Introduction to Robotics , Robot Anatomy & Kinematics

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Overview

- Robot definition
- Robotics laws
- Classifications and Applications in Field
- Advantages & disadvantage
- Robot anatomy, Manipulators
- Degree of Freedom
- Joints in Robots
- Robot coordinates - Robot arm configurations
- Forward kinematics and inverse kinematics of a robot .

Robot Definition

- A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

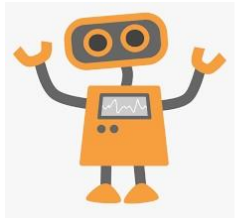
UAVs - Air

Land

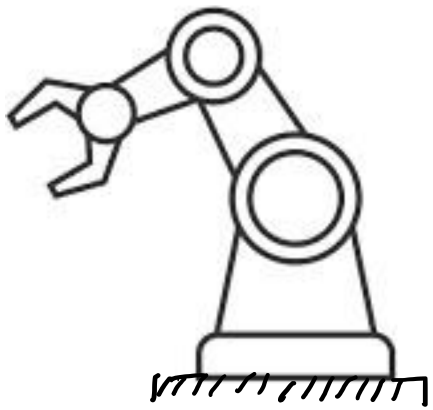
Rovers -

Underwater

Humanoid



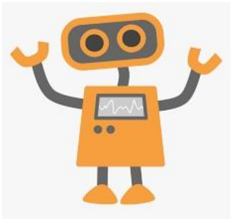
Industrial



Difference Between Robot & Machine

- A **machine** is a device that can repeatedly make pre-designed motions in order to help produce the desired result or outcome.
- A **robot**, on the other hand, is an intelligent device that is able to do much more than a **machine**. ... Through programming, a **robot** can be able to complete many different tasks in a production process.
- Robot can take own decision while machine can not that is the biggest difference.




Robots & Machines Difference

Similarities.
- power source.
- Links, Joints,

ROBOTS

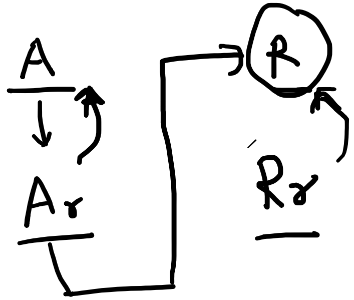
- It is a machine that acts independently of external controls.
- It is a machine built to carry out some complex task or group of tasks, especially one which can be programmed.
- It can be guided by an external control device or the control may be embedded within.
- It may convey a sense of intelligence or thought of its own.
- Ex: humanoids, UAV(Unmanned Aerial Vehicle) drones, etc.

MACHINES

- It is a physical tool which is controlled by users or external automation.
- It is a mechanical or electrical device that performs or assists in the performance of human tasks, whether physical or computational, laborious or for entertainment
- It can be driven by animals and people, by natural forces and by chemical, thermal, or electrical power,
- It has to be supervised or controlled by others.
- Ex: vehicles, appliances, etc

Robotic Laws by Assimov

•Isaac Asimov’s Three Laws of Robotics: The Three Laws of Robotics (often shortened to The Three Laws or known as Asimov’s Laws) are a set of rules devised by the science fiction author Isaac Asimov.

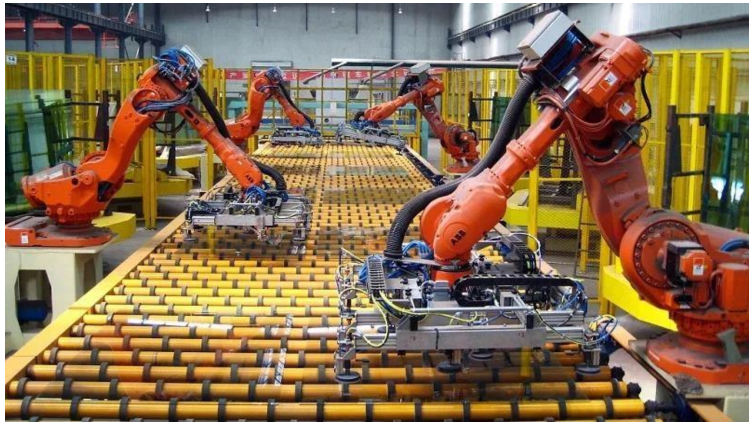


1st law :A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2nd law:A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

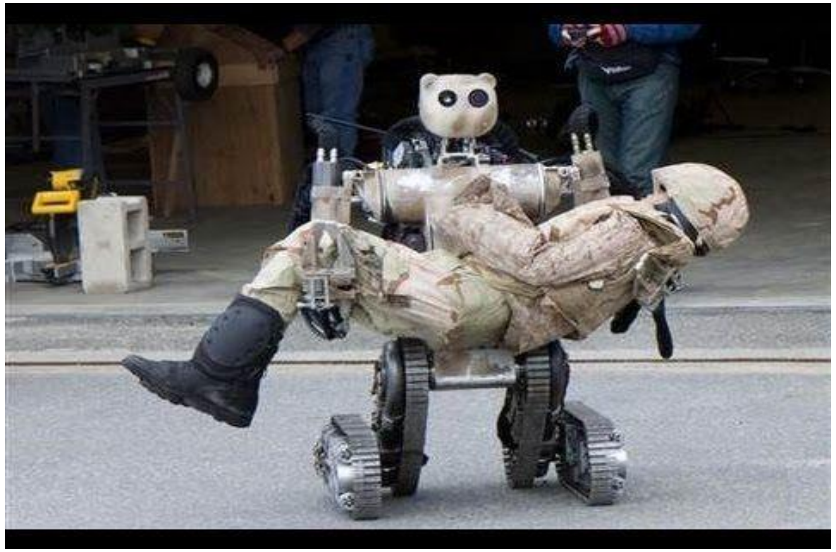
3rd law:A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws

