

BME Note (Dr. Durjyodhan Sethi)

Robot and its anatomy

1. Introduction

An industrial robot is a programmable machine. It possesses some human-like characteristics that resemble the human physical structure. The robots also respond to sensory signals in a manner that is similar to humans. Sensory perceptive devices such as sensors allow the robots to communicate and interact with other machines and to take simple decisions. The general commercial and technological advantages of robots are listed below:

- Robots are good substitutes to the human beings in hazardous or uncomfortable work environments.
- A robot performs its work cycle with a consistency and repeatability which is difficult for human beings to attain over a long period of continuous working.
- 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.
- Robots can be connected to the computer systems and other robotics systems. Nowadays robots can be controlled with wire-less control technologies. This has enhanced the productivity and efficiency of automation industry.

2. Robot anatomy and related attributes

Robot consists of a series of joints and links. Its anatomy deals with the study of different joints and links. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion. In most of the cases, only one degree-of-freedom is associated with each joint. Therefore the robot's complexity can be classified according to the total number of degrees-of-freedom they possess.

Each joint is connected to two links, one input link and the other one is output link. Joint provides controlled relative movement between the input link and output link. A robotic link is the rigid component of the robot manipulator. Most of the robots are mounted upon a stationary base, such as the floor. The robotic base and its connection to the first joint are termed as link-0. The first joint in the sequence is joint-1. Link-0 is the input link for joint-1, while the output link from joint-1 is link-1—which leads to joint-2. Thus link 1 is, simultaneously, the output link for joint-1 and the input link for joint-2. This joint-link-numbering scheme is further followed for all joints and links in the robotic systems.

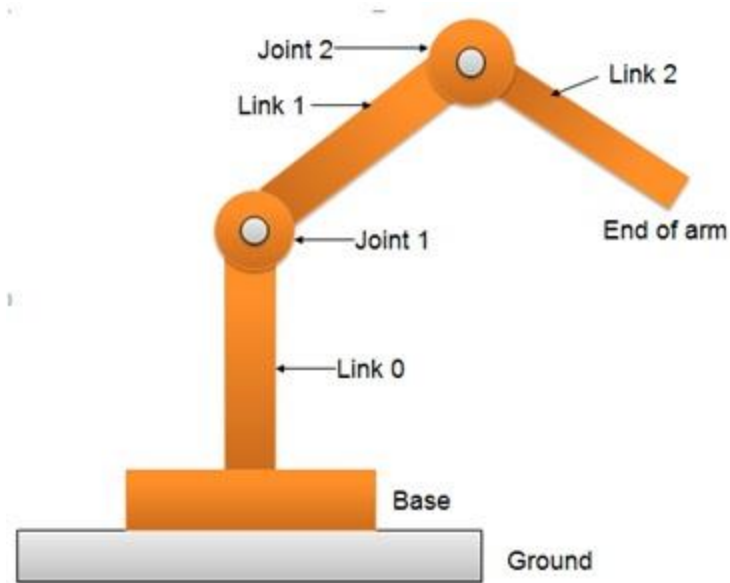


Fig. Joint-link scheme for robot manipulator

Nearly all industrial robots have mechanical joints that can be classified into following five types as shown in Figure.

