in up & down directions on the horizontal axis, and in & out motions in the vertical axis. The collective movement of traverse and horizontal stroke results in the *rectangular work volume*.
- ❖ It is inflexible, and best suitable for *pick and place* processes.
- ❖

2. Cylindrical configuration:

- ❖ A cylindrical configuration robot has an arm that has got the ability to reach horizontal and vertical directions. Moreover, it can make a rotary motion by placing the arm at the centre of the robot. As a result, this robot requires a *cylindrical* type of work volume for performing an operation.
- ❖ It is mostly used in the *material handling* process.

3. Polar configuration:

- ❖ The arm of a polar configuration robot does not move in up and down position on the vertical axis as done in the cylindrical configuration. It just makes the robot to rotate during the horizontal stroke by expanding the inner and outer circles. It results in the formation of an arc movement. As soon as this process finishes, the robot arm swings and gets *spherical work* volume.
- ❖ This type of robot is incorporated in the *Flexible Manufacturing System* (FMS) for picking up the tools from the floor.

4. Revolute configuration:

- ❖ A cylindrical configuration robot has an arm that has got the ability to reach horizontal and vertical directions. Moreover, it can make a rotary motion by placing the arm at the centre of the robot. As a result, this robot requires a *cylindrical* type of work volume for performing an operation.
- ❖ It is mostly used in the *material handling* process.

END EFFECTORS:

- ❖ In our discussion of robot configuration we motioned that can end effectors is usually attached to the robot's wrist. The end effectors enable the robot to accomplish a specific task because there is wide variety of tasks performed by industrial robots.
- ❖ There are two types of end effectors are
 1. Tools
 2. Grippers.

GRIPPERS:

- ❑ Gripper are the end effectors used to grasp and manipulate objects during the work cycle, machine loading and unloading application fall into this application.
- ❑ According to variety of parts, shapes, sizes and weights most grippers must be custom designed.

There are many different types of gripper used in industrial for different used.

❖ **Mechanical gripper:**

It consists of two or more fingers that can be actuated by the robot controller to open and close to hold the work part.

❖ **Vacuum gripper:**

In these types of gripper suction cups are used to hold the flat objects.

❖ **Magnetized devices:**

It is used for holding ferrous parts.

❖ **Adhesive devices:**

This is use an adhesive substance to hold a flexible material such as a fabric.

❖ **Simple mechanical devices:**

Used as hooks and scoops.

❖ **Dual gripper:**

1. It consists of two gripper devices in one end effectors for machine loading and unloading. With a single gripper the robot must reach into the production machine twice. But in dual gripper the robots picks up the next work part, while the machine is stilling processing the preceding part.
2. When the machine cycle is finished the robot reaches into the machine only once to remove the finished parts and load the next part. Thus reduce the cycle time per part.

Interchangeable fingers:

- That can be used on one finger mechanism. To accommodate different parts different fingers are attached to the gripper.

Sensory feedback:

- Sensory feedback in the finger that provides the gripper with capabilities such as:
 1. Sensing the presence of the work part.
 2. Applying a specified limit force to the work part during gripping.

Tool:

- The robot is uses tool to perform processing operation on the work part.
- Example of the tool used as end effectors by robot to perform processing like spot welding, arc welding, drilling, routing, grinding, spray painting gun, assembly.
- In some application, the robot may use multiple tools during work cycle.
Ex. - several sizes of routing or drilling bit must be applied to the work part.

SENSOR IN ROBOT:-

1. Tactile sensor:

- These are used to determine whether contact is made between the sensors and object.
- Tactile sensor can be divided into two types in robot application:
 - I. Touch sensors.
 - II. Force sensors.

2. Touch sensor:

It indicates simply that contact has been made with the object.

3. Force sensor:

It indicates the magnitude of the force with the object. This might be useful in a gripper to measure and control the force being applied to hold a delicate object.

4. Proximity sensor:

These indicate when an object is closer to the sensor, when this type of sensor is used to indicate the actual distance of the object. It is also called range sensor.

5. Temperature Sensor:

Temperature sensors are used to detect the surrounding temperature change. It is based on the principle of voltage difference change for a temperature change

6. Positioning Sensors:

Positioning sensors are used to approximate the position of a robot. The usual positioning sensor is a GPS (Global Positioning System).

