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WEEK 1: ROBOTICS

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Topic 1: Introduction to Robots and Robotics

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Introduction to Robots and Robotics

A Few Questions

- What is a robot?
- What is robotics?
- Why do we study robotics?
- How can we teach a robot to perform a particular task?
- What are possible applications of robots?
- Can a human being be replaced by a robot?,

and so on.

Definitions

- The term: robot has come from the Czech word: robota, which means forced or slave laborer
- In 1921, Karel Capek, a Czech playwright, used the term: robot first in his drama named Rossum's Universal Robots (R.U.R)
- According to Karel Capek, a robot is a machine look-wise similar to a human being

Robot has been defined in various ways:

1) According to **Oxford English Dictionary**
   A machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer

2) According to **International Organization for Standardization (ISO):** An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications

3) According to Robot Institute of America (RIA)

It is a reprogrammable multi-functional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks

Note: A CNC machine is not a robot

Robotics

- It is a science, which deals with the issues related to design, manufacturing, usages of robots
- In 1942, the term: robotics was introduced by Isaac Asimov in his story named Runaround
- In robotics, we use the fundamentals of Physics, Mathematics, Mechanical Engg., Electronics Engg., Electrical Engg., Computer Sciences, and others

3 Hs in Robotics

3 Hs of human beings are copied into Robotics, such as

- Hand
- Head
- Heart

Motivation

To cope with increasing demands of a dynamic and competitive market, modern manufacturing methods should satisfy the following requirements:

- **Reduced production cost**
- **Increased productivity**
- **Improved product quality**

Notes:

(1) Automation can help to fulfil the above requirements

(2) Automation: Either Hard or flexible automation

(3) Robotics is an example of flexible automation

A Brief History of Robotics

Year	Events and Development
1954	First patent on manipulator by George Devol, the father of robot
1956	Joseph Engelberger started the first robotics company: Unimation
1962	General Motors used the manipulator: Unimate in die-casting application

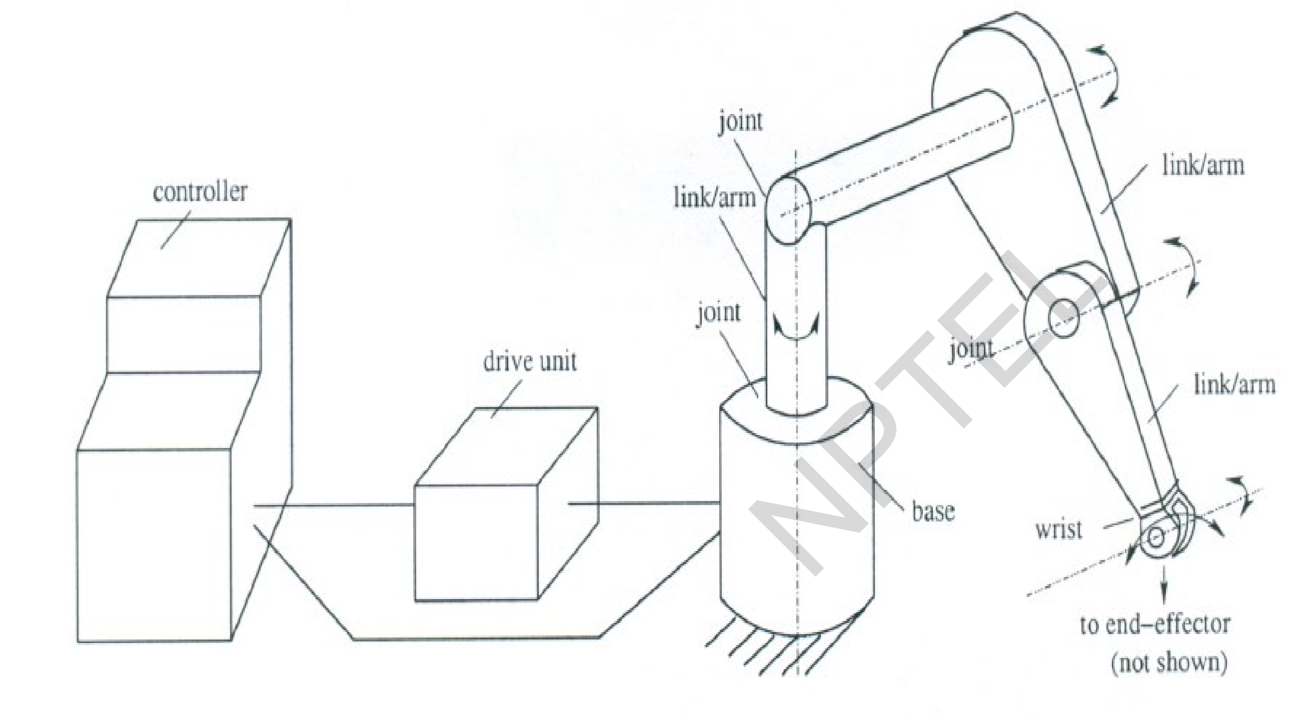
Year	Events and Development
1967	General Electric Corporation made a 4-legged vehicle
1969	❖ SAM was built by the NASA, USA ❖ Shakey, an intelligent mobile robot, was built by Stanford Research Institute (SRI)
1970	❖ Victor Scheinman demonstrated a manipulator known as Stanford Arm ❖ Lunokhod I was built and sent to the moon by USSR ❖ ODEX 1 was built by Odetics

