Robotics and Automation
18EI642

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What is a Robot?

Shape & Size

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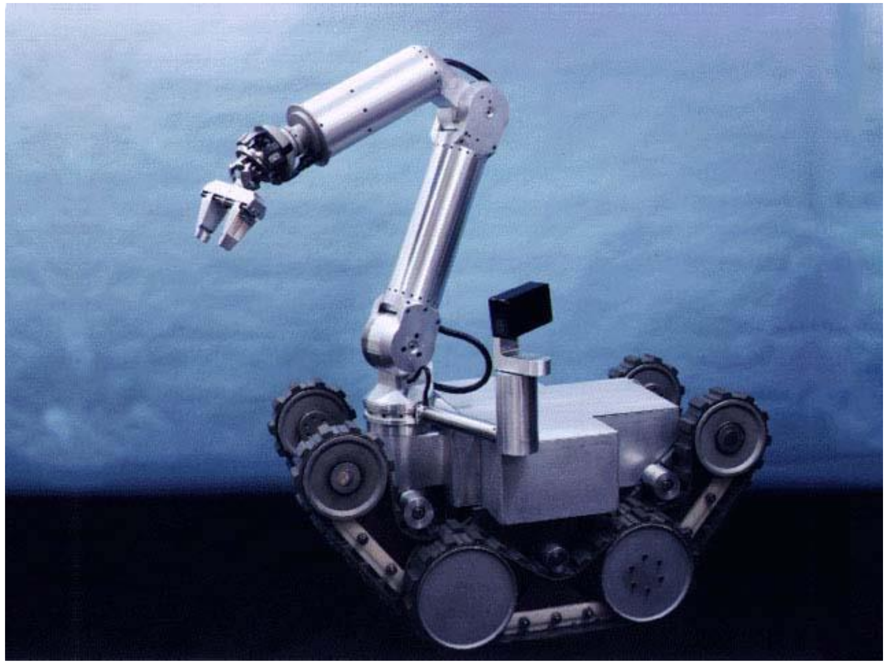

Robot Function

- Generate specific motion of joints
- Integrate tooling and sensors

Robot Processes

- Path following
- Repetitive configuration moves
- Tele robotics

Definition

Robotics Institute of America

"A robot is re-programmable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

A Robot is:

An electromechanical device that is:

Reprogrammable

Multifunctional

Sensible for environment

Key Terms

- **Repeatability -** Variability in returning to the same previously taught position/configuration
- **Accuracy -** Variability in moving to a target in space that has not been previously taught
- **Tool speed -** Linear speed capability when tool moving along a curvilinear path

Contd..

- **Screw speed** - Rotational speed when tool is being rotated about an axis in space
- **Joint interpolated motion** - Motion where joint taking longest time to make the joint change governs the motion and the other joints are slowed in proportion so that all joint accomplish their joint changes simultaneously with the slowest joint

Contd..

- TCF - Tool or terminal control frame
- TCP - Tool /terminal control point
- Joint limits - Either the software or physical hardware limits which constrain the operating range of a joint on a robot. The software limits have a smaller range than the hardware limits.

Contd..

Continuous path motion - Characterized by blending of motion between configurations or targets, usually with the loss of path accuracy at the target transitions, as the robot moves between configurations/targets.

Interpolation (kinematic) capabilities - Robot usually capable of both forward and inverse kinematics. Both combine to give the robot the capability to move in joint space and in Cartesian space. We typically refer to the moves as joint, linear, or circular interpolation.

Contd..

Forward kinematics - Specifying the joint values to accomplish a robot move to a new configuration in space. These may not be simple as it seems because secondary joints such as four-bar linkages, ball screws, etc. may be required to accomplish this motion.

Contd..

Inverse kinematics - Solving a mathematical model of the robot kinematics to determine the necessary joint values to move the tool to a desired target (frame) in space. This is accomplished by frame representation whereby a triad (xyz axes) is attached to the tool on the robot and a target frame is attached to the part or operating point in the workcell. The inverse kinematics determine the joint values required to align the tool triad with the target triad.

Vendors

Fanuc (Japan)	Kuka (Germany)
ABB (Sweden, US)	Adept (US)
Panasonic (Japan)	Seiko (Japan)
Sankyo (Japan)	Motoman (Japan)
Mitsubishi (Japan)	

Classification of Robot

According to the Japanese Industrial Robot Association(JIRA)

Class 1: Manual Handling Device: A device with multiple degrees of freedom that is activated by an operator

Class 2: Fixed sequence Robot: A device that performance the successive stages of a task according to a predetermined unchanging method and is hard to modify

Class 3: Variable-Sequence Robot : A device that performs the successive stages of a task according to a predetermined method easy to modify

Contd..

Class 4: Playback Robot : A human operator performs the task manually by leading the Robot

Class 5: Numerical Control Robot : The operator supplies the movement program rather than teaching it the task manually.

Class 6: Intelligent Robot : A robot with the means to understand its environment and the ability to successfully complete a task despite changes to the environment.

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Robotics Institute of America (RIA)

Considers class 3-6 as robots

Contd..

