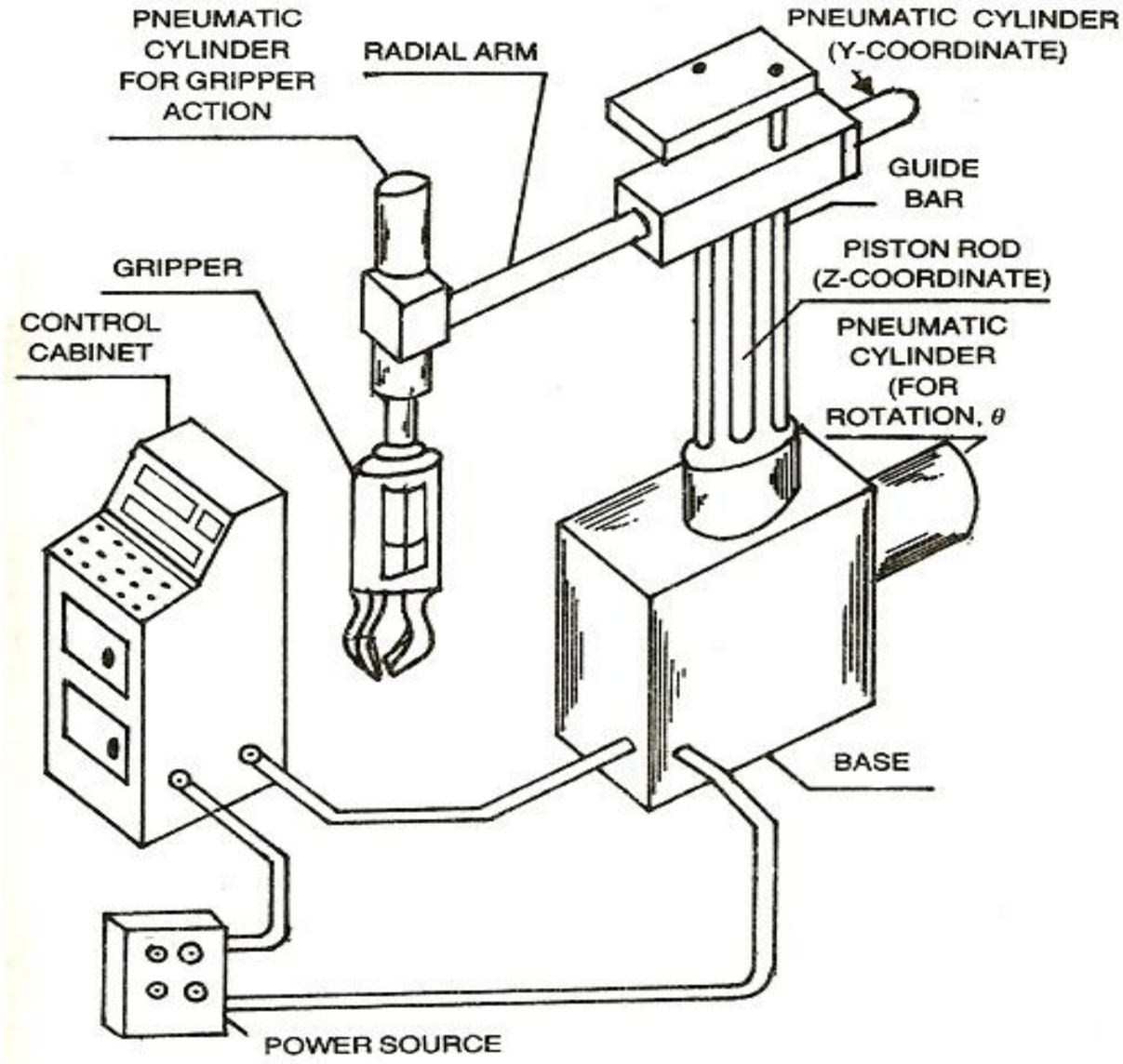
Robot Systems & Robot Anatomy

Robot components

- Base – fixed or mobile
- Manipulator arm with several degrees of freedom
- End-effector or gripper holding a part or tool
- Drives or actuators causing the manipulator arm or end-effector to move
- Controller with h/w and s/w for giving commands to the drives
- Sensors to feed back the info for further actions and to interact with the environment
- Interfaces connecting the robotic subsystems

Robot components



Robot Manipulator

- Mechanical part of the robot
- To facilitate the movement of the arm within the work envelope
- Capabilities
  - Max possible load bearing capability
  - Speed
  - Precision
  - Repeatability
- Simplest robot will have two or three axes arm
- Has a fixed or movable base.
- Has a free end where an end-effector or gripper or tool holder or any power device is attached.

Robot Manipulator

- Consists of several separate links making a chain.
- Three links to place the end-effector at a desired location inside work envelope.
- Three links to make up the wrist of the manipulator.
- The links are connected through lower pair connectors.

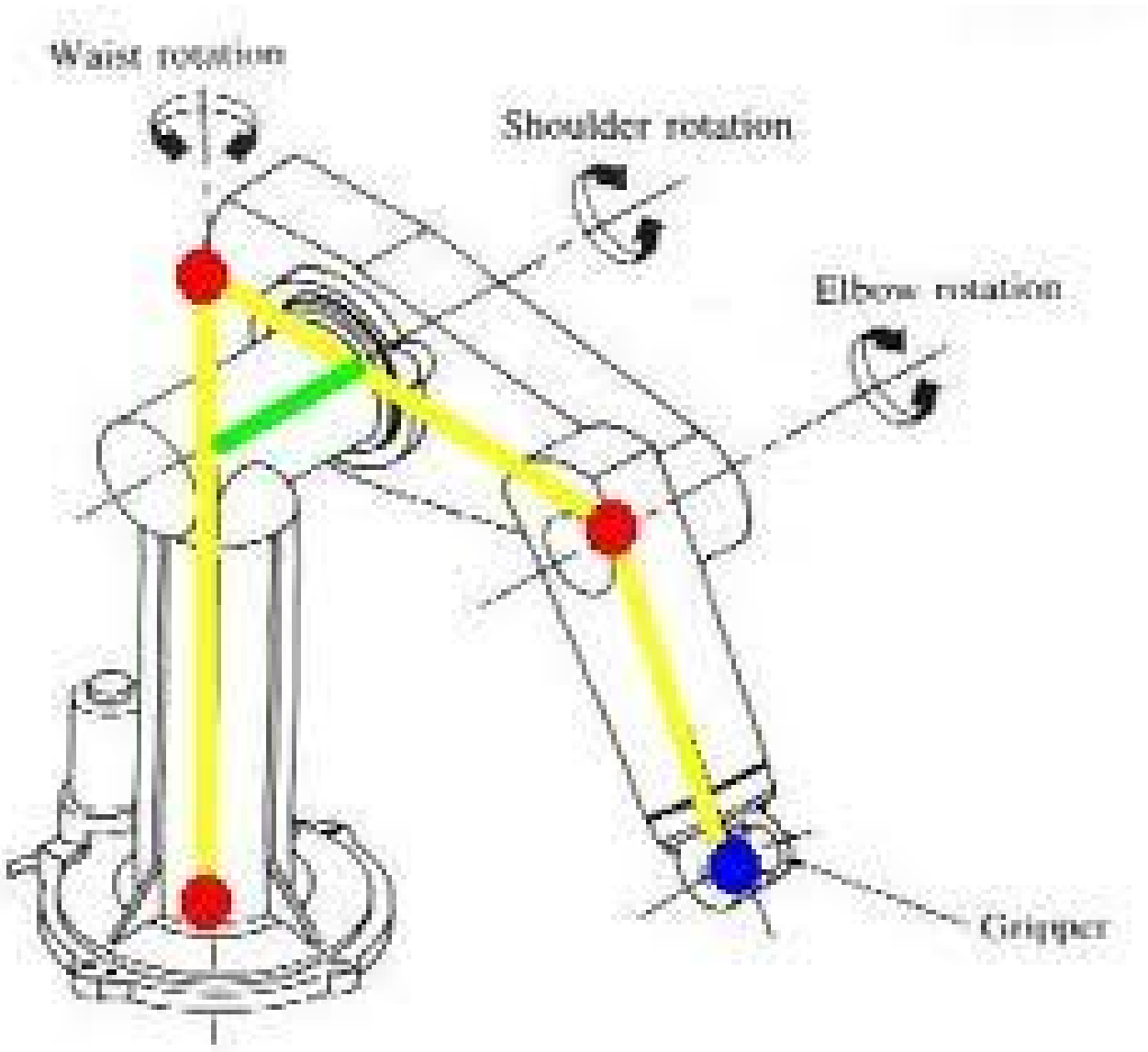
Degree of freedom

- The degree of freedom or grip of a robotic system can be compared to the way in which the human body moves.
- For each degree of freedom a joint is required.
- The degrees of freedom located in the arm define the configuration.
- Three degrees of freedom located in the wrist give the end effector all the flexibility.
- A total of six degrees of freedom is needed to locate a robot’s hand at any point in its work space.
- Although six degrees of freedom are needed for maximum flexibility, most robot employee only three to five degrees of freedom.
- The more the degrees of freedom, the greater is the complexity of motions encountered.