Robot Classifications & Applications - Robotic arm Industry Application



Robot Classifications & Applications - Arial Application

Robot Classifications & Applications - Millitary



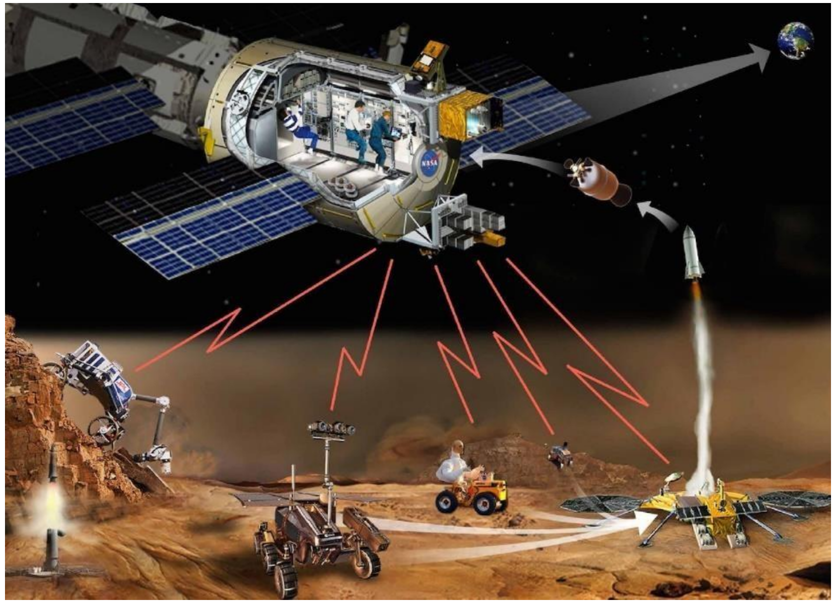
Robot Classifications & Applications - Medical Assist

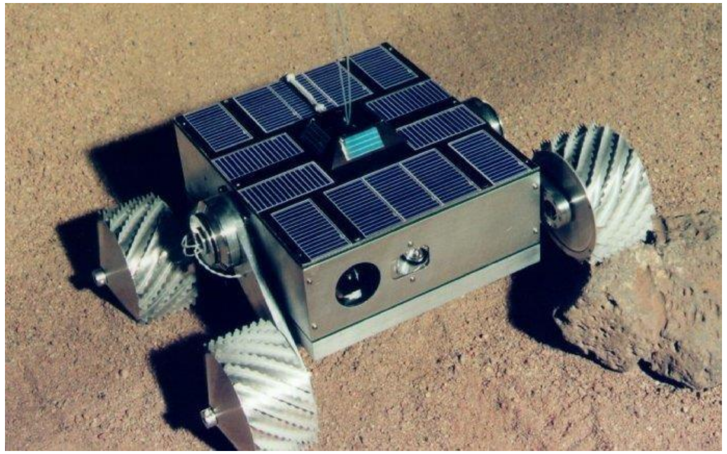
Robot Classifications & Applications - Agriculture




Robot Classifications Underwater

Robot Classifications Space Exploration





Robot Advantage & disadvantage

ADVANTAGES.

- Cost Effectiveness. There will be no lunchbreaks, holidays, sick leave or shift time allocated for **robotic** automation
- Improved Quality Assurance.
- Increased Productivity.
- Work In Hazardous Environments.
- Can do unreal things which can not be done by human

DISADVANTAGES.

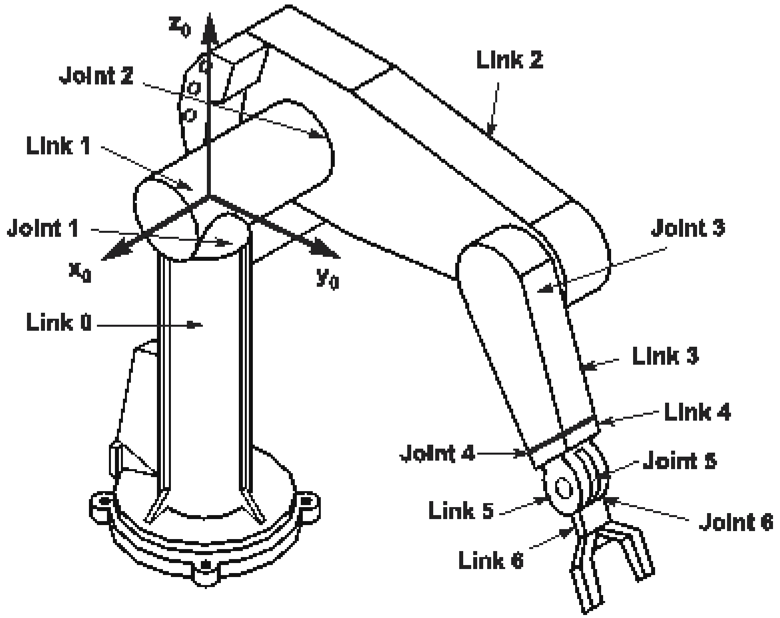
- Potential Job Losses.
- Initial Investment Costs.

Robot Anatomy :

Skeleton → Basic Components.

① structure
- Base / Frame
- Links, Joints,
- Joints

② End effector
③ Power Source,
④ Controller,

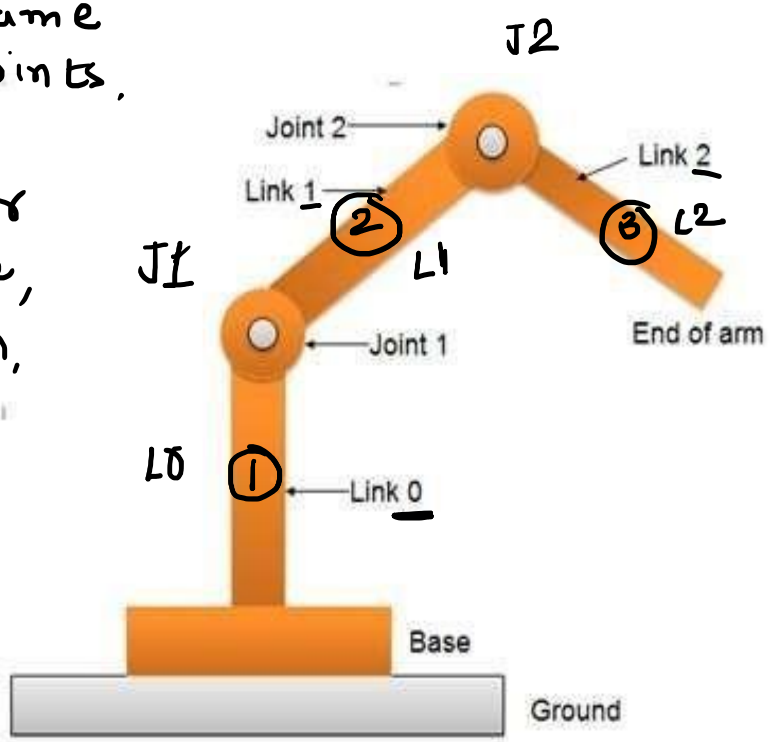


Basic Anatomy

- **Base (fixed / movable)**

•Manipulator consist of Arm & joints (all types)

