CIM&FMS

(Module-2)

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Syllabus

MODULE – II (12 HOURS)

Industrial Robotics: Robot anatomy, control systems, end effectors, sensors and actuators; fundamentals of NC technology, CNC, DNC, NC part programming; Robotic programming, Robotic languages, work cell control, Robot cleft design, types of robot application, Processing operations, Programmable Logic controllers: Parts of PLC, Operation and application of PLC, Fundamentals of Net workings; Material Handling and automated storage and retrieval systems, automatic data capture, identification methods, bar code and other technologies.

Learning Outcomes:

Students will be able to :

1. Know about the Industrial robots and its applications.
2. Robot anatomy, control systems, end effectors, sensors and actuators.
3. Understand about NC and CNC Machines and its programming.
4. Understand the fundamentals and application of PLC.
5. Explain about the Material handling system and AS/RS.
6. Understand about the bar code technologies.

Industrial Robotics

- 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."
- Industrial robots commercially and technologically important :

1. Robots can be substituted for humans in hazardous or uncomfortable work environments.

2. A robot performs its work cycle with a consistency and repeatability that cannot be attained by humans.

3. Robots can be reprogrammed. When the production run of the current task is completed, a robot can be reprogrammed and equipped with the necessary tooling to perform an altogether different task.

4.Robots are controlled by computers and can therefore be connected to other computer systems to achieve computer integrated manufacturing.

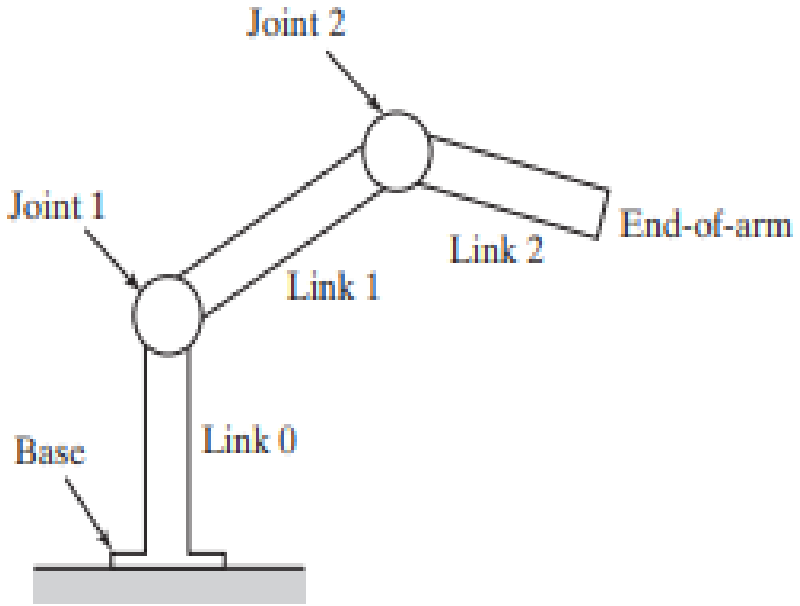
Robot Anatomy

- The physical construction of the body, arm and wrist of the machine
- The wrist is oriented in a variety of positions
- Relative movements between various components of body, arm and wrist are provided by a series of joints
- Joints provide either sliding or rotating motions
- The assembly of body, arm and wrist is called "Manipulator".
- The arm or manipulator of an industrial robot consists of a series of joints and links

Source: https://www.thomasnet.com/insights/industrial-robots-can-do-more-than-just-pick-and-place

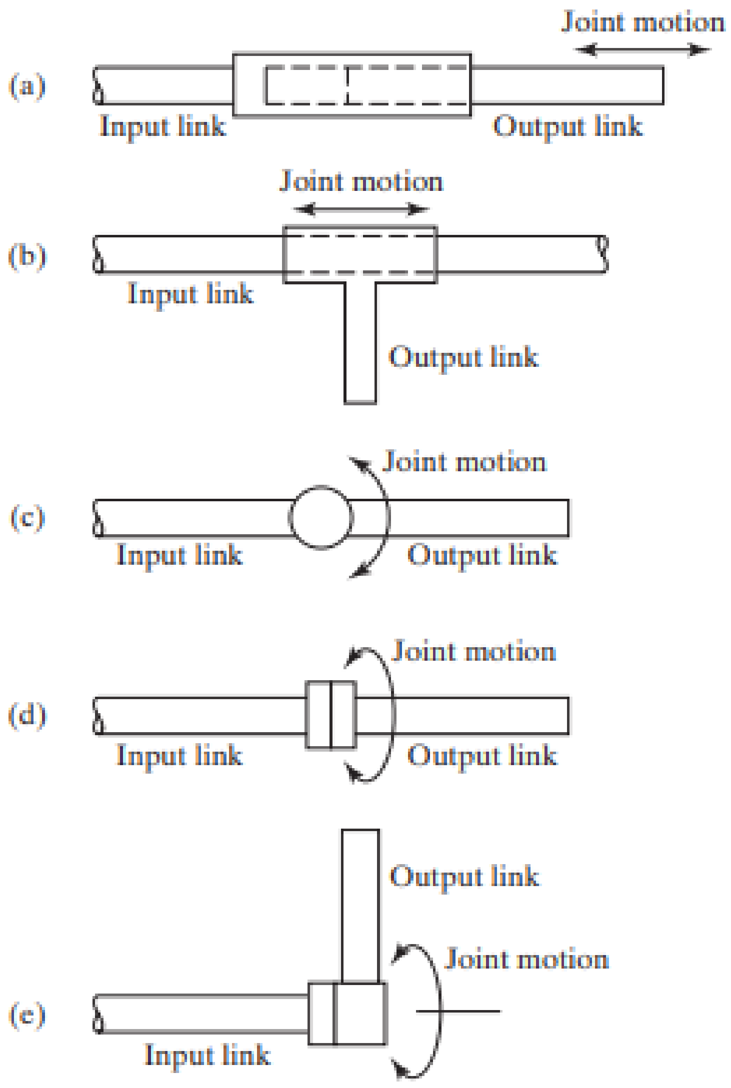
Joints and Links

- A robot's joint is similar to a joint in the human body as it provides relative motion between two parts of the body.
- 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 relative movement between the input link and the output link.



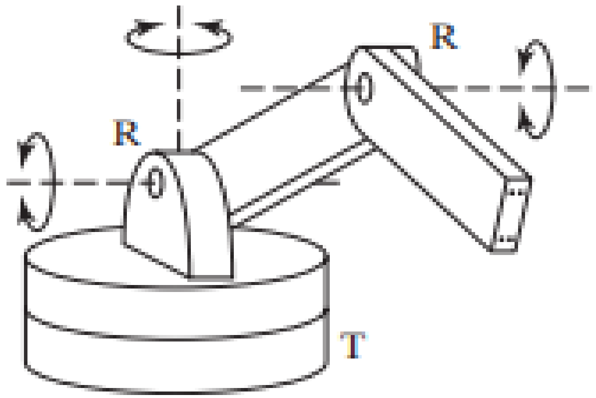
Joints

1. 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.
2. Orthogonal joint (type O joint). This is also a translational sliding motion, but the input and output links are perpendicular to each other.
3. 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.
4. 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.
5. 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.

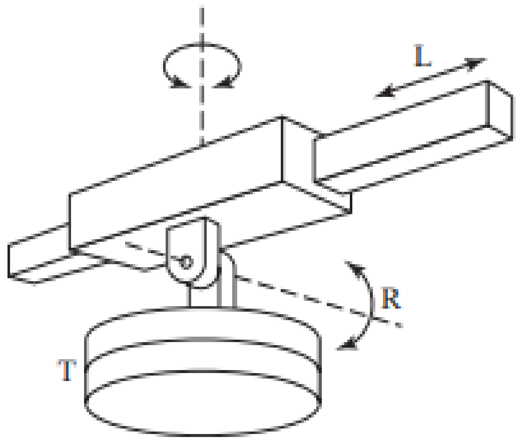


Body and Arm Configurations

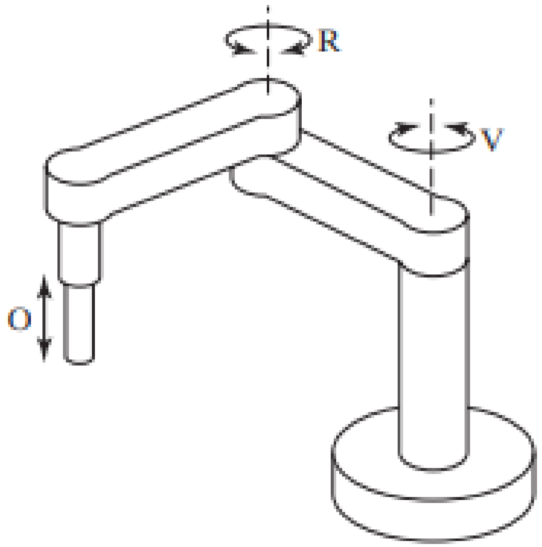
- Articulated robot (jointed-arm robot) TRR



- Polar configuration TRL

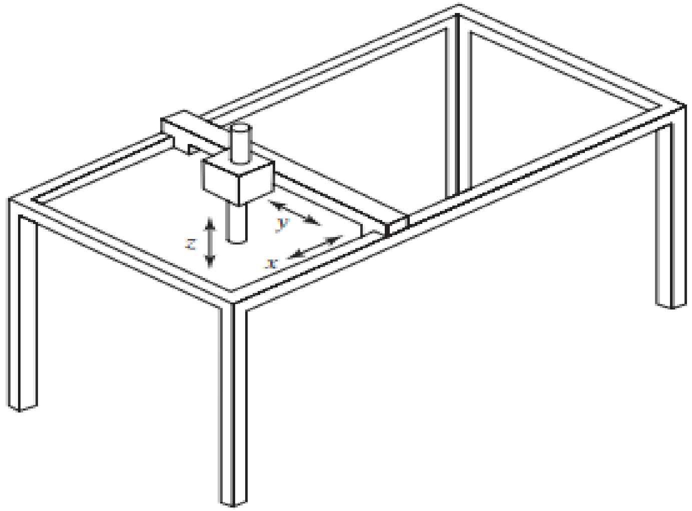


- SCARA(Selectively Compliant Arm for Robotic Assembly) VRO

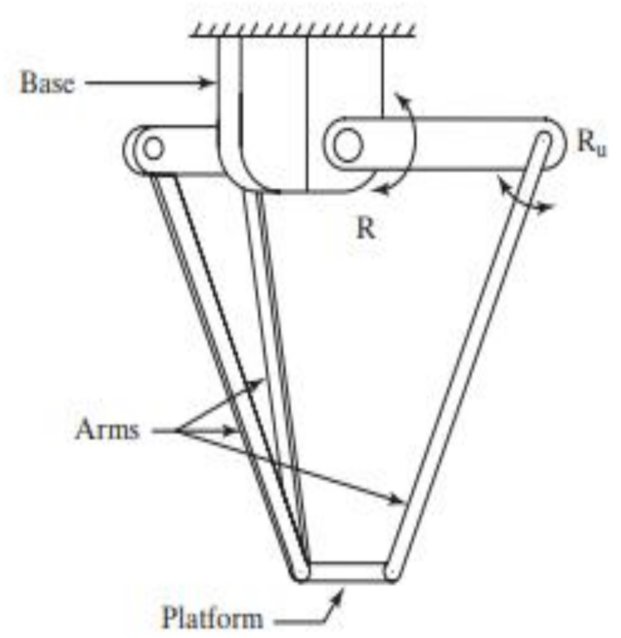


Body and Arm Configurations

- Cartesian coordinate robot (OOO)