Association Francaise de Robotique(AFR)

Type A: handling devices with manual control to telerobotics

Type B: Automatic handling devices with predefined cycles

Type C: Programmable servo controlled robots with continuous or point to point trajectories

Type D: same as type C with capability to acquire information from its environment

History of Robots

1922 Czech author Karel Capek wrote a story called Rossum's Universal Robots and introduced the word "Rabota"(meaning worker)

1952 The first NC machine was build at MIT

1954 George Devol developed the first programmable Robot.

1955 Denavit and Hartenberg developed the homogenous transformation matrices

1956 George Devol developed the magnetic controller a playback device Eckert and Maucley build the ENIAC computer at the university of Pennsylvania

Contd..

1961 US patent 2,988,237 was issued to George Devol for programmed Article transfer a basis for Unimate robots

1962 Unimation was formed, first industrial Robots appeared.

1967 Unimate introduced the MarkII robot. The foirst robot was imported to Japan for painy spraying applications

1968 an intelligent robot called is Shakey was build at Stanford Research institute(SRI)

1972 IBM worked on a rectangular coordinate robot for internal use. It eventually developed the IBM 7565 for sale

Contd..

1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.

1978 the first PUMA robot was shipped to GM by Unimation

1982 GM and Fanuc of Japan signed an agreement to build GM and Funuc robots

1983 Robotics became a very popular subject, both industry as well as academia many programs in the nation started teaching courses in robotics

1990 Cincinnati Milacron was acquired by ABB

Advantages

Greater flexibility, re-programmability, kinematics dexterity

Greater response time to inputs than humans

Improved product quality

Maximize capital intensive equipment in multiple work shifts

Accident reduction

Reduction of hazardous exposure for human workers

Automation less susceptible to work stoppages

Advantages

- Increase productivity, safety, efficiency, quality and consistency of products
- Can work in Hazardous Environments without the need for life support, comfort or concern about safety
- Need no environmental comfort such as lighting, air conditioning, ventilation and noise protection
- Can do multiple task simultaneously

Contd..

- Can work continuously without experiencing fatigue, boredom, do not get mad, no hangover, no medical insurance
- Have repeatable precision at all times
- Can be much more accurate than human
- Robots and their accessories can have beyond that of humans

Disadvantages

- Replacement of human labor
- Greater unemployment
- Significant retraining costs for both unemployed and users of new technology
- Advertised technology does not always disclose some of the hidden disadvantages
- Hidden costs because of the associated technology that must be purchased and integrated into a functioning cell. Typically, a functioning cell will cost 3-10 times the cost of the robot.

Components

Manipulator / Rover : This is the main body of the Robot and consists of links, joints and structural elements of the Robot.

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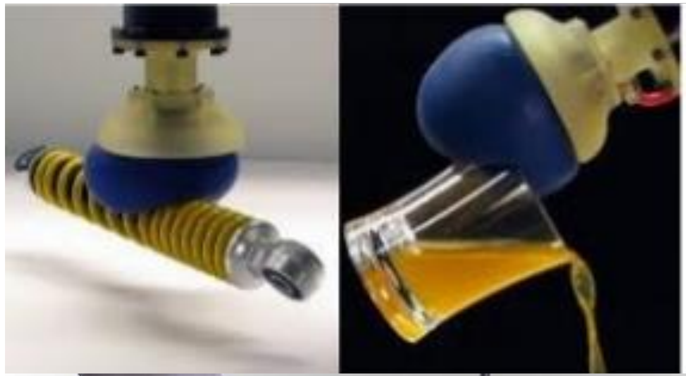

End Effector : This is the part that generally handles objects, makes connection to other machines, or performs the required tasks.

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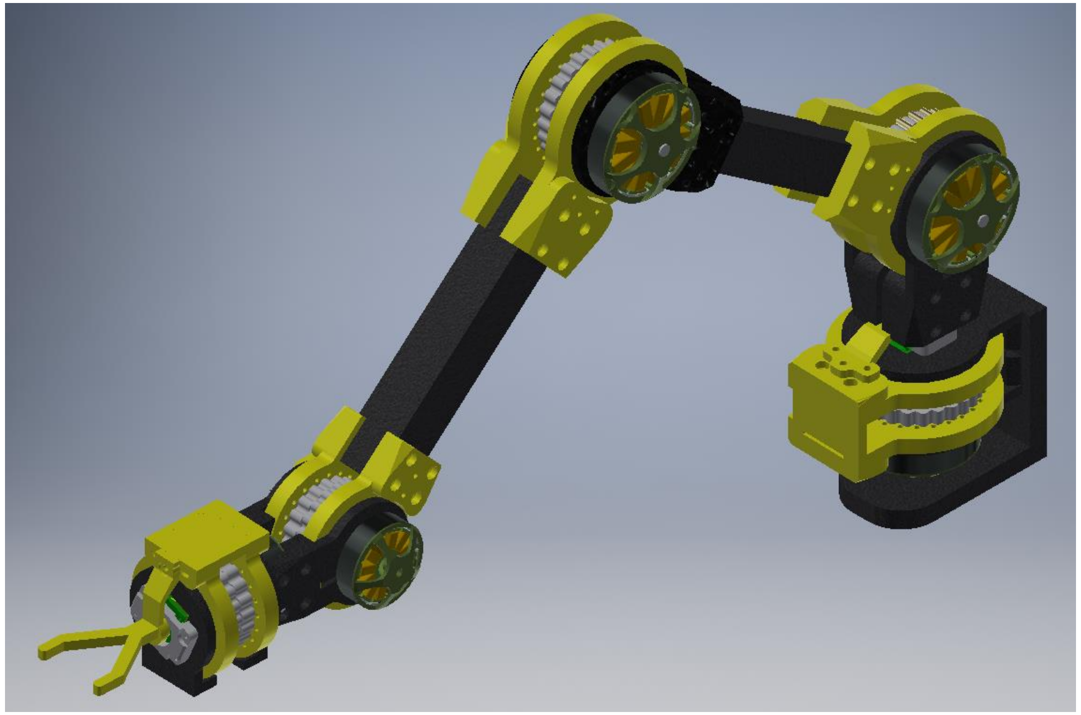
Actuators : Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.