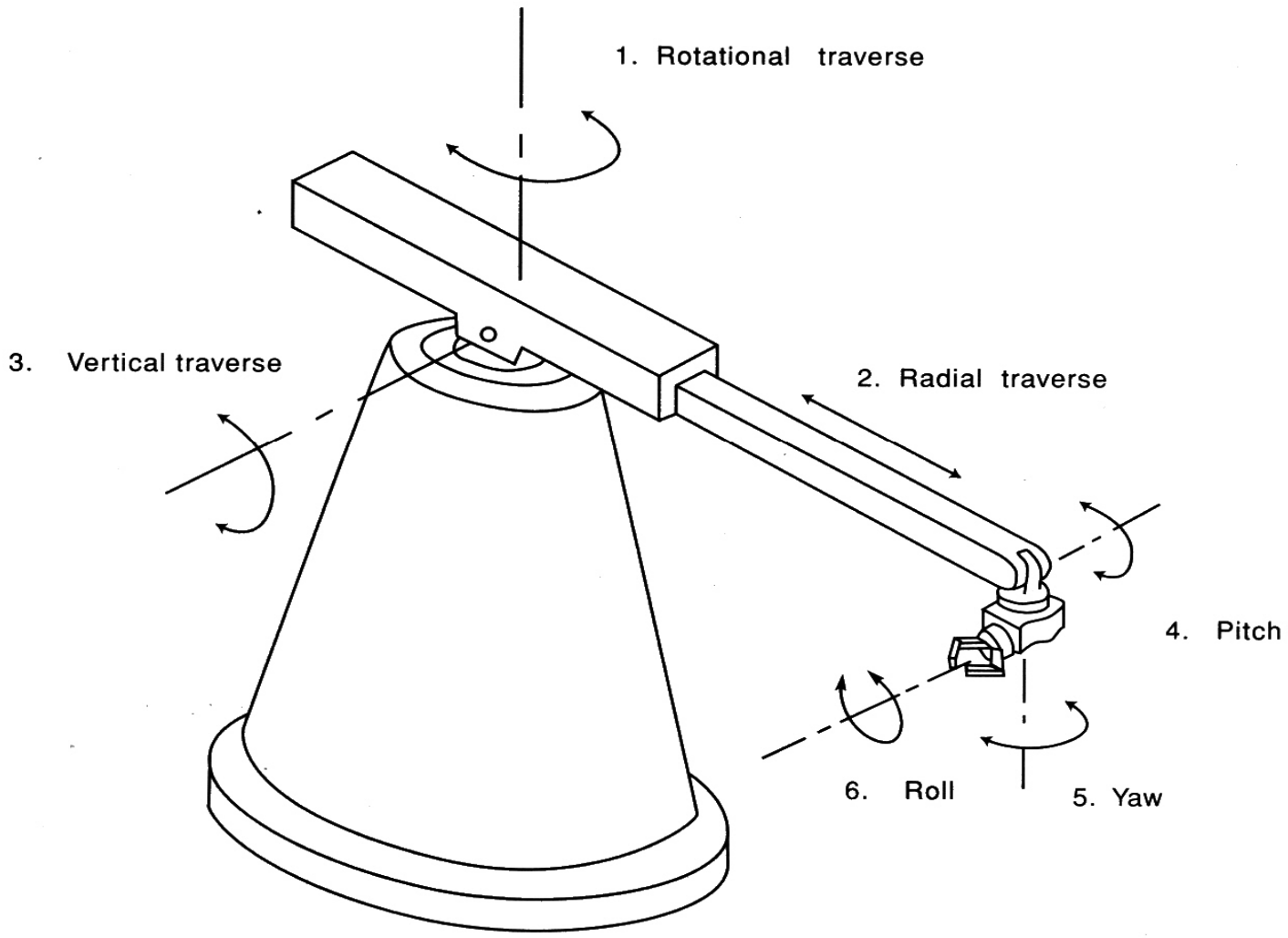
Degree of freedom

- The three degrees of freedom located in the manipulator arm are:
  - The rotational reverse: is the movement of the arm assembly about a rotary axis, such as left-and-right swivel of the robot's arm about a base.
  - The radial traverse: is the extension and retraction of the arm or the in-and-out motion relative to the base.
  - The vertical traverse: provides the up-and-down motion of the arm of the robotic system.

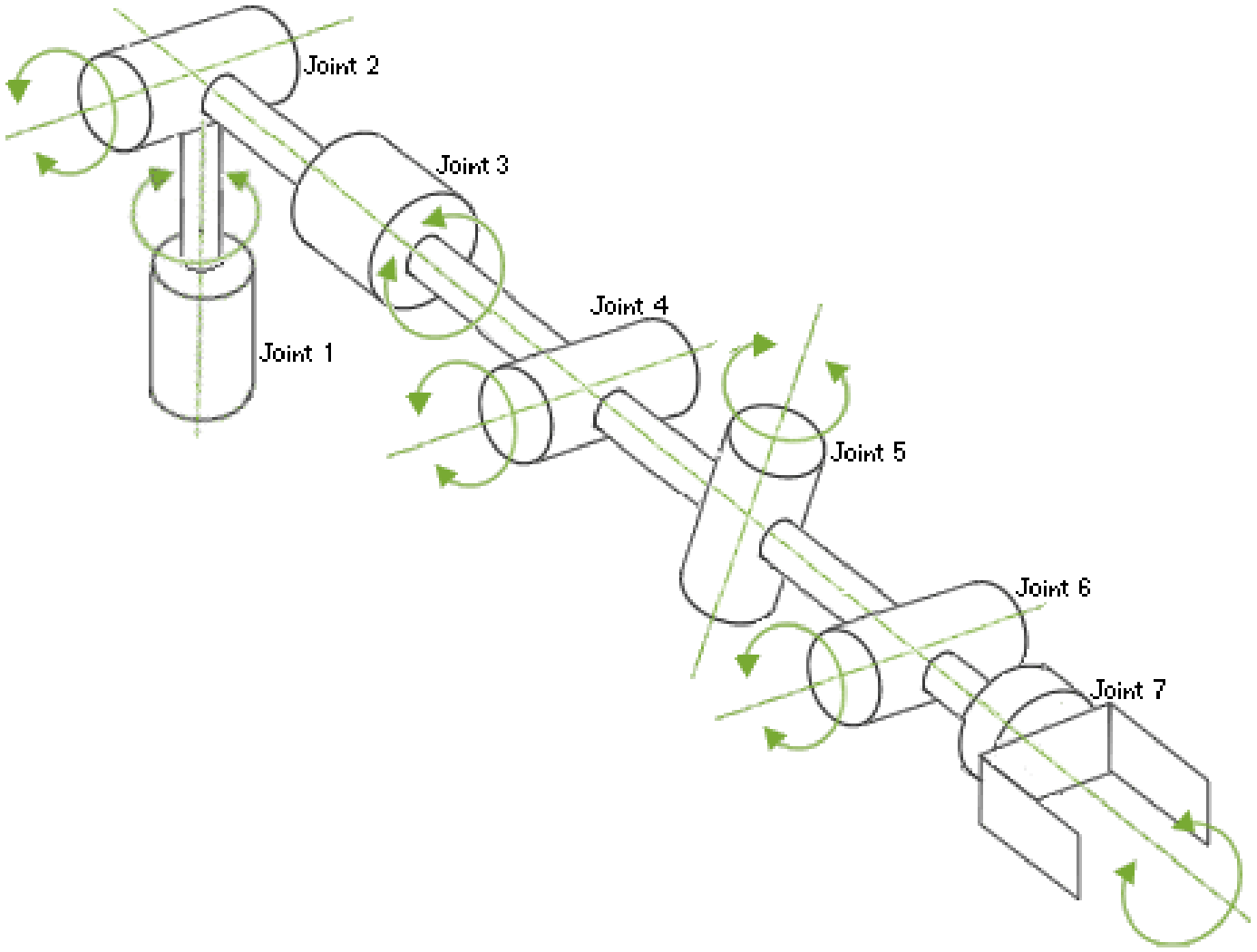
Degree of freedom



Degree of freedom



7 DoF

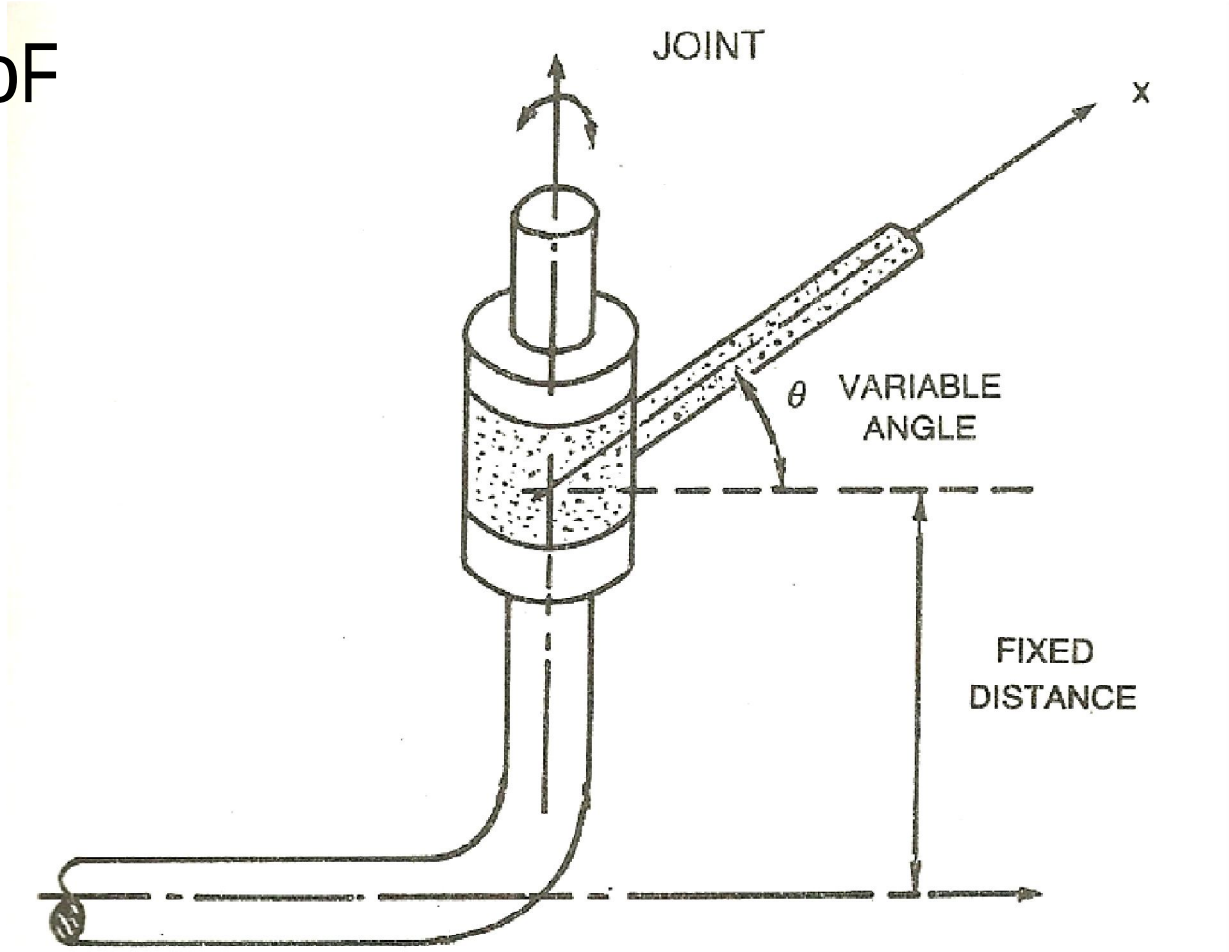


Lower pair connectors

- Used to connect links of the manipulator arm
- Types
  - Revolute Pair
  - Prismatic pair
  - Cylindrical pair
  - Spherical pair
  - Hooke joint