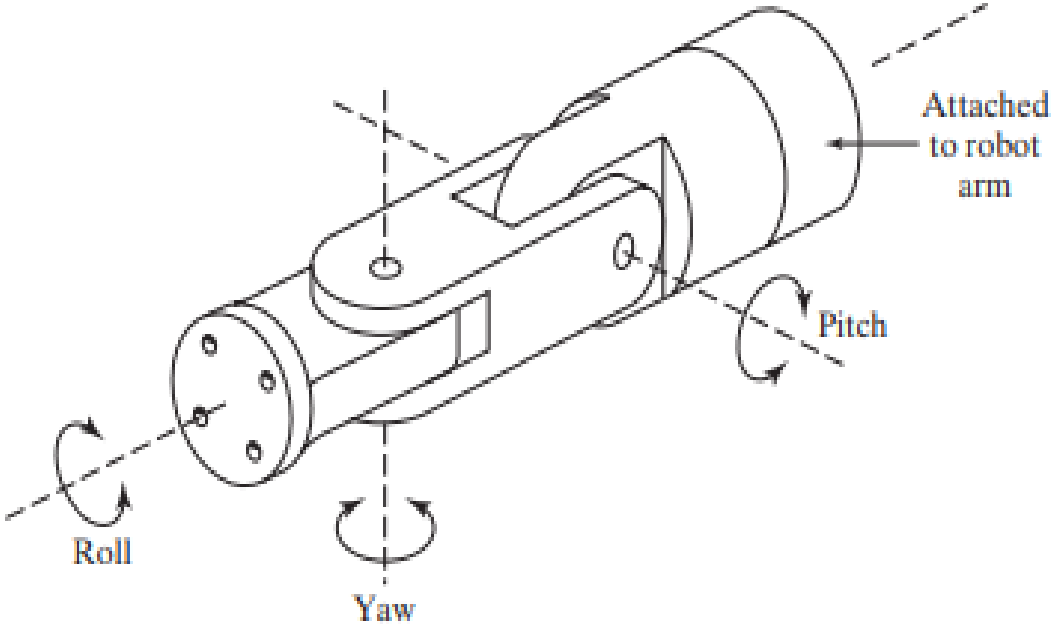


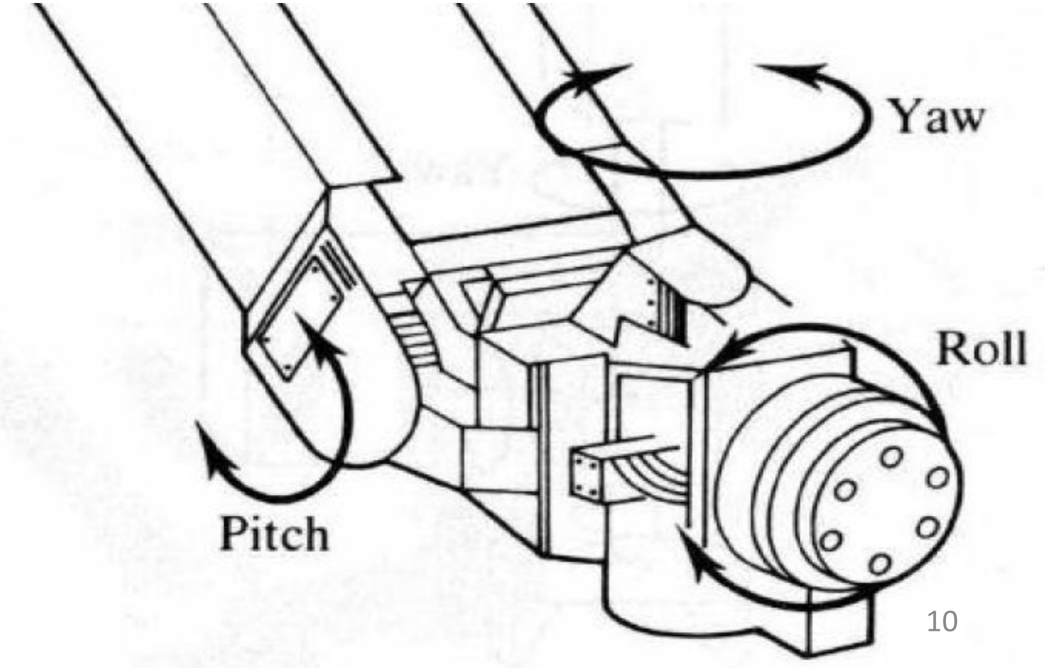
- Delta robot $3(RR_u)$



Wrist Configurations

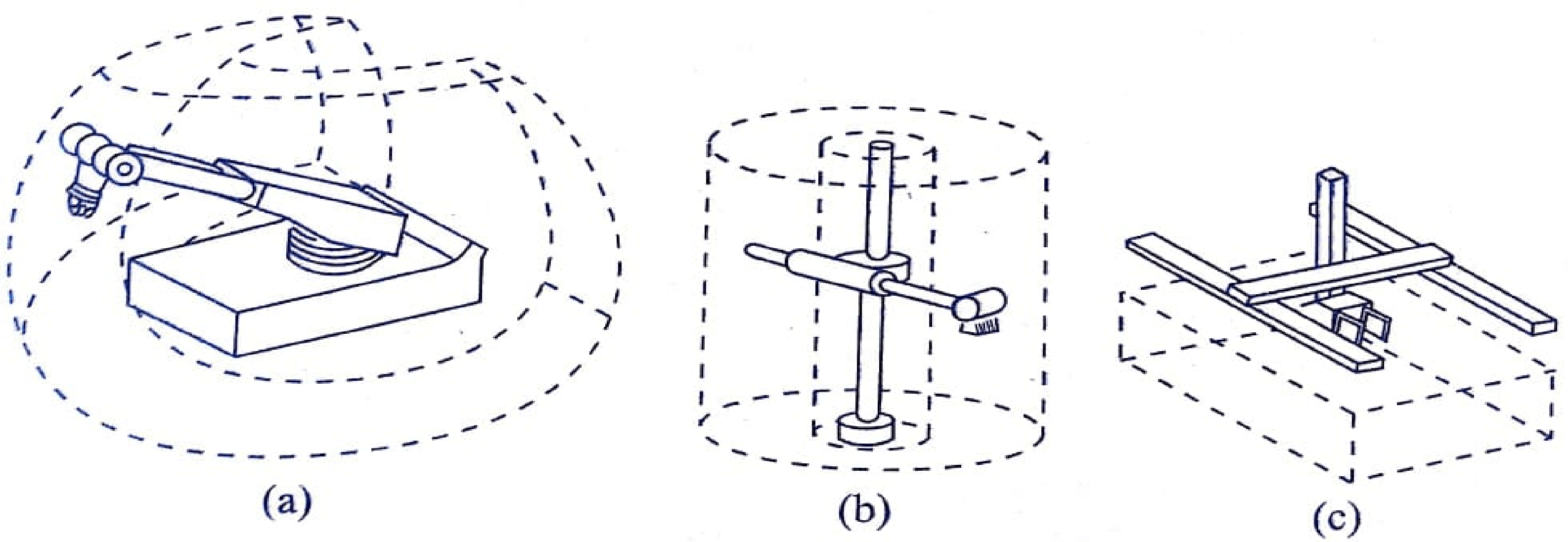
- Wrist movement enable the robot to orient the end effector properly to perform a task
- Provided with up to 3 DOF which are:
    1. Wrist Pitch/Bend: Provide up-and-down rotation to the wrist
    2. Wrist Yaw: Involve right-and-left rotation of the wrist
    3. Wrist Roll/Swivel: Is the rotation of the wrist about the arm axis





Robot Work Volume

- The work volume (also known as work envelope) of the manipulator is defined as the three-dimensional space within which the robot can manipulate the end of its wrist.
- End effector may not be capable of reaching certain points within the robot's normal work volume
- Larger volume costs more but can increase capabilities of robot
- It depends upon following physical characteristics:
  - Robot's configuration
  - Size of the body, arm and wrist components
  - Limits of the robot's joint movements