Year	Events and Development
1973	Richard Hohn of Cincinnati Milacron Corporation manufactured T^3 (The Tomorrow Tool) robot
1975	Raibart at CMU, USA, built a one-legged hopping machine, the first dynamically stable machine
1978	Unimation developed PUMA (Programmable Universal Machine for Assembly)

Year	Events and Development
1983	Odetics introduced a unique experimental six-legged device
1986	ASV (Adaptive Suspension Vehicle) was developed at Ohio State University, USA
1997	Pathfinder and Sojourner was sent to the Mars by the NASA, USA

Year	Events and Development
2000	Asimo humanoid robot was developed by Honda
2004	The surface of the Mars was explored by Spirit and Opportunity
2012	Curiosity was sent to the Mars by the NASA, USA
2015	Sophia (humanoid) was built by Hanson Robotics, Hong Kong

A Robotic System



Various Components

1. Base
2. Links and Joints
3. End-effector / gripper
4. Wrist
5. Drive / Actuator
6. Controller
7. Sensors

Interdisciplinary Areas in Robotics

Mechanical Engineering

- **Kinematics:** Motion of robot arm without considering the forces and /or moments
- **Dynamics:** Study of the forces and/or moments
- **Sensing:** Collecting information of the environment

Interdisciplinary Areas in Robotics (Cont.)

Computer Science

- Motion Planning: Planning the course of action
- Artificial Intelligence: To design and develop suitable brain for the robots

Electrical and Electronics Engg.

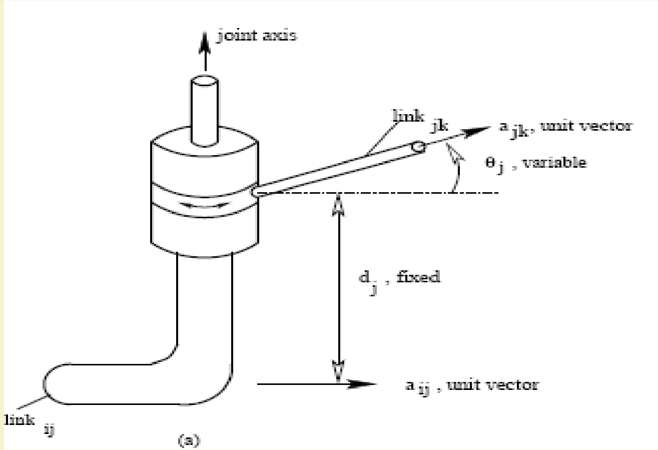
- Control schemes and hardware implementations

General Sciences

- Physics
- Mathematics

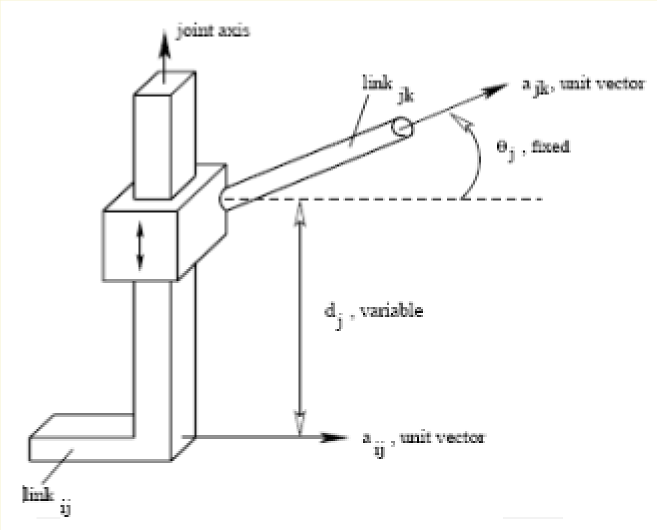
Connectivity / Degrees of Freedom of a Joint

It indicates the number of rigid (bodies) that can be connected to a fixed rigid body through the said joint



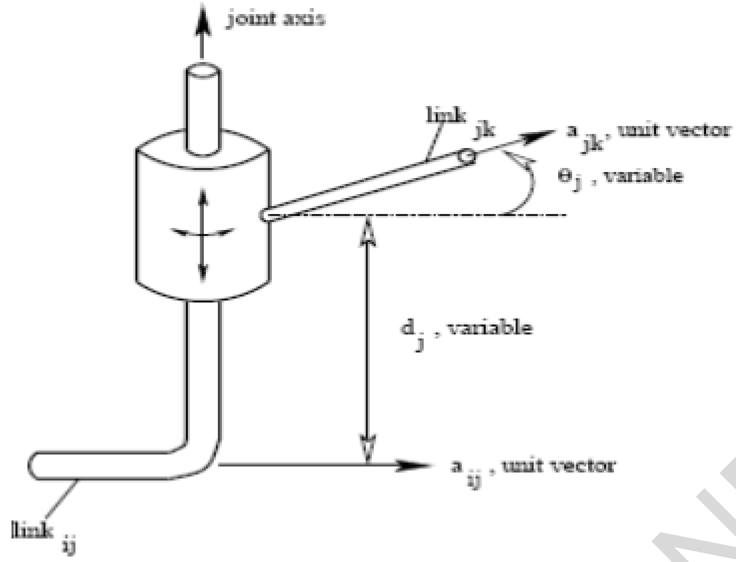
Joints with One dof

Revolute Joint (R)