7. Light Sensor:

A light sensor detects light and creates a difference in voltage. A robot's vision system has a computer-controlled camera that allows the robot to see and adjust its movements accordingly.

8. Sound Sensor:

Sound sensors are generally a microphone used to detect the equivalent voltage of sound and return. The sound it receives can be navigated by a simple robot.

9. Optical sensor:

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

PREDICTED QUESTIONS:

1. What is robot? (2 marks)
2. What is tactile sensor? (2 marks)
3. Write the application of an industrial robot? (5 marks)
4. State two types of end effectors? (5 marks)
5. State the Advantages and disadvantages of robot? (5 marks)
6. What is Robot anatomy? (5marks)
7. Explain the accuracy and repeatability of a robot? (5 marks)
8. Explain different sensors used in robot? (5 marks)
9. Write down all the parts of a Robot with the suitable diagram? (10 marks)
10. Write down various configuration of robot? (10 marks)

AUTOMATION & INDUSTRIAL APPLICATIONS

INTRODUCTION

- ❖ To increase productivity, to improve quality of the finished products and enhance the production efficiency industries or plants have led to an ever ground tendency to transfer more and more activities into power operated or mechanism operated activities.
- ❖ This has led to the use of two particular words mechanization and automation both in industries and workplace.

MECHANIZATION:

- ❖ Mechanization means a particular process operation or activity will be carried out with the use of power such as mechanical, electrical, hydraulic etc. Instead of being performed by a human being.
- ❖ The main objects of replacing human involvement by using power are
 - To reduce the labor cost.
 - To reduce overall process time
 - To minimize human fatigue.
 - To improve quality of products.
 - To increase production rate.
- ❖ Mechanization may be adopted for several operate like loading, unloading, material handling, tool feeding etc.
- ❖ Mechanization is the preliminary level of automation which is generally applicable to semi-automatic machine and equipment.

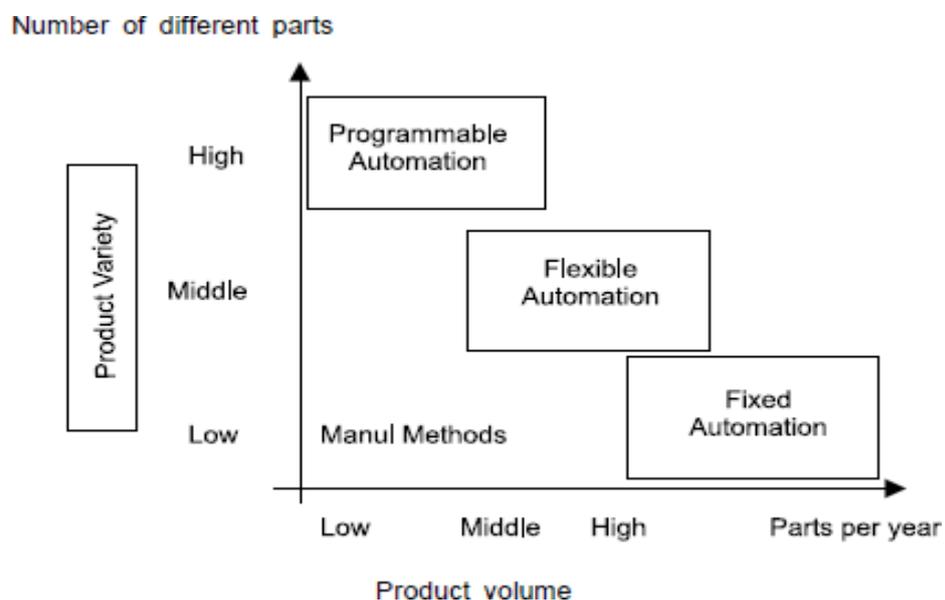
AUTOMATION:

- ❖ “The word automation means a system in which many or all of the process in the production, movement and inspection of parts or materials are automatically performed or controlled by self-operating devices”.
- ❖ Automation represents a higher degree of mechanization through which most of all of the operations or activities involved in manufacturing of a product or product are performed through automatic means i.e. without direct participation of a human being, except some aspect like rotating of machine, readjusting for correction.
- ❖ The degree of automation may vary from process to process and M/C to M/C. i.e. it may carry only partial automation or full automation.
- ❖ Partial automation means replacement of human activities or involvement by automatic means only partially.