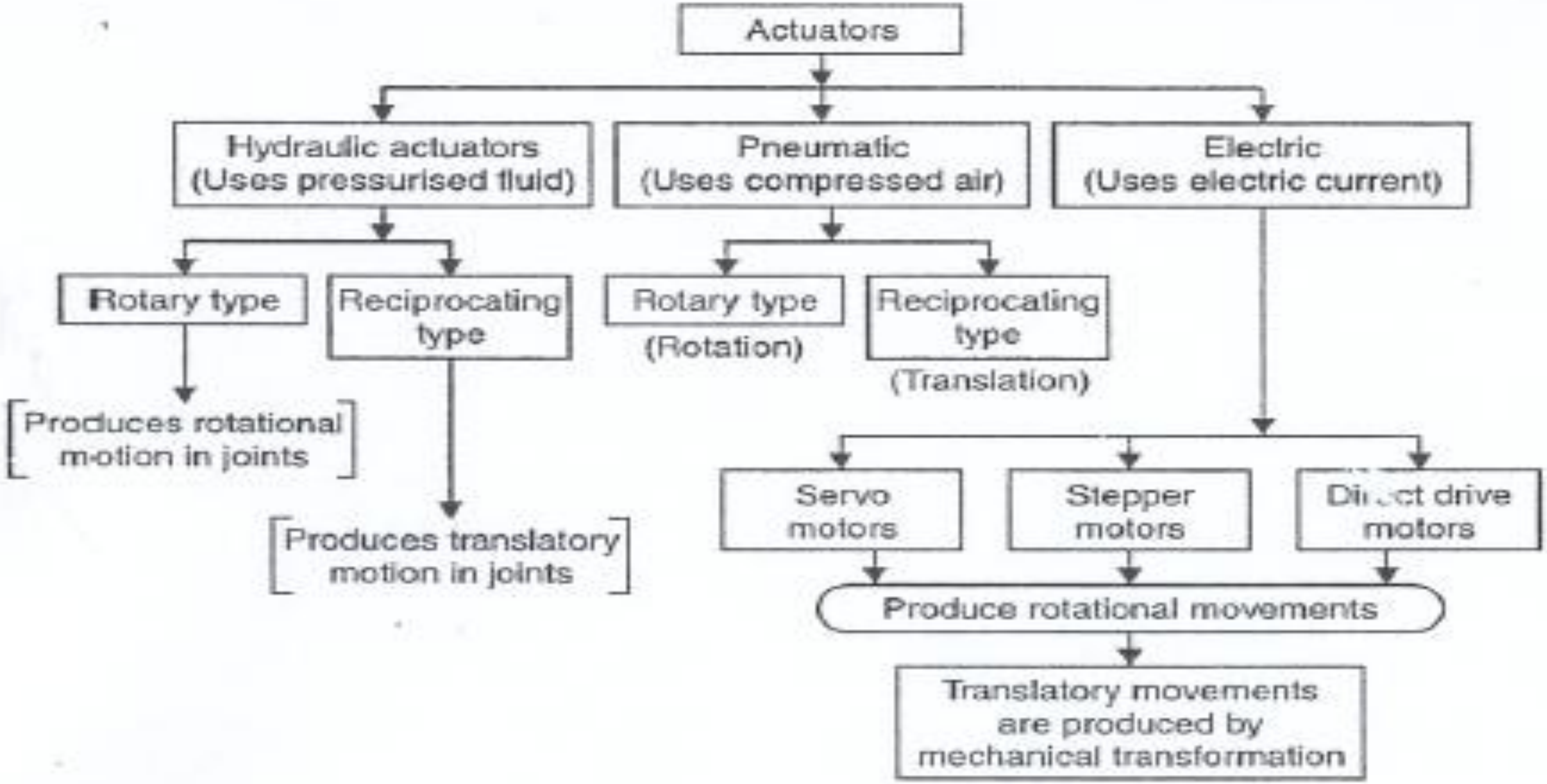


Work Volumes for Different Types of Robots : **(a) Polor, (b) Cylindrical, (c) Cartesian**

Drive Systems

- Capacity to move robot’s body, arm and wrist
- Determine speed of the arm movements, strength of the robot & dynamic performance
- Type of applications that the robot can accomplish
- Powered by three types of drive systems:
    1. Hydraulic
    2. Pneumatic
    3. Electric

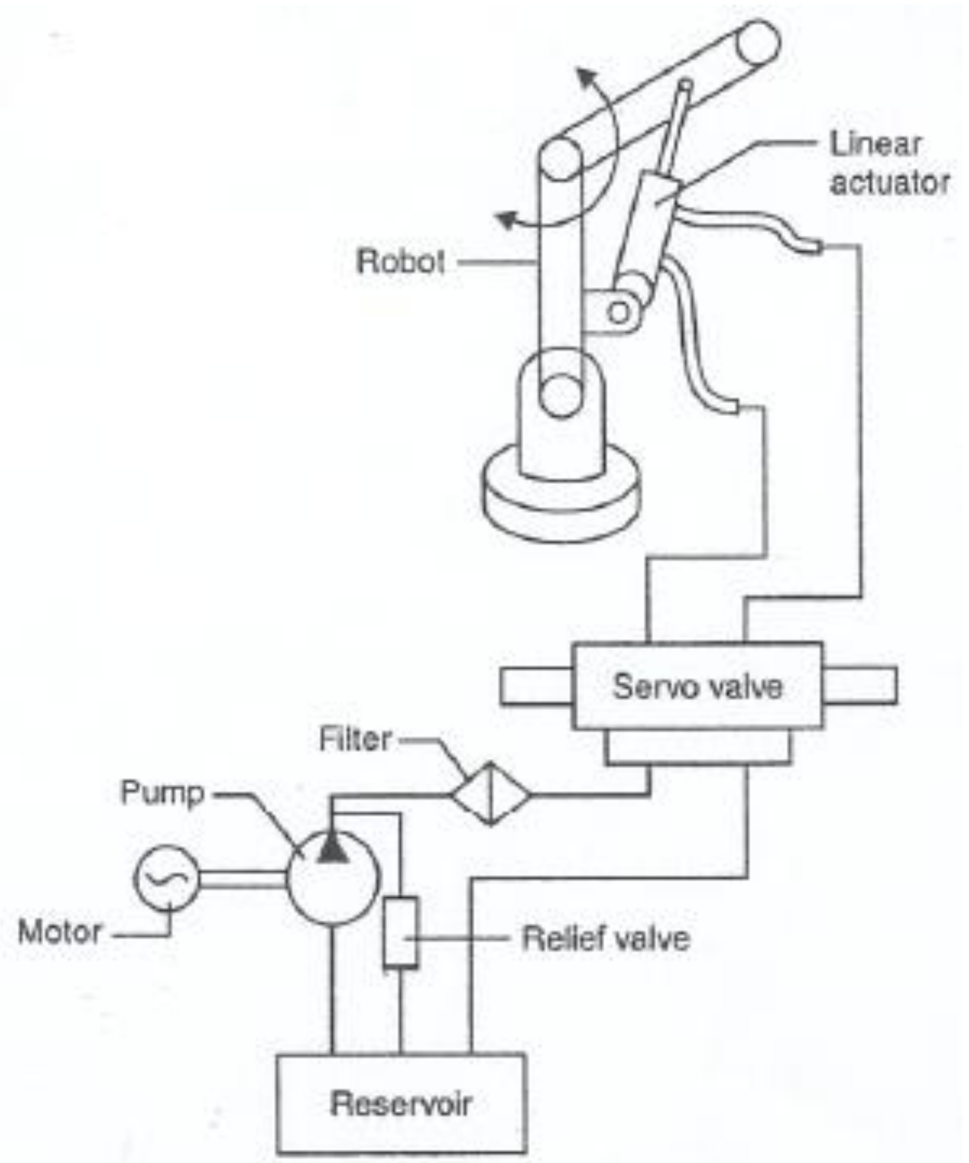
Drive Systems..



Drive Systems..

1. Hydraulic Drive

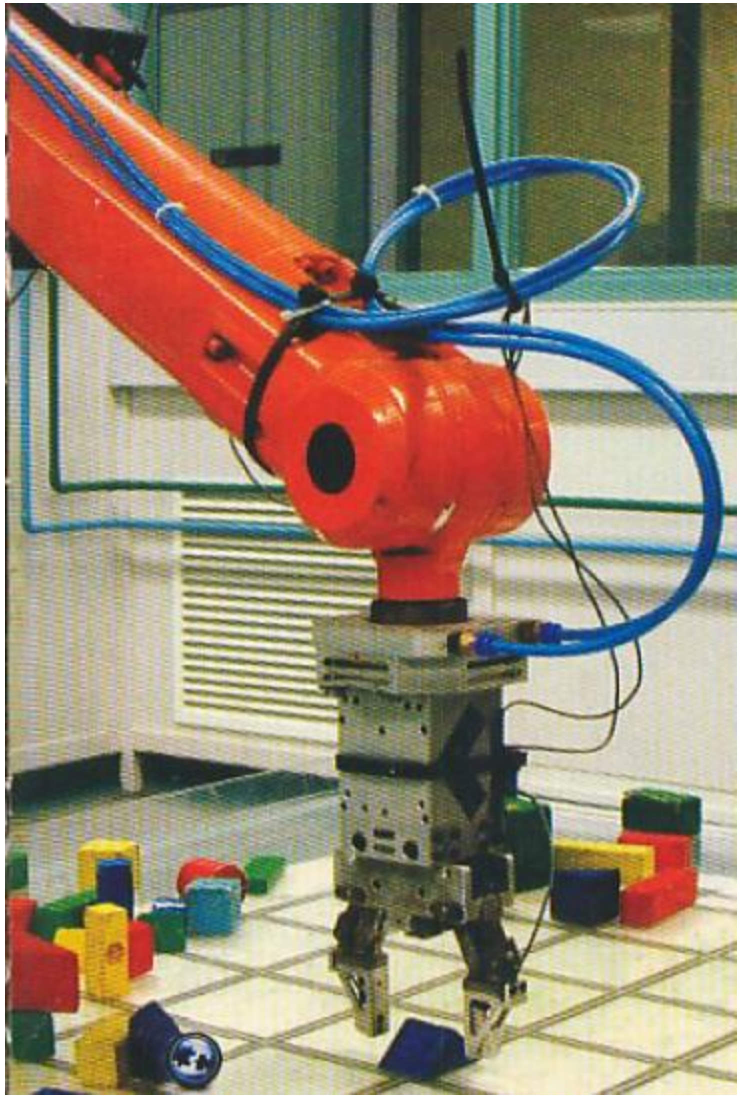
- ✓ Associated with large robot
- ✓ Provide greater speed & strength
- ✓ Add floor space
- ✓ Leakage of oil
- ✓ Provide either rotational or linear motions
- ✓ Applications such as:
  - Spray coating robot
  - Heavy part loading robot
  - Material handling robot
  - Translatory motions in cartesian robot
  - Gripper mechanism



Drive Systems..