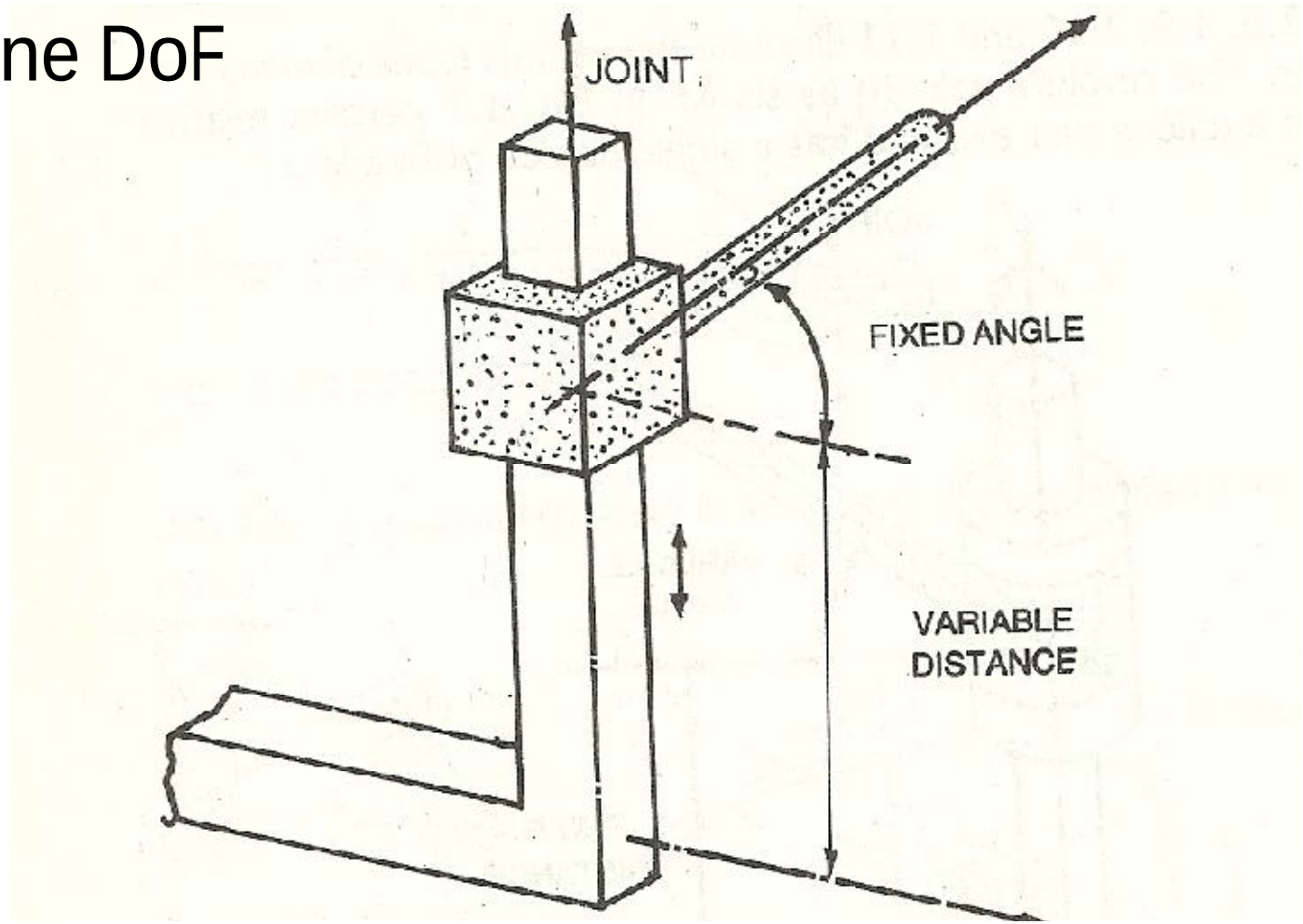
Revolute Pair

- Rotation about an axis
- Has one DoF



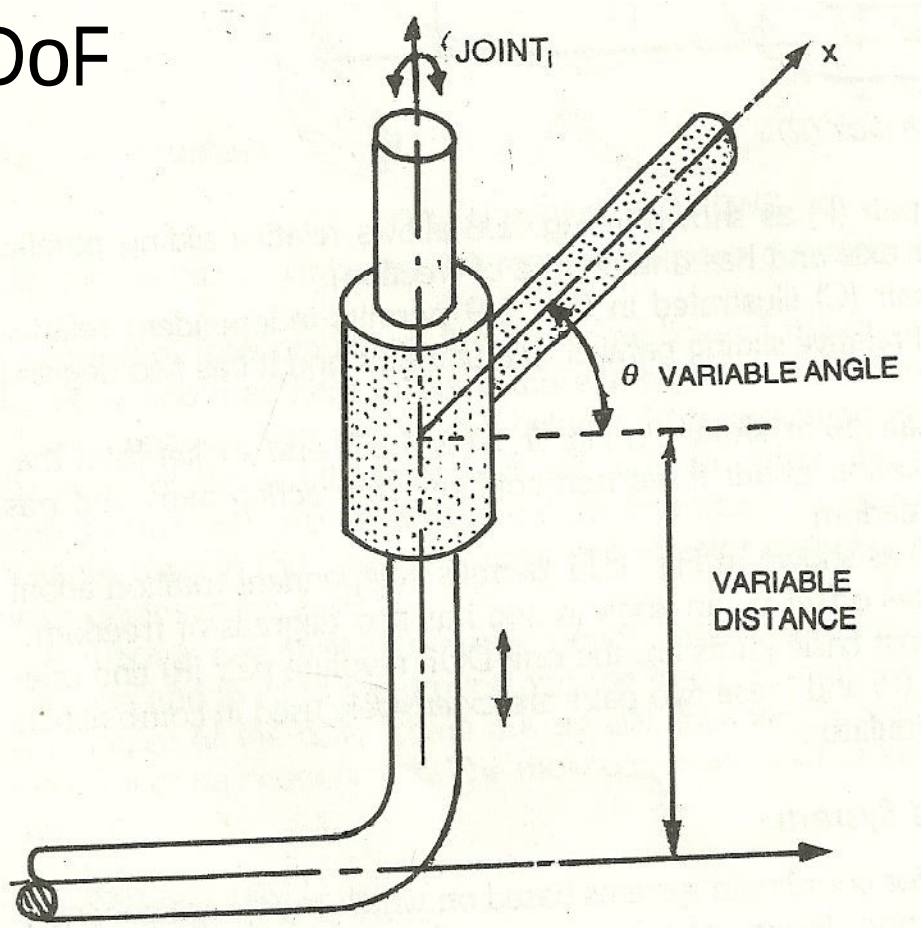
Prismatic pair

- Sliding parallel with an axis
- Has one DoF



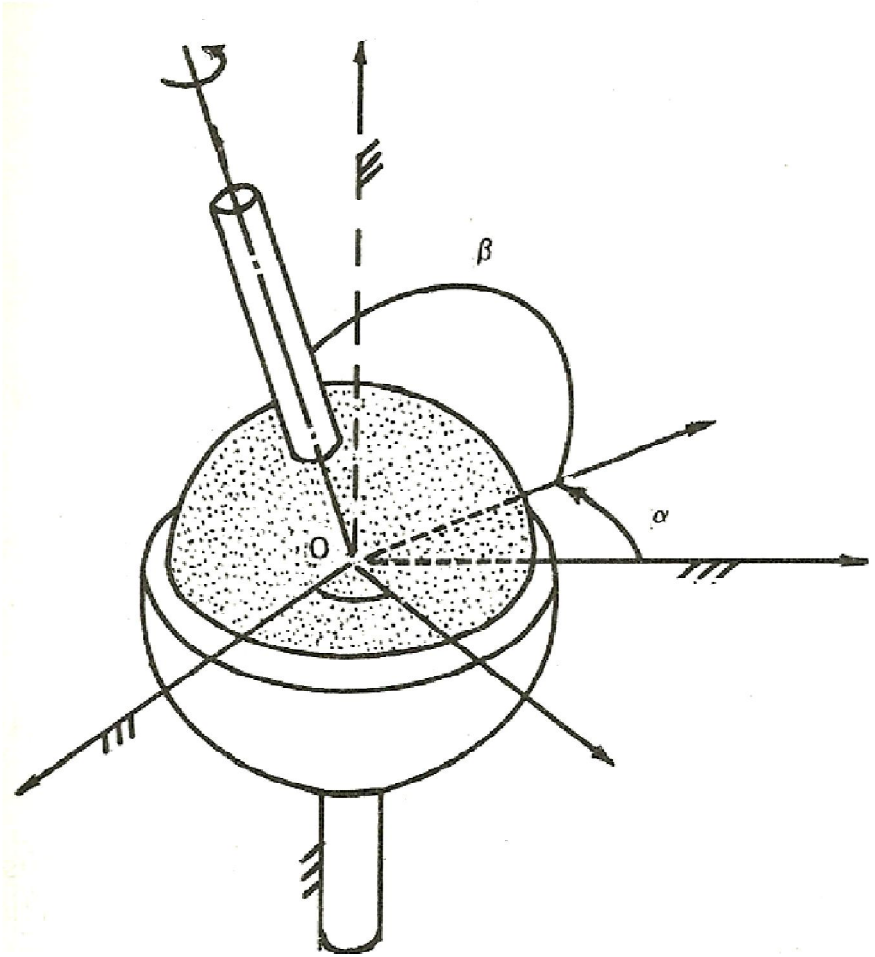
Cylindrical pair

- Rotation about and sliding parallel to an axis
- Has 2 DoF



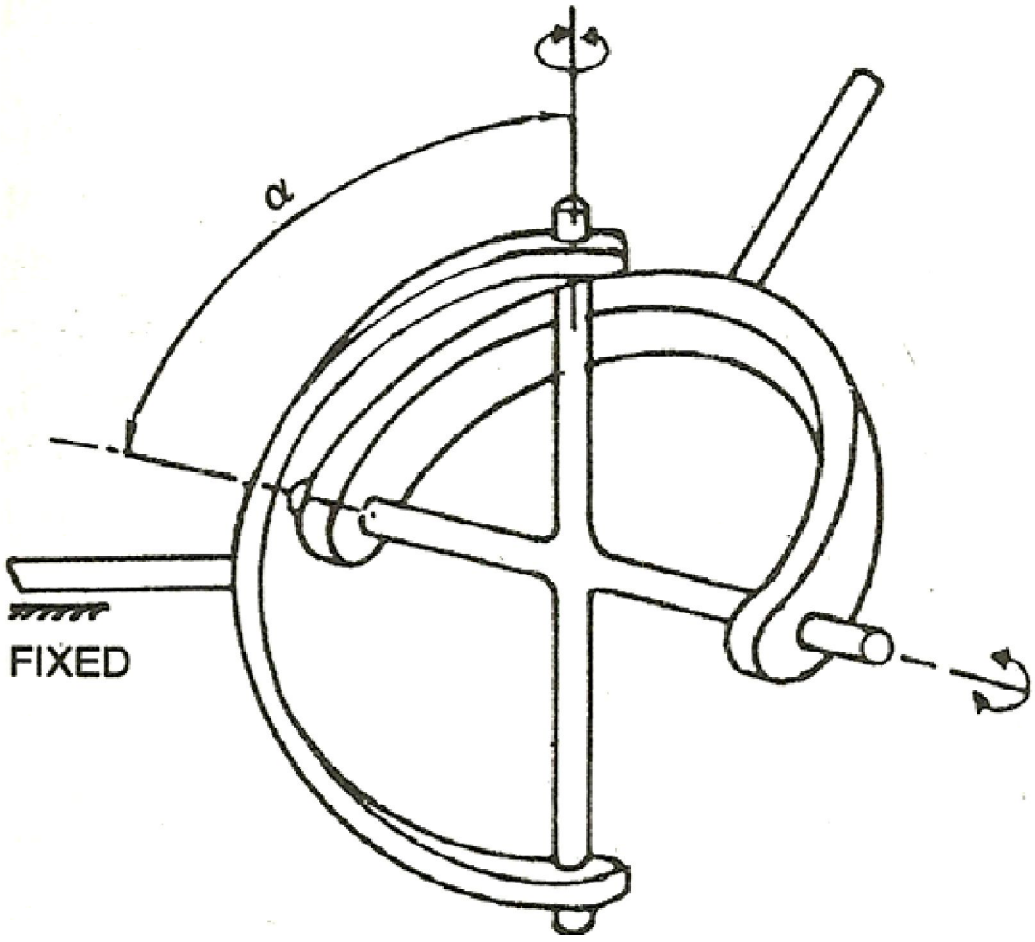
Spherical Pair

- It is a ball and socket joint that rotates about three interacting axes
- Has 3 DoF



Hooke joint

- Rotates about two intersecting axes offset by an angle α
- Has 3 DoF



Robot Coordination system

- Based on which robots are specified.
- Four types
  - Cartesian coordinate system
  - Cylindrical coordinate system
  - Polar or spherical coordinate system
  - Revolute coordinate system

Robot Coordination system

- Cartesian coordinate system
  - X,Y & Z coordinate axis
  - X coordinate – Left & Right motion
  - Y coordinate – Forward & Backward motion
  - Z coordinate – Up and Down motion