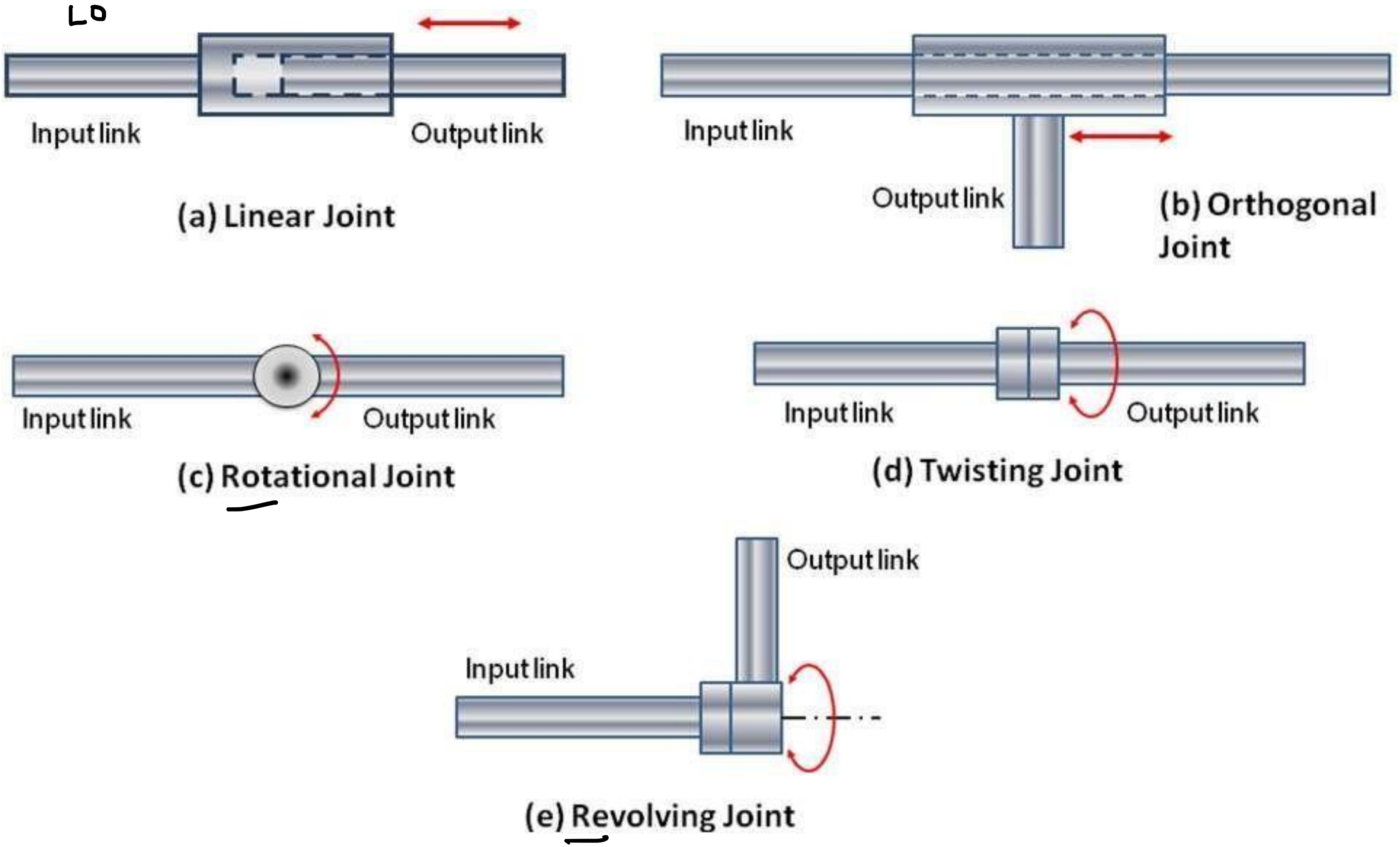
- **End effector**
  - **Gripper ,**
  - **Pick & place ,**
  - **Spray , Torch**
  - **Vacuum**
  - **Nozzle**



No Links(L) 3

No jonts (J) 2

Types of Joints



Types of Joints

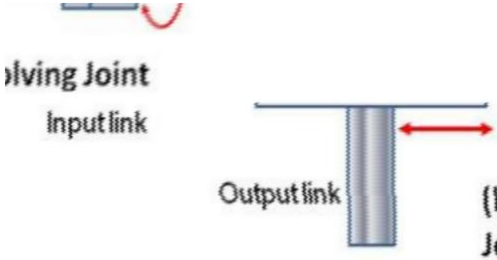
a) Linear joint (type L joint)

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.

(a) Linear Joint

b) Orthogonal joint (type U joint)

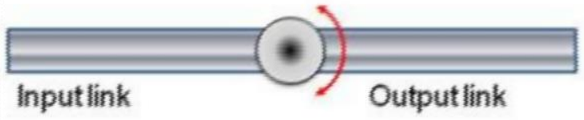
This is also a translational sliding motion, but the input and output links are perpendicular to each other during the move.



(b) Orthogonal Joint

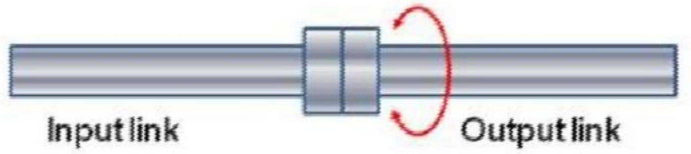
c) Rotational joint (type R joint)

This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.



(c) Rotational Joint

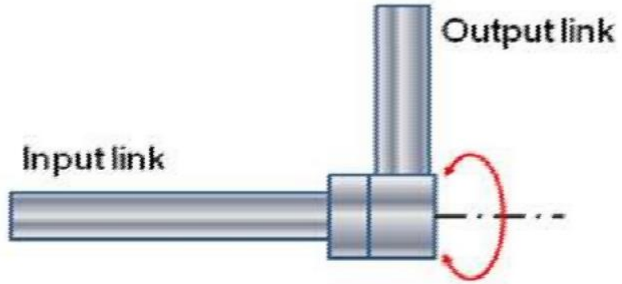
Types of Joints



(d) Twisting Joint

d) Twisting joint (type T joint)

This joint also involves rotary motion, but the axis or rotation is parallel to the axes of the two links.