2. Pneumatic Drive

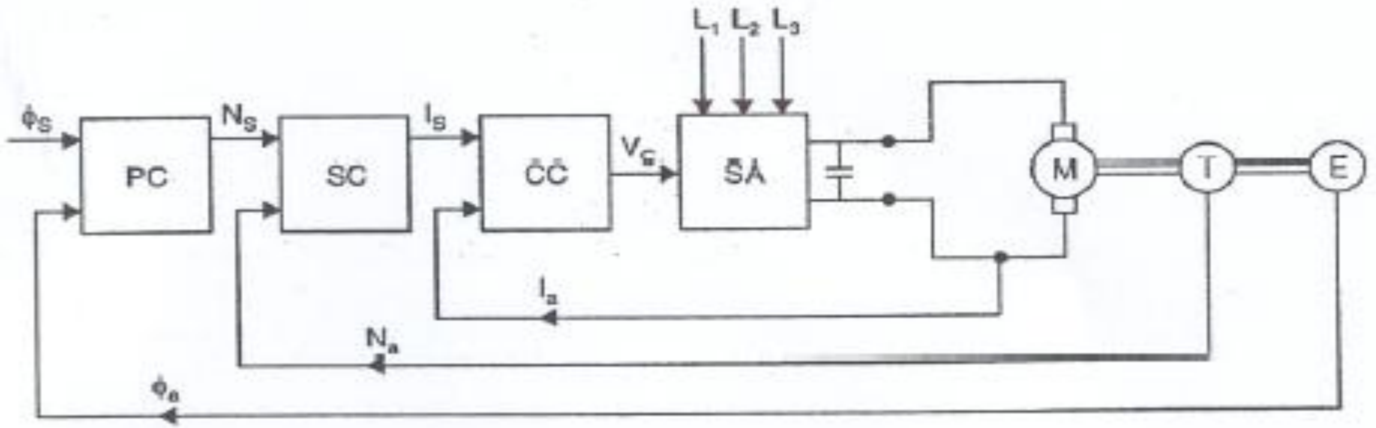
- ✓ Reserved for smaller robot
- ✓ Limited to “pick-and-place” operations with fast cycles
- ✓ Drift under load as air is compressible
- ✓ Provide either rotational or linear motions
- ✓ Simple and low cost components
- ✓ Used to open and close gripper



Drive Systems..

3. Electric Drive

- ✓ Rotor, stator, brush and commutator assembly
- ✓ Rotor has got windings of armature and stator has got magnets
- ✓ The brush and the commutator assembly switch the current in armature windings
- ✓ The most commonly used are DC servomotors, AC servomotors and stepper motors

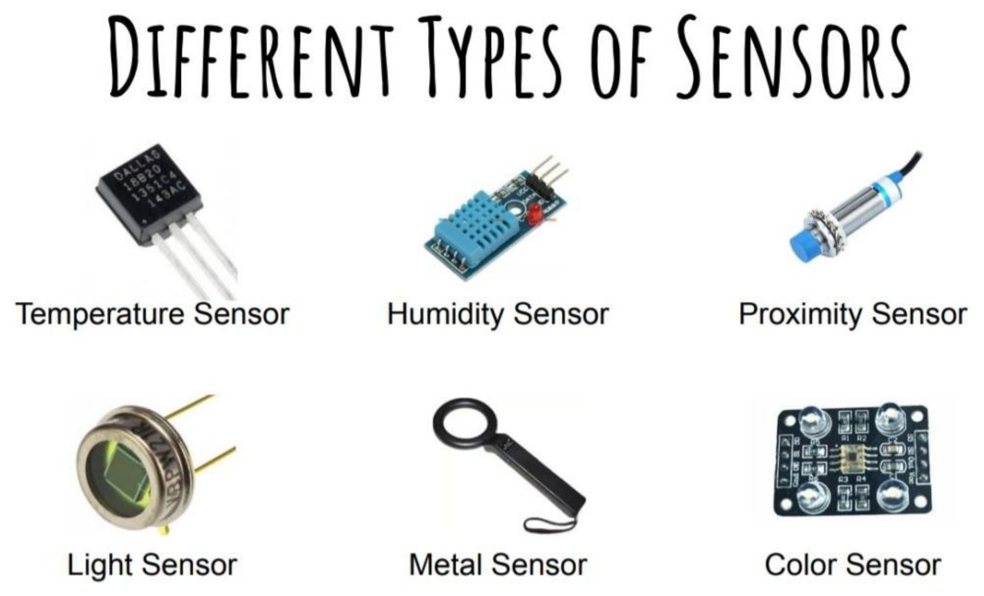


PC = Position controller
SC = Speed controller
CC = Current controller
SA = Servo amplifier
M = DC/AC motor
T = Tacho-generator
E = Encoder.

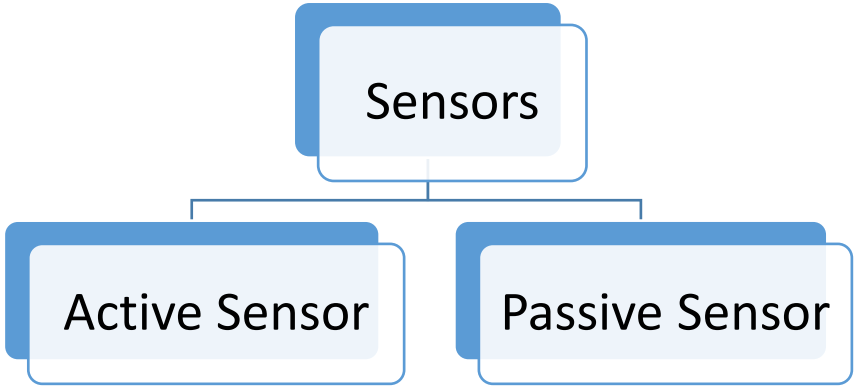
N_a = actual speed
ϕ_a = actual position
I_a – actual current
L_1, L_2, L_3 = 3-phase supply.
ϕ_s, N_s, I_s, = desired position, speed and current
V_c = control voltage.

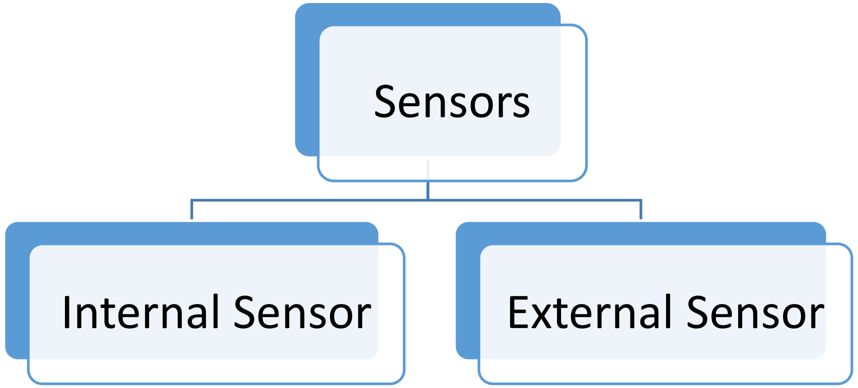
Sensors in Robotics

- 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.
- 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.
- A wide variety of sensors are available for collecting data from the manufacturing process for use in feedback control.



Category	Examples of Physical Variables
Mechanical	Position (displacement, linear and angular), velocity, acceleration, force, torque, pressure, stress, strain, mass, density
Electrical	Voltage, current, charge, resistance, conductivity, capacitance
Thermal	Temperature, heat, heat flow, thermal conductivity, specific heat
Radiation	Type of radiation (e.g., gamma rays, X-rays, visible light), intensity, wavelength
Magnetic	Magnetic field, flux, conductivity, permeability
Chemical	Component identities, concentration, pH levels, presence of toxic ingredients, pollutants





- An ***active sensor*** responds to the stimulus without the need for any external power.
- An example is a thermocouple, which responds to an increase in temperature by generating a small voltage (millivolt range) that is functionally related to temperature.
- A ***passive sensor*** requires an external source of power in order to operate.
- e.g A thermistor illustrates this case. It also measures temperature, but its operation requires an electric current to be passed through it. As the temperature increases, the thermistor’s electrical resistance is altered. The resistance can be measured and related back to temperature.
- Sensors used in industrial robotics can be classified into two categories:

  (1) internal

  (2) external

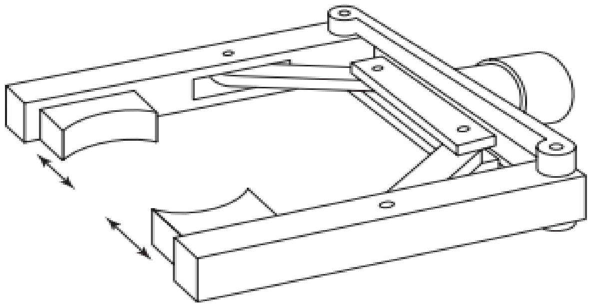
- Internal sensors are components of the robot and are used to control the positions and velocities of the robot joints.
- External sensors are external to the robot and are used to coordinate the operation of the robot with other equipment in the cell.
- **Tactile sensors**: These are used to determine whether contact is made between the sensor and another object.
- **Tactile sensors** can be divided into two types in robot applications:

  (1) touch sensors

  (2) force sensors.
- **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.
- **Other sensors**: A miscellaneous category includes other types of sensors that might be used in robotics, such as devices for measuring temperature, fluid pressure, fluid flow, electrical voltage, current, and various other physical properties.

End Effectors

- The end effector enables the robot to accomplish a specific task.
- The end effector is usually custom-engineered and fabricated for each different application.
- The two categories of end effectors :
  1. Grippers and
  2. Tools



- Grippers Types:

Mechanical grippers, consisting of two or more fingers that can be actuated by the robot controller to open and close on the work part.

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

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.

Tools

- The robot uses tools to perform processing operations on the work part.
- The robot manipulates the tool relative to a stationary or slowly moving object (e.g., work part or subassembly).

Robot Programming

- 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.
- A robot is programmed by entering the programming commands into its controller memory. Different robots use different methods of entering the commands.
- Three programming methods can be distinguished:

  (1) leadthrough programming,

  (2) computer-like robot programming languages,

  (3) off-line programming.

Leadthrough Programming

- In leadthrough programming, the task is taught to the robot by moving the manipulator through the required motion cycle, simultaneously entering the program into the controller memory for subsequent playback.
- There are two methods of performing the leadthrough procedure:

  (1) Powered leadthrough

  (2) Manual leadthrough.
- ***Powered leadthrough*** is commonly used as the programming method for playback robots with point-to-point control.
- It involves the use of a teach pendant (handheld control box) that has toggle switches and/or contact buttons for controlling the movement of the manipulator joints.
- Using the toggle switches or buttons, the programmer power-drives the robot arm to the desired positions, in sequence, and records the positions into memory.
- During subsequent playback, the robot moves through the sequence of positions under its own power.

