Industrial Robotics

L-24

Contents

Industrial Robot

- Industrial robot is a general-purpose, programmable machine possessing certain anthromorphic characteristics
- The most obvious anthromorphic characteristics of an industrial robot is its mechanical arm, that is used to perform various industrial task
- Other human-like characteristics are the robot’s capability to respond to sensory inputs, communicate with other machines and make decisions

Reasons for the commercial and technological importance of industrial robots include the following

(i) Robots can be substituted for humans in hazardous or uncomfortable work environments

(ii) A robot performs its work cycle with consistency and repeatability that cannot be attained by humans

(iii) 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

(iv) Robots are controlled by computers and can therefore be connected to other computer systems to achieve computer integrated manufacturing

1) Robot anatomy and related attributes

a) Joints and Links

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 or axis as it is sometimes called, provides the robot with so called degree of freedom (d.o.f) of motion. In nearly all cases, only one degree of freedom is associated with a joint. Robots are often classified according to the total number of degrees of freedom they possess

(i) Linear joint (type L joint)
(ii) Orthogonal Joint (type O joint)
(iii) Rotational joint (type R joint)
(iv) Twisting joint (type T joint)
(v) Revolving joint (type V joint)

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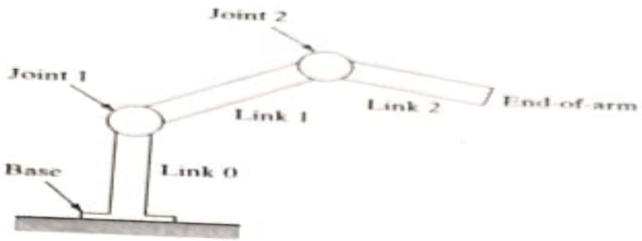

Figure 7.1 Diagram of robot construction showing how a robot is made up of a series of joint-link combinations.

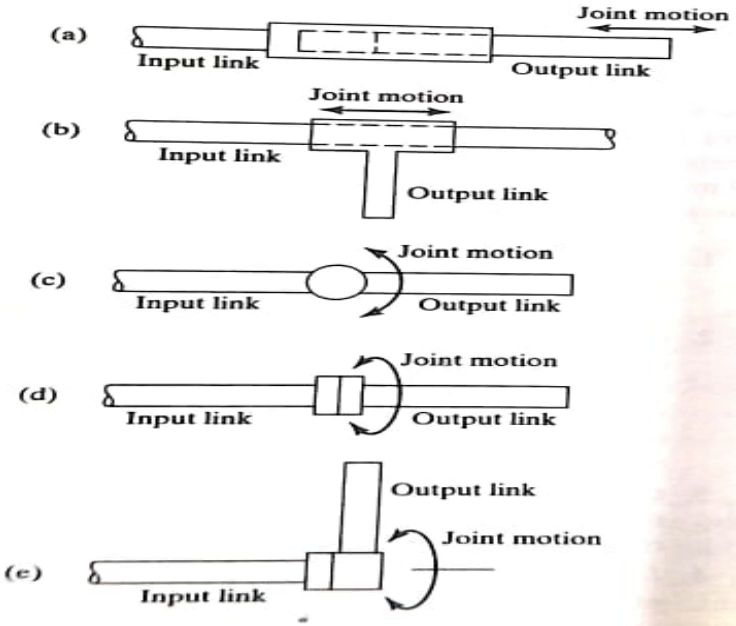

Figure 7.2 Five types of joints commonly used in industrial robot construction: (a) linear joint (type L joint), (b) orthogonal joint (type O joint), (c) rotational joint (type R joint), (d) twisting joint (type T joint), and (e) revolving joint (type V joint).

b) Common Robot Configurations

- There are usually three degrees of freedom associated with the body and arm and either two or three degrees of freedom associated with the wrist.
- At the end of the manipulator’s wrist is a device related to the task that must be accomplished by the robot. The device called an end effector is usually either (i) a gripper for holding a workpart (ii) a tool for performing some process.