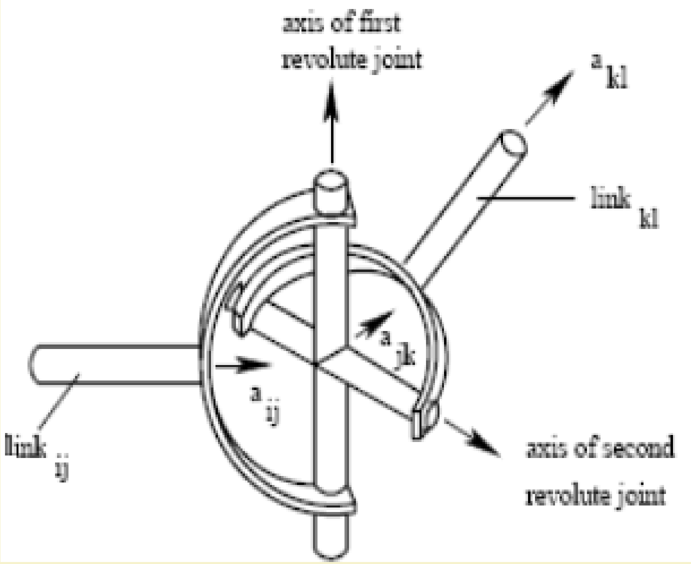
Joints with One dof

Prismatic Joint (P)



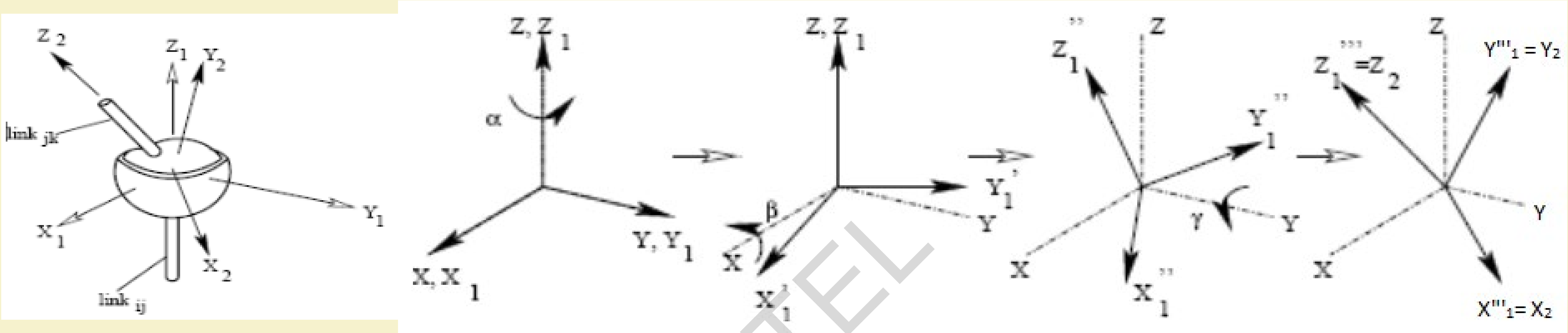
Joints with two dof

Cylindrical Joint (C)



Joints with two dof

Hooke Joint or Universal Joint (U)

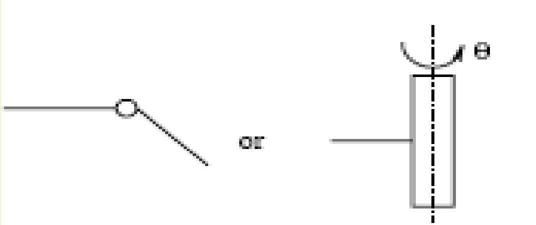


Joints with three dof

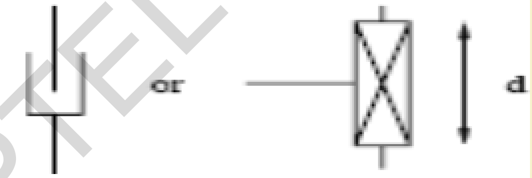
Ball and Socket Joint / Spherical Joint (S')

Representation of the Joints

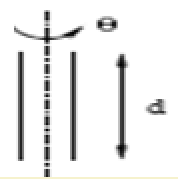
Revolute joint (R)



Prismatic joint (P)

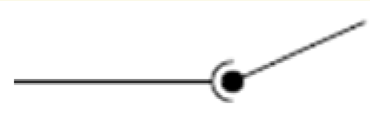


Cylindrical joint (C)