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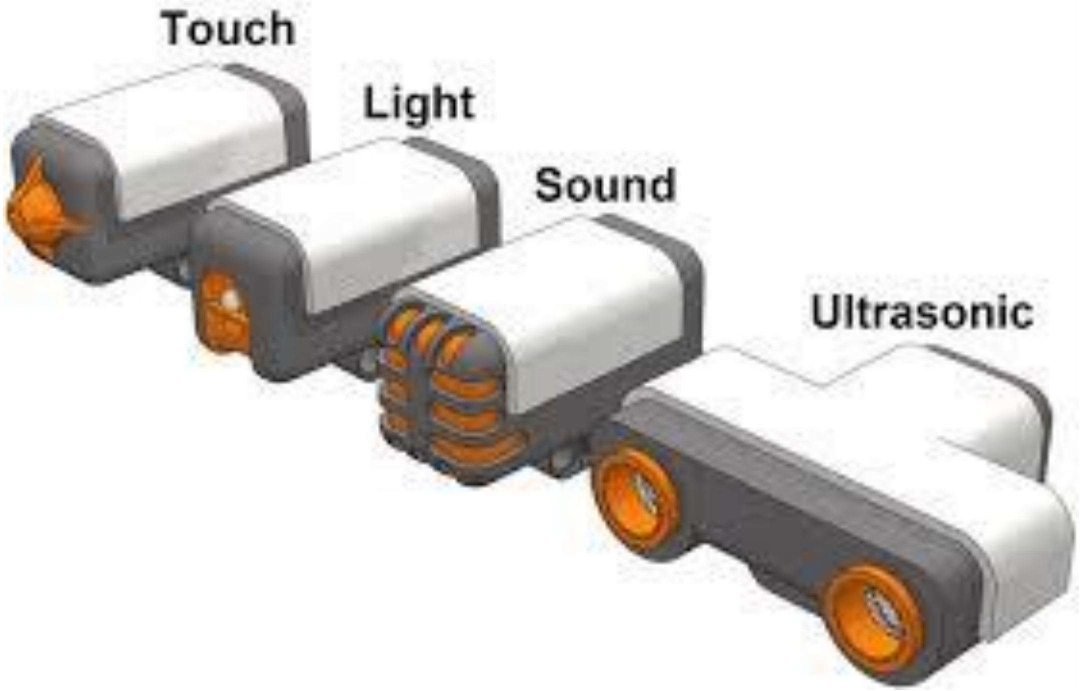
Sensors : Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Robots are often equipped with external sensory devices such as a vision system, touch and tactile sensors etc which help to communicate with the environment



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Controller : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.

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Processor: brain of the robot, It calculates the motion of robot joints

Software: 3 groups of software

i. operating system

ii. Robotic software

Iii. Collection of routines and application programmes

Degrees of freedom

Degrees of freedom (DOF) :Number of independent parameters that define its configuration or state

OR

The minimum number of independent variables or coordinates required for specifying the position of a dynamical system consisting of one or more particle

$F = Nd - k$

Where N - number of particles

d - dimensions of the particle.

K- no of constraints

Example

Consider a particle moving along x-direction in three dimensional space

$d=3$,

$N=1$,

$k=2$

Constraint

$k=2$ means that particle cannot move in y and z directions.

degrees of freedom would be $f=1$

Example

where two particles are moving freely in XY plane.