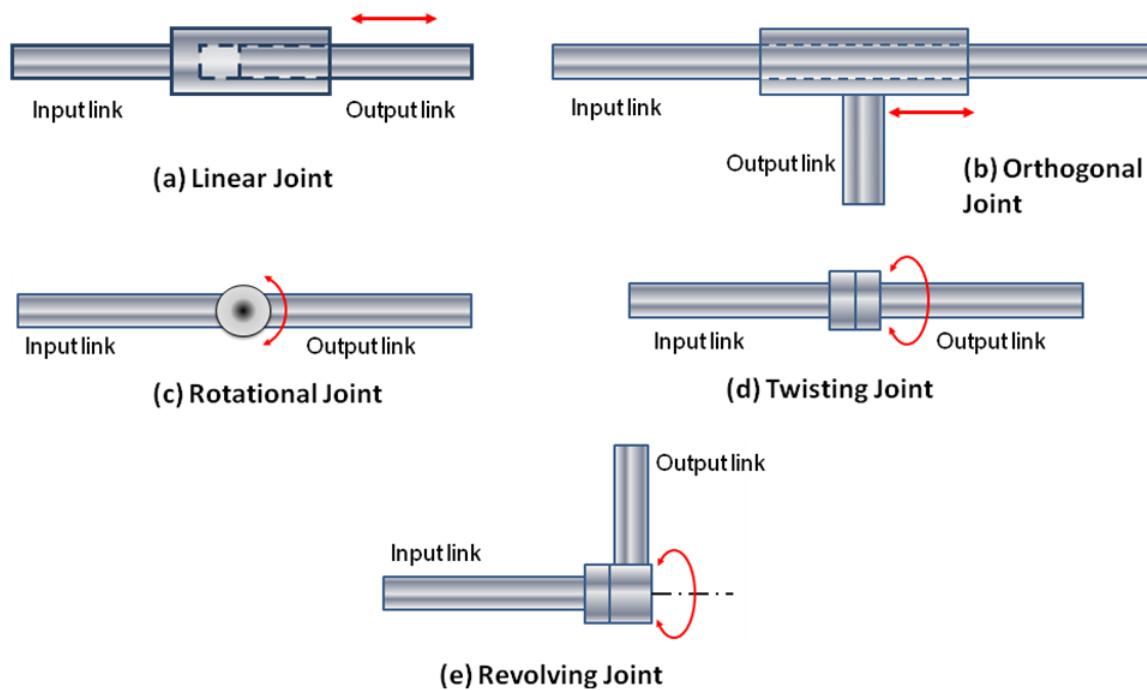


Fig. Types of Joints

a) 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 being parallel.

b) Orthogonal joint (type U joint)

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

c) 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.

d) 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.

e) Revolving joint (type V-joint)

In this type, axis of input link is parallel to the axis of rotation of the joint. However the axis of the output link is perpendicular to the axis of rotation.

2.2 Common Robot Configurations

Basically the robot manipulator has two parts viz. a body-and-arm assembly with three degrees-of-freedom; and a wrist assembly with two or three degrees-of-freedom.

For body-and-arm configurations, different combinations of joint types are possible for a three-degree-of-freedom robot manipulator. Five common body-and-arm configurations are outlined in figure.

a. Polar configuration

It consists of a sliding arm L-joint, actuated relative to the body, which rotates around both a vertical axis (T-joint), and horizontal axis (R-joint).

b. Cylindrical configuration

It consists of a vertical column. An arm assembly is moved up or down relative to the vertical column. The arm can be moved in and out relative to the axis of the column. Common configuration is to use a T-joint to rotate the column about its axis. An L-joint is used to move the arm assembly vertically along the column, while an O-joint is used to achieve radial movement of the arm.

c. Cartesian co-ordinate robot

It is also known as rectilinear robot and x-y-z robot. It consists of three sliding joints, two of which are orthogonal O-joints.

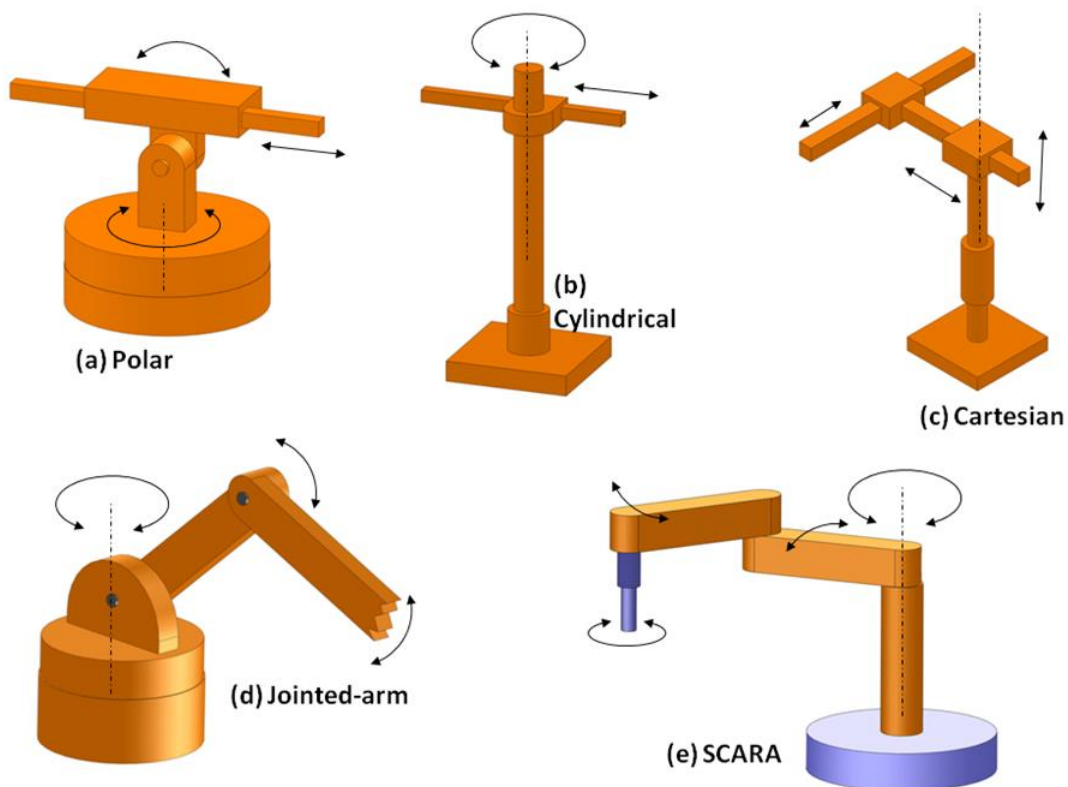


Fig. Common Body-and-Arm configurations

d. Jointed-arm robot

It is similar to the configuration of a human arm. It consists of a vertical column that swivels about the base using a T-joint. Shoulder joint (R-joint) is located at the top of the column. The output link is an elbow joint (another R joint).

e. SCARA

Its full form is 'Selective Compliance Assembly Robot Arm'. It is similar in construction to the jointer-arm robot, except the shoulder and elbow rotational axes are vertical. It means that the arm is very rigid in the vertical direction, but compliant in the horizontal direction.