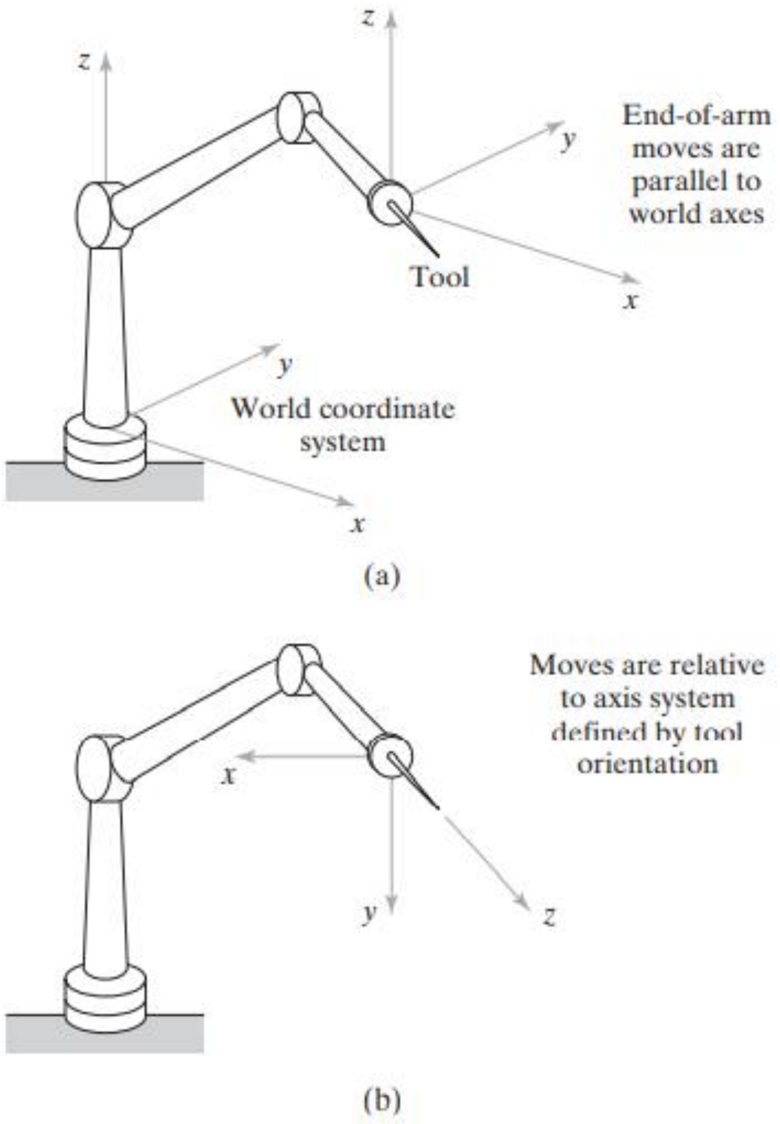
Leadthrough Programming

- Manual leadthrough is convenient for programming playback robots with continuous path control where the continuous path is an irregular motion pattern such as in spray painting.
- This programming method requires the operator to physically grasp the tool attached to the end of the arm and move it through the motion sequence, recording the path into memory.

Motion Programming.

(1) world-coordinate system

(2) tool-coordinate system



Robot Programming Languages

- The use of textual programming languages became an appropriate programming method as digital computers took over the control function in robotics.
- Textual programming languages for robots provide the opportunity to perform the following functions over leadthrough programming :

1. Enhanced sensor capabilities, including the use of analog as well as digital inputs and outputs.
2. Improved output capabilities for controlling external equipment
3. Program logic that is beyond the capabilities of leadthrough methods
4. Computations and data processing similar to computer programming languages
5. Communications with other computer systems

Motion Programming.

- **MOVE P1**: which commands the robot to move from its current position to a position and orientation defined by the variable name P1. The point P1 must be defined, and the most convenient way to define P1 is to use either powered leadthrough or manual leadthrough to place the robot at the desired point and record that point into memory.
- **HERE P1/ LEARN P1** : used in the leadthrough procedure to indicate the variable name for the point.

e.g (236, 158, 65, 0, 0, 0)

- It is to represent the joint positions for a six-axis manipulator. The first three values (236, 158, 65) give the joint positions of the body-and-arm, and the last three values (0, 0, 0) define the wrist joint positions. The values are specified in millimeters or degrees, depending on the joint types.

- **MOVES P1** : variants of the MOVE statement.
- It denotes a move that is to be made using straight line interpolation. The suffix S on MOVE designates straight line motion.
- **DMOVE :** The prefix D is interpreted as delta and DMOVE represents a delta move, or incremental move.
- DMOVE (4, 125) : it is desired to move joint 4 (corresponding to a twisting motion of the wrist) from 0 to 125.
- The new joint coordinates of the robot would therefore be given by (236, 158, 65, 125, 0, 0).
- Approach and depart statements are useful in material handling operations.
- The **APPROACH** statement moves the gripper from its current position to within a certain distance of the pickup (or drop-off) point, and then a MOVE statement positions the end effector at the pickup point.
- After the pickup is made, a **DEPART** statement moves the gripper away from the point.

APPROACH P1, 40 MM

MOVE P1

(command to actuate gripper)

DEPART 40 MM

- The destination is point P1, but the APPROACH command moves the gripper to a safe distance (40 mm) above the point.
- A **PATH** in a robot program is a series of points connected together in a single move.

e.g DEFINE PATH123 = PATH1P1,P2,P32

- This is a path that consists of points P1, P2, and P3.
- A MOVE statement is used to drive the robot through the path.

e.g **MOVE PATH123**

- The speed of the robot is controlled by defining either a relative velocity or an absolute velocity.

```
SPEED 0.5 MPS
EXECUTE PROGRAM1
```

- It indicates that the program named PROGRAM1 is to be executed by the robot at a speed of 0.5 m/sec

Material Transport System

- Material handling is defined by the Material Handling Industry of America as "the movement, protection, storage and control of materials and products throughout the process of manufacture and distribution, consumption and disposal"
- The term commonly used for the larger system is **logistics**, which is concerned with the acquisition, movement, storage, and distribution of materials and products, as well as the planning and control of these operations in order to satisfy customer demand.
- Logistics can be:

  1. External logistics
  2. Internal logistics

Material Handling Equipment

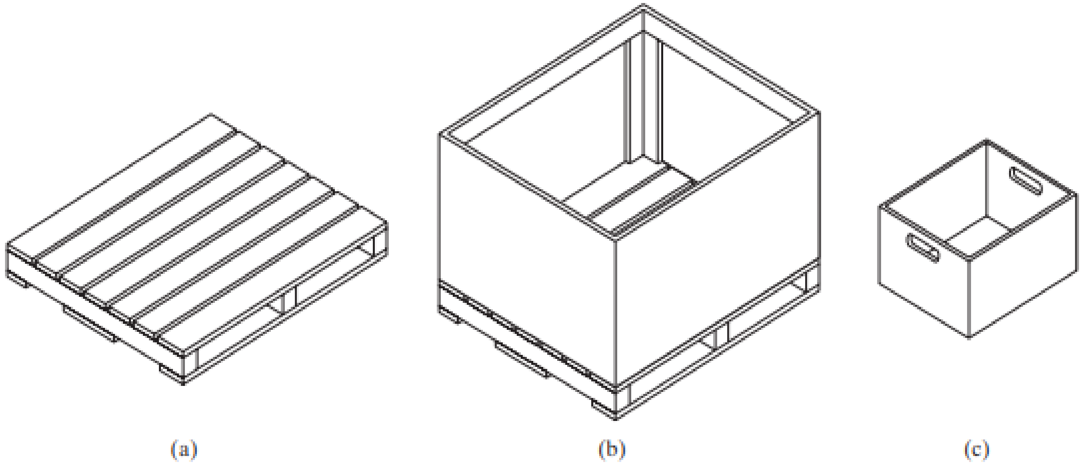
(1) Transport equipment e. g industrial trucks, automated guided vehicles, rail-guided vehicles, conveyors, hoists and cranes

(2) Positioning equipment

(3) Unit load formation equipment e.g wooden pallet, pallet box

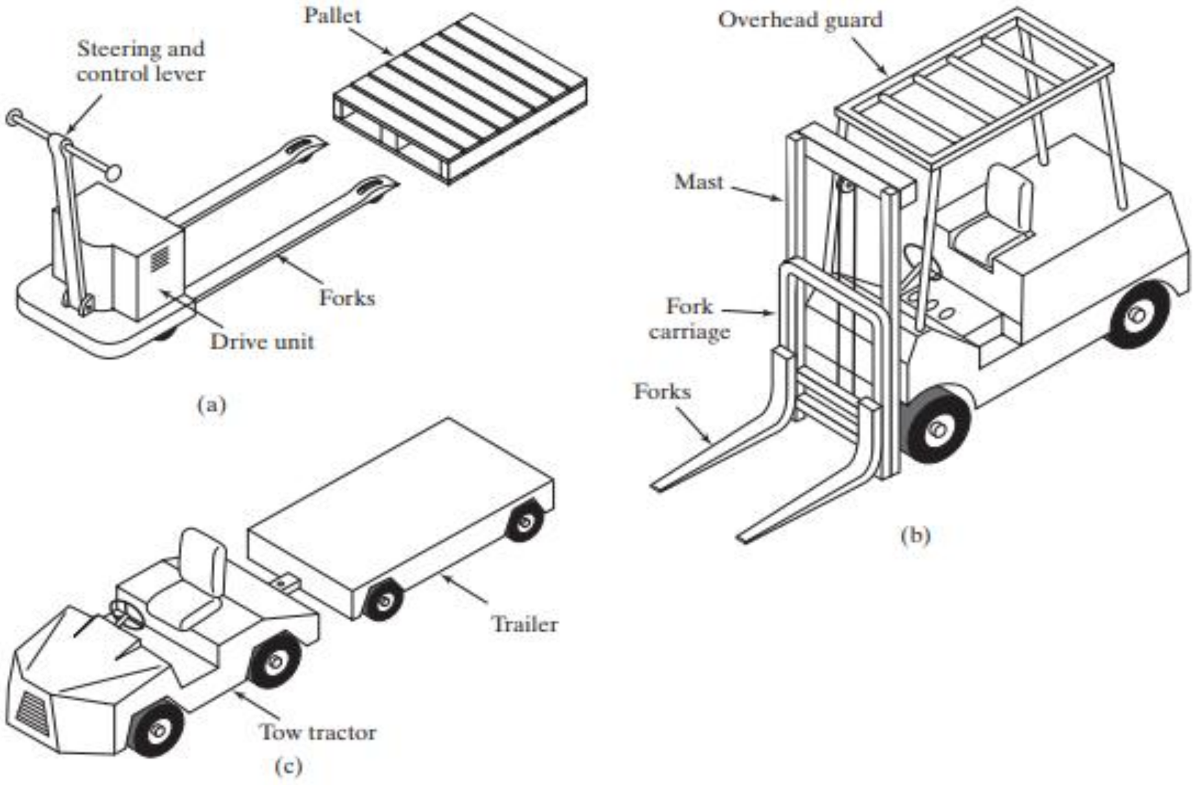
(4) Storage equipment

(5) Identification and control equipment.