- ❖ In full automation the human involvement is totally eliminated and the process is carried out and controlled through automatic means along with proper feedback system.
- ❖ Full automation will include all aspects of manufacturing such as loading, unloading, handling, services etc.

TYPES OF AUTOMATION:

1. FIXED AUTOMATION.
2. PROGRAMMABLE AUTOMATION.
3. FLEXIBLE AUTOMATION.



FIXED AUTOMATION:

- ❖ Fixed automation is a system in which the sequences of processing operation are fixed and equipment or machines are designed according to a particular sequence.
- ❖ The arrangements of equipment and machines are simple but expensive due to more no of machine required, however production rate is high but flexibility is less i.e. it cannot be used for other products.
- ❖ Ex - mechanized assemble liner, machining transfer lines.
- ❖ Advantages:
 1. Low unit cost
 2. Automated material handling
 3. High production rate.
- 1. Disadvantages:
 1. High initial Investment
 2. Relatively inflexible in accommodating product changes.

PROGRAMMABLE AUTOMATION:

- ❖ In programmable automation products and equipment are designed with capability to the change the sequence of operation to produced different products.
- ❖ The operation sequence is controlled by a program which is a set of instruction coded so that the system can read and interpret them.
- ❖ New program can be prepared for new products and entered into the equipment so that flexibility is more than fixed automation.
- ❖ But high investment in generally purpose of machine and low production rate. However it is basically used for batch production.
- ❖ Ex - N.C machine tool, Industrial Robot.
- ❖ Advantages:
 1. Flexible to deal with design variations.
 2. Suitable for batch production.
- 2. Disadvantages:
 1. High investment in general purpose equipment
 2. Lower production rate than fixed automation.

FLEXIBLE AUTOMATION:

- ❖ Flexible automation is an extension of programmable automation which is capable of producing a variety of products with no time loss for change over from one product to the next.
- ❖ It is basically used for continuous production of various mixture of products i.e. very high flexibility with medium production rate but very expensive.
- ❖ It has the capability to change part program with no lost production time and very low set up time i.e. down time is very low. Now it is more advanced stage due to invention of computer system.
- ❖ Ex - FMS.
- ❖ Advantages:
 1. Continuous production of variable mixtures of product.
 2. Flexible to deal with product design variation.
- ❖ Disadvantages:
 1. Medium production rate
 2. High investment.
 3. High 'unit cost relative to fixed automation.

NEED OF AUTOMATION:

- ❖ To increase productivity i.e. output per unit hour or to increase labor productivity this is archived with automation.

- ❖ To reduce the cost of labor because machine can be produce at higher rate of output i.e. automation results in a lower cost of unit of product.
- ❖ To overcome difficult of labor shortage in advance country automation is fully utilized.
- ❖ Less time required.
- ❖ High finished products are produced.

DIFFERENCE BETWEEN FIXED AUTOMATION AND FLEXIBLE AUTOMATION:

Fixed Automation	Flexible Automation
<ul style="list-style-type: none"> ▪ Fixed automation refers to the use of special purpose equipment to automate a fixed sequence of processing or assembly operations 	<ul style="list-style-type: none"> ▪ A flexible automation system is capable of producing a variety of parts with virtually no time loss for changeovers from one part style to the next.
<ul style="list-style-type: none"> ▪ It is relatively difficult to accommodate changes in the product design 	<ul style="list-style-type: none"> ▪ There is no lost production time while reprogramming the system and altering the physical set up.
<ul style="list-style-type: none"> ▪ Production rate is high. 	<ul style="list-style-type: none"> ▪ Production rate is low as compared to fixed automation.
<ul style="list-style-type: none"> ▪ Flexibility is less. 	<ul style="list-style-type: none"> ▪ Flexibility is high.
<ul style="list-style-type: none"> ▪ Low unit cost. 	<ul style="list-style-type: none"> ▪ High unit cost as compared to fixed automation.
<ul style="list-style-type: none"> ▪ EX.-Mechanized assemble liner, machining transfer lines. 	<ul style="list-style-type: none"> ▪ EX- FMS.