Robot wrist assemblies consist of either two or three degrees-of-freedom. A typical three-degree-of-freedom wrist joint is depicted in Figure 7.5.4. The roll joint is accomplished by use of a T-joint. The pitch

joint is achieved by recourse to an R-joint. And the yaw joint, a right-and-left motion, is gained by deploying a second R-joint.

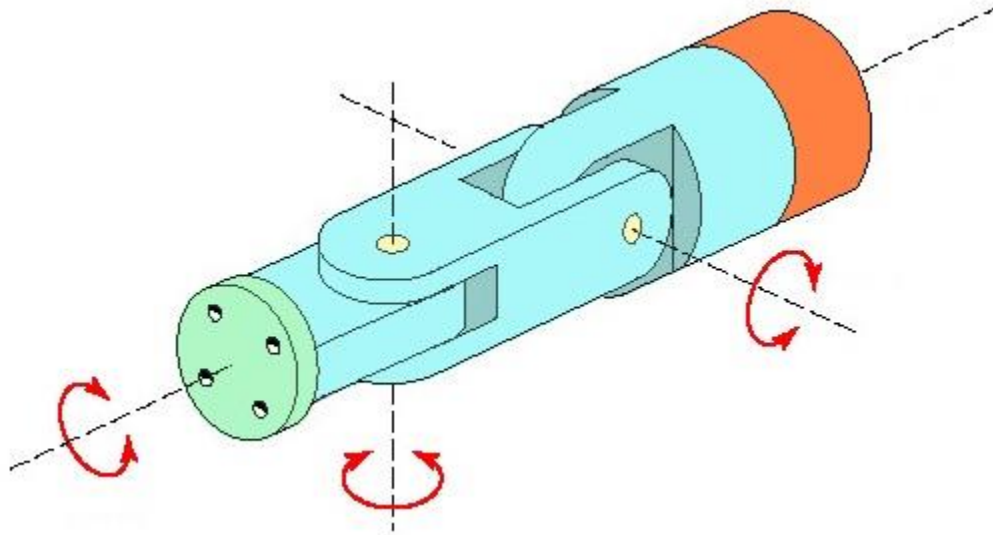


Fig. 7.5.4: Robotic wrist joint

The SCARA body-and-arm configuration typically does not use a separate wrist assembly. Its usual operative environment is for insertion-type assembly operations where wrist joints are unnecessary. The other four body-and-arm configurations more-or-less follow the wrist-joint configuration by deploying various combinations of rotary joints viz. type R and T.

Basically three types of drive systems are commonly used to actuate robotic joints. These are electric, hydraulic, and pneumatic drives. Electric motors are the prime movers in robots. Servo-motors or stepper motors are widely used in robotics. Hydraulic and pneumatic systems such as piston-cylinder systems, rotary vane actuators are used to accomplish linear motions, and rotary motions of joints respectively.

Pneumatic drive is regularly used for smaller, simpler robotic applications; whereas electric and hydraulic drives may be found applications on more sophisticated industrial robots. Due to the advancement in electric motor technology made in recent years, electric drives are generally favored in commercial applications. They also have compatibility to computing systems. Hydraulic systems, although not as flexible as electrical drives, are generally used where larger speeds are required. They are generally employed to carry out heavy duty operations using robots.

The combination of drive system, sensors, and feedback control system determines the dynamic response characteristics of the manipulator. Speed in robotic terms refers to the absolute velocity of the manipulator at its end-of-arm. It can be programmed into the work cycle so that different portions of the cycle are carried out at different velocities. Acceleration and deceleration control are also important

factors, especially in a confined work envelope. The robot's ability to control the switching between velocities is a key determinant of the manipulator's capabilities. Other key determinants are the weight (mass) of the object being manipulated, and the precision that is required to locate and position the object correctly. All of these determinants are gathered under the term 'speed of response', which is defined as the time required for the manipulator to move from one point in space to the next. Speed of response influences the robot's cycle time, which in turn affects the production rate that can be achieved.

Stability refers to the amount of overshoot and oscillation that occurs in the robot motion at the end-of-arm as it attempts to move to the next programmed location. More oscillations in the robotic motion lead to less stability in the robotic manipulator. However, greater stability may produce a robotic system with slower response times.

Load carrying capacity is also an important factor. It is determined by weight of the gripper used to grasp the objects. A heavy gripper puts a higher load upon the robotic manipulator in addition to the object mass. Commercial robots can carry loads of up to 900 kg, while medium-sized industrial robots may have capacities of up to 45kg.