- Cylindrical coordinate system
  - Three DoF – 2 linear motions and 1 rotational
  - Radial in or out (r)
  - angular motion (θ) about vertical axis
  - Up or down motion (z axis)

Robot Coordination system

- Polar or spherical coordinate system
  - Three DoF – 1 linear motions and 2 rotational
  - Radial in or out (r)
  - angular motion (θ) about vertical axis
  - angular motion (ϕ) about an axis perpendicular to vertical axis
- Revolute coordinate system
  - 3 DoF like human waist, shoulder and elbow joints

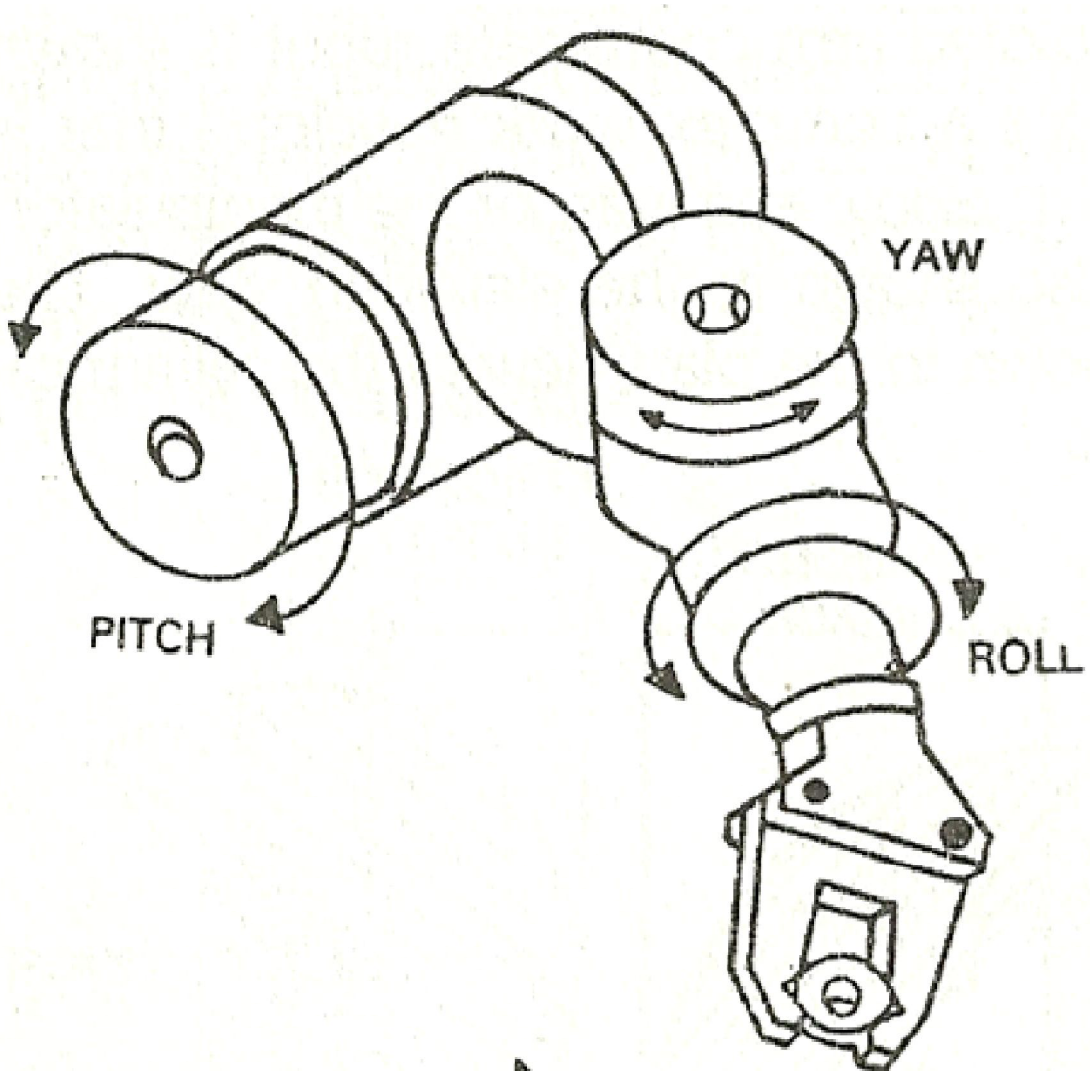
Work envelopes

- Volume of space surrounding the robot manipulator.
- Depends on robot coordinate systems

Robot Wrist

- To position the end-effector at any 3 D space in the work envelope.
- The three degrees of freedom located in the wrist are
  - Pitch or bend: up-and-down movement of the wrist.
  - Yaw: right-and-left movement of the wrist.
  - Roll or swivel: rotation of the hand.

