

# Robot Fundamentals

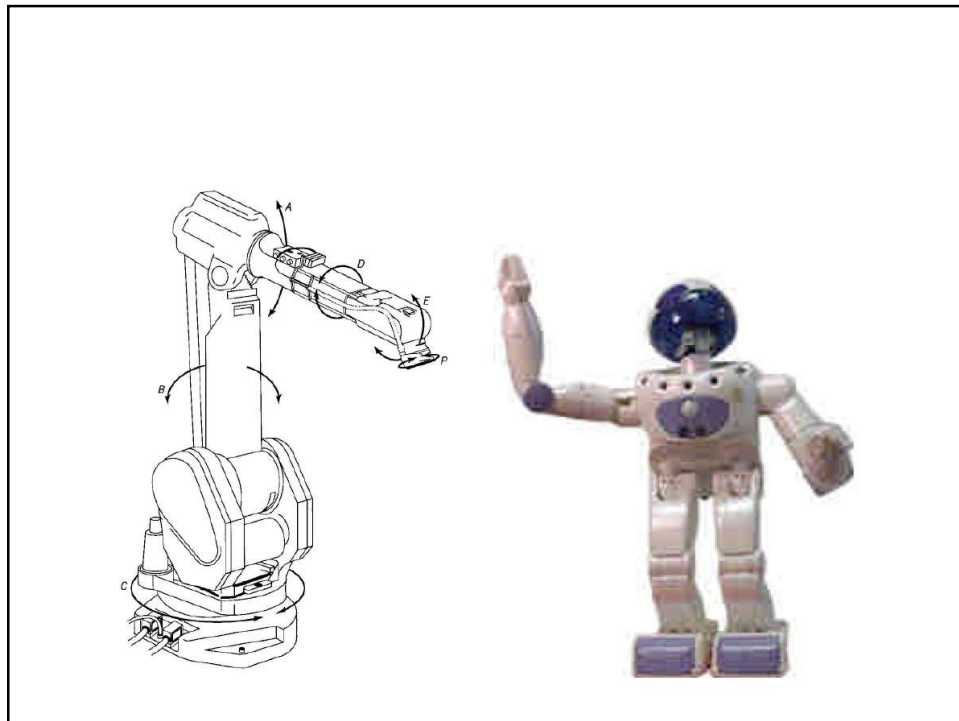
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## Robotics

### What is an Industrial Robot?

- An industrial robot is a programmable, multi-functional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for the performance of a variety of tasks.
- An industrial robot consists of a number of rigid links connected by joints of different types, controlled and monitored by a computer.

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## Power sources for robots

1. *Hydraulic drive*: gives a robot great speed and strength. These systems can be designed to actuate linear or rotational joints. The main disadvantage of a hydraulic system is that it occupies floor space in addition to that required by the robot.
2. *Electric drive*: compared with a hydraulic system, an electric system provides a robot with less speed and strength. Accordingly, electric drive systems are adopted for smaller robots. However, robots supported by electric drive systems are more accurate, exhibit better repeatability, and are cleaner to use.
3. *Pneumatic drive*: are generally used for smaller robots. These robots, with fewer degrees of freedom, carry out simple pick-and-place material handling operations.

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## Sensors in Robotics

1. *Position sensors*: are used to monitor the position of joints. Information about the position is fed back to the control systems that are used to determine the accuracy of joint movements.
2. *Range sensors*: measure distances from the reference point to other points of importance. Range sensing is accomplished by means of television cameras or sonar transmitters and receivers.
3. *Velocity sensors*: are used to estimate the speed with which a manipulator is moved. The velocity is an important part of dynamic performance of the manipulator. Variations in acceleration during the movements between points give rise to the dynamic nature of the manipulator. Inertial forces due to changes in acceleration, damping forces due to changes in velocity, and spring forces due to elongation in the links caused by gravity and the weights carried should be monitored and controlled to fine-tune the dynamic performance of the manipulator.
4. *Proximity sensor*: are used to sense and indicate the presence of an object within a specified distance or space without any physical contact.