N=2

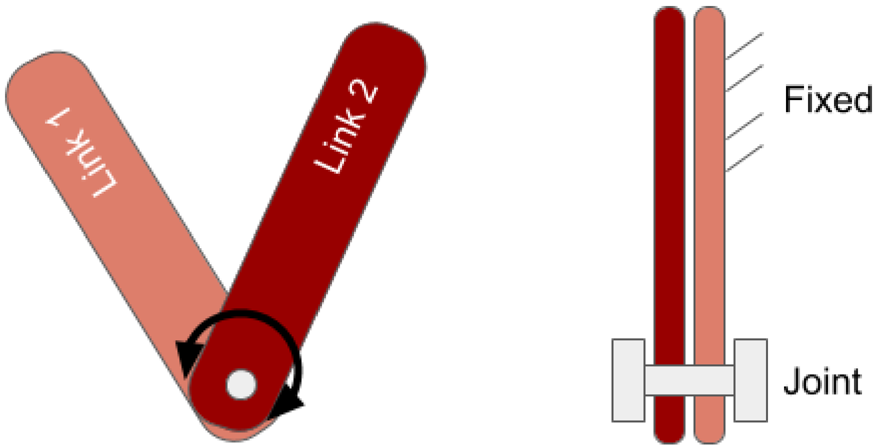
D=2

K=0

F=ND-K

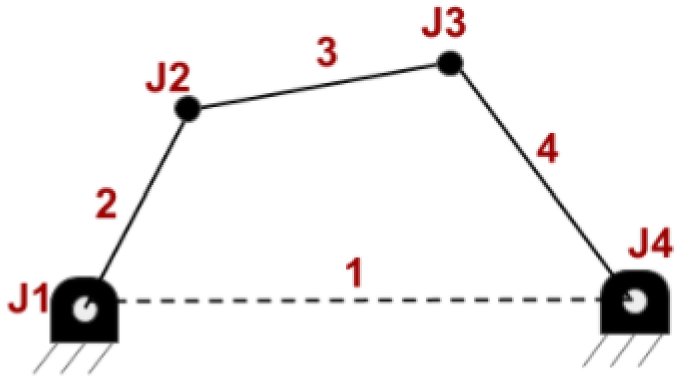
F=4

Example



Links are used to transfer motion from one point to another point

Example



DOF=3x(n-1)-2xl-h

N=Total no of links

L=no of lower pairs

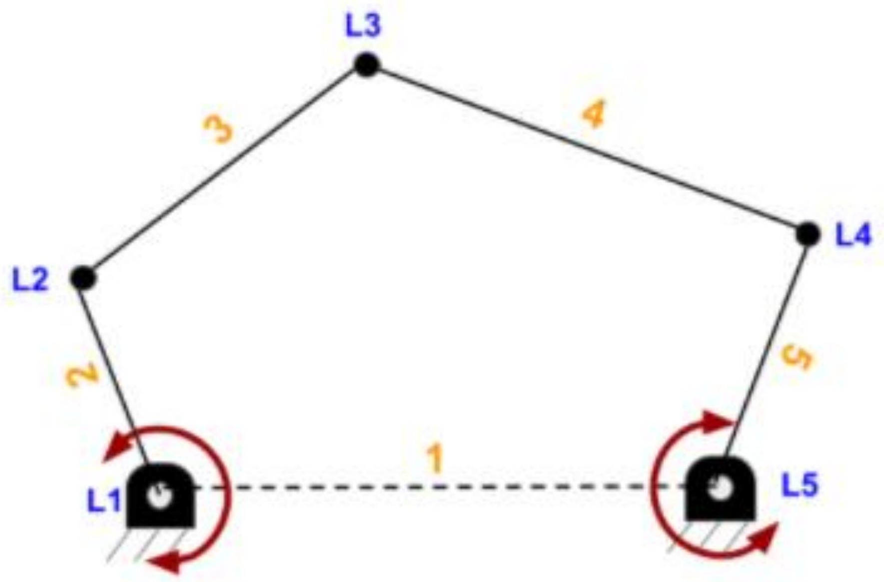
H=no of higher pairs

N=4

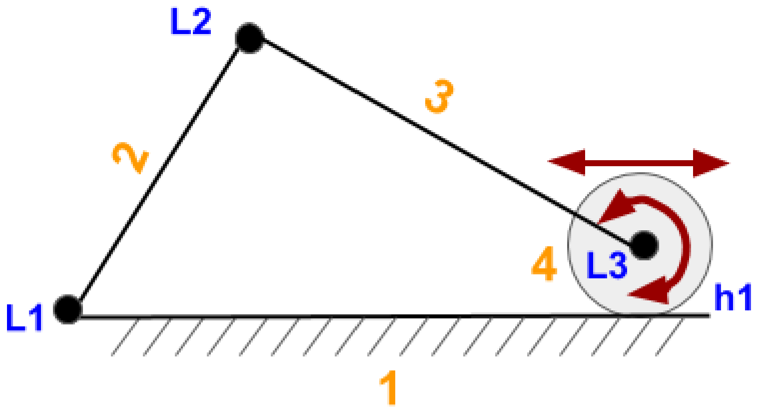
L=4

H=0

DOF = 2

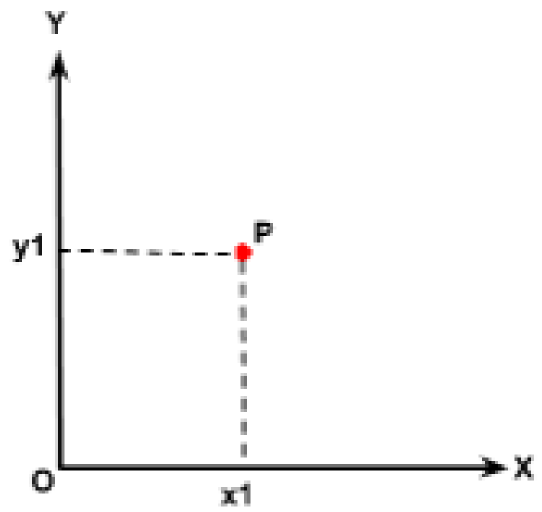


DOF=2




Roll
Yaw
Pitch

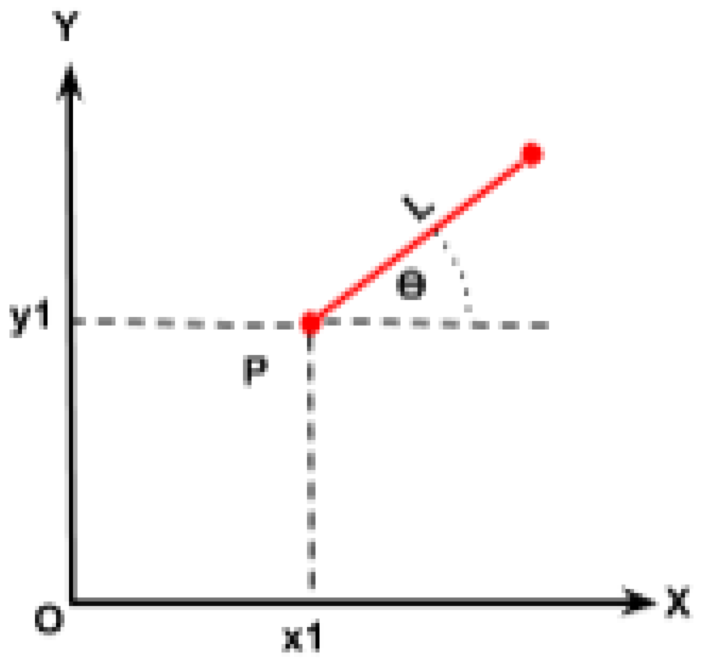
Example



To define the position of point P in 2 Dimensional space its distance from origin in X and Y axis is required

DOF=2

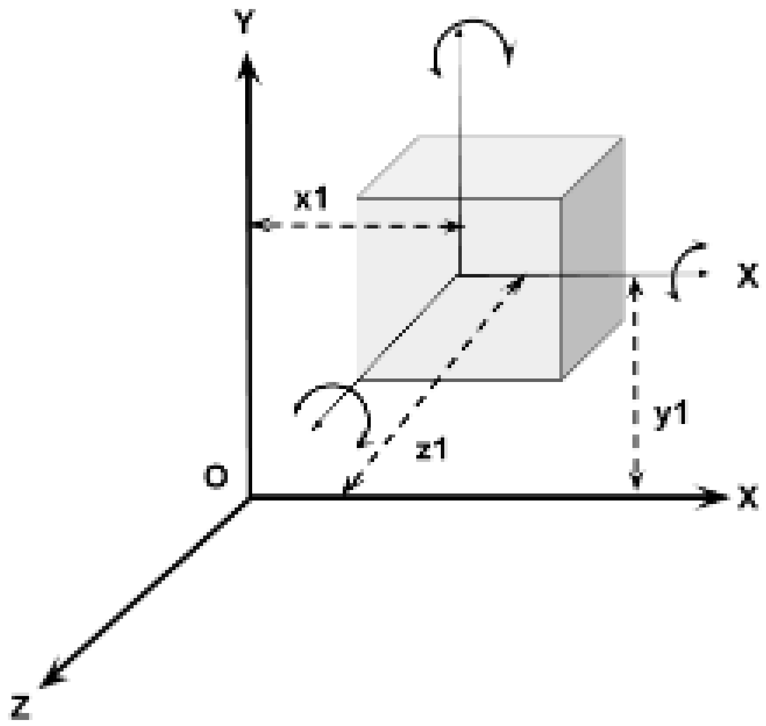
Example



The distance from origin in X and Y axis and angle from X-axis is required

DOF=3

DOF of a rigid body in 3D plane



To define the position of a rigid body in 3D space

Its distance from origin in X, Y, Z and angle from XY, XZ, YZ plane is required.

DOF=6

Difference between lower pair and Higher pair joints

Lower pair joint: 2 elements of a pair joined together with the surface contact between them

OR

only one input is required to define the motion of the lower pair joint

Higher pair: only one point or line is responsible to form a joint between 2 links

OR

More than one inputs are required to define the motion of higher pair joints

Robotic ARM

Consider a robot arm built to work like a human arm.

Shoulder motion : can take place as pitch (up and down) or yaw (left and right), Rotation (roll)

Elbow motion: can occur only as pitch.

Wrist motion : can occur as pitch, yaw &Rotation (roll)

Such a robot arm has seven degrees of freedom

1 DOF

The position of a single railcar (engine) moving along a track has one **degree of freedom** because the position of the car is defined by the distance along the track.

3 DOF

An automobile with highly stiff suspension can be considered to be a rigid body traveling on a plane (a flat, two-dimensional space). This body has three independent degrees of freedom consisting of two components of translation and one angle of rotation. Skidding or drifting is a good example of an automobile's three independent degrees of freedom.