ROBOT APPLICATION IN MANUFACTURING

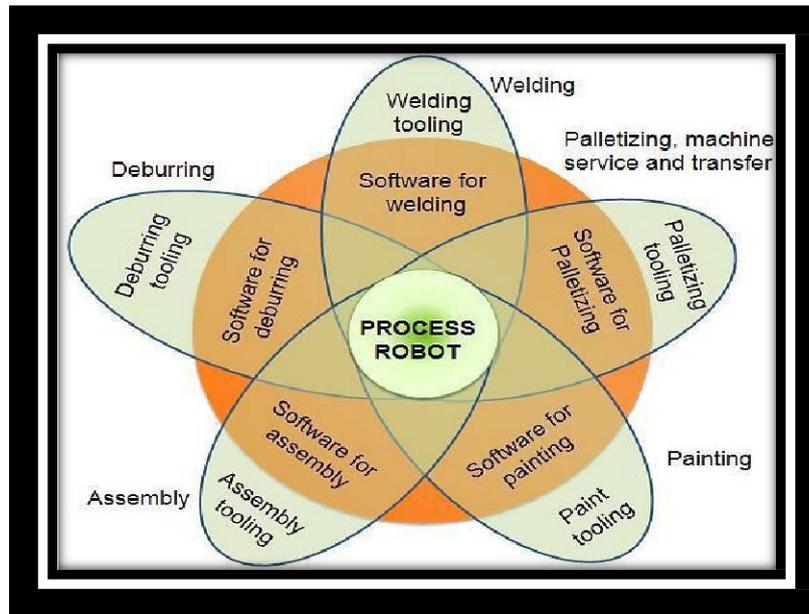


Figure shows a diagram which depicts an overview of applications of robots in manufacturing. The general characteristics of industrial work situations that tend to promote the substitution of robots for human labor.

Characteristics of situations where robots may substitute for humans

➤ Hazardous work environment for humans In situations

Where the work environment is unsafe, unhealthy, uncomfortable, or otherwise unpleasant for humans, robot application may be considered.

➤ Repetitive work cycle

If the sequence of elements in the work cycle is the same, and the elements consist of relatively simple motions, robots usually perform the work with greater consistency and repeatability than humans.

➤ Difficult handling for humans

If the task requires the use of heavy or difficult-to-handle parts or tools for humans, robots may be able to perform the operation more efficiently.

➤ Multi-shift operation

A robot can replace two or three workers at a time in second or third shifts, thus they can provide a faster financial payback.

➤ Infrequent changeovers

Robots' use is justified for long production runs where there are infrequent changeovers, as opposed to batch or job shop production where changeovers are more frequent.

➤ Part position and orientation are established in the work cell

Robots generally don't have vision capabilities, which means parts must be precisely placed and oriented for

Material Handling Applications

Robots are mainly used in three types of applications: material handling; processing operations; and assembly and inspection. In material handling, robots move parts between various locations by means of a gripper type end effectors. Material handling activity can be sub divided into material transfer and machine loading and/or unloading

Application	Description
Material transfer	<ul style="list-style-type: none"> • Main purpose is to pick up parts at one location and place them at a new location. Part re-orientation may be accomplished during the transfer. The most basic application is a pick-and-place procedure, by a low-technology robot (often pneumatic), using only up to 4 joints. • More complex is palletizing, where robots retrieve objects from one location, and deposit them on a pallet in a specific area of the pallet, thus the deposit location is slightly different for each object transferred. The robot must be able to compute the correct deposit location via powered lead- through method, or by dimensional analysis. • Other applications of material transfer include de-palletizing, stacking, and insertion operations.
Machine loading and/or unloading	<ul style="list-style-type: none"> • Primary aim is to transfer parts into or out-of a production machine. • There are three classes to consider: <ul style="list-style-type: none"> o machine loading—where the robot loads the machine o machine unloading—where the robot unloads the machine o machine loading and unloading—where the robot performs both actions

	<ul style="list-style-type: none"> • Used in die casting, plastic molding, metal machining operations, forging, press-
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Processing Operations

In processing operations, the robot performs some processing activities such as grinding, milling, etc. on the work part. The end effector is equipped with the specialized tool required for the respective process. The tool is moved relative to the surface of the work part. Table outlines the examples of various processing operations that deploy robots.