Body and Arm Configurations

(i) Polar configurations
(ii) Cylindrical configurations
(iii) Cartesian coordinate robot
(iv) Jointed arm robot
(v) SCARA

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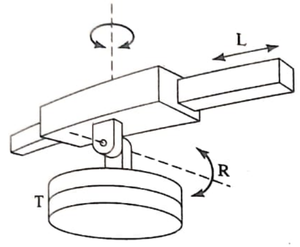

Figure 7.3 Polar coordinate body-and-arm assembly.

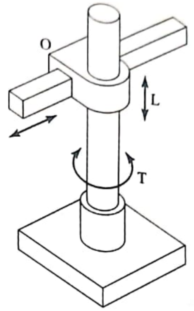

Figure 7.4 Cylindrical body-and-arm assembly.

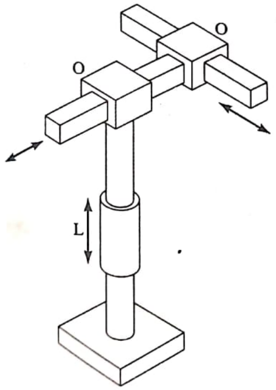

Figure 7.5 Cartesian coordinate body-and-arm assembly.

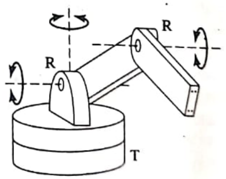

Figure 7.6 Jointed-arm body-and-arm assembly.

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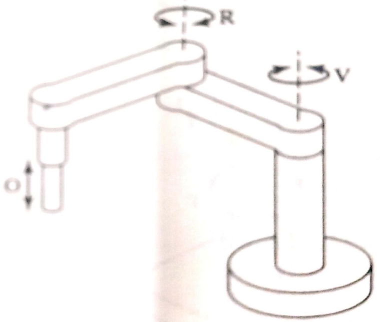


Figure 7.7 SCARA body-and-arm assembly.

Wrist Configurations

(i) Roll, using T joint to accomplish rotation about the robots arm axis

(ii) Pitch, which involves up and down rotation, typically using R joint

(iii) Yaw, which involves right and left rotation also accomplished by means of an R-joint

Work Volume: The work volume (the term work envelope is also used) of a manipulator is defined as the envelope or space within which the robot can manipulate the end of its wrist.

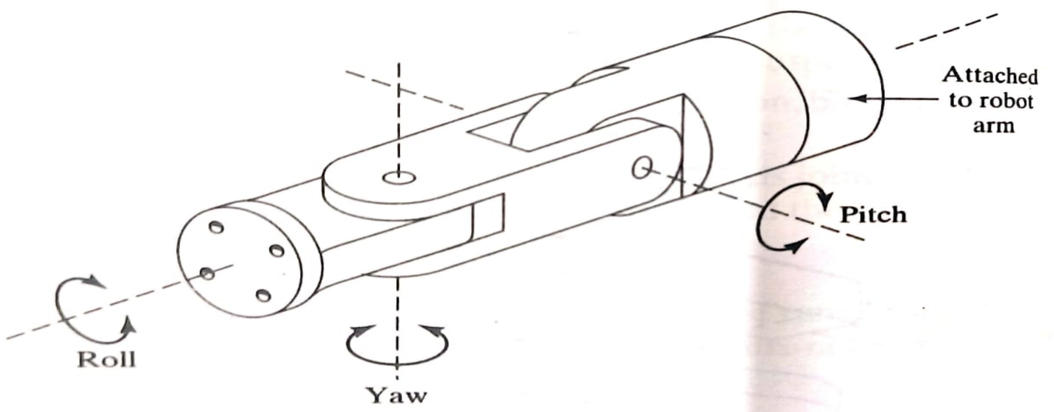


Figure 7.8 Typical configuration of a three-degree-of-freedom wrist assembly showing roll, pitch, and yaw.