½ Degree freedom robot

Joint have the ability to move its movement is not fully controlled

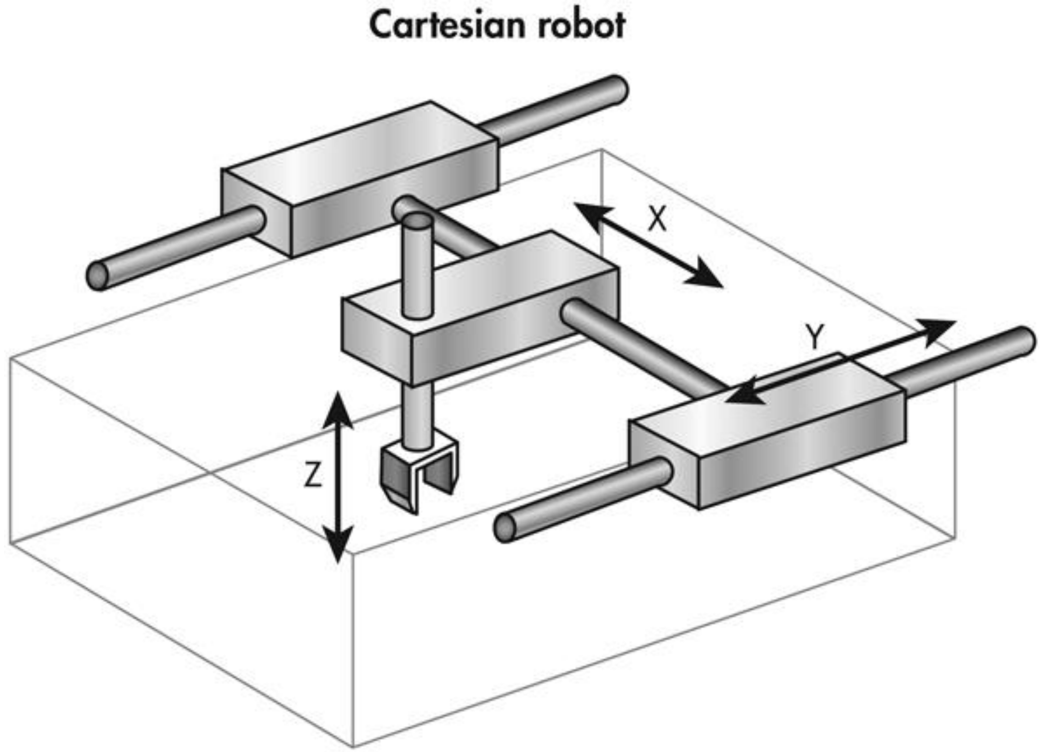
The arm can be fully extended or retracted no control position can be achieved between the two

Joints

1. linear joints (Prismatic) : Hydraulic , Pneumatic or linear electric actuators
2. Rotational joints (Revolute): Hydraulic or Pneumatic rotary joints are common
3. Spherical joints, and revolving joints.

Robot Coordinates

Cartesian/Rectangular Gantry(3P) : These Robots are made of 3 Linear joints that orient the end effector, which are usually followed by additional revolute joints.



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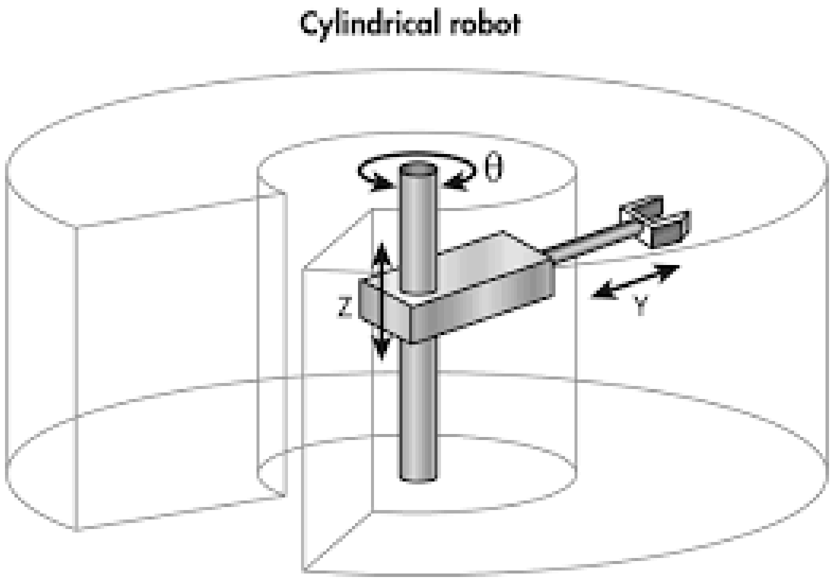
Cylindrical (R2P): Cylindrical coordinate Robots have 2 prismatic joints and one revolute joint.



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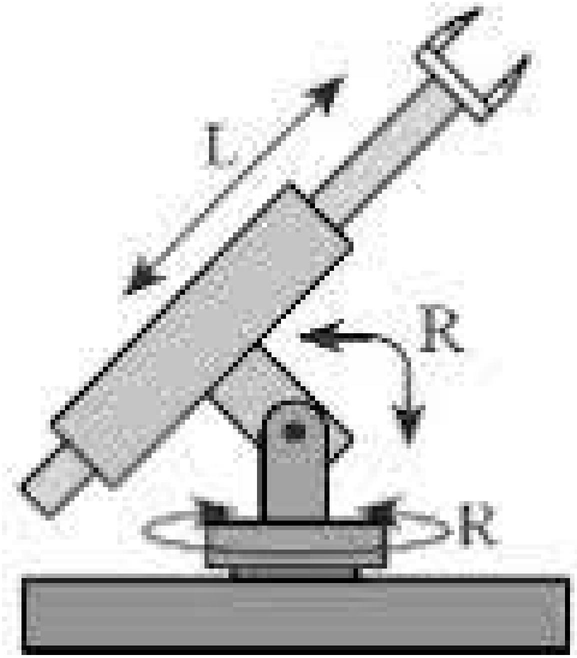
Spherical joint (2RP): They follow a spherical coordinate system, which has one