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## End Effector

The hand of a robot: End-effector mounted on the wrist enables the robot to perform specified tasks. Various types of end-effectors are designed for the same robot to make it more flexible and versatile.

1. *Grippers*: are generally used to grasp and hold an object and place it at a desired location. Grippers can be classified as mechanical grippers, vacuum or suction cups, magnetic grippers, adhesive grippers, hooks, scoops, and so forth.
2. *Tools*: a robot is required to manipulate a tool to perform an operation on a workpart. Here the tool acts as end-effector. Spot-welding tools, arc-welding tools, spray-painting nozzles, and rotating spindles for drilling and grinding are typical examples of tools used as end-effectors.

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## Robot Characteristics

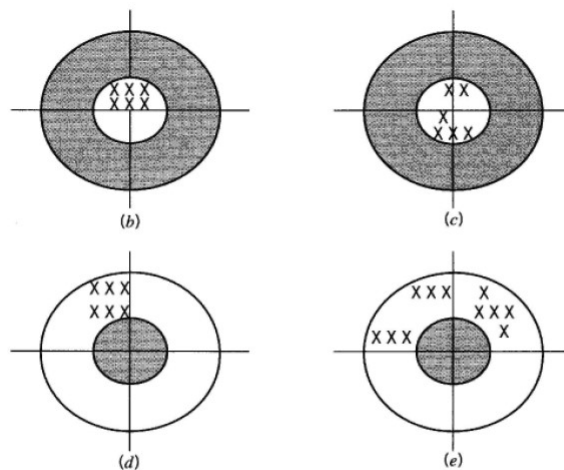
Robot movement and precision: speed of response and stability are two important characteristics of robot movement. Speed defines how quickly the robot arm moves from one point to another. Stability refers to robot motion with the least amount of oscillation. Speed and stability are often conflicting. The precision of robot movement is defined by three basic features:

1. Spatial resolution: The spatial resolution of a robot is the smallest increment of movement into which the robot can divide its work volume. It depends on the system's control resolution and the robot's mechanical inaccuracies. For a particular axis, the number of separate increments is given by

$$\text{Number of increments} = 2^n$$

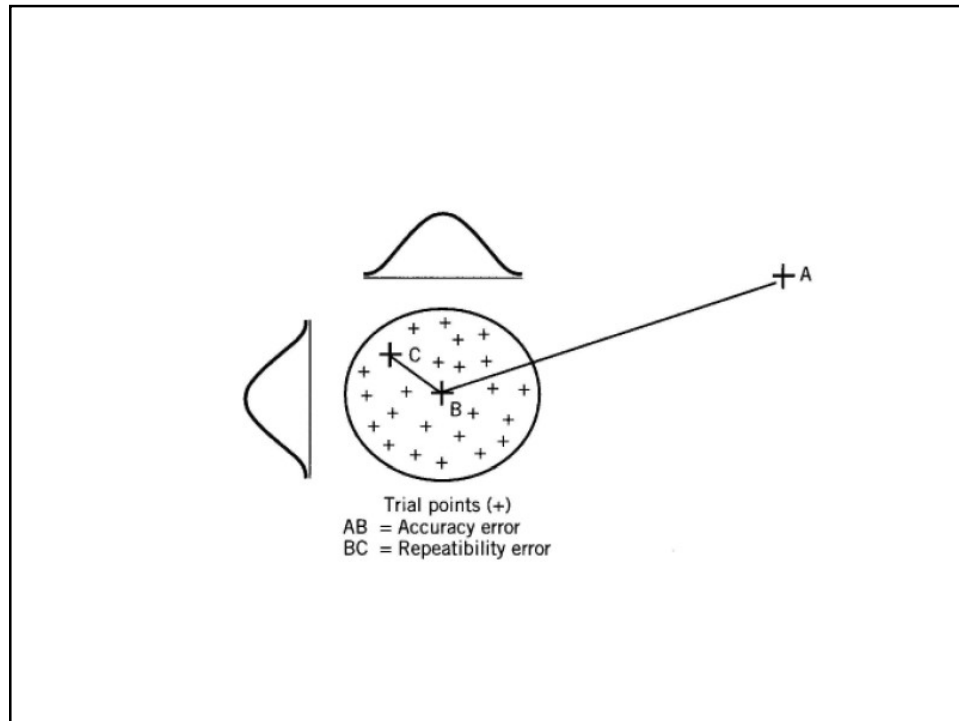
where  $n$  is the number of bits in the control memory