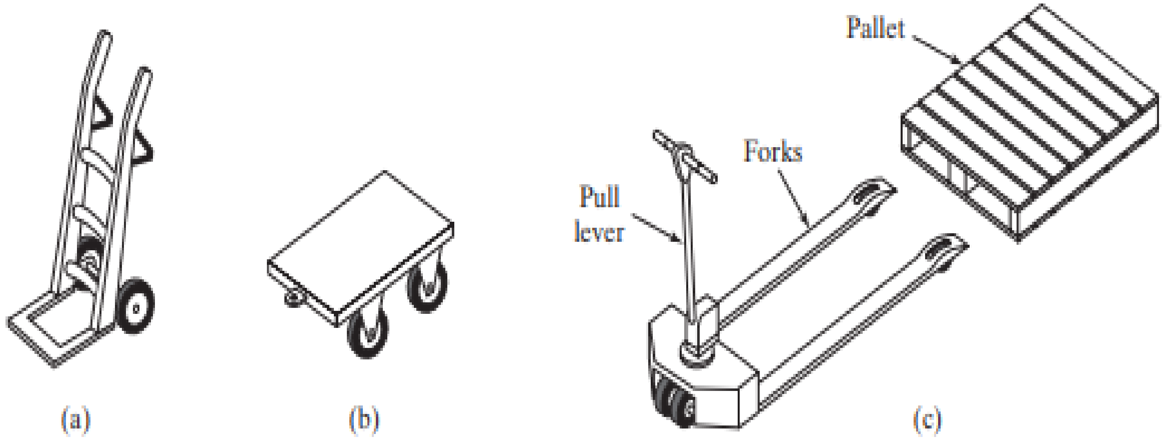


Material Transport Equipment

(1) Industrial trucks, manual and powered;
(2) Automated guided vehicles;
(3) Rail-guided vehicles;
(4) Conveyors;
(5) Cranes and hoists



(a) walkie truck, (b) forklift truck, and (c) towing tractor.



(a) Two wheel hand truck, (b) four-wheel dolly, and (c) hand-operated low-lift pallet truck

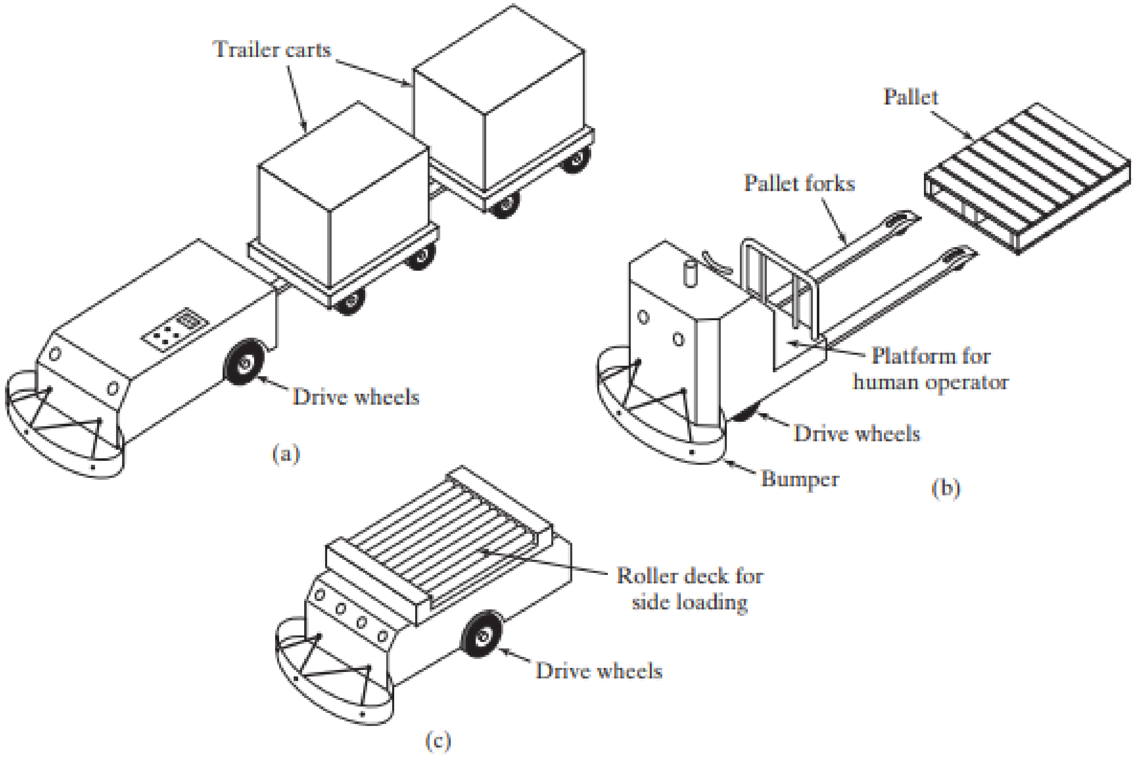
Automated Guided Vehicles

- An automated guided vehicle system (AGVS) is a material handling system that uses independently operated, self-propelled vehicles guided along defined pathway.
- The AGVs are powered by on-board batteries that allow many hours of operation (8–16 hr is typical) before needing to be recharged.
- Automated guided vehicles can be divided :

  (1) towing vehicles for driverless trains

  (2) pallet trucks

  (3) unit load carrier



(a) driverless automated guided train, (b) AGV pallet truck, and (c) unit load carrier.

Vehicle Guidance Technologies

- The guidance system is the method by which AGVS pathways are defined and vehicles are controlled to follow the pathways.
- The technologies used in commercial AGV systems for vehicle guidance:

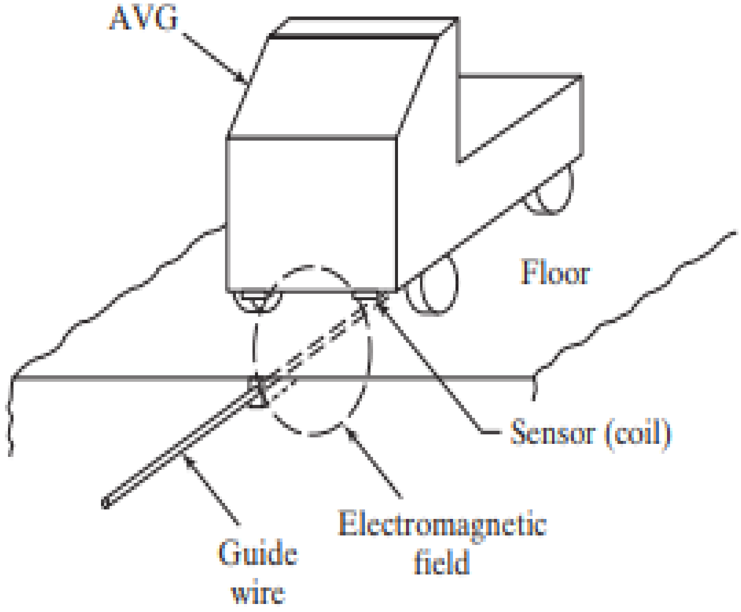
  (1) imbedded guide wires,

  (2) paint strips,

  (3) magnetic tape,

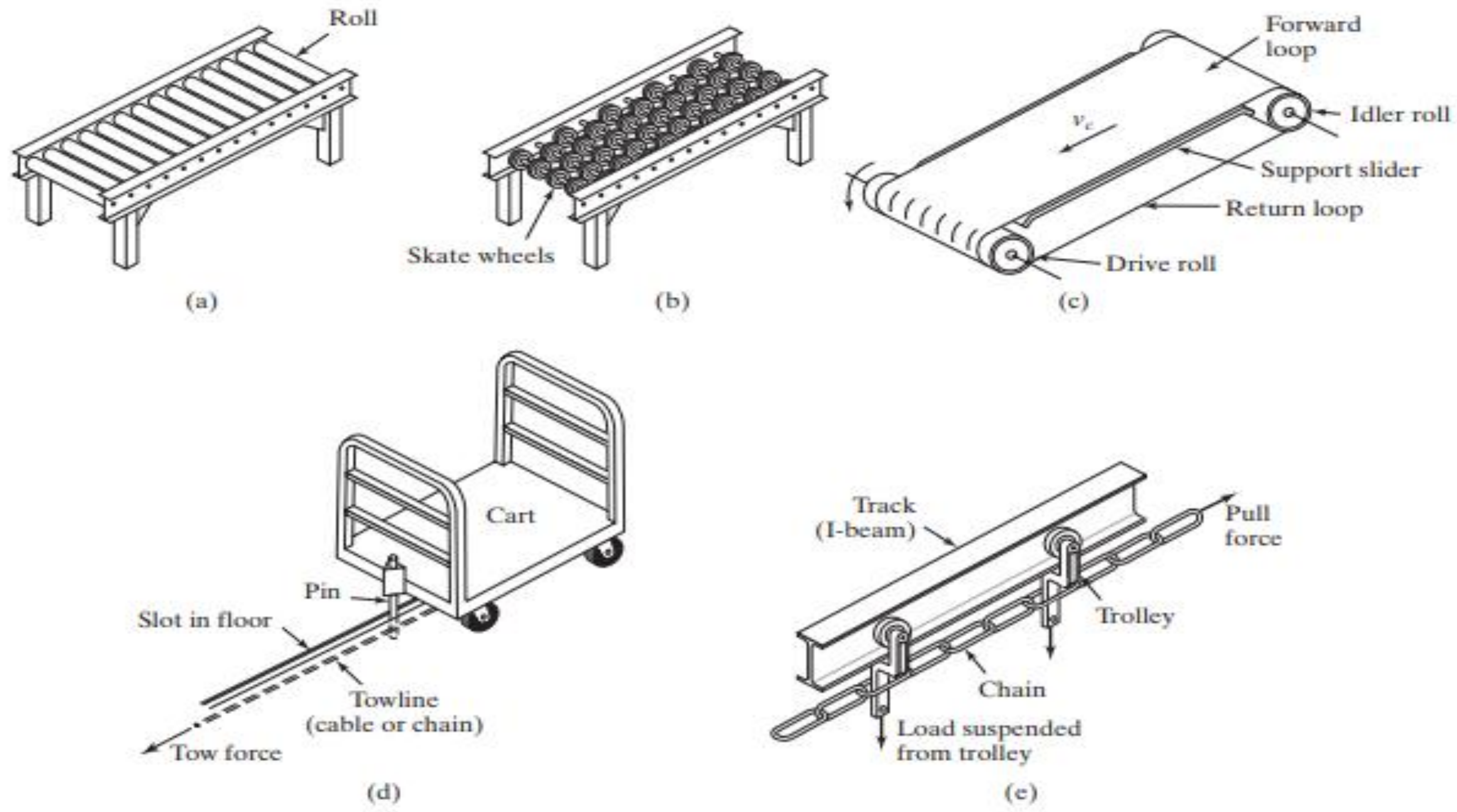
  (4) laser-guided vehicles (LGVs),

  (5) inertial navigation.