Process	Description
Spot Welding	Metal joining process in which two sheet metal parts are fused together at localized points of contact by the deployment of two electrodes that squeeze the metal together and apply an electric current. The electrodes constitute the spot welding gun, which is the end effectors tool of the welding robot.
Arc Welding	Metal joining process that utilizes a continuous rather than contact welding point process, in the same way as above. Again, the end effector is the electrodes used to achieve the welding arc. The robot must use continuous path control, and a jointed arm robot consisting of six joints is frequently used.
Spray Coating	Spray coating directs a spray gun at the object to be coated. Paint or some other fluid flows through the nozzle of the spray gun, which is the end effector and is dispersed and applied over the surface of the object. Again, the robot must use continuous path control, and is typically programmed using manual lead-through. Jointed arm robots seem to be the most common anatomy for this application.
Other applications	Other applications include: drilling, routing, and other machining processes; grinding, wire brushing, and similar operations; water jet cutting.

SENSORS

INTRODUCTION

- A sensor is a device that detects and responds to some type of input from the physical environment.
- The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing.
- Sensors are generally classified into two groups:
 1. internal sensors
 2. External sensors.
- Internal sensors such as it obtain the information about the robot itself. Ex- position sensor, velocity sensor, acceleration sensors, motor torque sensor, etc,
- External sensors gather the information in the surrounding environment. Such as cameras, range sensors (IR sensor, laser range finder, and ultrasonic sensor) contact and proximity sensors (photodiode, IR detector, RFID, touch, etc.) and force sensors.

REQUIREMENT OF SENSOR

- ❖ The sensor is an electronic device that measures physical attributes such as temperature, pressure, distance, speed, torque, acceleration, etc., from equipment, appliances, machines and any other systems.
- ❖ The sensor produces an electrical signal/optical signal using multiple technologies proportional to the inputs. These Signals are either interpreted into a readable format or passed on to the next stage for further processing.
- ❖ Sensors are broadly grouped into analog and digital sensors. Analog sensors measure the exact value of physical variables, whereas digital sensors measure the status. Applications classify sensors, Property sensed, Technology used and Systems where they are deployed.

TYPES OF SENSORS

1. Light Sensor

A light sensor detects light and creates a difference in voltage. A robot's vision system has a computer-controlled camera that allows the robot to see and adjust its movements accordingly.

The two primary light sensors in robots are Photo resistor and Photovoltaic cells. Other light sensors like phototubes, phototransistors; CCDs, etc. are rarely used.

a) A **photo resistor** is a type of resistor whose resistance varies with light intensity changes; more light leads to less resistance, and less light leads to more resistance. They can be easily implemented in light-dependent robots.

b) **Photovoltaic cells** convert solar radiation into electricity. This is especially helpful when planning a solar robot. While the photovoltaic cell is considered as an energy source, a smart implementation combined with transistors and capacitors can convert this into a sensor.



SOUND SENSOR

- Sound sensors are generally a microphone used to detect the equivalent voltage of sound and return. The sound it receives can be navigated by a simple robot.
- Imagine a robot turning right to a pulpit, turning left for two palpitations. Complex robots may use the same microphone for voice recognition.
- Sound sensors are not as easy as light sensors because sound sensors generate a minimal voltage difference which should be amplified to produce a measurable change in voltage. Voice systems also use robots with voice commands.



PROXIMITY SENSOR

This is a type of sensor which can detect the presence of a nearby object within a given distance, without any physical contact. The working principle of a Proximity sensor is simple. A transmitter transmits an electromagnetic radiation or creates an electrostatic field and a receiver receives and analyzes the return signal for interruptions. There are

different types of Proximity sensors and we will discuss only a few of them which are generally used in robots.

1. **Infrared (IR) Transceivers:** An IR LED transmits a beam of IR light and if it finds an obstacle, the light is simply reflected back which is captured by an IR receiver. Few IR transceivers can also be used for distance measurement.
2. **Ultrasonic Sensor:** These sensors generate high frequency sound waves; the received echo suggests an object interruption. Ultrasonic Sensors can also be used for distance measurement.
3. **Photo resistor:** Photo resistor is a light sensor; but, it can still be used as a proximity sensor. When an object comes in close proximity to the sensor, the amount of light changes which in turn changes the resistance of the Photo resistor. This change can be detected and processed.