Robot Wrist



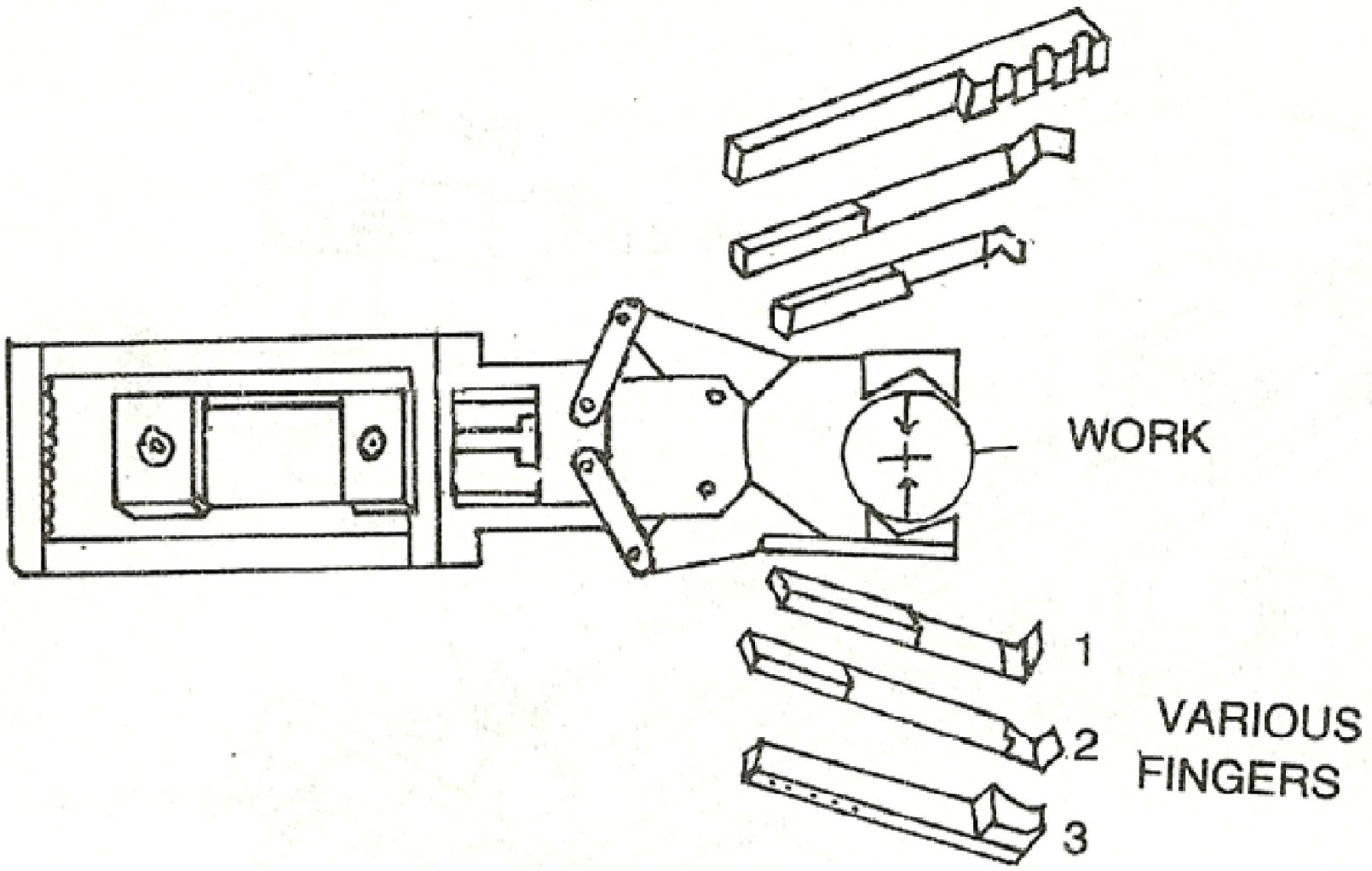
Robot End-effectors

- It is a gripper or end of arm mounted on the robot wrist
- It is task specific.
- Gripping methods
  - Mechanical clamping
  - Magnetic gripping
  - Vacuum gripping

Mechanical clamping

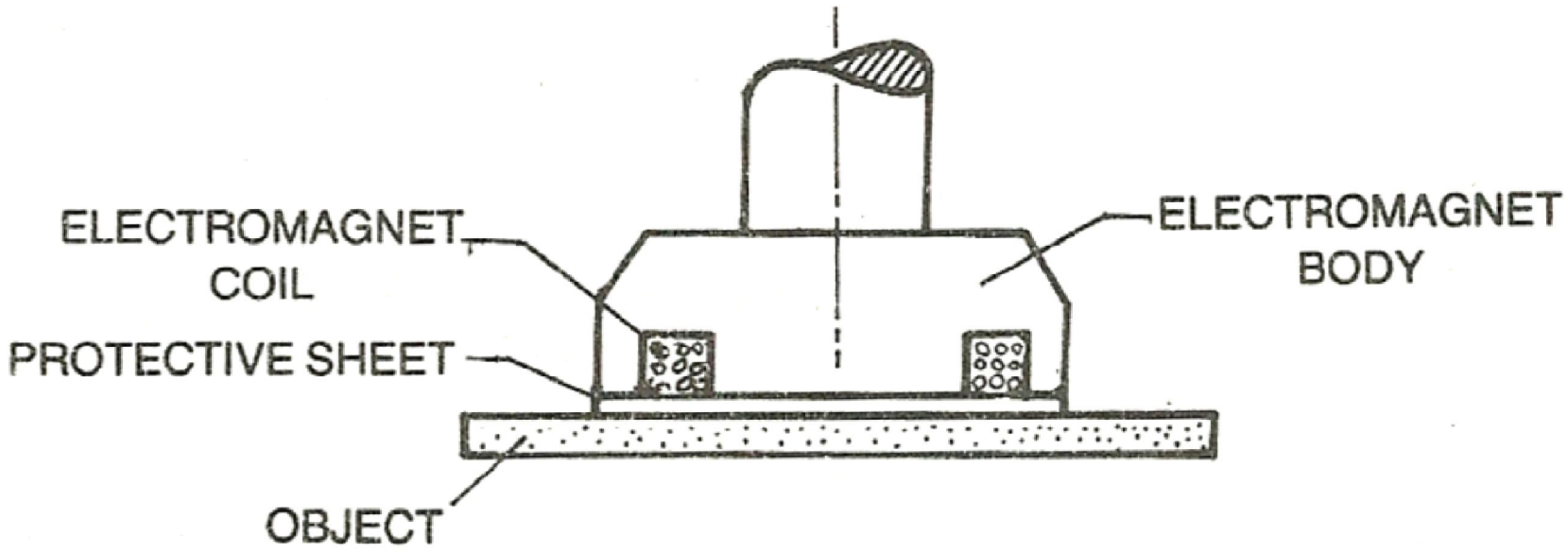
- Types
  - Vice type mechanism
  - Hooking or lifting mechanism
  - Scooping mechanism
- Interchangeable finger tips actuated by linear drive system – Pneumatic or hydraulic or electrical motors – servo or stepper motors
- Applications
  - Forging and metal working industries.

Mechanical clamping



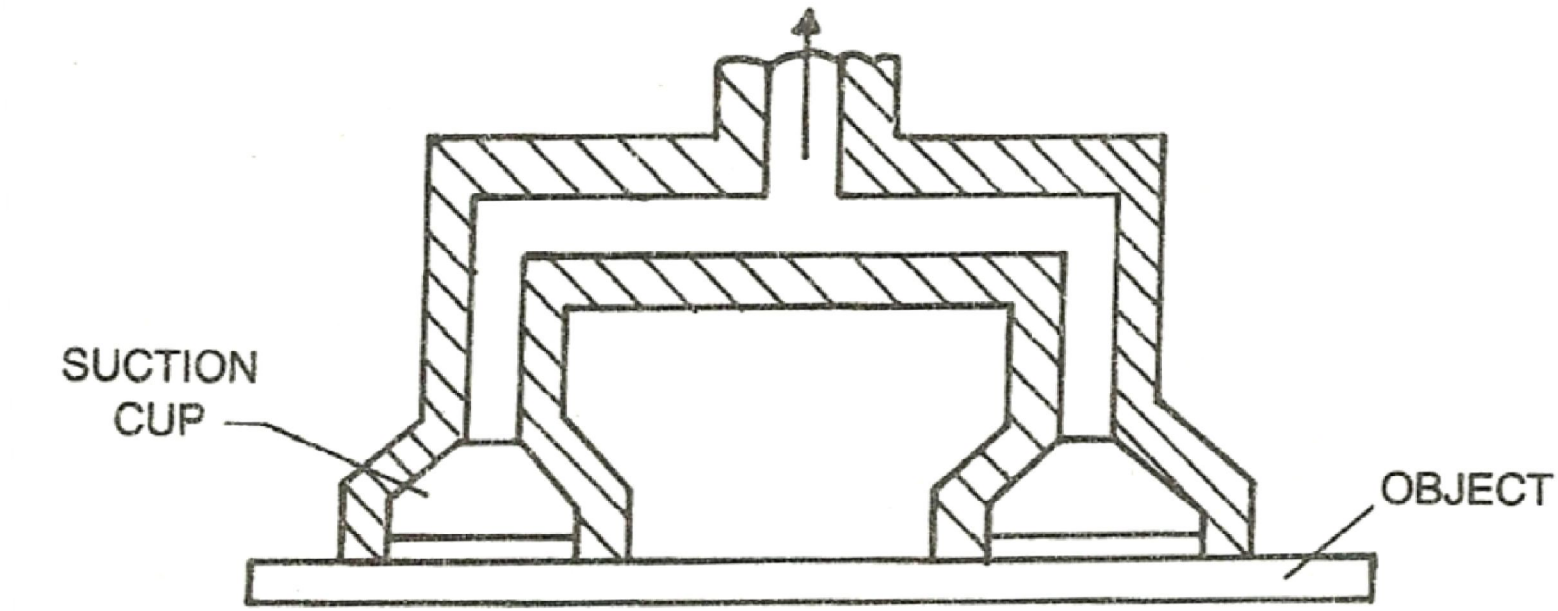
Magnetic gripping

- To fetch ferrous components.
- By the principle of electromagnetism



Vacuum gripping

- Suction cups to hold and transfer lighter objects.
- Vacuum pumps are used create vacuum.