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**FIGURE 2** (a) Accuracy and repeatability; (b), high accuracy and high repeatability; (c) high accuracy and low repeatability; (d) low accuracy and high repeatability; (e) low accuracy and low repeatability.

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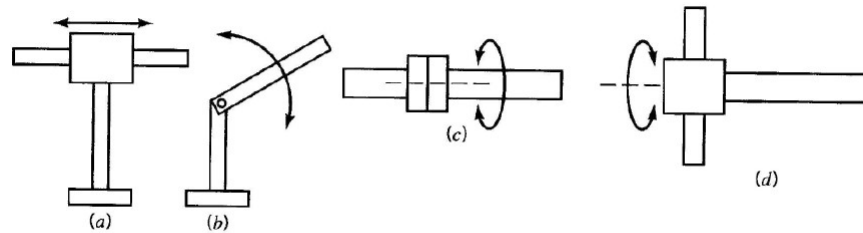


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### The Robotic Joints

- A robot joint is a mechanism that permits relative movement between parts of a robot arm. The basic movements required for the desired motion of most industrial robots are:
  - Rotational movement: this enables the robot to place its arm in any direction on a horizontal plane.
  - Radial movement: this enables the robot to move its end-effector radially to reach distant points.
  - Vertical movement: this enables the robot to take its end-effector to different heights.

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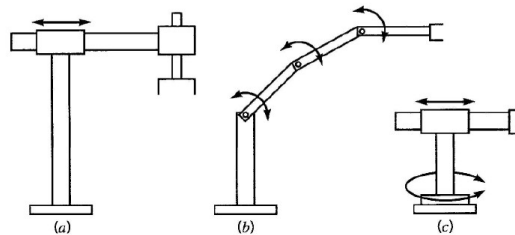
**FIGURE 3** Types of joints: (a) linear joint; (b) rotational joint; (c) twisting joint; (d) revolving joint.

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Designate the robot configurations shown in Figure 4, using the joint notation scheme.

**Solution**

- (a) This configuration has two linear joints. Hence, it is designated LL.
- (b) This configuration has three rotational joints. Hence, it is designated RRR.
- (c) This configuration has one twisting joint and one linear joint. This is indicated by TL.



**FIGURE 4** Robot configurations for Example 2: (a) LL robot; (b) RRR robot; (c) TL robot.

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For the following joint notation, give sketches to illustrate the robot arm configuration.

(a) LRL, (b) RRL, (c) TRL and, (d) LVL.