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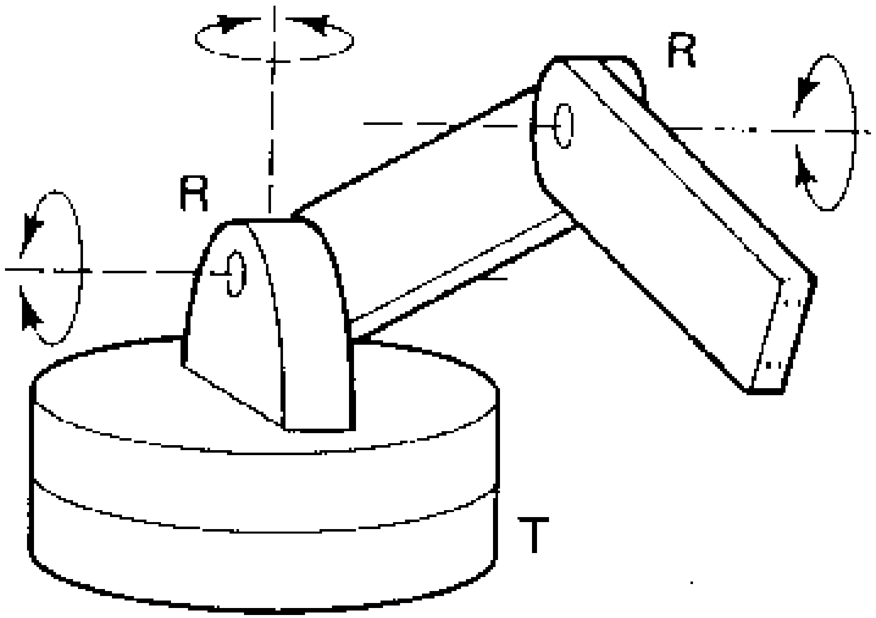
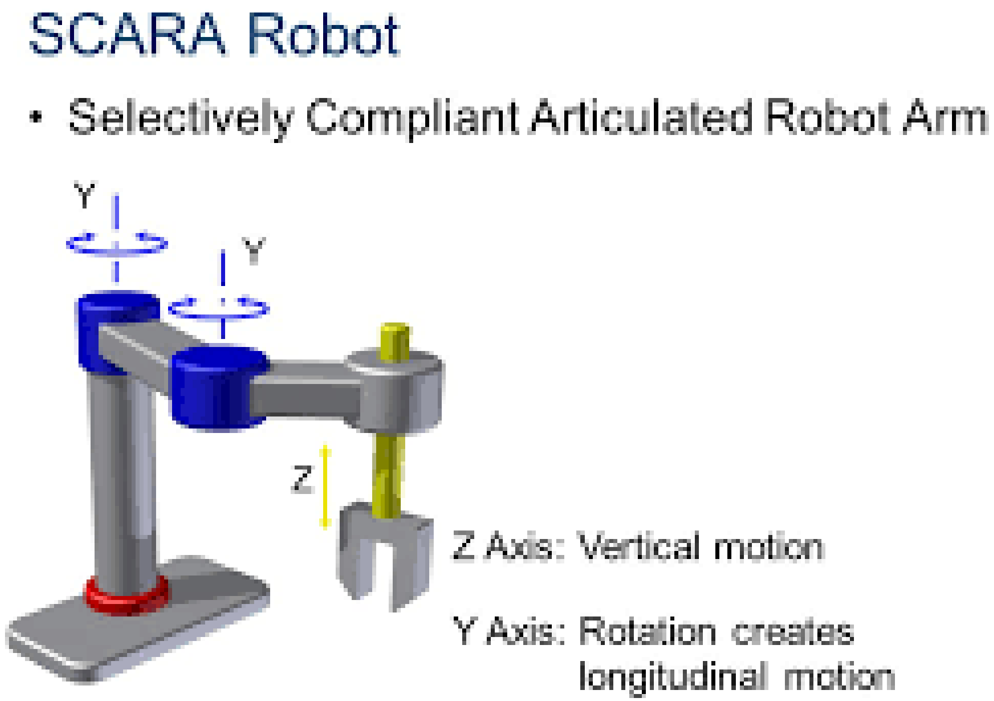
Articulated/anthropomorphic(3R) : An articulated robot’s joints are all revolute, similar to a human’s arm.



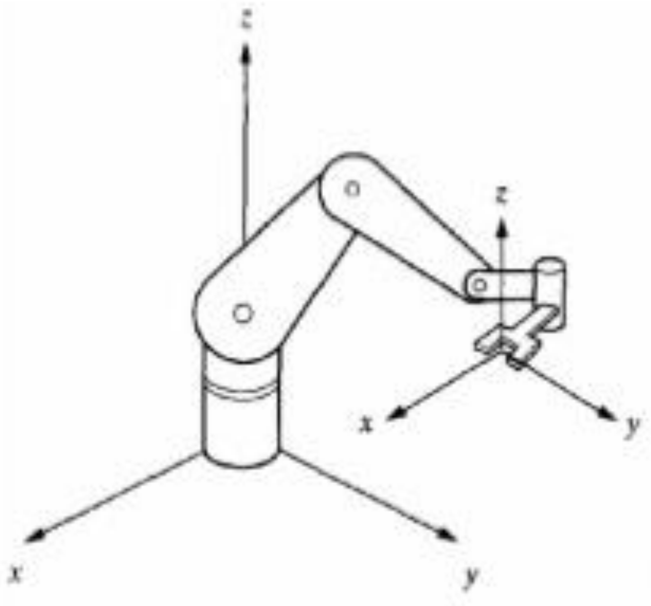
SCARA robot

Selective Compliance Assembly Robot Arm (SCARA) (2R1P): They have two revolute joints that are parallel and allow the Robot to move in a horizontal plane, plus an additional prismatic joint that moves vertically