There are many different kinds of proximity sensors and only a few of them are generally preferred for robots. For example, Capacitive Proximity sensors are available which detects change in capacitance around it. Inductive proximity sensor detects objects and distance through the use of induced magnetic field.

DISTANCE SENSOR

Most proximity sensors can also be used as distance sensors, or commonly known as **Range Sensors**; IR transceivers and Ultrasonic Sensors are best suited for distance measurement.

1. **Ultrasonic Distance Sensors:** The sensor emits an ultrasonic pulse and is captured by a receiver. Since the speed of sound is almost constant in air, which is 344m/s, the time between send and receive is calculated to give the distance between your robot and the obstacle. Ultrasonic distance sensors are especially useful for underwater robots.
2. **Infrared Distance sensor:** IR circuits are designed on triangulation principle for distance measurement. A transmitter sends a pulse of IR signals which is detected by the receiver if there is an obstacle and based on the angle the signal is received, distance is calculated. SHARP has a family of IR transceivers which are very useful for distance measurement. A simple transmit and receive using a couple of transmitters and receivers will still do the job of distance measurement, but if you require precision, then prefer the triangulation method
3. **Laser range Sensor:** Laser light is transmitted and the reflected light is captured and analyzed. Distance is measured by calculating the speed of light and time taken for the light to reflect back to the receiver. These sensors are very useful for longer distances.

4. **Encoders:** These sensors (not actually sensors, but a combination of different components) convert angular position of a shaft or wheel into an analog or digital code. The most popular encoder is an optical encoder which includes a rotational disk, light source and a light detector (generally an IR transmitter and IR receiver). The rotational disk has transparent and opaque pattern (or just black and white pattern) painted or printed over it. When the disk rotates along with the wheel the emitted light is interrupted generating a signal output. The number of times the interruption happens and the diameter of the wheel can together give the distance travelled by the robot.
5. **Stereo Camera:** Two cameras placed adjacent to each other can provide depth information using its stereo vision. Processing the data received from a camera is difficult for a robot with minimal processing power and memory. If opted for, they make a valuable addition to your robot.

PRESSURE SENSOR

Pressure sensor measures pressure. Tactile pressure sensors are useful in robotics as they are sensitive to touch, force and pressure. If you design a robot hand and need to measure the amount of grip and pressure required to hold an object, then this is what you would want to use.

TACTILE SENSOR

Tactile Sensor is a device specifying an object's contact. Often used in everyday objects such as elevator buttons and lamps, which dim or brighten by touching the base, a tactile sensor allows the robot to touch and feel. These sensors are used to measure applications and gently interact with the environment. It can be sorted into two principal types: Touch Sensor and Force Sensor.

a) Touch Sensor or Contact Sensor: Touch Sensor is capable of sensing and detecting sensor and object touch. Some of the commonly used simple devices are micro-switches, limit switches, etc. These sensors are mostly used for robots to avoid obstacles. When these sensors hit an obstacle, it triggers a task for the robot, which can be reversed, turned, switched on, stopped, etc.

b) Force Sensor: Force sensor is included in calculating the forces of several functions, such as machine loading & unloading, material handling, and so on, performed by a robot. This sensor will also be a better assembly process to check problems.

TEMPERATURE SENSORS

Temperature sensors are used to detect the surrounding temperature change. It is based on the principle of voltage difference change for a temperature change; this voltage change will provide the surrounding temperature equivalent. Temperature sensing applications include air temperature, surface temperature, and immersion temperature.



ROBOTIC DRIVE SYSTEM AND CONTROLLER

INTRODUCTION

- ❖ The actions of the individual joints must be controlled in order for the manipulator to perform a desired motion. The robot's capacity to move its body, arm, and wrist is provided by the drive system used to power the robot. The joints are moved by actuators powered by a particular form of drive system.
- ❖ Common drive systems used in robotics are electric drive, hydraulic drive, and pneumatic drive.