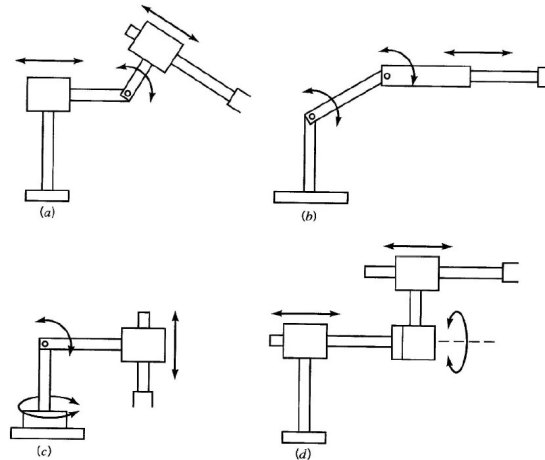


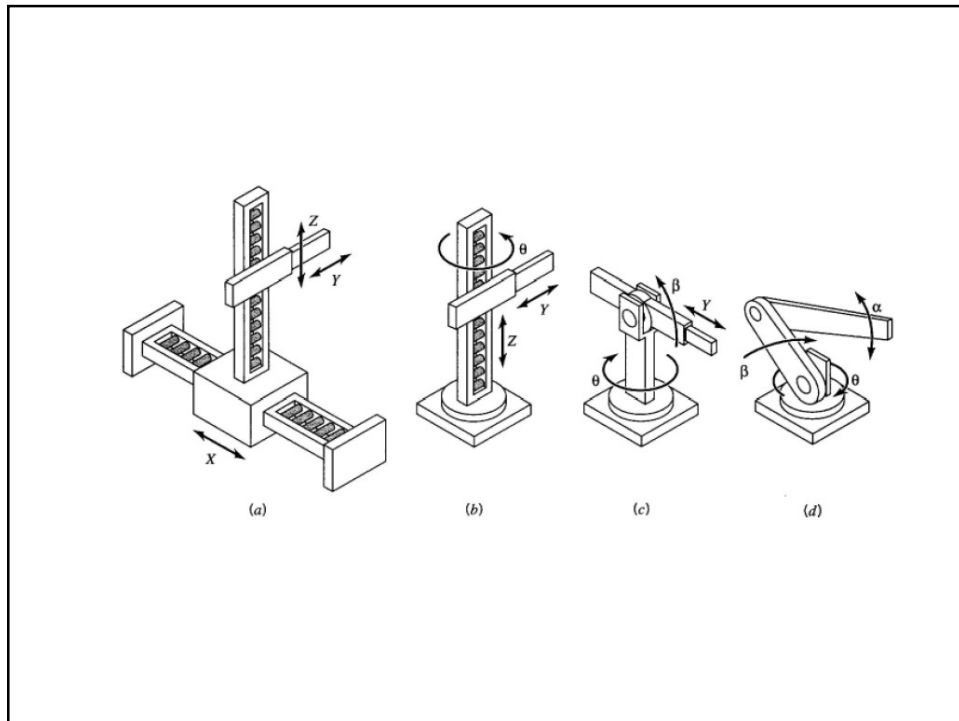
FIGURE 5 Robot configurations for Example 3: (a) LRL robot; (b) RRL robot; (c) TRL robot; (d) LVL robot.

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### Robot Classification and Robot Reach

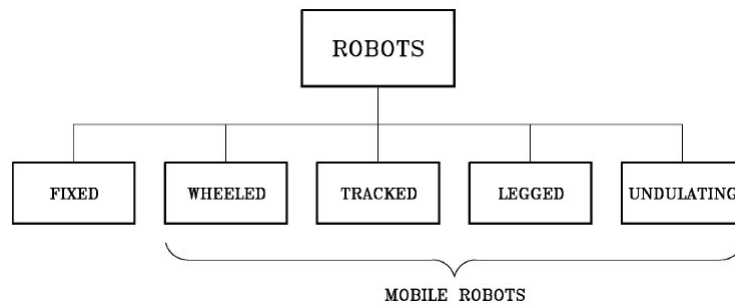
- Classification based on Physical configurations, four basic configurations are identified with most of the commercially available industrial robots.
  1. *Cartesian configuration*: consist of links connected by linear joints (L). (a) is designated as LLL, they are also called rectilinear robots. Another robot that is similar to this configuration is a gantry robot.
  2. *Cylindrical configuration*: robots have one rotate (R) joint at the base and linear (L) joints succeed to connect to the links. (b) in this configuration can be designed as TLL.
  3. *Polar configuration*: have a work space of spherical shape. Generally, the arm is connected to the base with a twisting (T) joint and rotate (R) and/or linear (L) joints follow. (c) for this configuration can be TRL or TRR. TRR (also called articulated robot) robot more closely resembles the human arm.
  4. *Jointed-arm configuration*: is combination of cylindrical and articulated configurations. The arm of robot is connected to the base with a twisting joint. (d) Rotate joints connect the links in the arm. The most popular robot, which is very close to this configuration, is SCARA (selective compliance assembly robot arm). In the SCARA robot rotations take place in horizontal planes, thus reducing the possibility of large deformations in the links.