Joint Drive Systems

c) Robot joints are actuated using any of three possible types of drive systems

(i) Electric

(ii) Hydraulic

(iii) Pneumatic

2) Robot Control Systems

(i) Limited sequence control

1)Playback with point to point control

2) Playback with continuous path control

a) Greater storage capacity b) Interpolation calculations

(ii) Intelligent Control

1) Interact with its environment
2) Make decisions when things go wrong during the work cycle
3) Communicate with humans
4) Make computations during motion cycle
5) Respond to advanced sensor inputs such as machine vision

Robot control system

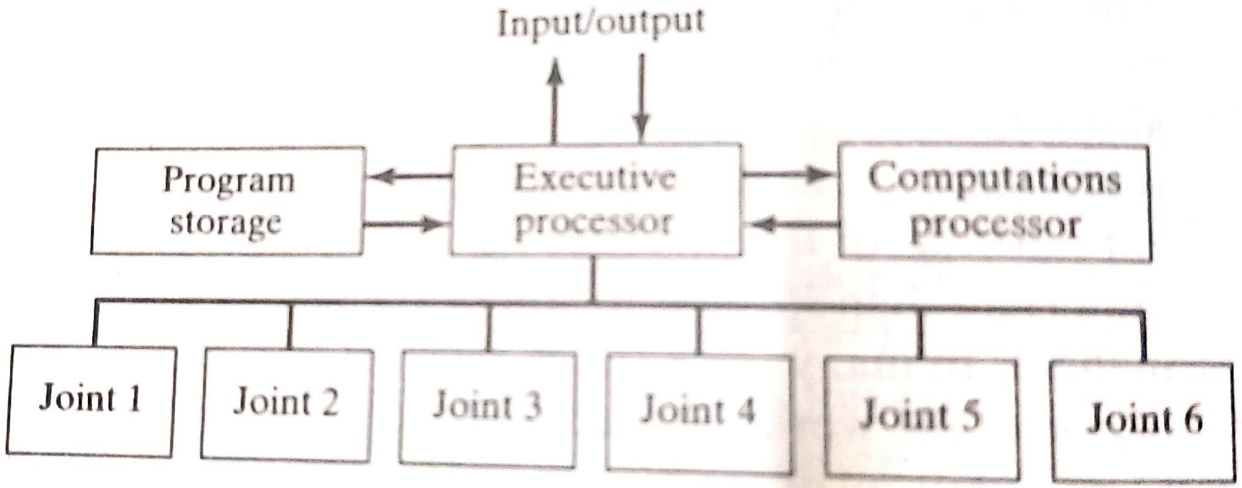


Figure 7.9 Hierarchical control structure of a robot microcomputer controller.

3) End Effectors

a) Grippers: The grippers are end effectors used to grasp and manipulate objects during the work cycle. The objects are usually workparts that are moved from one location to another in the cell.

The grippers used in industrial robot applications include the following:

(i) Mechanical grippers
(ii) Vacuum grippers
(iii) Magnetized devices
(iv) Adhesive devices
(v) Simple mechanical devices

The mechanical grippers are the most common gripper type. Some of the innovations and advances in mechanical gripper technology include:

(i) Dual grippers
(ii) Interchangeable fingers
(iii) Sensory feedback
(iv) Multiple fingered grippers
(v) Standard gripper products

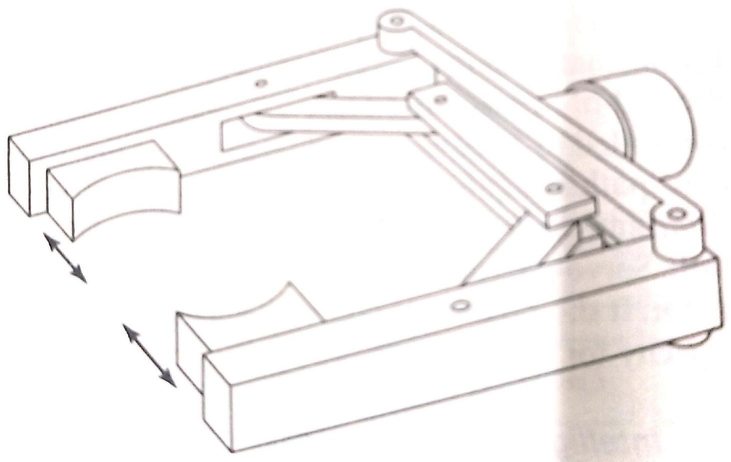


Figure 7.10 Robot mechanical gripper.

b) Tools

Examples of the tools used as end effectors by robots to perform processing applications include:

(i) Spot welding gun
(ii) Arc welding tool
(iii) Spray painting gun
(iv) Rotating spindle for drilling, routing, grinding and so forth
(v) Assembly tool (e.g automatic screw driver)
(vi) Heating torch
(vii) Water jet cutting tool

4) Sensors in Robotics

It is of two types 1) Input sensor: used for controlling position and velocity of the various joints of the robot 2) External sensor: used to coordinate the operation of the robot with other equipment in the cell.

