CLASSIFICATION OF ROBOTS

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1. Different systems of classification of robots:

The robots are classified on the basis of:
i) Coordinate system utilized in designing the mechanical structure.
ii) Control method used for various robotic axes.

2. Classification of robots according to coordinate system.

On the basis of coordinate system, the robots can be classified into the following types.

a) Cartesian coordinate robot.
b) Cylindrical coordinate robot.
c) Spherical or polar coordinate robot.
d) Articulated robot.

a) Cartesian coordinate robot:

In cartesian coordinate robot:

• The first three joints are all prismatic, the resulting notation for this configuration is ‘PPP’.

• The three sliding joints correspond to moving the wrist up and down, in and out, and back and forth.

• The work envelope or work volume that this configuration generates is a rectangular parallelepiped.

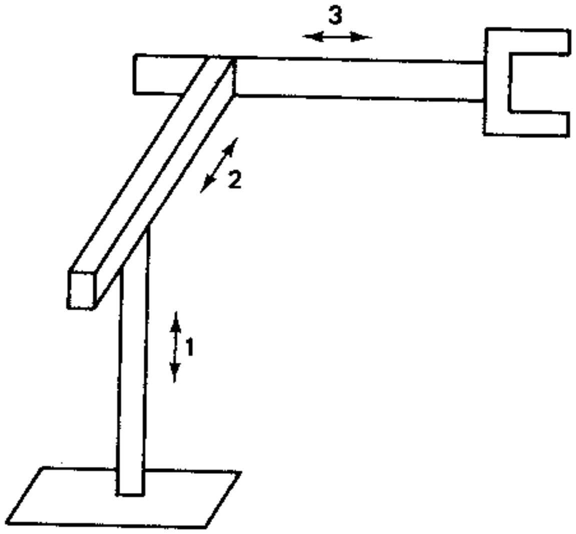

Fig.1: Cartesian Coordinate robot

- When a Cartesian coordinate robot is mounted from above in a rectangular frame, it is referred to as a gantry robot.

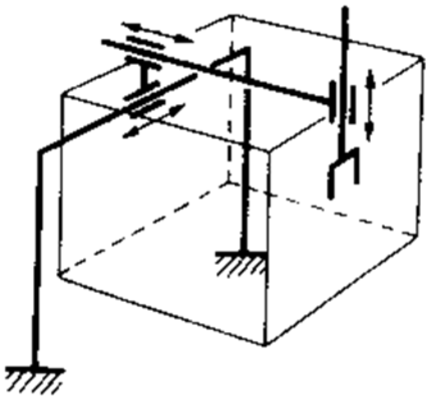

Fig.2: Workspace of a cartesian coordinate robot.

- This configuration produces robots with very stiff structures. As a consequence, large robots can be built. These large robots, often called gantry robots, resemble overhead gantry cranes. Gantry robots sometimes manipulate entire automobiles or inspect entire aircraft.

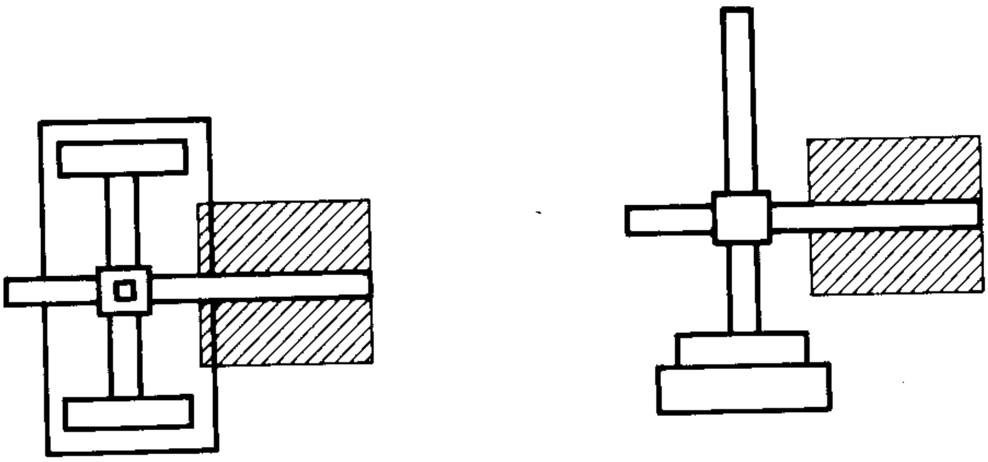

Fig.3: Side view and top view of Cartesian robot and workspace.