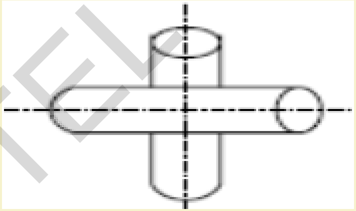


Representation of the Joints

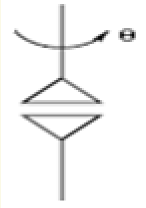
Spherical joint (S')



Hooke joint (U)



Twisting joint (T)



Kinematic Diagram

Degrees of Freedom of a System

It is defined as the minimum number of independent parameters / variables / coordinates needed to describe a system completely

Notes

- A point in 2-D: 2 dof; in 3-D space: 3 dof
- A rigid body in 3-D: 6 dof
- Spatial Manipulator: 6 dof
- Planar Manipulator: 3 dof

Redundant Manipulator

Either a Spatial Manipulator with more than 6 dof or a Planar Manipulator with more than 3 dof

Under-actuated Manipulator

Either a Spatial Manipulator with less than 6 dof or a Planar Manipulator with less than 3 dof

Mobility/dof of Spatial Manipulator

Let us consider a manipulator with n rigid moving links and m joints

C_i: Connectivity of i-th joint; i = 1, 2, 3,........., m

No. of constraints put by i-th joint $= (6 - C_i)$

Total no. of constraints $= \sum_{i=1}^{m}(6 - C_i)$

Mobility of the manipulator $\mathrm{M} = 6n - \sum_{i=1}^{m}(6 - C_i)$

It is known as Grubler's criterion.

Mobility/dof of Planar Manipulator

Let us consider a manipulator with n rigid moving links and m joints

C_i: Connectivity of i-th joint; i = 1, 2, 3,………, m

No. of constraints put by i-th joint $= (3 - C_i)$

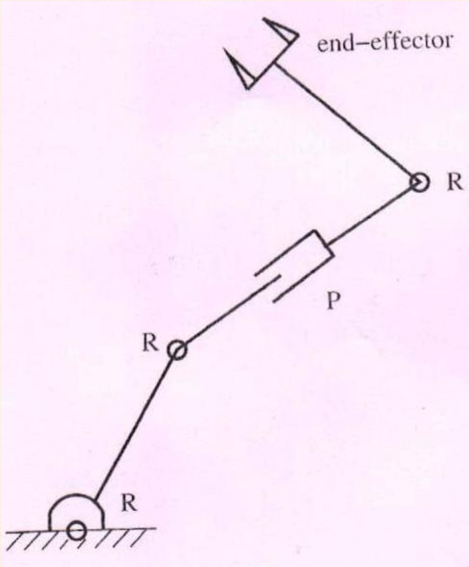
Total no. of constraints $= \sum_{i=1}^{m}(3 - C_i)$

Mobility of the manipulator $\mathrm{M} = 3n - \sum_{i=1}^{m}(3 - C_i)$

It is known as Grubler's criterion.

Numerical Example

Serial planar manipulator



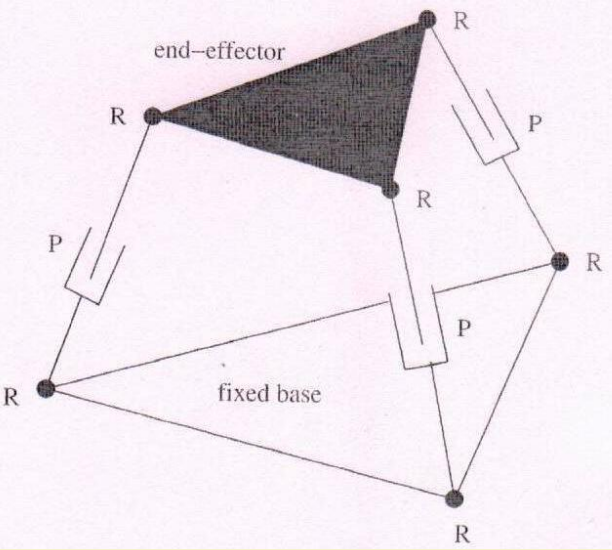
$$n = 4, \quad m = 4$$

$$C_1 = C_2 = C_3 = C_4 = 1$$

Mobility/dof:

$$M = 3n - \sum_{i=1}^{m} (3 - C_i) = 3 \times 4 - 8 = 4$$

Parallel planar manipulator



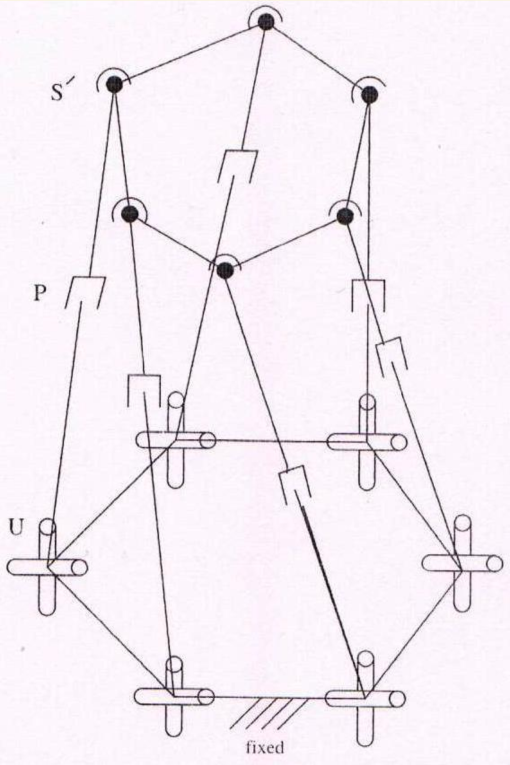
$$n = 7, \quad m = 9$$

$$C_i = 1, \qquad where\ i = 1, \ldots, 9$$

Mobility/dof:

$$M = 3n - \sum_{i=1}^{m} (3 - C_i) = 3 \times 7 - 18 = 3$$

Parallel spatial manipulator



$$n = 13,\ m = 18$$

Mobility/dof:

$$M = 6n - \sum_{i=1}^{m}(6 - C_i) = 6 \times 13 - 72 = 6$$

Classification of Robots

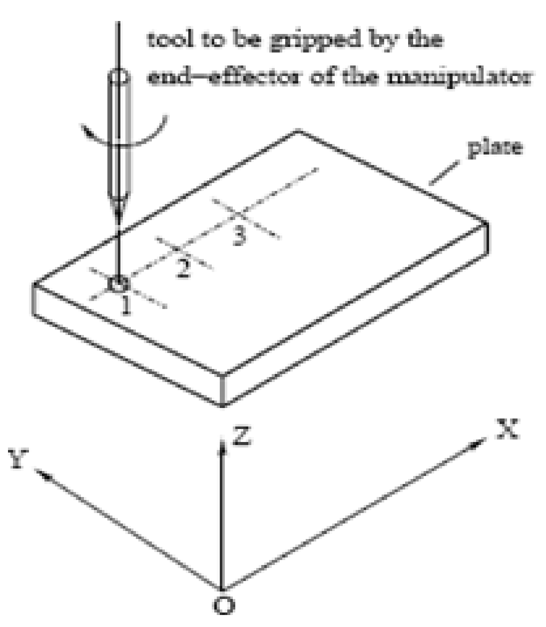
❖ Based on the Type of Tasks Performed

1. Point-to-Point Robots

Examples:

Unimate 2000

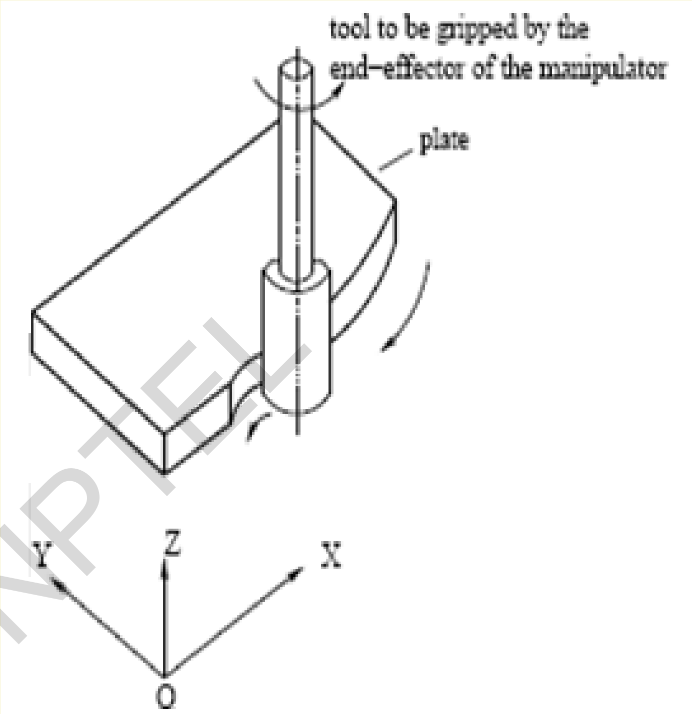
T^3



2. Continuous Path Robots

Examples:

PUMA
CRS



❖ Based on the Type of Controllers

1. Non-Servo-Controlled Robots

- Open-loop control system

Examples: Seiko PN-100

- Less accurate and less expensive

2. Servo-Controlled Robots

- Closed-loop control system

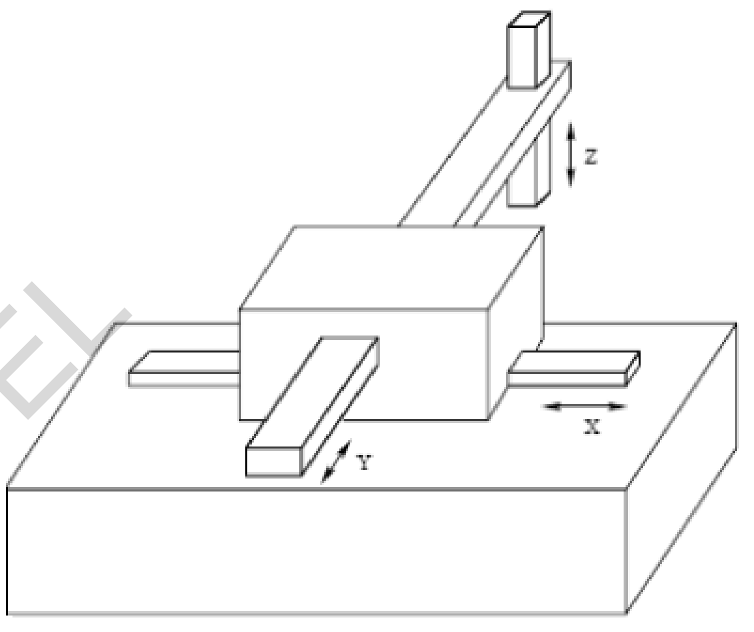
Examples: Unimate 2000, PUMA, T^3

- More accurate and more expensive

❖ Based on Configuration (coordinate system) of the Robot

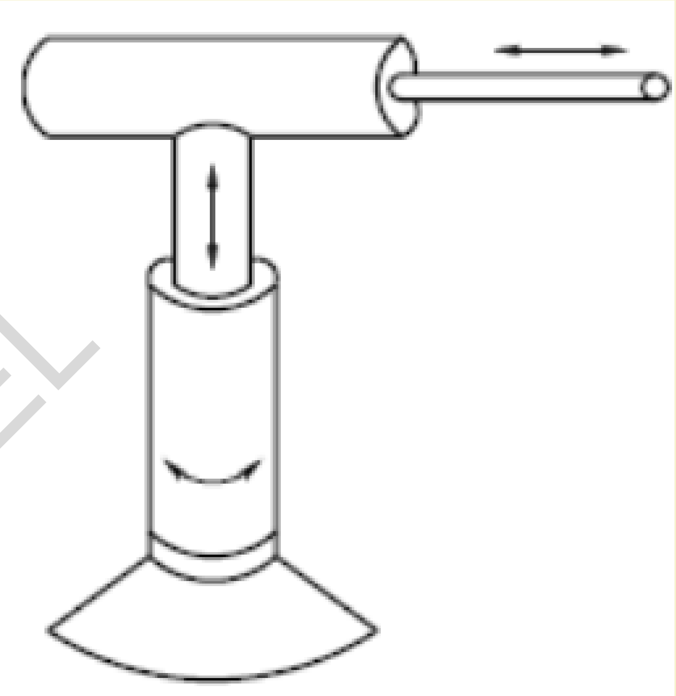
1. Cartesian Coordinate Robots

- Linear movement along three different axes
- Have either sliding or prismatic joints, that is, SSS or PPP
- Rigid and accurate
- Suitable for pick and place type of operations
- Examples: IBM's RS-1, Sigma robot



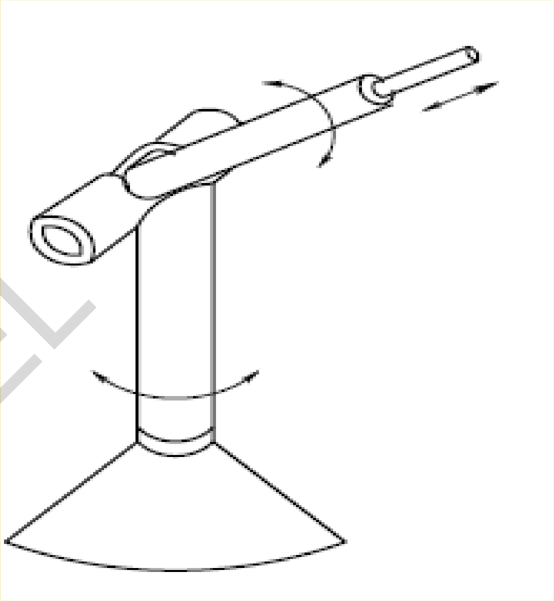
2. Cylindrical Coordinate Robots

- Two linear and one rotary movements
- Represented as TPP, TSS
- Used to handle parts/ objects in manufacturing
- Cannot reach the objects lying on the floor
- Poor dynamic performance
- Examples: Versatran 600



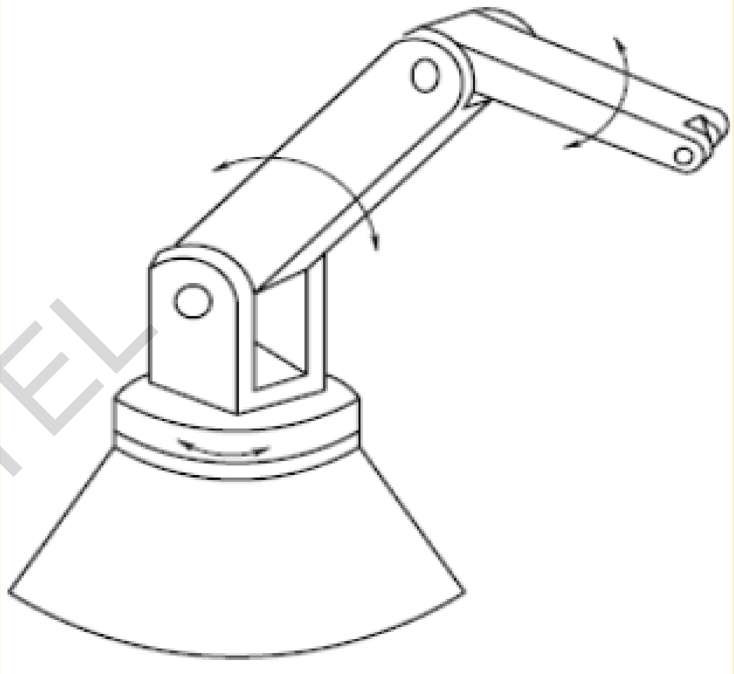
3. Spherical Coordinate or Polar Coordinate Robots