Robot Actuators

- Arms require power to move to a desired position or location.
- Power drive system or actuators does this process.
- Types
  - Pneumatic
  - Hydraulic
  - Electric

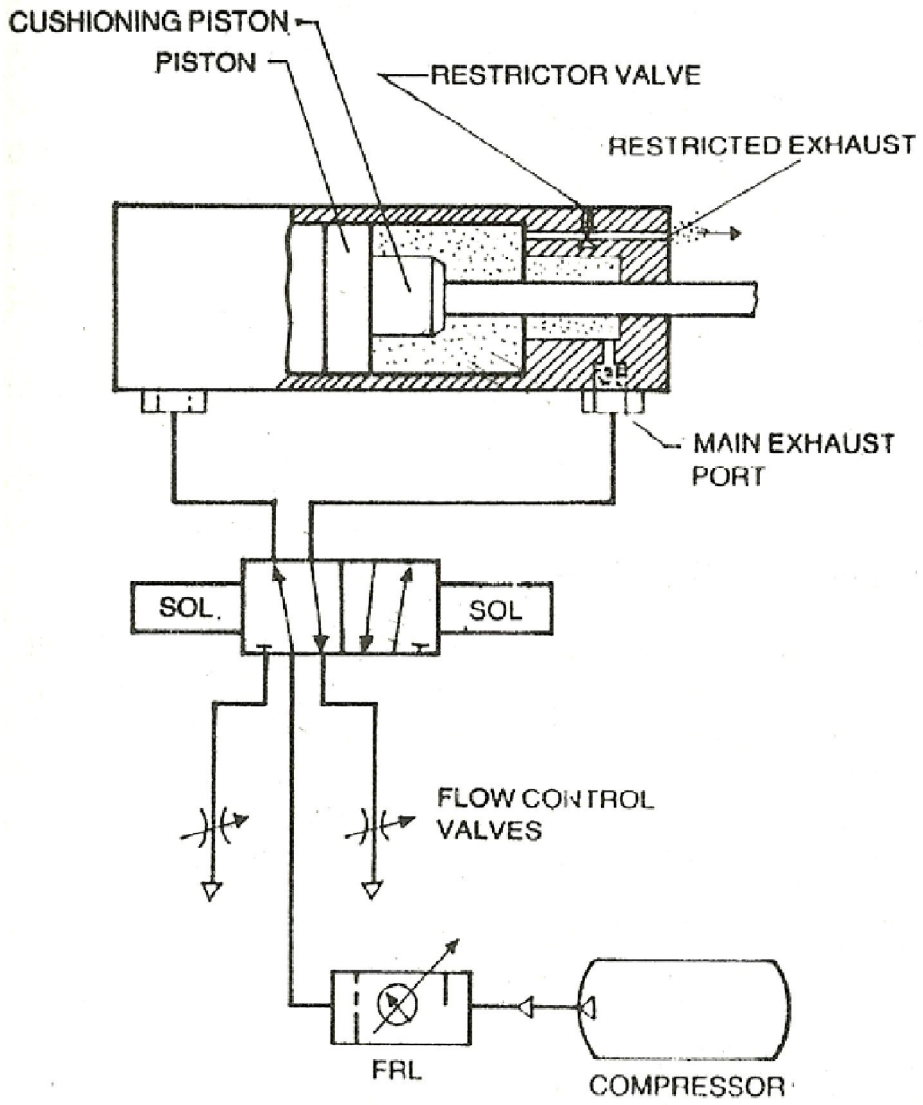
Pneumatic power drives

- Employs linear actuator - double acting cylinders or rotary actuators – vane motors.
- Uses compressed air to move the arms.
- Advantage is simple construction.
- Disadvantages
  - Slow response
  - Reduced repeatability

Pneumatic power drives

- Compressed air is directed through filter, regulator and lubricator (FRL) to the hose pipes.
- Then the air flow to the pneumatic cylinder through direction control valve.
- Direction of the piston depends on the air supplied to the two ends of the cylinder.

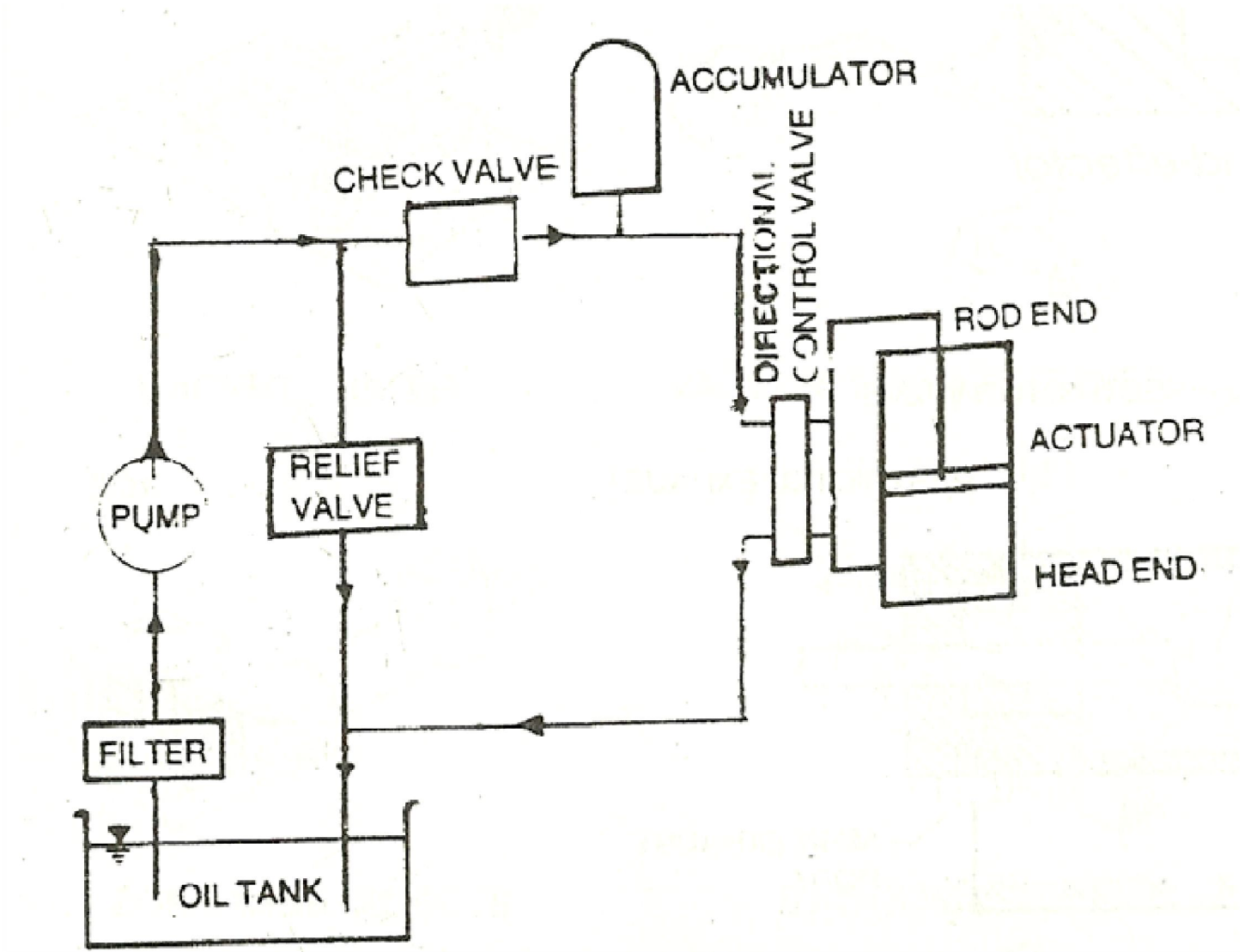
Pneumatic power drives



Hydraulic system

- Electric motor pumps oil from reserve tank to hydraulic actuators – double acting cylinders through control valves.
- For rotary motion, hydraulic motors are used.
- Provides greater power and torque but expensive.

Hydraulic system



Electric Drives

- Uses DC servo motors, stepper motors.
- Most reliable and inexpensive.