Mechanical drive system

- ❖ The drive system determines the speed of the arm movement, the strength of the robot, dynamic performance, and, to some extent, the kinds of application.
- ❖ A robot will require a *drive system* for moving their arm, wrist, and body. A drive system is usually used to determine the capacity of a robot. For actuating the robot joints, there are *three different types* of drive systems available such as:
 1. □ Electric drive system,
 2. □ Hydraulic drive system, and
 3. □ Pneumatic drive system.
- ❖ The most importantly used two types of drive systems are electric and hydraulic.

Electric drive system:

- ❖ The electric drive systems are capable of moving robots with *high power* or speed.
- ❖ The actuation of this type of robot can be done by either DC servo motors or DC stepping motors. It can be well – suited for rotational joints and as well as linear joints.
- ❖ Electric drive systems do not generally provide as much speed or power as hydraulic systems. However, the accuracy and repeatability of electric drive robots are usually better. Consequently, electric robots tend to be smaller. Require less floor space, and their applications tend toward more precise work such as assembly.
- ❖ In this System, power is developed by an electric current. It required little maintenance and the operation is noise less. The one disadvantage of this system is that it is slightly costlier. An example for this type of drive system is *Maker 110 robot*.

HYDRAULIC DRIVE SYSTEM:

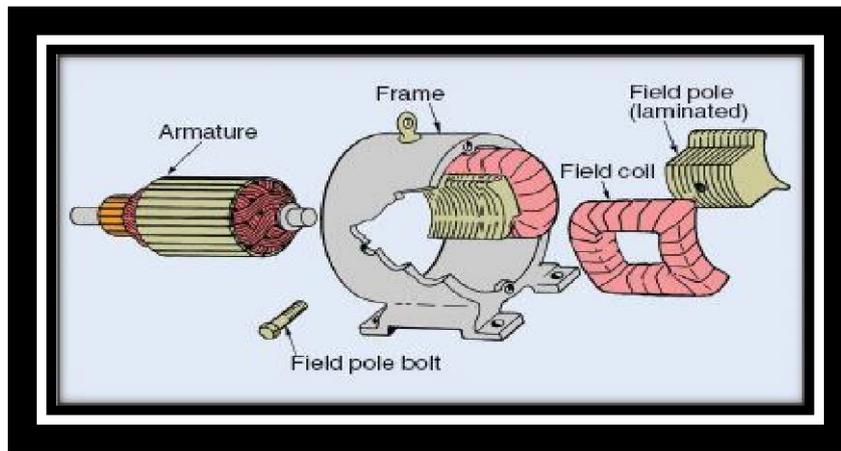
- ❖ Hydraulic drive is generally associated with larger robots, such as the Unimate 2000 series.
- ❖ This type of system can also be called as non-air powered cylinders. In this system, oil is used as a working fluid instead of compressed air. Hydraulic system need pump to generate the required pressure and flow rate. These systems are quite complex, costly and require maintenance.
- ❖ The usual advantages of the hydraulic drive system are that it provides the robot with greater speed and strength.
- ❖ The disadvantages of the hydraulic drive system are that it typically adds to the floor space required by the robot, and that a hydraulic system is inclined to leak on which is a nuisance.

PNEUMATIC DRIVE SYSTEM

- ❖ The pneumatic drive systems are especially used for the small type robots, which have less than five degrees of freedom. It has the ability to offer fine accuracy and speed.
- ❖ In this system, air is used as a working fluid; hence it is also called air-powered cylinders. Air is compressed in the cylinder with the aid of pump the compressed air is used to generate the power with required amount of pressure and flow rates.
- ❖ This drive system can produce rotary movements by actuating the rotary actuators. The translational movements of sliding joints can also be provided by operating the piston. The price of this system is less when compared to the hydraulic drive.
- ❖ The drawback of this system is that it will not be a perfect selection for the faster operations.

DC MOTORS

Figure 2-1 illustrates the construction of a DC servomotor, consisting of a stator, a rotor, and a commutation mechanism. The stator consists of permanent magnets, creating a magnetic field in the air gap between the rotor and the stator. The rotor has several windings arranged symmetrically around the motor shaft. An electric current applied to the motor is delivered to individual windings through the brush-commutation mechanism, as shown in the figure. As the rotor rotates the polarity of the current flowing to the individual windings is altered. This allows the rotor to rotate continually.