Conveyors

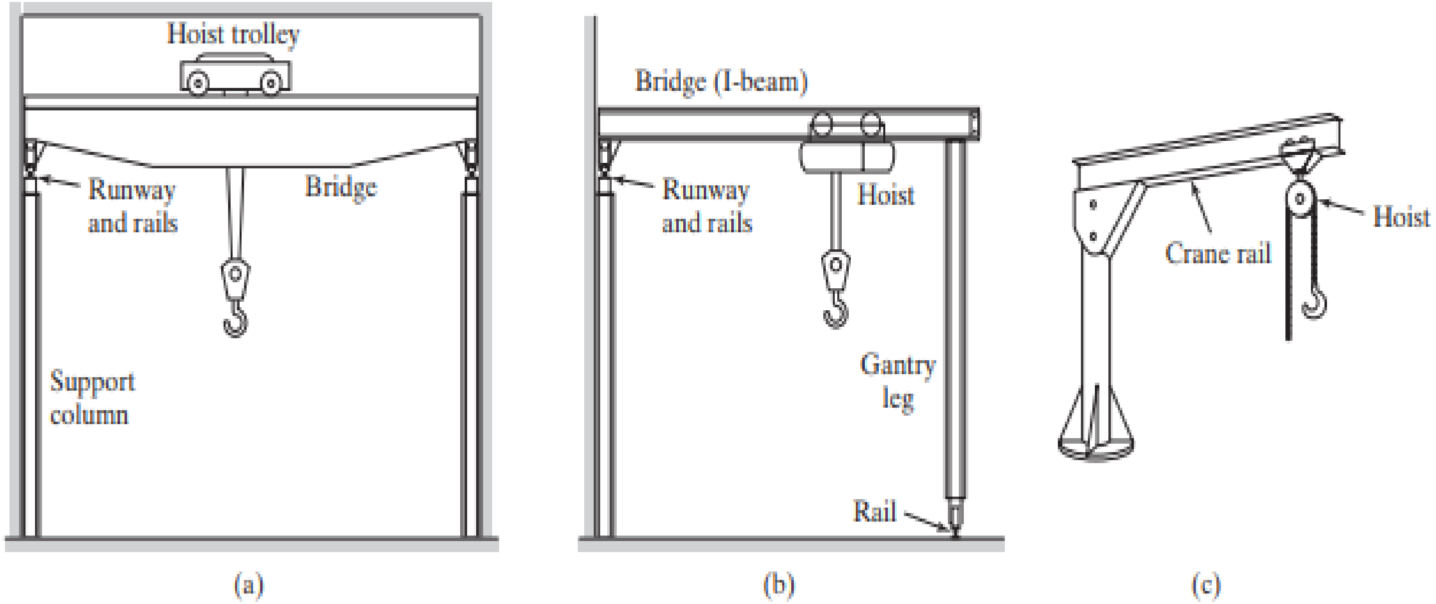
- A conveyor is a mechanical apparatus for moving items or bulk materials, usually inside a facility between specific locations over a fixed path.

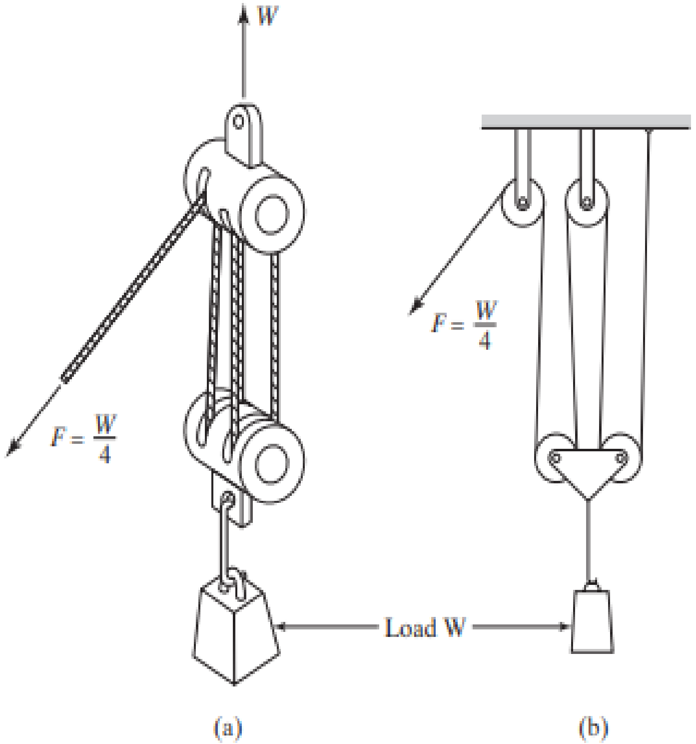


(a) Roller conveyor, (b) skate-wheel conveyor, (c) belt (flat) conveyor (d) in-floor towline conveyor (e) overhead trolley conveyor.

Cranes and Hoists

- Cranes are used for horizontal movement of materials in a facility, and hoists are used for vertical lifting.





(a) bridge crane, (b) gantry crane , and (c) jib crane.

Storage Systems

- The function of a material storage system is to store materials for a period of time and to permit access to those materials when required.
- Some production plants and storage facilities use manual methods for storing and retrieving materials.
- Storage equipment is divided into two major categories:

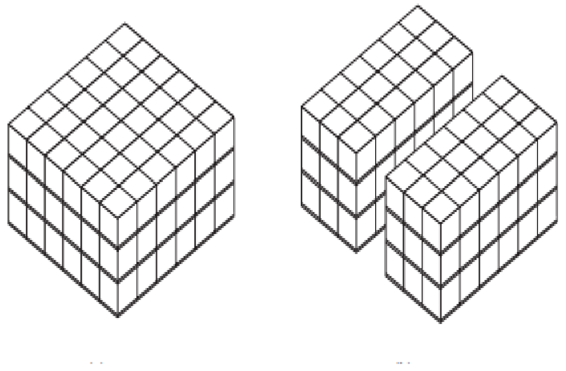
    (1) conventional storage methods

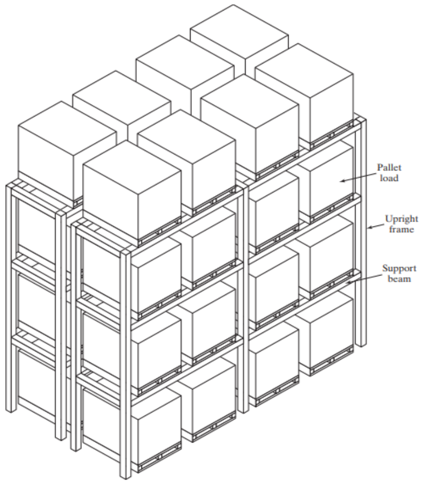
    (2) automated storage systems.

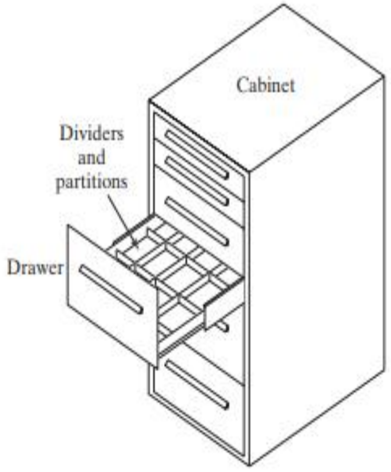
Type	Description
1. Raw materials	Raw stock to be processed (e.g., bar stock, sheet metal, plastic molding compound)
2. Purchased parts	Parts from vendors to be processed or assembled (e.g., castings, purchased components)
3. Work-in-process	Partially completed parts between processing operations and parts awaiting assembly
4. Finished product	Completed product ready for shipment
5. Rework and scrap	Parts that do not meet specifications, either to be reworked or scrapped
6. Refuse	Chips, swarf, oils, other waste products left over after processing; these materials must be disposed of, sometimes using special precautions
7. Tooling and supplies	Cutting tools, jigs, fixtures, molds, dies, welding wire, and other tools used in production; supplies such as helmets and gloves
8. Spare parts	Parts needed for maintenance and repair of factory equipment
9. Office supplies	Paper, paper forms, writing instruments, and other items used in support of plant office
10. Plant records	Records on product, production, equipment, personnel, etc. (paper documents and electronic media)

Conventional storage methods

Storage Equipment	Advantages and Disadvantages	Typical Applications
Bulk storage	Highest density is possible Low accessibility Low cost per square foot	Storage of low turnover, large stock, or large unit loads
Rack systems	Low cost Good storage density Good accessibility	Palletized loads in warehouses
Shelves and bins	Some stock items not clearly visible	Storage of individual items on shelves and commodity items in bins
Drawer storage	Contents of drawer easily visible Good accessibility Relatively high cost	Small tools Small stock items Repair parts
Automated storage systems	High throughput rates Facilitates use of computerized inventory control system Highest cost equipment Facilitates integration with automated material handling systems	Work-in-process storage Final product warehousing and distribution center Order picking Kitting of parts for electronic assembly