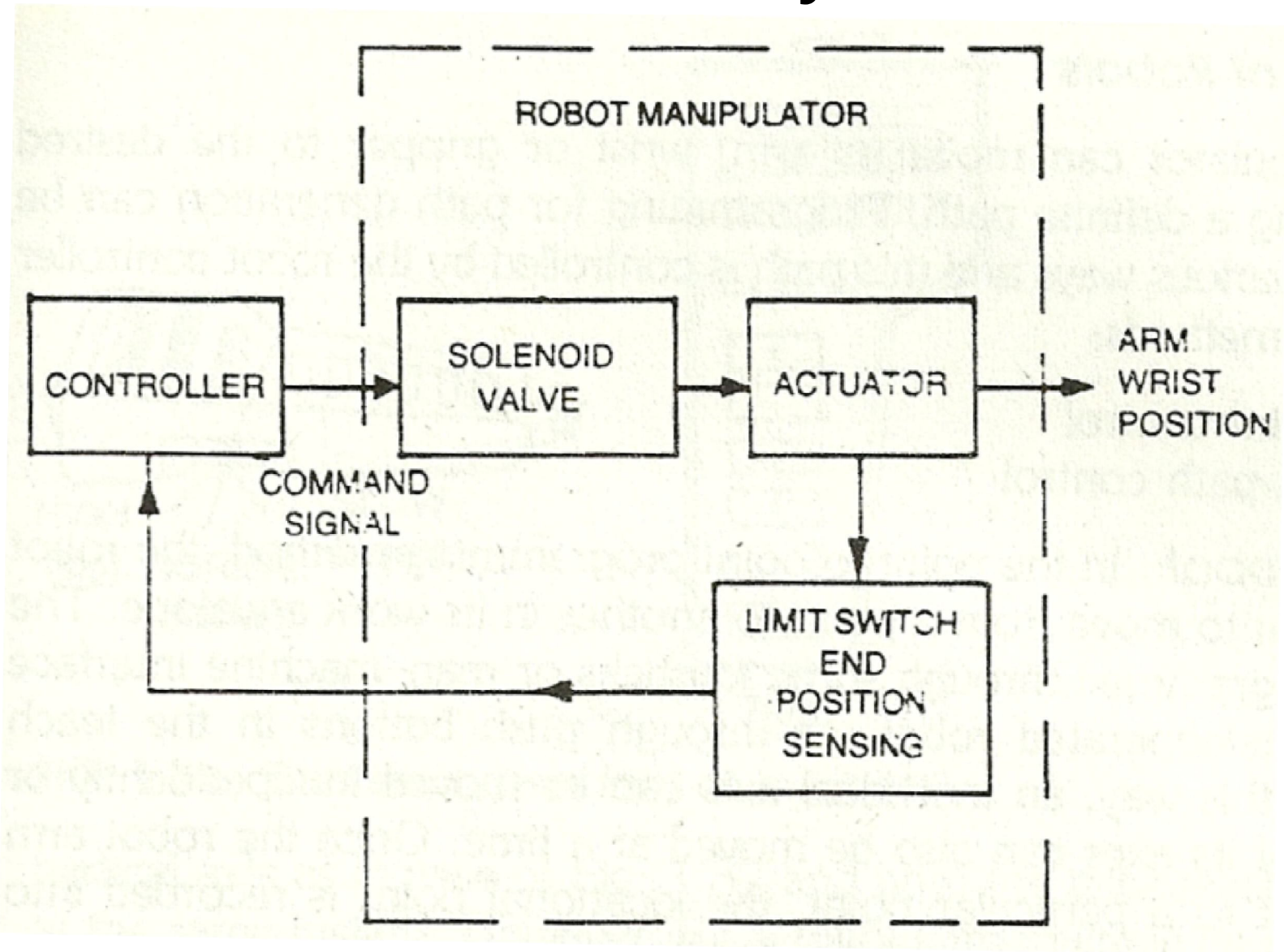
Robot Controllers

- Manipulator moves its arms, wrist and end-effector after it receives signals from the controller.
- Controller is the brain of a robot.
- Control system can be of two types
  - Open loop systems
  - Closed loop systems
- Control may be grouped as
  - Non-servo system
  - Servo systems

Non-servo system

- Drive signals are sent to the actuator via a solenoid valve.
- As soon as the actuator drives the end-effector to the desired position, a signal thru limit switch is sent back indicating that the arm has reached the position.
- It is also called as Bang-Bang controlled system.

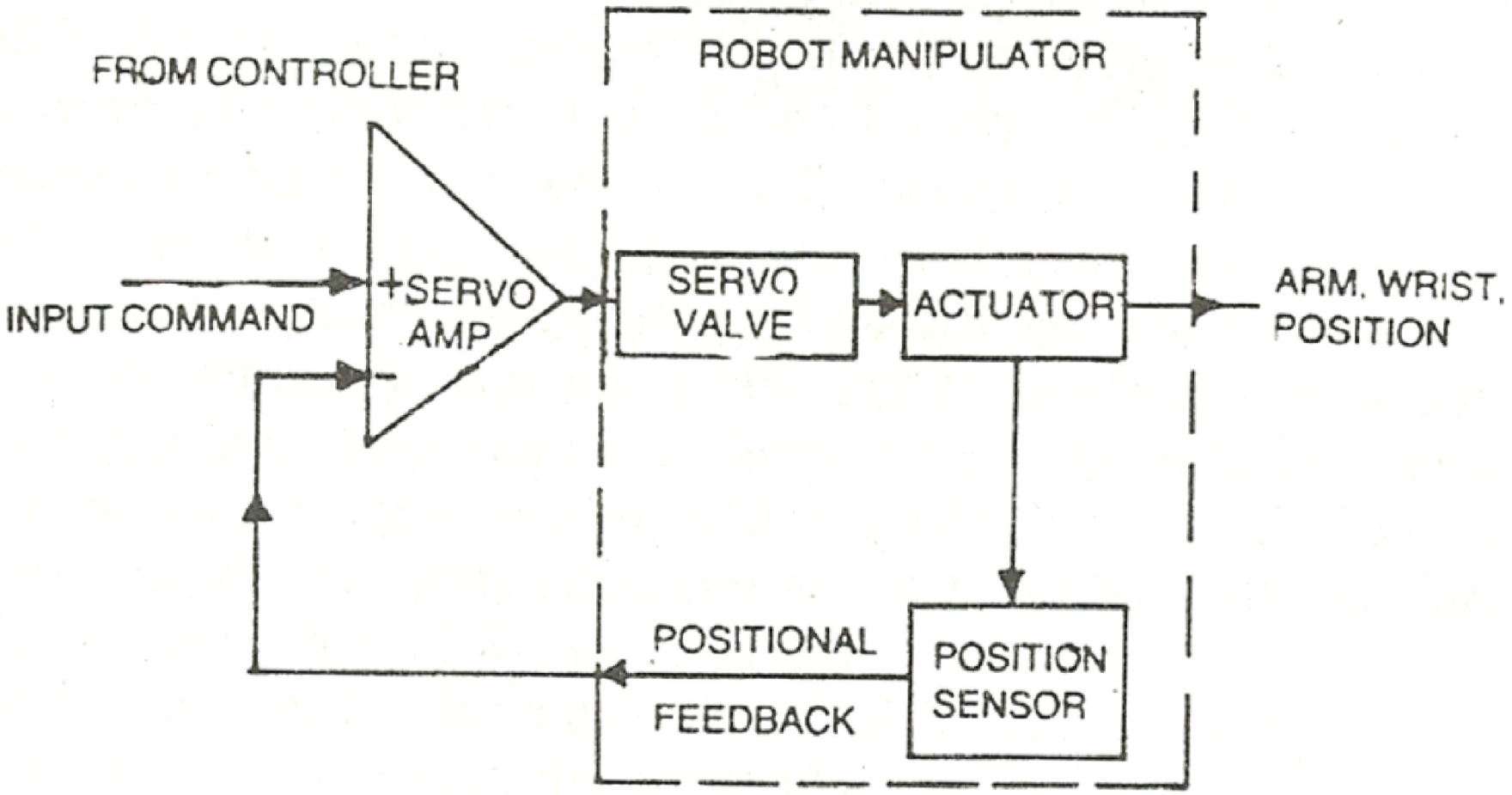
Non-servo system



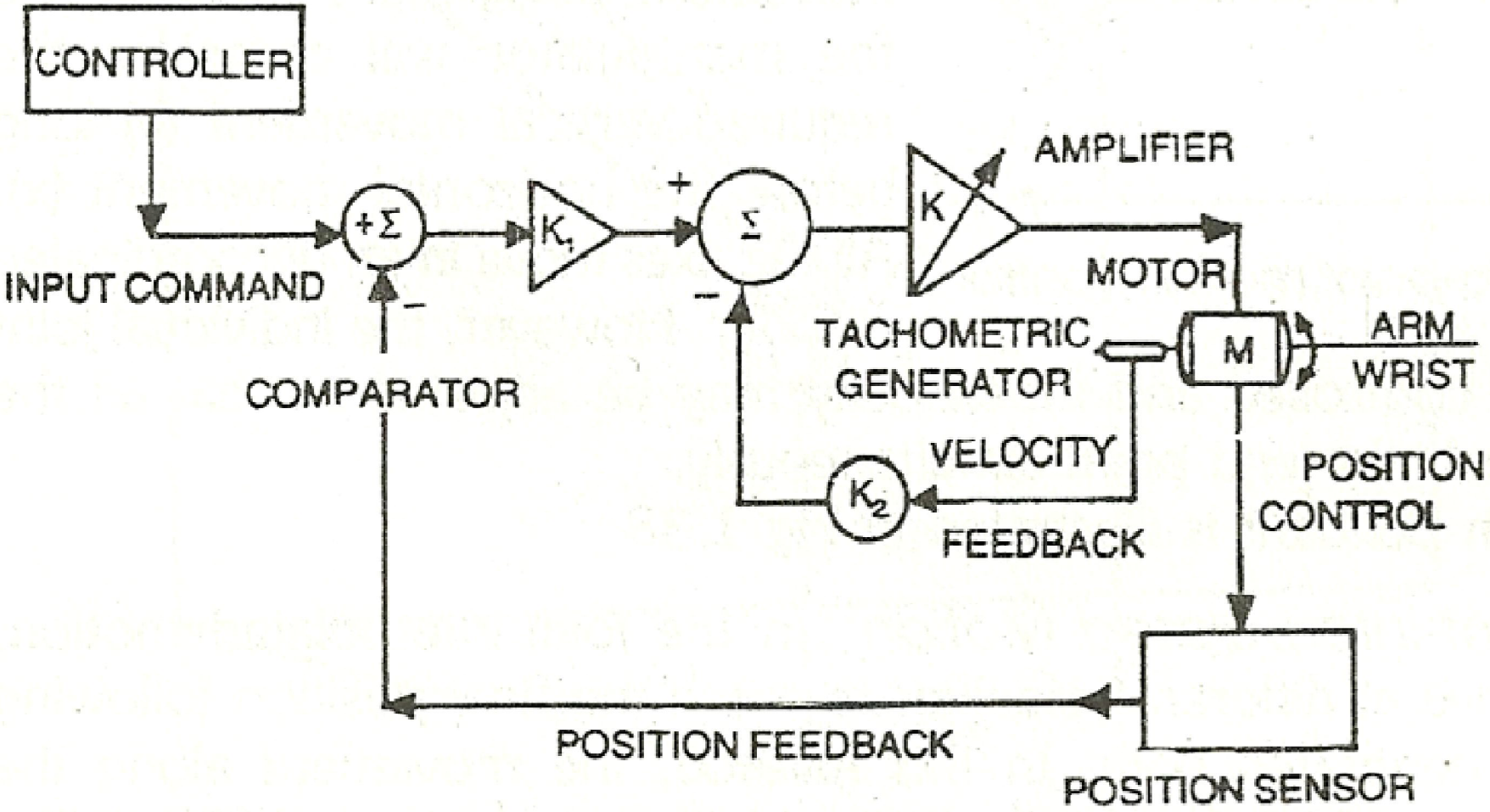
Servo control system

- Drive signals are sent to the actuator via servo valve and the actuator moves its arm, wrist and end-effector to a current position.
- Continuous measurement is taken to estimate the error between the current and desired position.
- Error signal is sent back to monitor the position.
- As soon as error becomes zero, the desired location is achieved and the actuator stops moving.