Reference Frames

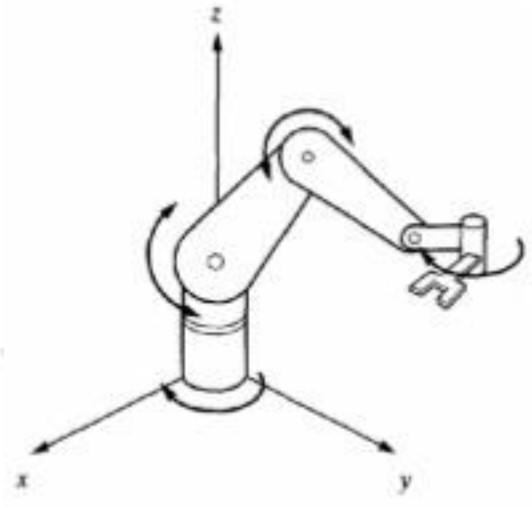
World Reference Frame which is a universal coordinate frame, as defined by the x-y-z axes. In this case the joints of the robot move simultaneously so as to create motions along the three major axes



World reference frame

Contd

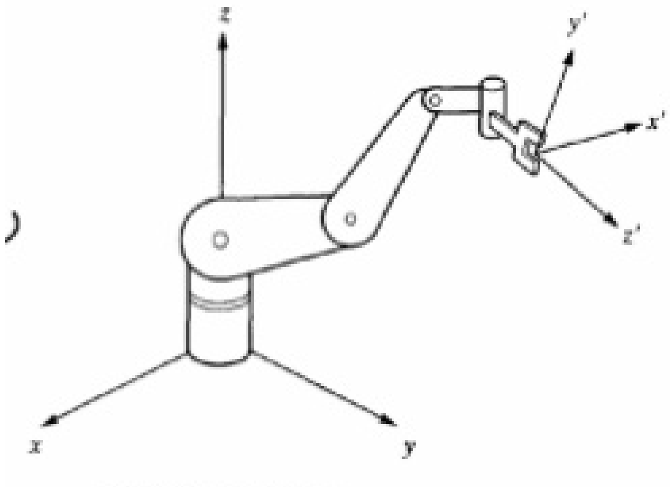
Joint Reference Frame: which is used to specify movements of each individual joint of the Robot. In this case each joint may be accessed individually and thus only one joint moves at a time.



Joint reference frame

Contd..

Tool Reference Frame which specifies the movements of the Robots hand relative to the frame attached to the hand. The x',y'and z' axes attached to the hand define the motions of the hand relative to this local frame. All joints of the Robot move simultaneously to create coordinated motions about the Tool frame.



Tool reference frame

Work Envelope concept

1. Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a **Workspace**.

2. Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach

Robot Characteristics

Payload: **Payload** is the weight the **robot** can lift.

Payload includes the weight of the End of Arm Tooling (EOAT) and the weight of the product being picked.

Contd..

Robot reach is the distance from the center of the **robot** to the fullest extension of the **robotic** arm. This measurement determines the **robot's** work envelope.

Contd..

“**Precision**, also referred to as repeatability [in **robotics**], is the ability of an industrial **robot** to bring its end effector to the same position and orientation, over and over again,

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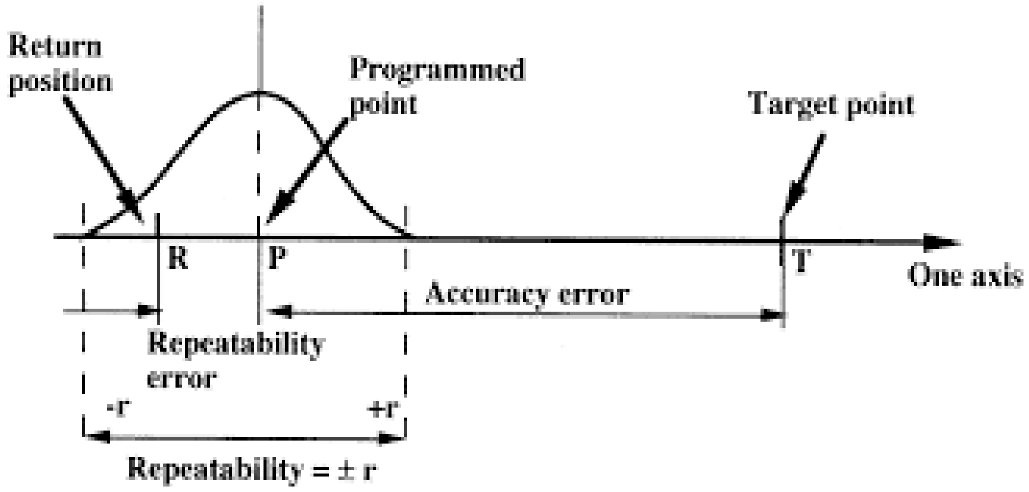
repeatability of **robot** might be defined as its ability to achieve repetition of the same task.



Asimov's laws of Robotics

Isaac Asimov's

Three Laws of Robotics

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Robot programming modes

Teaching Pendant.

Simulation/Offline **Programming**.

Where Used and Applied

- Welding
- Painting
- Surface finishing
- Aerospace and automotive industries
- Light assembly such as in the micro-electronics industries, or consumer products industries
- Inspection of parts (e.g., CMM)
- Underwater and space exploration
- Hazardous waste remediation

What Can Robots Do:

Jobs that are dangerous for humans