(e) Revolving Joint

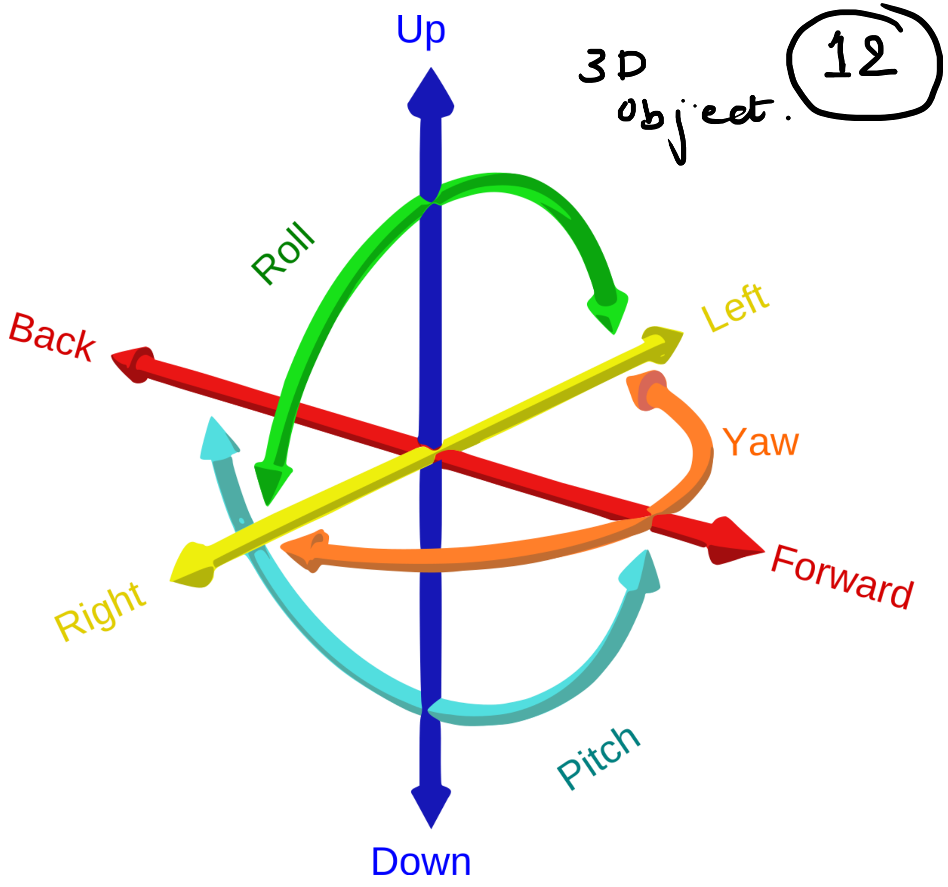
e) Revolving joint (type V-joint, V from the “v” in revolving)

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.

Degree of Freedom (DOF)

3 Direction → 2 ⇒ total 6
3 Orient → Rotate 2 ⇒ total 6
3D object. 12

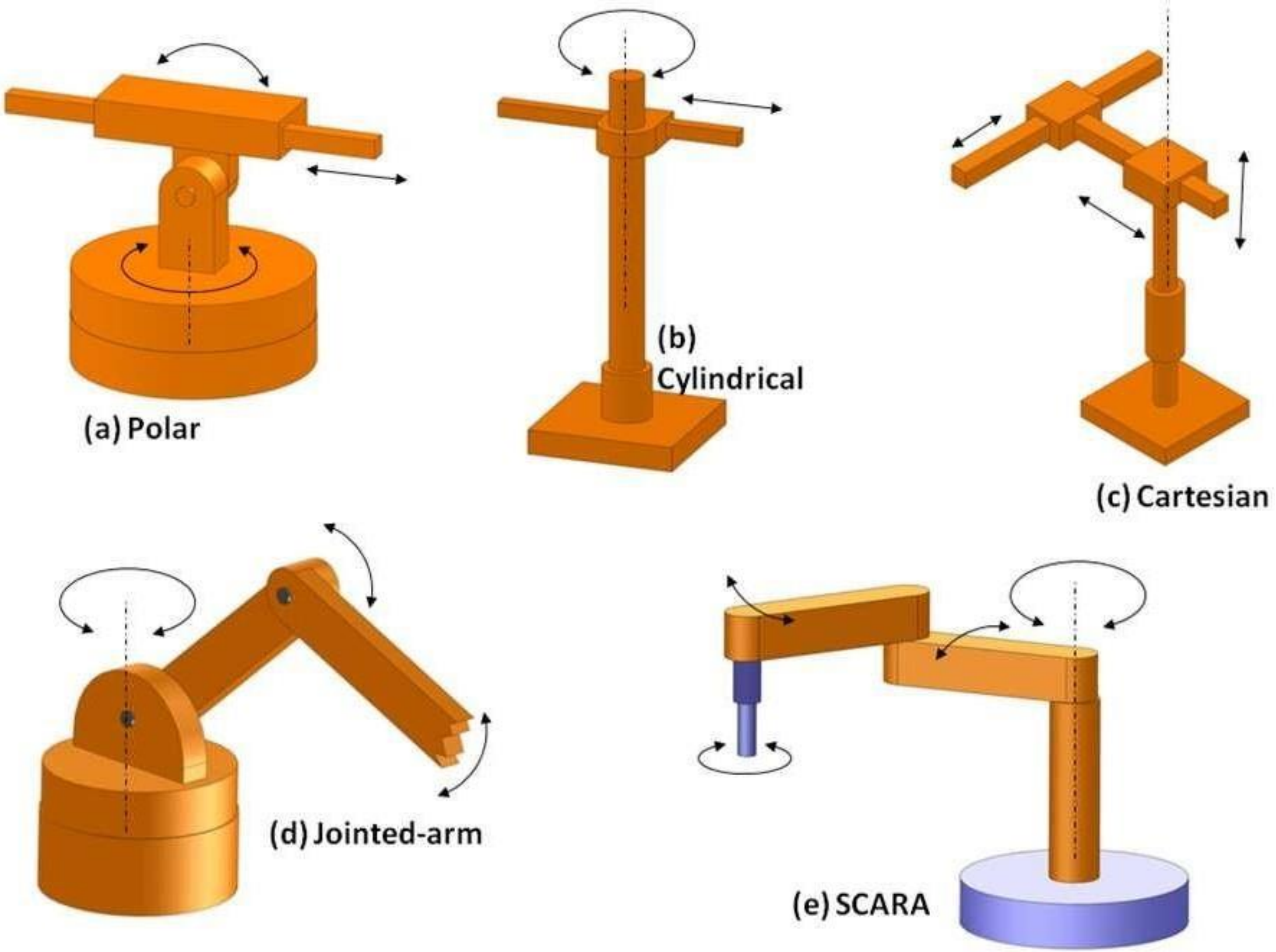
- **Degree** of **freedom** basically refers to the number of ways in which an object can move. Now, simply put, there are 2 fundamental means of movement:
- Translation (⟷) 6 T (DOF)
- Rotation 6 R (DOF)
- Translation can be further broken down into 3 kinds of movements:
- Forward - Backward
- Left - Right
- Up - Down
- Rotation can also be further broken down into 3 kinds of movements:
- Pitch
- Yaw
- Roll