- As the first three joints are decoupled it is simpler to design.
- The primary disadvantage is that all of the feeders and fixtures associated with an application must be "inside" the robot. Thus, application work cells for cartesian robots become very machine dependent. The size of the robot's support structure limits the size and placement of fixtures and sensors. These limitations make retrofitting Cartesian robots into existing work cells extremely difficult.
- This configuration is useful for table-top assembly applications and as gantry robots, for transfer of material or cargo.
- Example: Cincinnati Milacron T^3 gantry robot.

b) Cylindrical coordinate robot:

If the first joint of Cartesian-coordinates robot is replaced with a revolute joint (to form the configuration 'RPP'), this produces a cylindrical-coordinate robot

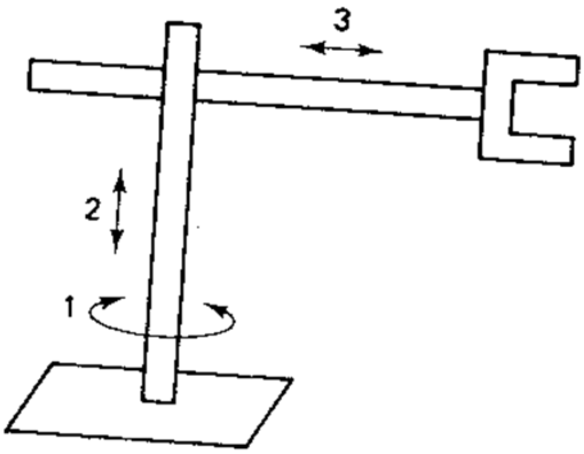

Fig.4: Cylindrical Coordinate robot

- The revolute joint swings the arm back and forth about a vertical base axis. Usually, a full 360^0 rotation in q is not permitted, due to restrictions imposed by hydraulic, electrical, or pneumatic connections or lines.

- The prismatic joints then move the wrist up and down along the vertical axis in and out along a radial axis. Since there will be some minimum radial position, the work envelope generated by this joint configuration is the volume between two vertical concentric cylinders.

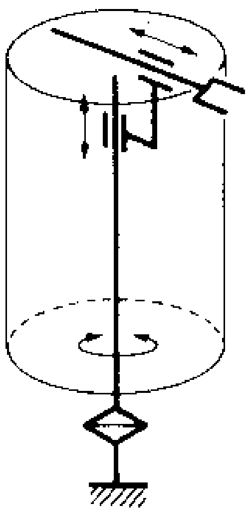

Fig.5: Workspace of Cylindrical Coordinate Robot.

- The joint variables are cylindrical coordinates and thus the three axes of this robot generate a work envelope in the shape of a cylinder.

- The problem of elevating a workpiece or tool in a vertical, straight line is an easy one for the robot of a cylindrical configuration.

- The disadvantage of robots of cylindrical configuration is that they cannot reach around obstacles.

- Example: GMF: M-100 robot.

c) Spherical or polar coordinate robot:

If the second joint of a cylindrical-coordinate robot is replaced with a revolute joint (so that the configuration is then 'RRP'), this produces a spherical coordinate robot as shown in the below figure:

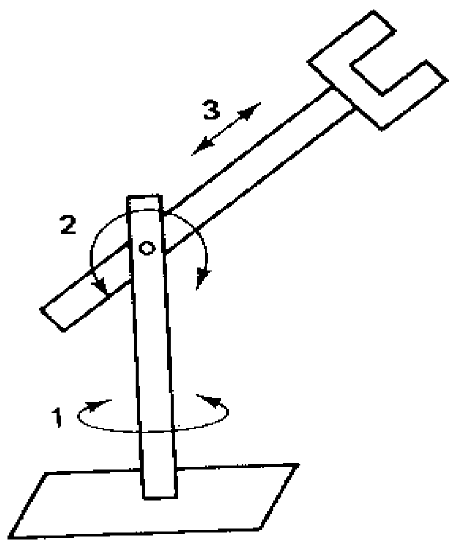

Fig.7: Spherical coordinate robot

- The first revolute joint swings the arm back and forth about a vertical base axis, while the second revolute joint pitches the arm up and down about a horizontal shoulder axis.

- The prismatic joint moves the wrist radially in and out.

- The work envelope generated in this case is the volume between two concentric spheres. The spheres are typically truncated from above and below, and behind by limits on the ranges of travel of the joints.

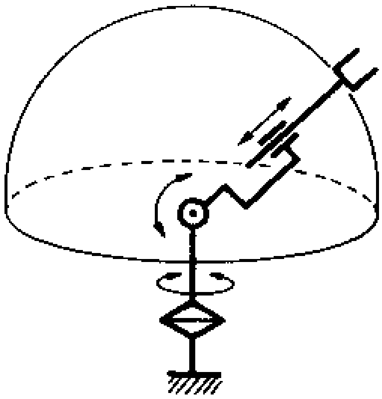

Fig.8: Workspace of a spherical

• A typical robot motion is to elevate a workpiece along a vertical path while maintaining the orientation of the workpiece. It is seen that for the polar configuration robot, this requires simultaneous, coordinated motion in three axes: shoulder, arm extension, and wrist pitch. The articulating robot has a problem of similar complexity, requiring simultaneous, coordinated motion in shoulder, elbow and wrist pitch.

• Example: Stanford manipulator.

d) Articulated or joined coordinate robot:

- When the last remaining prismatic joint is replaced by a revolute joint (to yield the configuration 'RRR'), this produces an articulated –coordinate robot. An articulated-coordinate robot the is dual of a Cartesian robot in the sense that all three of the major axes are revolute rather than prismatic.

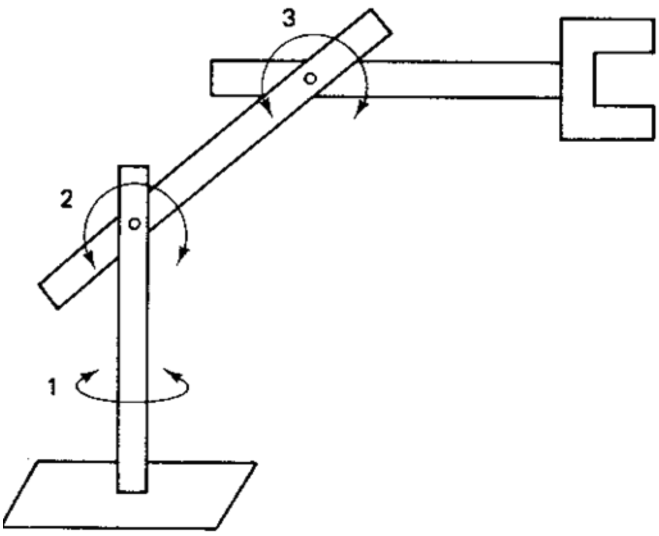

Fig.10: Articulated coordinate robot

• The articulated-coordinate robot is the most andromorphic configuration; that is, it most closely resembles the anatomy of the human arm. Articulated robots are also called revolute robots. An example of an articulated-coordinate robot is shown in Figure 10.