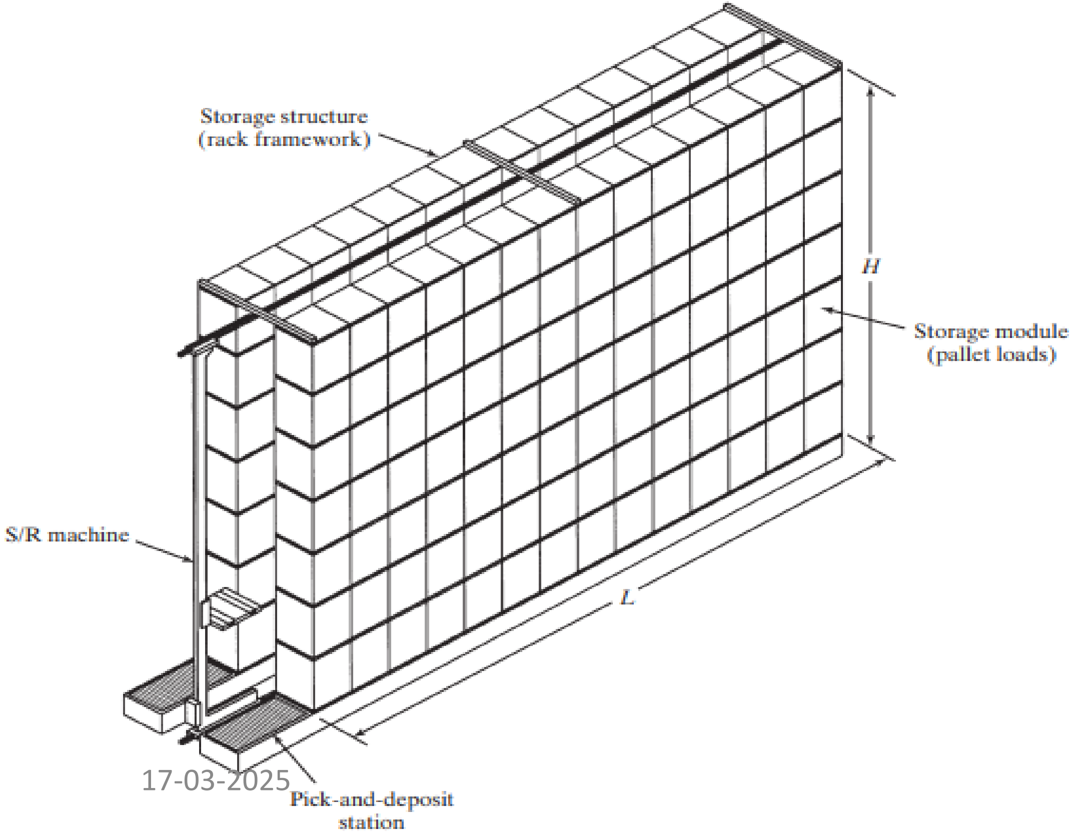


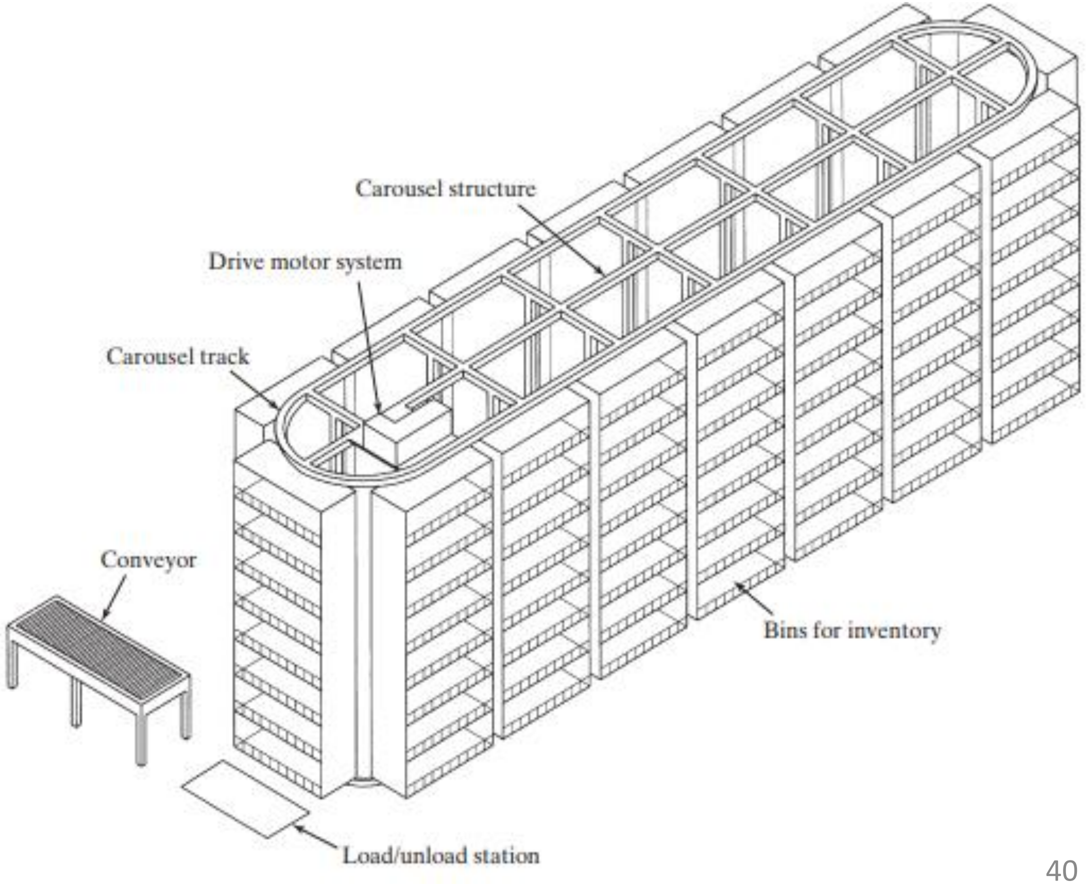
Automated storage systems

- Automated storage systems divide into two general types:

  (1) fixed-aisle automated storage/retrieval systems

  (2) carousel storage systems.





Feature	Fixed-Aisle AS/RS	Carousel Storage System
Storage structure	Rack system to support pallets or shelf system to support tote bins	Baskets suspended from overhead conveyor trolleys
Motions	Linear motions of S/R machine	Revolution of conveyor trolleys around oval track
Storage/retrieval operation	S/R machine travels to compartments in rack structure	Conveyor revolves to bring baskets to load/unload station
Replication of storage capacity	Multiple aisles, each consisting of rack structure and S/R machine	Multiple carousels, each consisting of oval track and storage bins

AS/RS Types

- Unit load AS/RS
- Deep-lane AS/RS
- Miniload AS/RS
- Man-on-board S/RS
- Automated item retrieval system.
- Vertical lift modules (VLM)

AS/RS Applications

- Buffer storage in production
- Support of just-in-time delivery.
- Kitting of parts for assembly
- Compatible with automatic identification systems.
- Computer control and tracking of materials
- Support of factory-wide automation

Automatic identification and data capture (AIDC)

- It refers to technologies that provide direct entry of data into a computer or other microprocessor-controlled system without using a keyboard.
- Automatic identification systems are being used increasingly to collect data in material handling and manufacturing applications.
- Automatic identification technologies consist of three principal components:

1. **Data encoder** : A code is a set of symbols or signals that usually represent alpha numeric characters. When data are encoded, the characters are translated into a machine-readable code.

2. **Machine reader or scanner :** This device reads the encoded data, converting them to alternative form, usually an electrical analog signal.

3. **Data decoder:** This component transforms the electrical signal into digital data and finally back into the original alphanumeric characters.

- AIDC technologies can be divided into the following six categories:

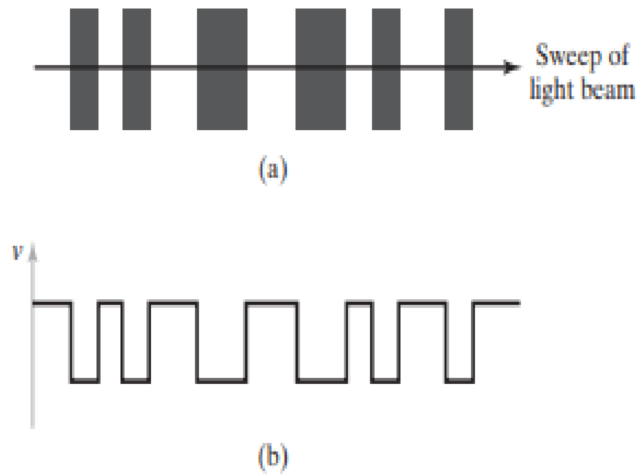
1. Optical: bar codes, optical character recognition, and machine vision
2. Electromagnetic: RFID
3. Magnetic: magnetic stripe
4. Smart card: chip card and integrated circuit card
5. Touch techniques: touch screens and button memory
6. Biometric: voice recognition, fingerprint analysis, and retinal eye scans.

Bar Code Technology

- Bar codes divide into two basic types:

  (1) linear, the encoded data are read using a linear sweep of the scanner

  (2) two-dimensional, the encoded data must be read in both directions.



(a) width-modulated, (b) height-modulated,

(a) bar code and (b) corresponding electrical signal.

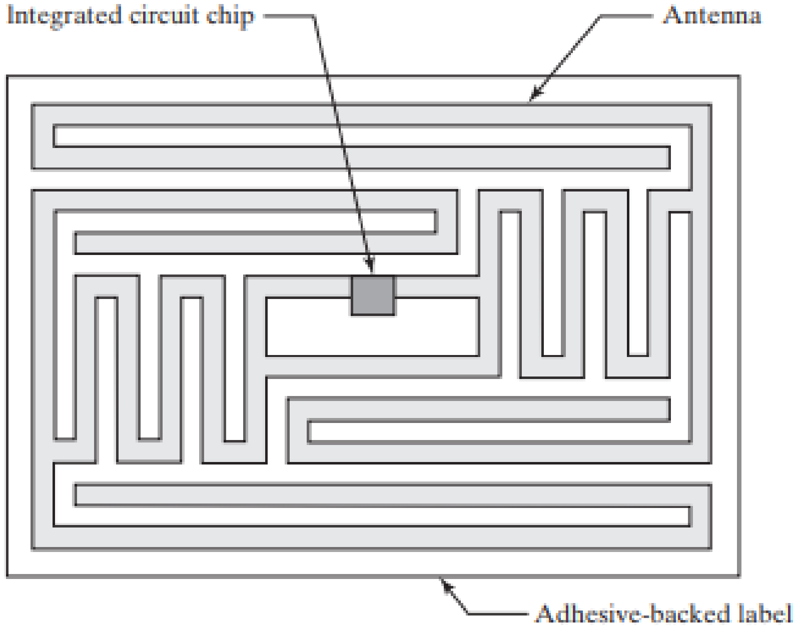
Two-Dimensional Bar Codes

A 2-D stacked bar code

A 2-D matrix bar code

Radio frequency identification technology (RFID)

- Radio frequency identification, an identification tag or label containing electronically encoded data is attached to the subject item, which can be a part, product, or container (e.g., carton, tote pan, pallet).
- The identification tag consists of an integrated circuit chip and a small antenna



Comparison	Bar Codes	RFID
Technology	Optical	Radio frequency
Read-write capability	Read only	Read-write available
Storage capacity	14–16 digits (linear bar codes)	96–256 digits
Line-of-sight reading	Required	Not required
Reusability	One-time use	Reusable
Cost per label	Very low	About 10 times the cost of bar code for passive tag
Durability	Susceptible to dirt and scratches	More durable in plant environment