Robot classifications

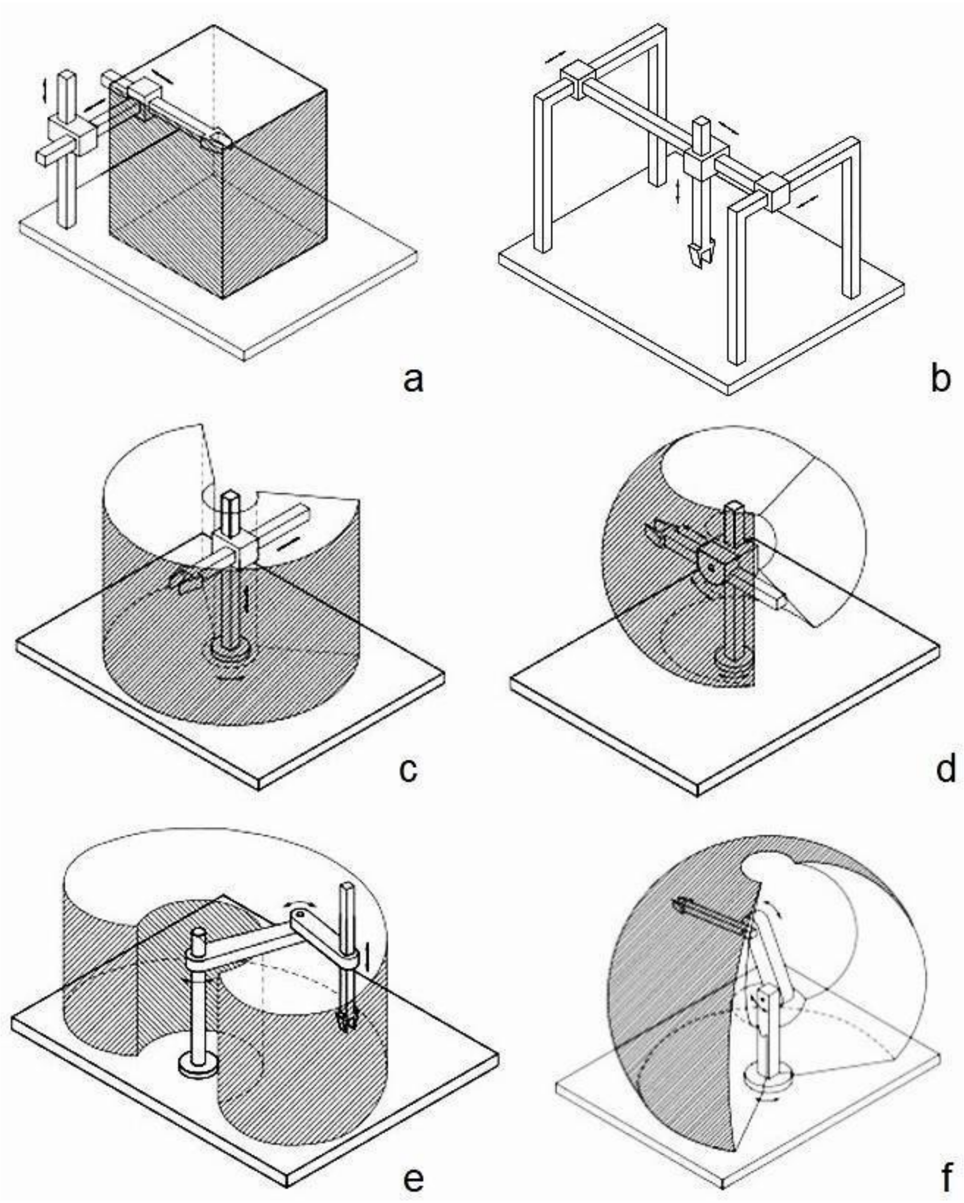
- Based on Robot Arm Configuration
  - Cartesian coordinate
  - Cylindrical coordinate
  - Polar coordinate
  - Jointed arm configuration
  - SCARA
- Based on Power Source
  - Pneumatic
  - Hydraulic
  - Electric
  - hybrid
- Based on path control
  - Limited Sequence Robot
  - Point to point control
  - Path controlled Robot

Robot Arm configurations



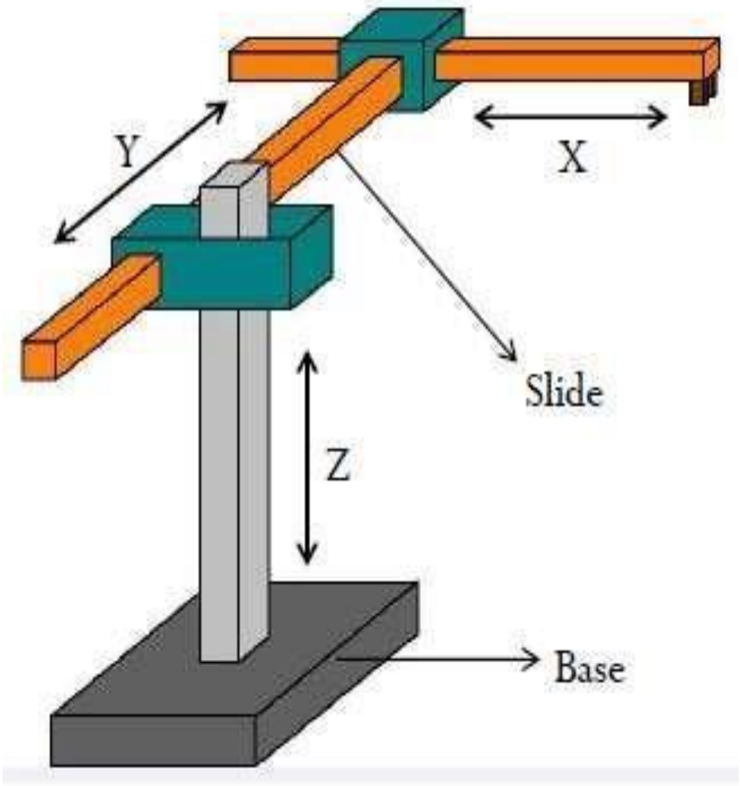
Work envelope of Robotic arm

- Work volume or work envelope refers to the space within which the robot can manipulate its wrist end.
- The work volume is determined by the following physical characteristics:
  1. Robot's physical configuration.
  2. Sizes of the body, arm and wrist components.
  3. Limits of robot's joint movements.