Servo control system



Servo control loop with positional and velocity feedback



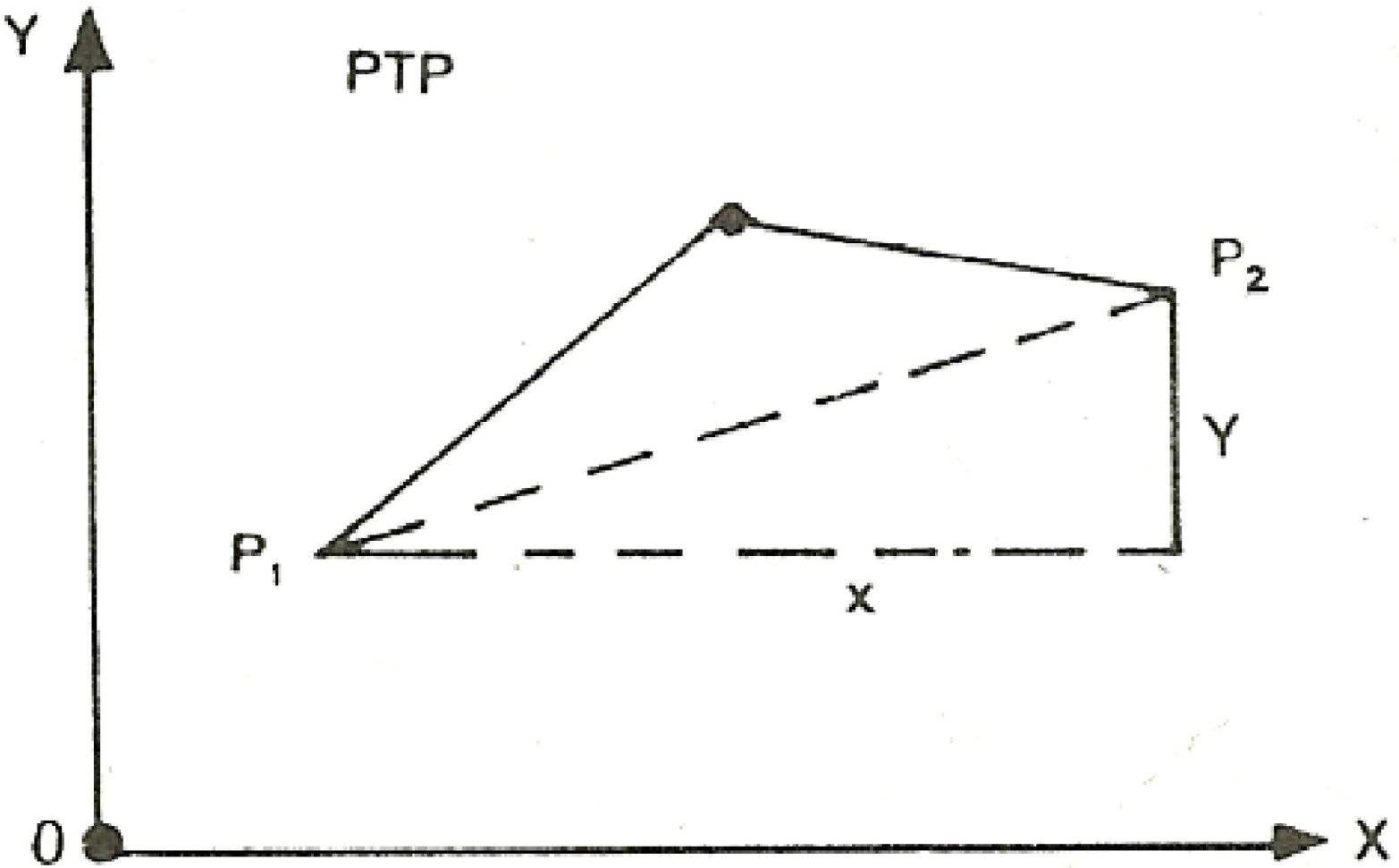
Motion control of robots

- The path of robot arm is controlled by two methods.
- Point-point control
- Continuous path control

Point-point control

- Two modes
  - Teaching mode
  - Auto mode
- Programming is done through joysticks or human-machine interface (HMI) or push buttons.
- Teaching mode
  - Robot arm is made to move from one point to a particular point and the location of it is recorded.
  - From the first point the arm moves to second point and the location of it is also recorded.
- Auto mode
  - All the points recorded are played back.
  - Now the robot arm move from point to point and reach the desired location.

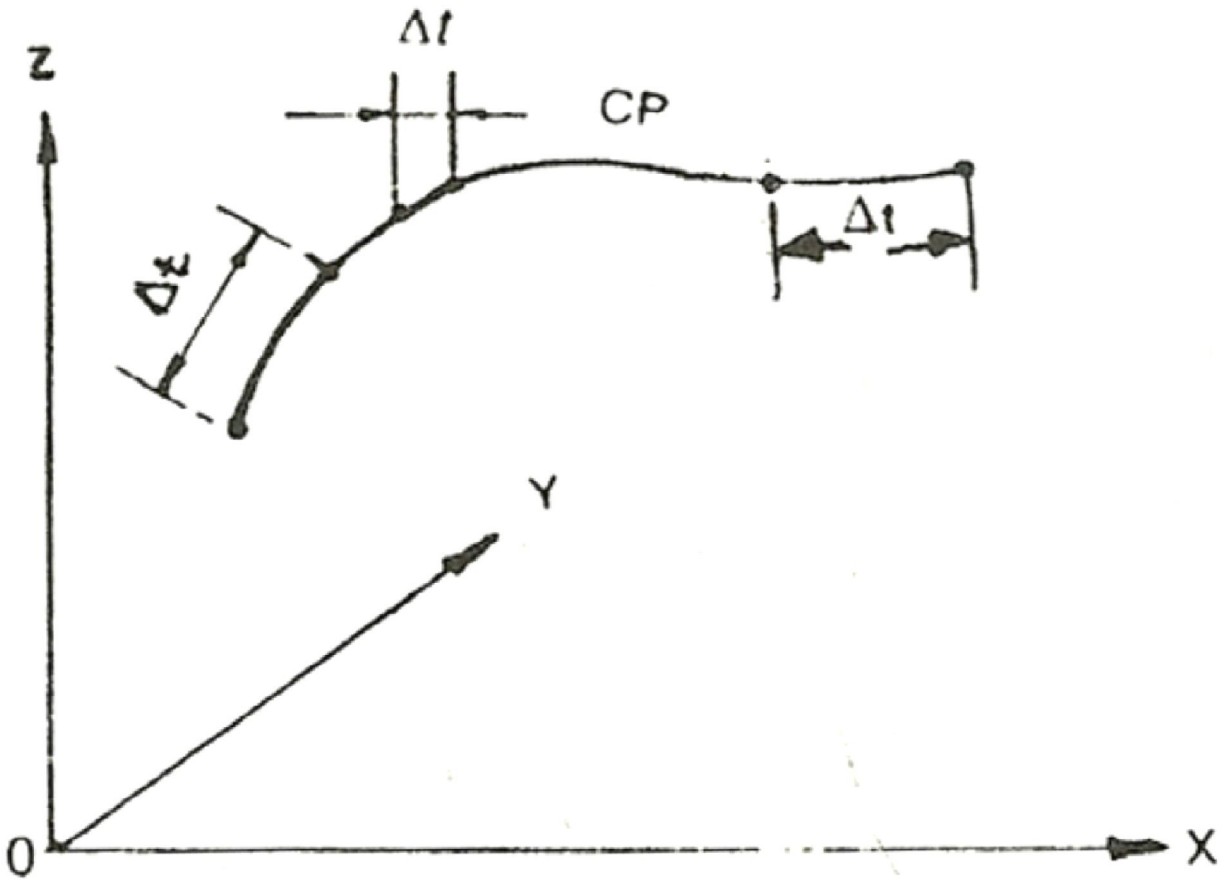
Point-point control



Continuous path control

- Point to point motion described very closely or continuously on a time base.
- Several hundreds of individual points can be recorded in the controller's memory.
- Path of the robot arm may be any curve or an arc of a circle.
- When the recorded points are played back, the robot moves continuously through the stored points.

Continuous path control



Robot controllers

- Types of controller
  - Drum controller
  - Air logic controller
  - Programmable controller
  - Microprocessor based controller
  - Mini-computer based controller

Robot controllers

- Drum controllers
  - As the drum rotates, it actuates those switches which are wired to hydraulic or pneumatic valves.
- Air logic controllers
  - Employs number of pneumatic valves which in turn control the opening and closing of main valves.
- Programmable controller
  - Sequential order in which the switch are to be operated is kept in memory.

Robot controllers

- Microprocessor based Controller
  - Microprocessors are employed to program the sequential tasks and store them in its memory.
  - It is versatile, programmable and has good memory.
- Mini computer based controller
- Uses computer as the controller
- Used for more complicated systems

Programming methods

- Methods
  - Lead through programming
  - Teach pendent programming
  - Textual programming

Robot sensors

- Need
  - To receive information from the environment
  - To sense and measure the geometric parameters of the object
  - To determine the power required for the end-effectors.
- The sensor signal has to be
  - Transmitted
  - Processed
  - Interpreted

Robot sensors

- Types
  - Tactile sensors
    - Contact sensors
    - Force sensors
    - Torque sensors
    - Touch sensors
    - Position sensors
- Non-tactile sensors
  - Electro-optical sensors
  - Proximity sensors
  - Range imaging sensors

Robot sensors