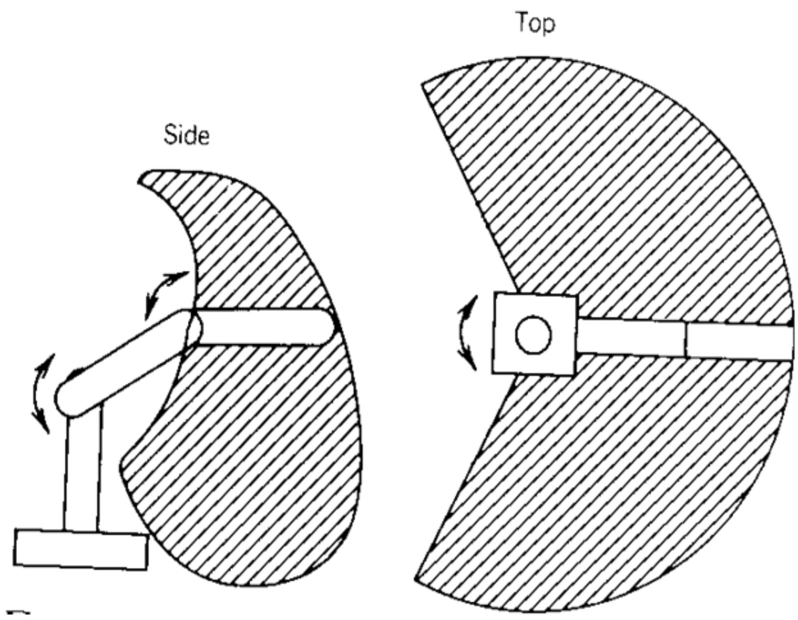

Fig.11: Articulated robot with workspace (a) Side view (b) Top view.

• Here the first revolute joint swings the robot back and forth about a vertical base axis.

• The second joint pitches the arm up and down about a horizontal shoulder axis, and the third joint pitches the forearm up and down about a horizontal elbow axis.

• These motions create a complex work envelope, with a side-view cross section typically being crescent-shaped (Figure 11).

• The configuration provides for relatively large freedom for movement in a compact space because articulated robots provide the least intrusion of the manipulator structure into the workspace, making them capable of reaching into confined spaces. They require much less overall structure than Cartesian robots, making them less expensive for applications needing smaller workspaces.

• Example: PUMA

3. Classification of robots according to control method:

The robots can be classified according to control method into following types:

a) Non-servo-controlled robots.

b) Servo-controlled robots.

a) Non-servo-controlled robot:

- Non-servo-controlled robots are also called limited-sequence robots, endpoint robot, pick-and-place robot or bang-bang robot.

- According to this control the axes remain in motion until the limits of travel for each are reached. Only two positions for each individual axis are assumed.

- There is no monitoring (via external sensors) of the motion at any intermediate point. The feedback devices are simply pair of adjustable limit switches and mechanical stoppers.

- They are relatively high-speed machines because of the small size of the arm and the full power applied to the axis actuators (pneumatic or hydraulic cylinders), since a control valve can provide the full flow of air or oil to the actuator.

- They are low cost and easy to maintain and operate.
- This class of robot has limited flexibility with respect to positioning and programming.

- They have been mainly used in materials-handling tasks for investment casting, die-casting, conveyor loading, palletizing, multiple parts handling, machine loading and injection moulding.

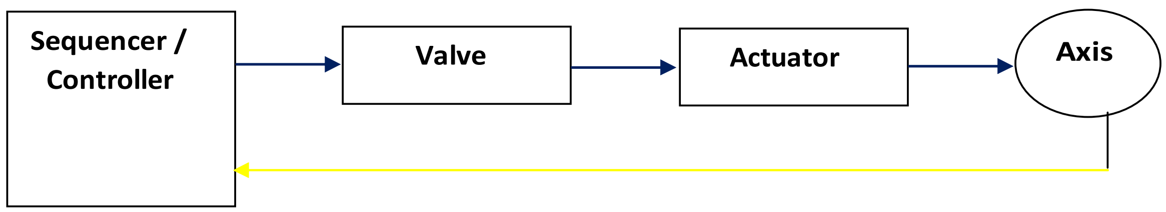

Fig.12: Control loop for a non-servo robot

- The controller or sequencer sends signal to the control valve for the axis motion. The control valve opens admitting air or oil to the actuator, which would be either pneumatic or hydraulic. The actuator starts the robot axis moving. The valve remains open, and the member continues to move until it is physically restrained by contact with an end stop. A limit switch placed at the end stop is used to signal the end of travel back to the controller, which then commands the control valve to close. If the controller is a sequencer or device capable of sending a sequence of control signals, it then indexes to the next step, and the controller again provides an output signal. These signals may go to the actuators or the robot manipulator or to external devices, such as the gripper. The process is replaced until the entire sequence of steps is completed.