ROBOT CONTROL SYSTEMS FOR PATH CONTROL

- ❖ The actuations of the individual joints must be controlled in a coordinated fashion for the manipulator to perform a desired motion cycle.
- ❖ Robot controllers can be classified into four categories:
 - a. **Limited sequence control.**
 - b. **Point-to-point control.**
 - c. **Continuous path control.**
 - d. **Intelligent control.**
- ❖ **Limited sequence control** uses mechanical stops to provide the extreme ranges of motion and when motion command is used, the joint is driven until the mechanical stop is reached. This technique is no longer used.
- ❖ **Point-to-point** involves the specification of the starting point and end point (and often intermediate points) of the robot motion requiring a control system which renders some feedback at those points. This technique is used for spot welding, pick-and-place operations and so on.
- ❖ **Continuous Path Control** requires the robot end effector to follow a stated path from the starting point to the end point. This technique is required in many applications that require the actual tracing of a contour, for instance, in arc welding or spray painting. The continuous path robots usually follow a series of closely spaced points on a path and these points are defined by the control unit rather than the programmer. In many cases, the paths between points are straight lines
- ❖ **Intelligent Control** An intelligent robot is one that exhibits behavior that makes it seem intelligent. Some of the characteristics that make a robot appear intelligent include the capacity to :
 - Interact with its environment.
 - Make decisions when things go wrong during the work cycle.
 - Make computations during the motion cycle.

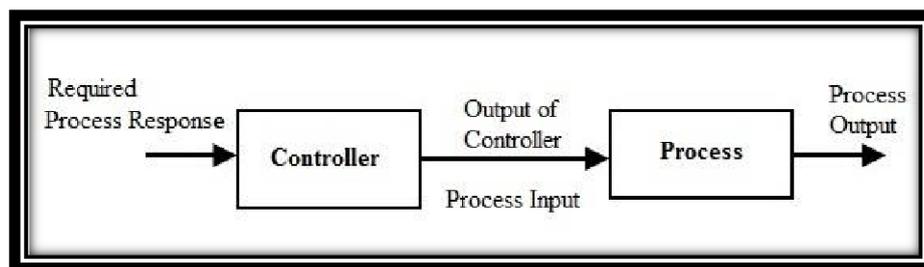
- Respond to advanced sensor inputs such as machine vision

ROBOT CONTROLLER

- ❖ The behavior of the system can be determined with the help of a differential equation is known as the control system. So it controls different devices as well as systems with the help of control loops.
- ❖ Control systems are classified into two types
 1. open loop control system
 2. closed loop control system

Open loop control system

- ❖ The working of the open loop control system which depends on time is also called the open-loop control system. It doesn't have any feedback.
- ❖ It is very simple, needs low maintenance, quick operation, and cost-effective. The accuracy of this system is low and less dependable.
- ❖ The main advantages of the open-loop control system are easy, needs less protection; operation of this system is fast & inexpensive and the disadvantages are, it is reliable and has less accuracy.
- ❖ Example - The clothes dryer is one of the examples of the open-loop control system. In this, the control action can be done physically through the operator. Based on the clothing's wetness, the operator will fix the timer to 30 minutes. So after that, the timer will discontinue even after the machine clothes are wet. The dryer in the machine will stop functioning even if the preferred output is not attained. This displays that the control system doesn't feedback. In this system, the controller of the system is the timer.



Closed loop control system

- ❖ The closed-loop control system can be defined as the output of the system that depends on the input of the system. This control system has one or more feedback loops among its input & output.
- ❖ This system provides the required output by evaluating its input. This kind of system produces the error signal and it is the main disparity between the output and input of the system.

- ❖ The main advantages of the closed-loop control system are accurate, expensive, reliable, and requires high maintenance.
- ❖ Example:-The best example of the closed-loop control system is AC or air conditioner. The AC controls the temperature by evaluating it with the nearby temperature. The evaluation of temperature can be done through the thermostat. Once the air conditioner gives the error signal is the main difference between the room and the surrounding temperature.
- ❖ So the thermostat will control the compressor. These systems are accurate, expensive, reliable, and requires high maintenance.