Cartesian Arm Configuration

- In this there are three orthogonal directions X,Y andZ.
- X-coordinate axis may represent left and right motion.
- Y-coordinate axis may represent forward and backward motion.
- Z-coordinate axis may represent up and down motions.
- Example of Cartesian System is *Overhead Crane Movement.*
- Work envelope is Box



- Applications:
- Pick and place operation.
- Adhesive applications.
- Assembly and sub assembly.
- Nuclear material handling.
- Welding

Cylindrical Arm Configuration

- Two Translation & One Rotation Joint
- Work envelope is Hollow Cylinder

- Applications:

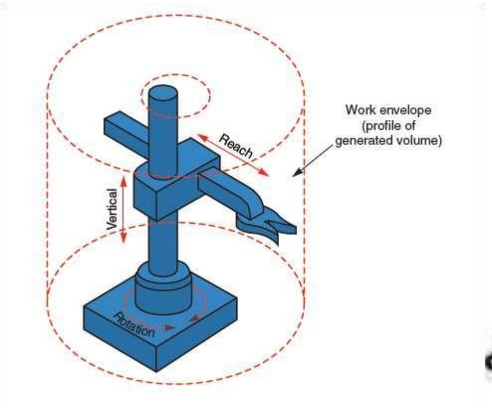
  Assembly.

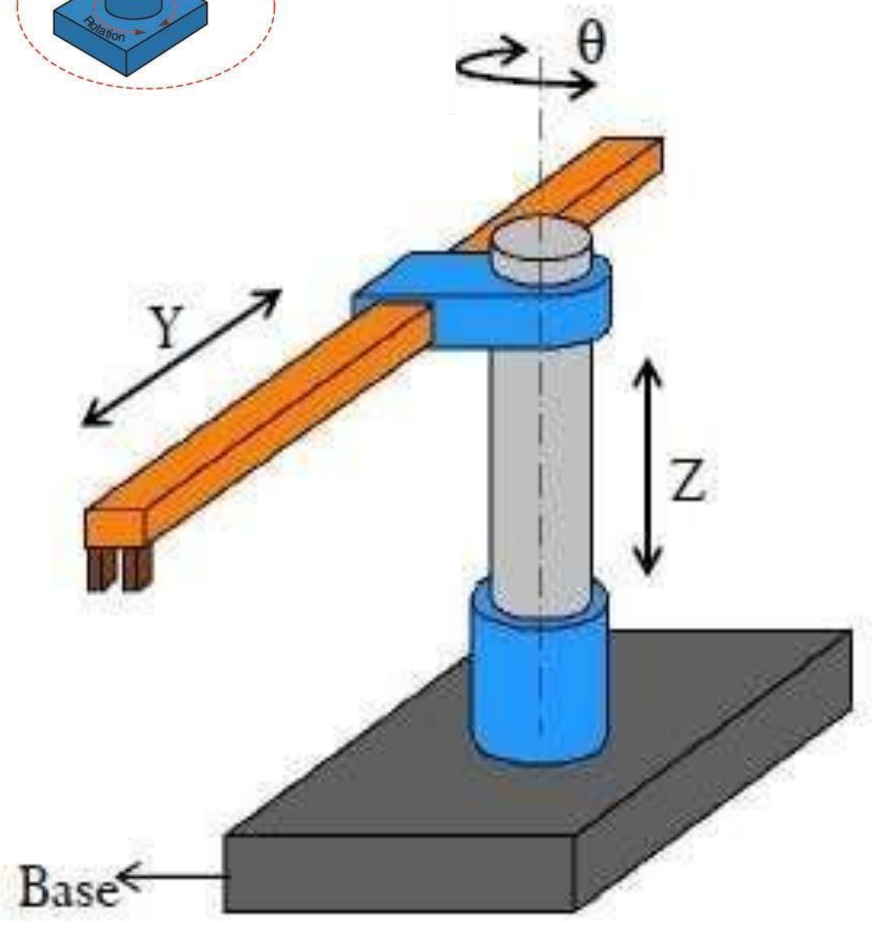
  Coating application

  Die casting.

  Foundry and forging application

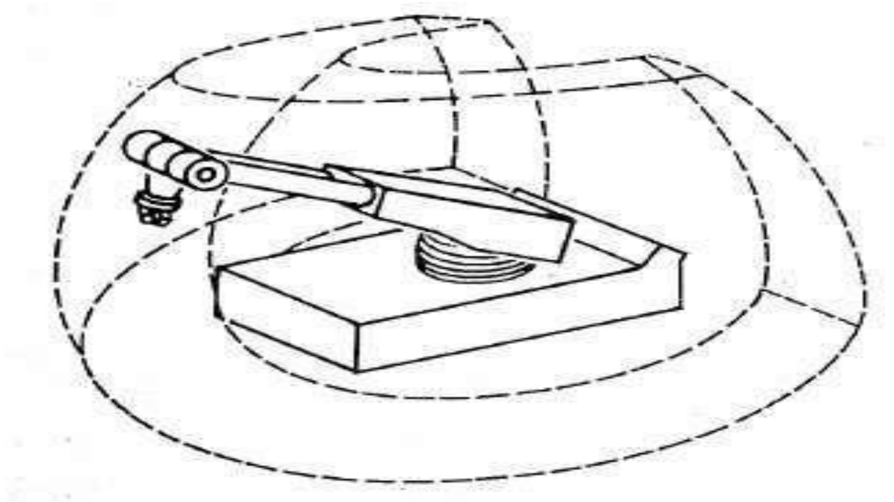
  Machine loading and unloading.

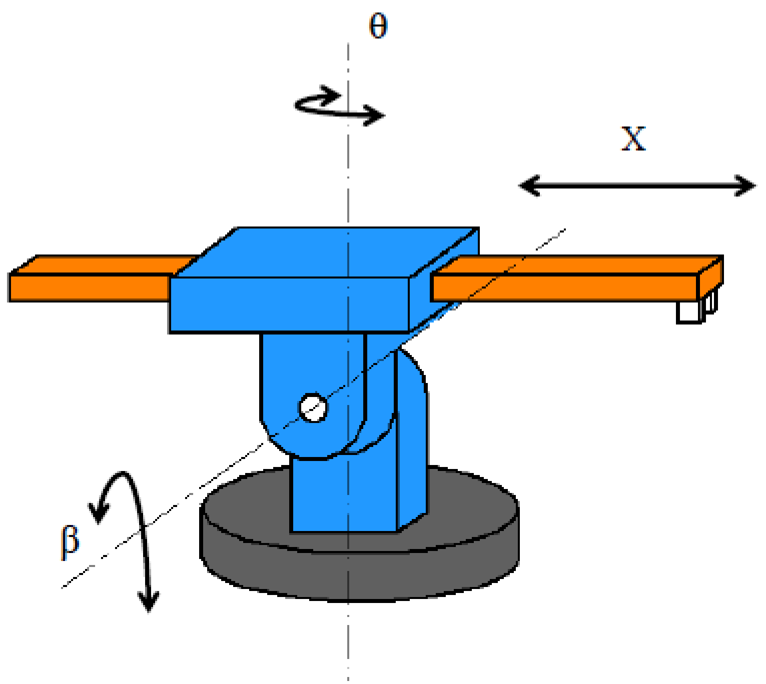




Polar Arm Configuration

- Two Rotation & One Translation types of joint
- Work envelope is partial Sphere
- Applications:
  - Die casting.
  - Forging.
  - Glass handling.
  - Injection molding.
  - Stacking and unstacking.