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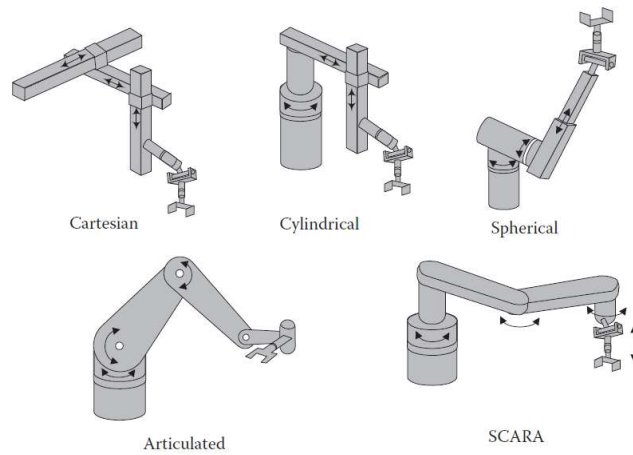
## Robot Classification



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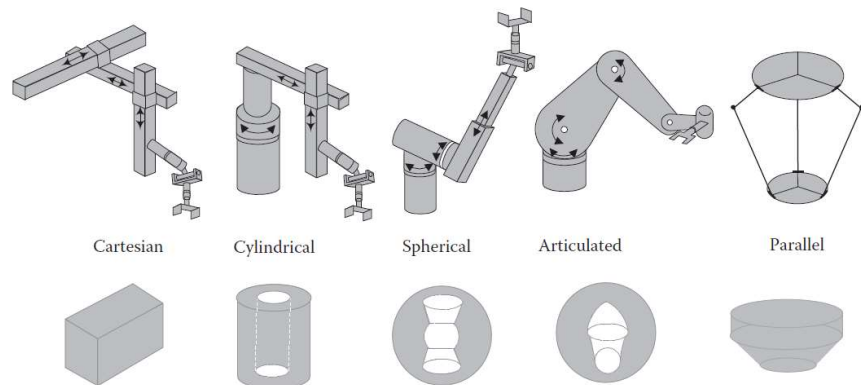


## Robot Configurations



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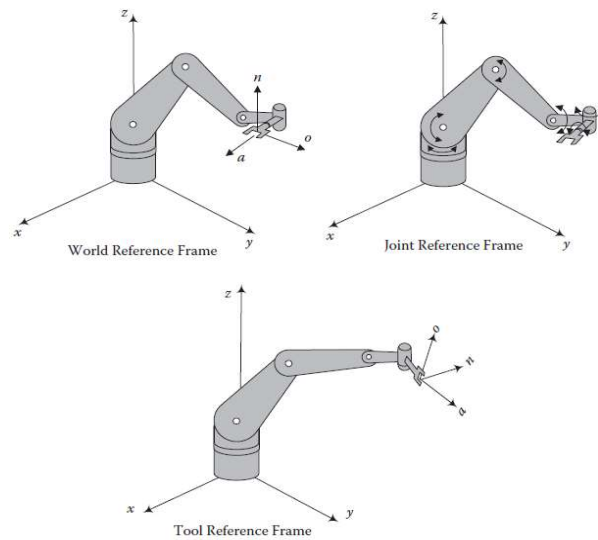
## Work space



**Figure** Typical approximate workspaces for common robot configurations.

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## A robot's World, Joint, and Tool reference frames



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## Components of Robotic System