Other more advanced sensor technology includes:

(i) Tactile sensors- touch sensor, force sensor
(ii) Proximity sensors
(iii) Optical sensors
(iv) Machine vision
(v) Other sensors

5) Industrial Robot Applications

It is there for avoidable situations for humans

(i) Hazardous work environment for humans
(ii) Repetitive work cycle
(iii) Difficult handling for humans
(iv) Multishift operation
(v) Infrequent operation
(vi) Part position and orientation are established in the work cell.

a) Material Handling Applications

(i) Material Transfer
(ii) Machine Loading and or Unloading
1) Machine Loading 2) Machine unloading 3) Machine Loading and unloading

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

(i) Die casting
(ii) Plastic molding
(iii) Metal machining operations
(iv) Forging
(v) Pressworking
(vi) Heat treating

b) Processing Operations

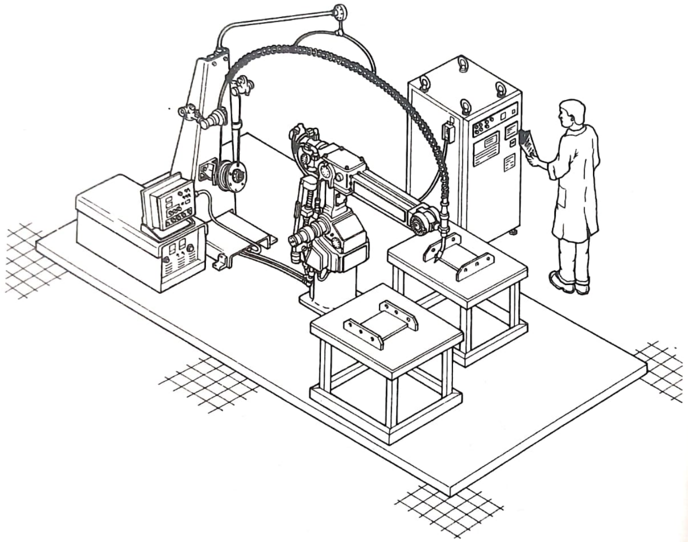


Figure 7.12 Robot arc welding cell.

(i) Spot welding
(ii) Continous arc welding
(iii) Spray Coating

Other processes applications

(i) Drilling, routing and other machining processes
(ii) Grinding, wire brushing and similar operations
(iii) Waterjet cutting
(iv) Laser cutting
(v) Riveting

C) Assembly and Inspection

- In assembly it involves the addition of two or more parts to form a new entity called subassembly. The new subassembly is made secure by fastening two or more parts together using mechanical fastening techniques (such as screws, nuts and rivets) or joining processes (e.g welding, brazing, soldering or adhesive bonding)
- The inspection is done to ensure (i) making sure that given process has been completed (ii) ensuring that parts have been added in assembly as specified, (iii) identifying flaws in raw materials and finished parts.In inspection, the task performed by robots can be divided into the following two cases

(a)The robot performs loading and unloading tasks to support an inspection or testing machine. The robot picks parts that enter the cell, loads and unloads them to carry out the inspection process and places them at the cell output. In some cases, the inspection may result in parts sortation that must be accomplished by the robot. Depending on the quality level, the robot places the parts in different containers or on different exit conveyors

(b) The robots manipulates an inspection device, such as mechanical probe to test the product.