b) Servo-controlled robot:

- In servo-controlled robots' information about the position and velocity is continuously monitored and feedback to the control system associated with each of the joints of the robot.
- Each axis loop is "closed" Use of closed –loop-control permits the manipulator members to be commanded to move and stop anywhere within the limits of travel for individual axes.
- Servo controlled robots have larger memory capacity than non-servo controlled robots. They can store more position and hence that the motion can be significantly more complex and smoother.

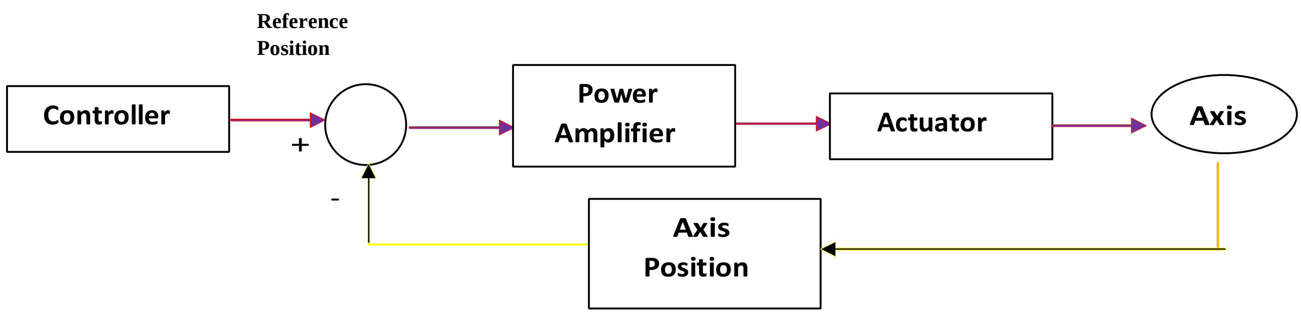

Fig.13: Control loop of a servo-controlled robot

- A basic servo-controlled system receives its reference position signal from the sequence controller. The axis position measurement devices also provide a feedback signal proportional to its current location. The difference between the desired and current position is called the error signal. This signal is converted to the proper form and applied to the actuator. If there is a large difference, a large signal is applied to the actuator and its moves quickly. If the error signal is zero, no signal is applied to the actuator, since it is at the desired location. With proper design, the action of this feedback is very smooth and reliable.

- Upon start of execution, the controller addresses the memory location of the first command position and also reads the actual position of the axis from the position – measuring device. The desired and actual position signals are subtracted to form an error signal. The error signal is then amplified and converted to a velocity signal is then amplified and converted to a velocity signal. The actual velocity signal is read from a velocity –measuring device, such as a tachometer. The difference between the desired and actual velocities is used as another error signal. This velocity error is fed to a compensation network, which serves to keep the controlled motion stable. The output of this network is amplified and used to control the actuating device that moves the robot arm. The position and velocity feedback signals are linked directly to the robot axis.

- As the actuators move the manipulator’s axis, the feedback signals are compared with the desired position data, generating new error signals that are used to command the robot. This process continues until the error signals are effectively reduced to zero, and the axes come to rest at the desired position. The controller then addresses the next memory location and responds appropriately until the entire sequence or program has been executed.

- One of the main features of the servo-controlled robot is its versatility. It can move to any point within its limit of travel. It is also possible to control the velocity, acceleration, and declaration between program points.

- These are two types of servo-controlled robots:
  i) Point-to-point servo-controlled robot.
  ii) Continuous –path servo-controlled robot.

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