- One linear and two rotary movement
- Represented as TRP, TRS
- Suitable for handling parts/objects in manufacturing
- Can pick up objects lying on the floor
- Poor dynamic performance
- Examples: Unimate 2000B



4. Revolute Coordinate or Articulated Coordinate Robots

- Rotary movement about three independent axes
- Represented as TRR
- Suitable for handling parts/components in manufacturing system
- Rigidity and accuracy may not be good enough
- Examples: T3, PUMA



- **Based on Mobility Levels**

1. **Robots with fixed base (also known as manipulators)**

Manipulators

Serial
PUMA, CRS

Parallel
Stewart platform

- **Based on Mobility Levels (contd.)**

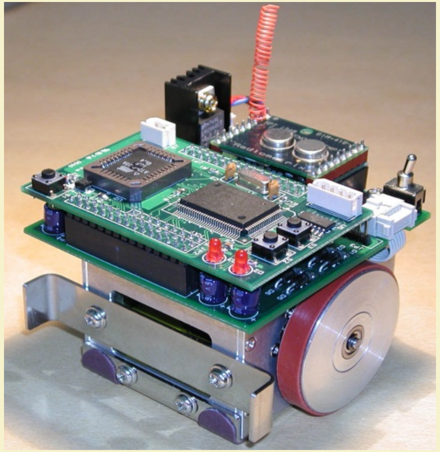
2. Mobile robots

Mobile robots

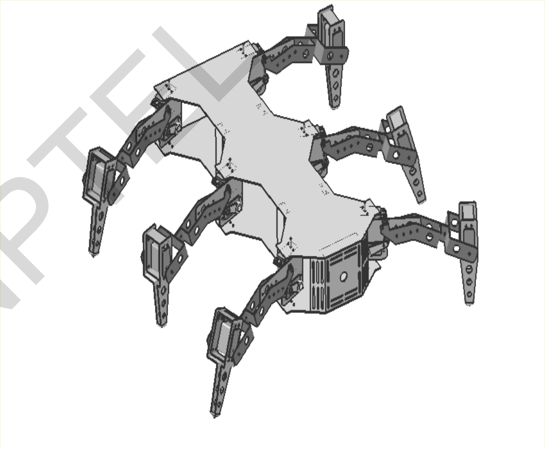
- **Wheeled robots**
- **Tracked robots**
- **Multi-legged robots**

- **Based on Mobility Levels (contd.)**

2. Mobile robots



Wheeled Robot



Six-legged Robot

Workspace of Manipulators

It is the volume of space that the end-effector of a manipulator can reach

Workspace

Dextrous

Reachable

Dextrous Workspace

It is the volume of space, which the robot's end-effector can reach with various orientations