6) Robot Programming

There are three programming methods:

(a) Leadthrough Programming:

1) Power leadthrough

2) Manual leadthrough

Motion Programming:

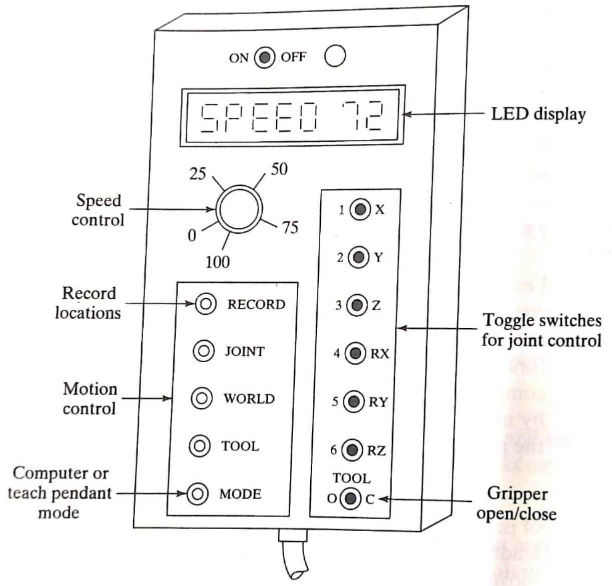


Figure 7.13 A typical robot teach pendant.

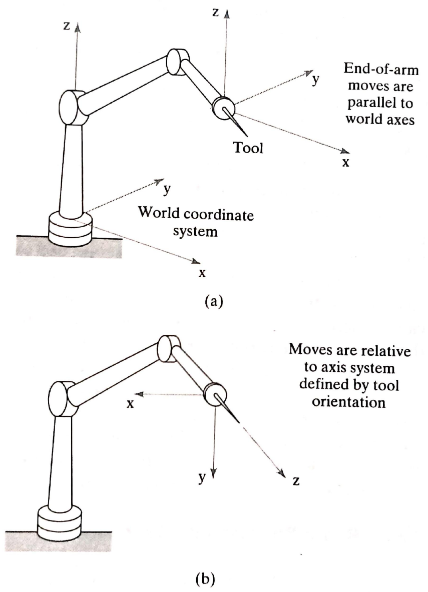


Figure 7.14 (a) World coordinate system. (b) Tool coordinate system.

b)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 that leadthrough programming cannot readily accomplish. Like

(i) Enhanced sensor capabilities, including the use of analog as well as digital inputs and outputs

(ii) Improved output capabilities for controlling external equipment

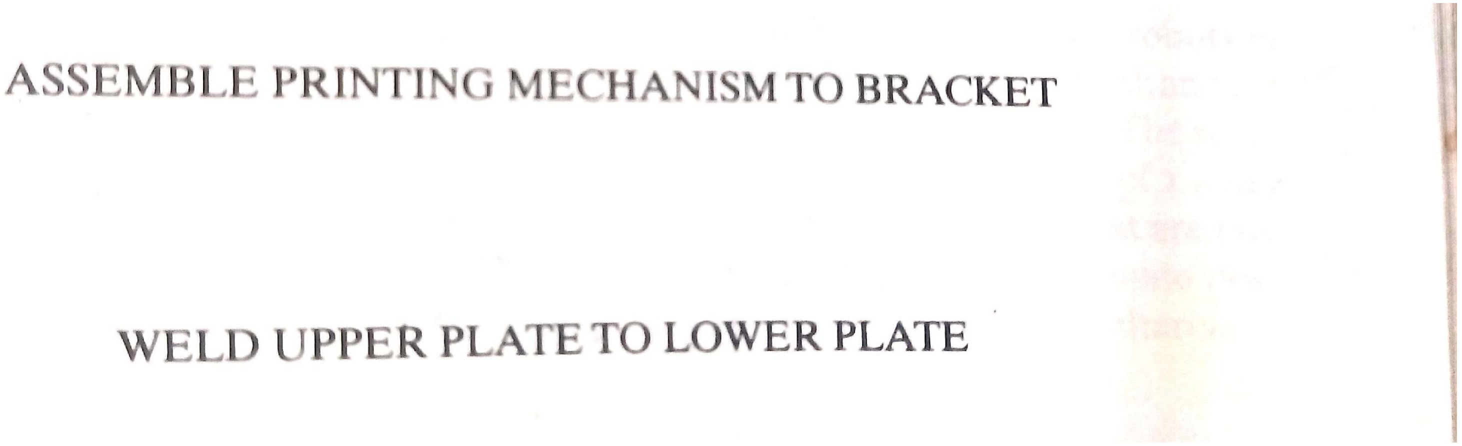
(iii) Program logic that is beyond the capabilities of leadthrough methods

(iv) Computations and data processing similar to computer programming languages

(v) Communication with other computer systems

C) Simulation and off-line Programming

- Off-line programming permits the robot program to be prepared at a remote computer terminal and downloaded to the robot controller for execution.
- In true off-line programming, there is no need to physically locate the positions in the workspace for the robot as required with present textual programming languages.