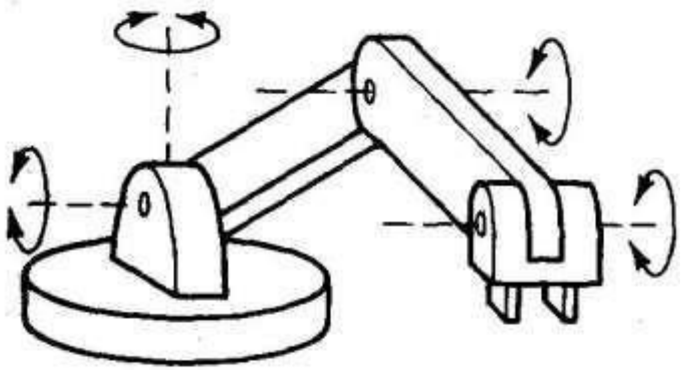


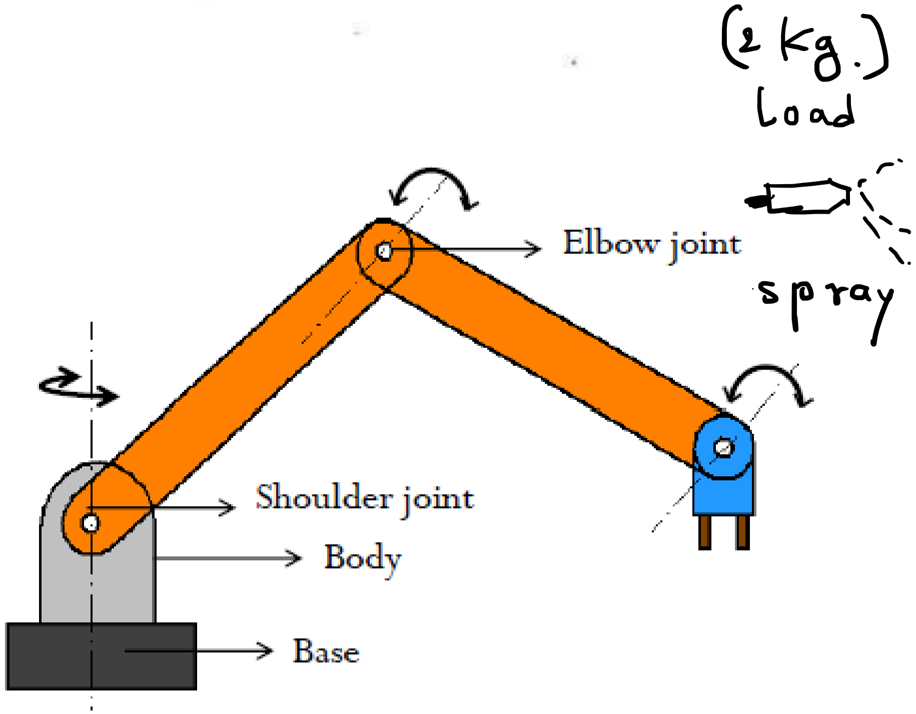
Jointed Arm Configuration

- These components are connected by two rotary joints corresponding to shoulder

- Work envelope is Partial Sphere

- Applications:
- Pick and place operation.
- Adhesive applications.
- Assembly and sub assembly.
- Nuclear material handling.
- Welding





SCARA

axes
3-axis, 4 axis.

- SCARA is a special type of jointed arm configuration.
- It stands for Selective Compliance Automated Robot Arm (or) Selective Compliance Articulated Robot Arm.
- It is similar to jointed-arm except that the vertical axes are used for shoulder and elbow joints to be compliant in horizontal direction vertical insertion tasks.

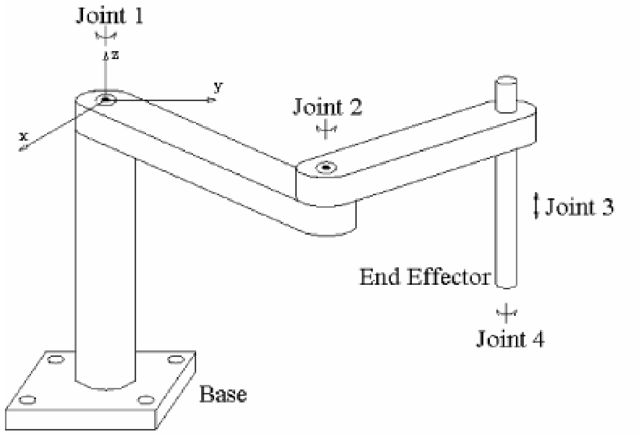
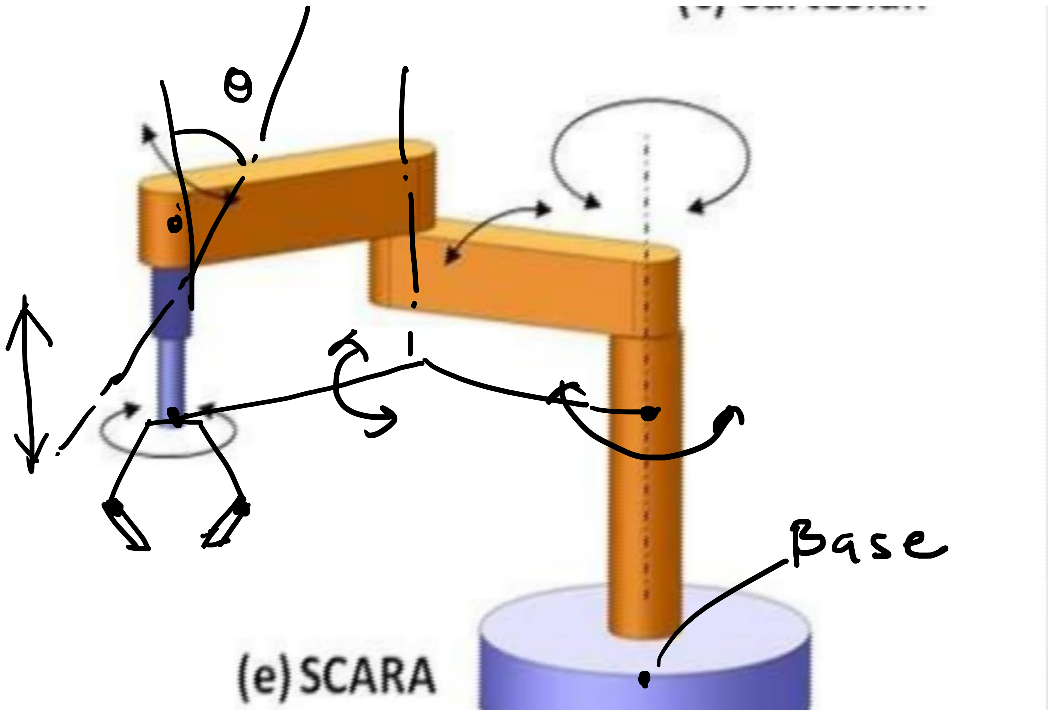


Figure 5. SCARA - Selective Compliance Assembly Robot Arm.