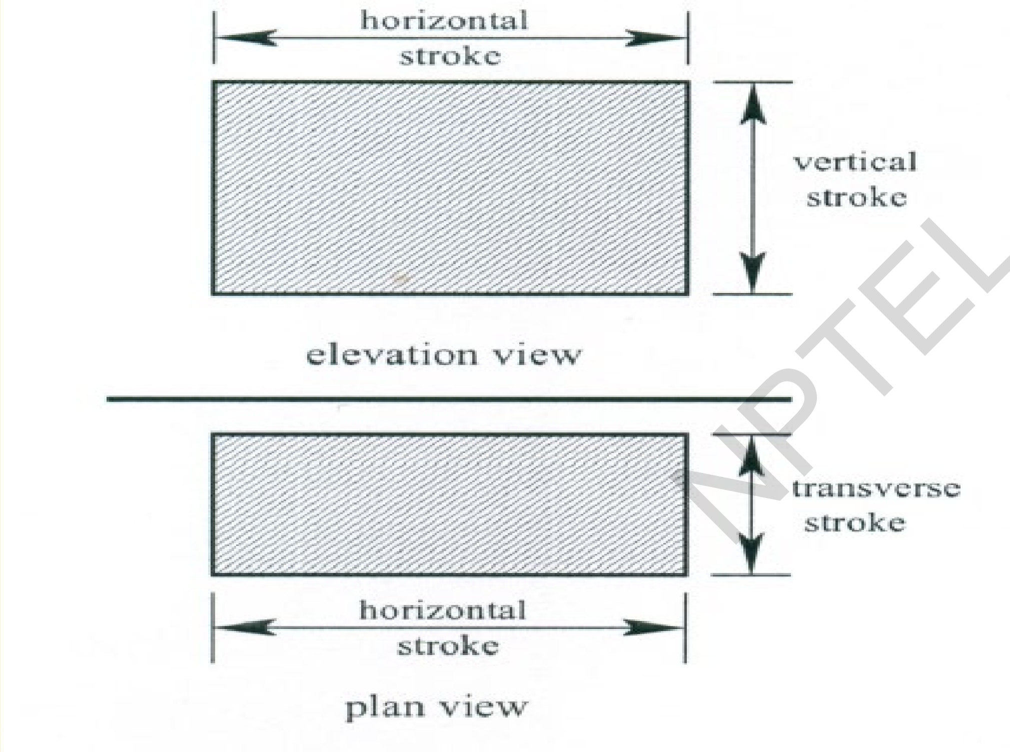
Reachable Workspace

It is the volume of space that the end-effector can reach with one orientation

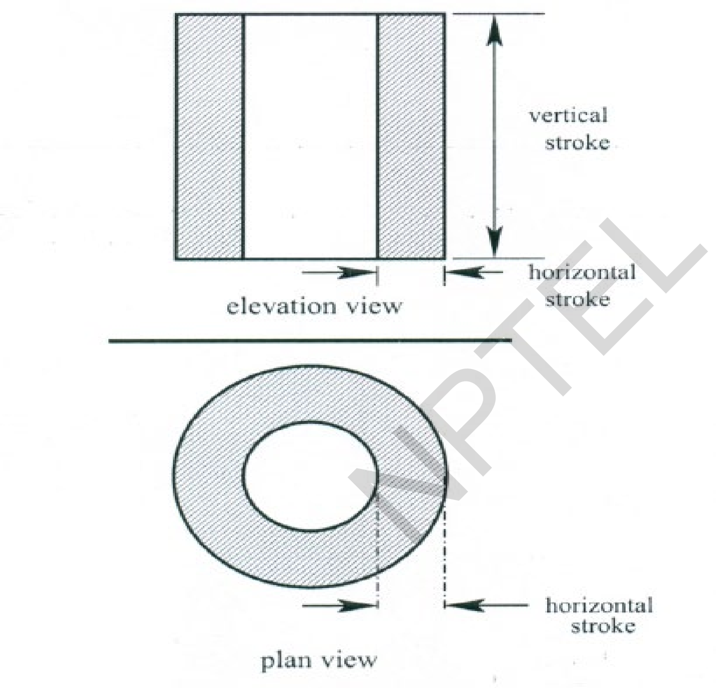
Note

Dextrous workspace is a subset of the reachable workspace

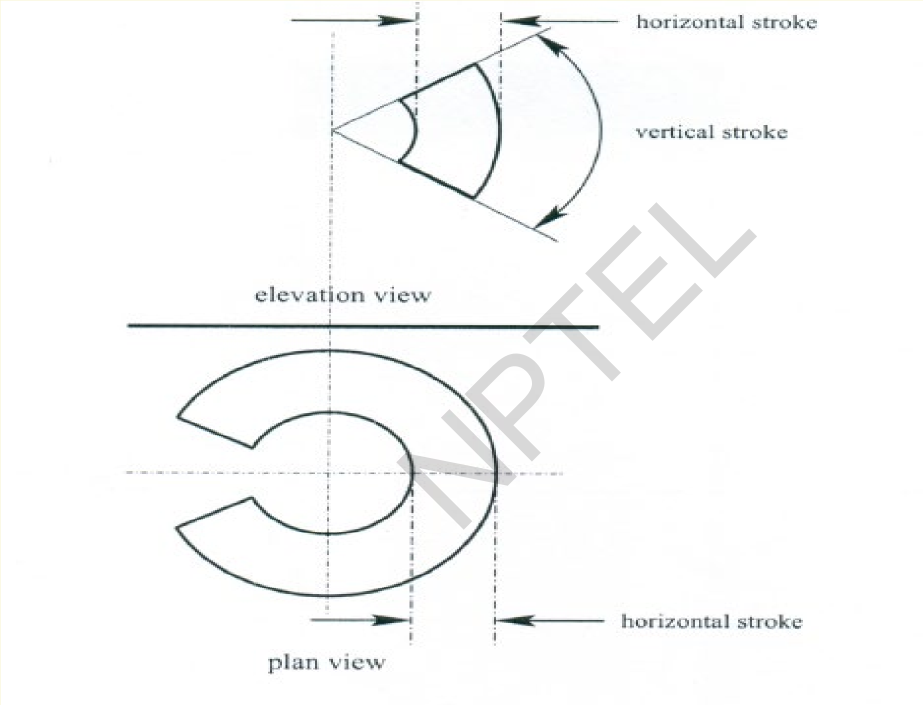
Workspace of Cartesian Coordinate Robot



Workspace of Cylindrical Coordinate Robot



Workspace of Spherical Coordinate Robot



Workspace of Revolute Coordinate Robot