7) Engineering Analysis of Industrial Robots

Two areas that are central to the operation of an industrial robot

a)Manipulator Kinematics:

It is concerned with the position and orientation of the robot's end-of-arm or the end effector attached to it,as function of time but without regard for the effects of force or mass.

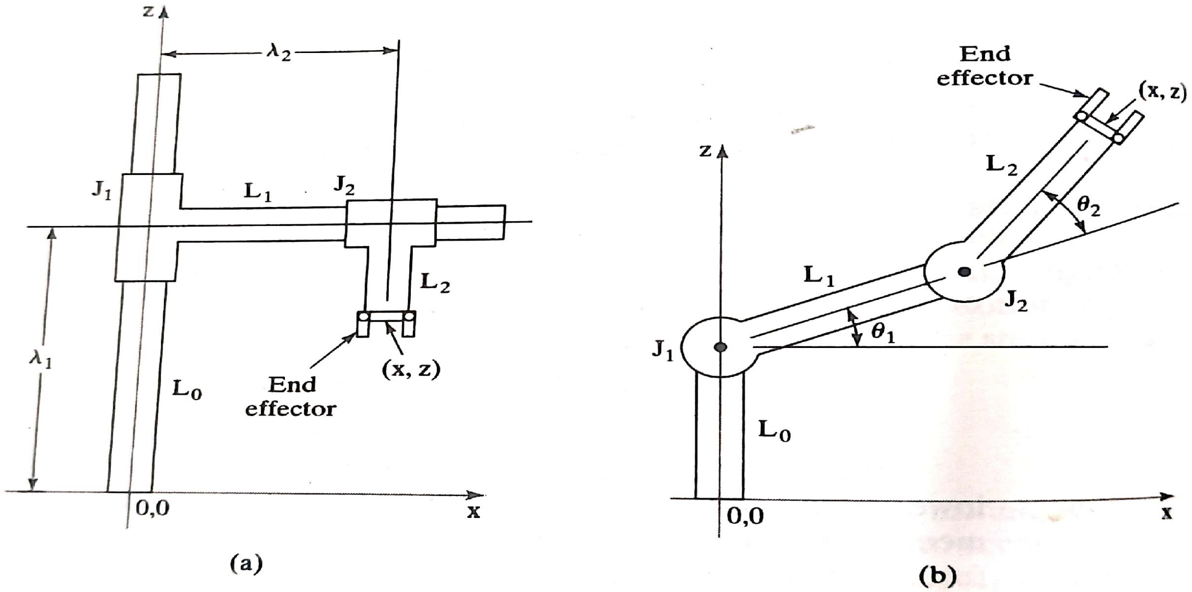


Figure 7.15 Two manipulators with two degrees-of-freedom: (a) an OO robot and (b) an RR robot.

b) Accuracy and Repeatability

- The capacity of the robot to position and orient the end of its wrist with accuracy and repeatability is an important control attribute in nearly all industrial applications.
- There are several terms that must be defined in the context of this discussion

(i) Control resolution: It is the capability of robot controller and positioning system to divide the range of the joint into closely spaced points that can be identified by the controller

(ii) Accuracy: It is measure of the robot's ability to position the end of wrist at the desired location in the work volume

$$\text{Accuracy} = \frac{CR}{2} + 3\sigma$$

where CR = control resolution from Eq. (7.18).

(iii) Repeatability: It is the measure of robot's ability to position its end-of-wrist at a previously taught point in the work volume.

$$\text{Repeatability} = \pm 3\sigma$$

where σ = standard deviation of the error distribution.