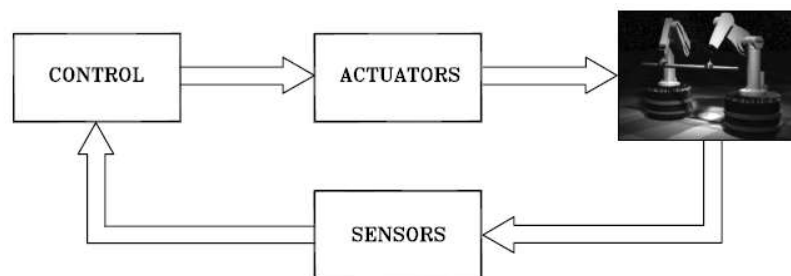


Fig. 1.1. Components of a robotic system

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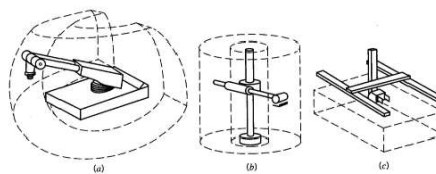
### Classification Based on Control Systems

1. *Point-to-point (PTP) control robot*: is capable of moving from one point to another point. The locations are recorded in the control memory. PTP robots do not control the path to get from one point to the next point. Common applications include component insertion, spot welding, hole drilling, machine loading and unloading, and crude assembly operations.
2. *Continuous-path (CP) control robot*: with CP control, the robot can stop at any specified point along the controlled path. All the points along the path must be stored explicitly in the robot's control memory. Typical applications include spray painting, finishing, gluing, and arc welding operations.
3. *Controlled-path robot*: the control equipment can generate paths of different geometry such as straight lines, circles, and interpolated curves with a high degree of accuracy. All controlled-path robots have a servo capability to correct their path.

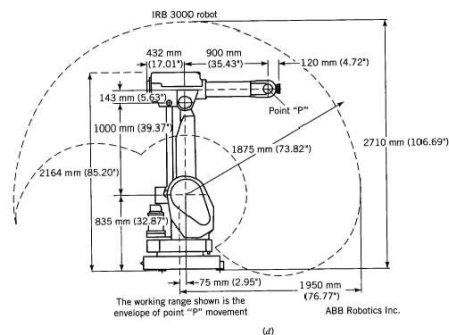
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### Robot Reach

Polar; (b)Cylindrical robot; (c)Cartesian; (d)Joint arm (revolute) robot.



Basic range and floor space drawings



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### Robot Selection

- The technical features are the prime considerations in the selection of a robot.
  1. Degrees of freedom
  2. Control system to be adopted
  3. Work volume
  4. Load-carrying capacity
  5. Accuracy and repeatability

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### The characteristics of robots generally considered in a selection process include

1. Size of class
  - Micro ( $x \leq 1$  m)
  - Small ( $1 < x \leq 2$  m)
  - Medium ( $2 < x \leq 5$  m)
  - Large ( $x > 5$  m)
2. Degrees of freedom: the cost of increases with increasing number of DOF.
3. Velocity
4. Actuator type
5. Control mode
6. Repeatability
7. Lift capacity
8. Right-Left traverse
9. Up-down-traverse
10. In-out-traverse
11. Yaw
12. Pitch
13. Roll
14. Weight of the robot

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### Robot Applications

- The common industrial applications of robots in manufacturing involve loading and unloading of parts.
  1. The robot unloading parts from die-casting machines
  2. The robot loading a raw hot billet into a die, holding it during forging, and unloading it from the forging die
  3. The robot loading sheet blanks into automatic presses, with the parts falling out of the back of the machine automatically after the press operation is performed
  4. The robot unloading molded parts formed in injection molding machines
  5. The robot loading raw blanks into NC machine tools and unloading the finished parts from the machines
- a single-machine robotic cell application
- a single-machine cell with a double-gripper robot
- multi-machine robotic cell applications
- welding
- spray painting
- assembly
- other applications