Forward & Inverse kinematics in Robot

Forward Kinematics :

- Procedure of Finding the position and orientation of End effector from the known joints and links

Inverse Kinematics :

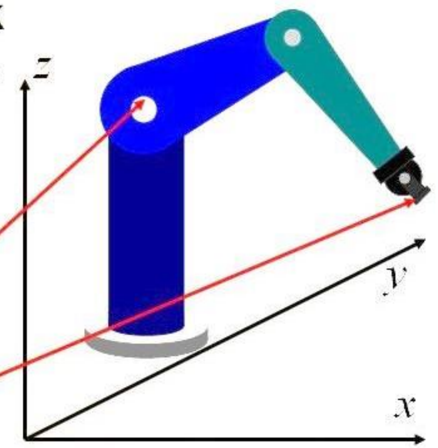
- Procedure of finding the From given position and orientation of the Robotic arm find the joint variables & link variable

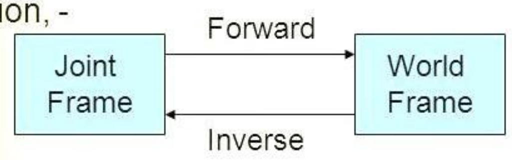
- Given the various joint and link parameters, compute the end-effector (tool) location in task space.
- Given joint variables

$$q = (q_1, q_2, q_3, q_4, q_5, q_6, \cdots q_n)$$

$$Y = (x, y, z, O, A, T) \quad \text{or} \quad Y = \begin{bmatrix} R & p \\ 0 & 1 \end{bmatrix}$$

  - End-effector position and orientation, - Formula?





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Robot specifications:

(i) Number of axes: – Higher number of axis (↑ complexity)

(ii) Load carrying capacity – According to application.

(iii) Speed (mm/sec) -

(iv) Reach & stroke

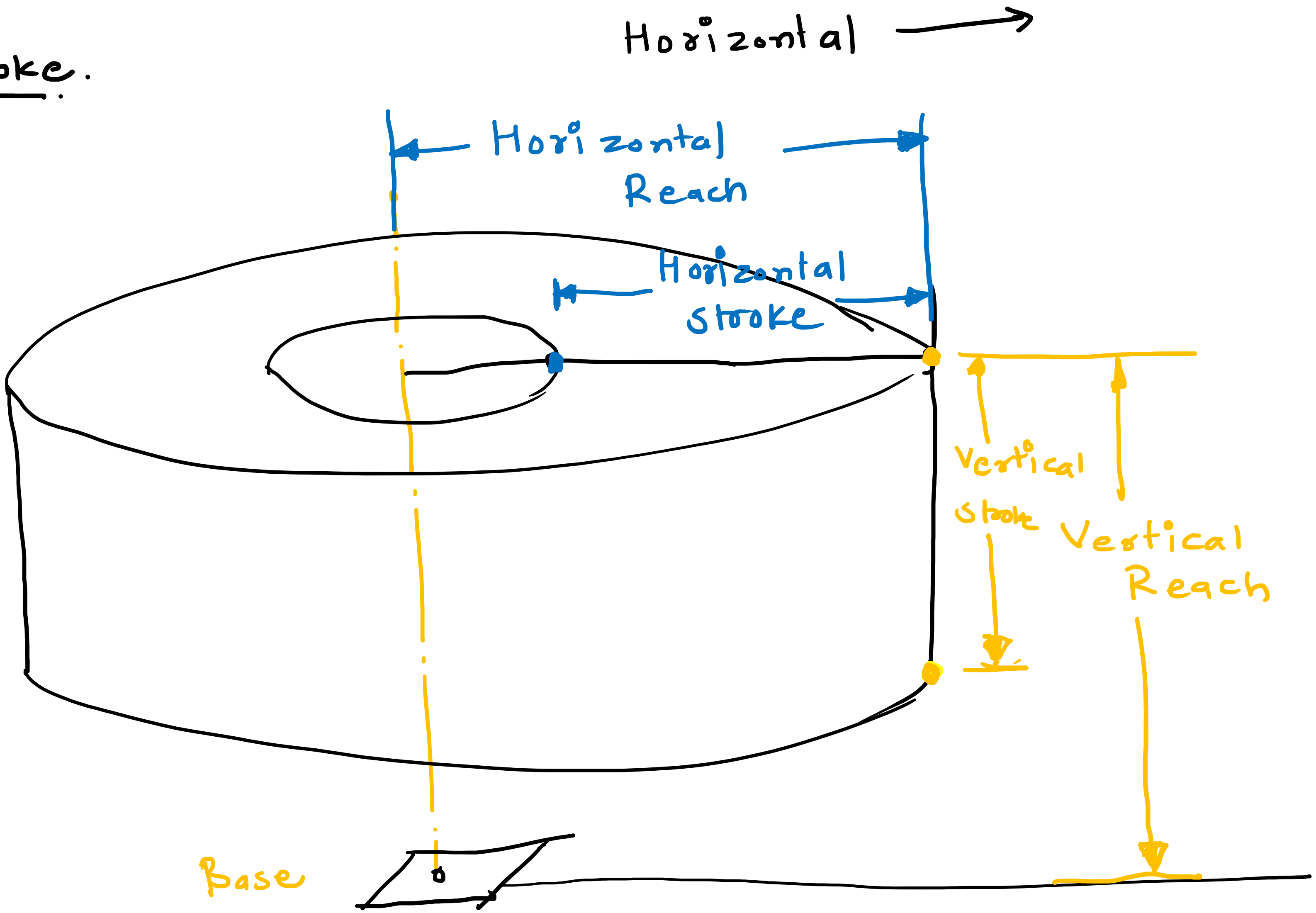
(v) Tool orientation.

(vi) Precision, Accuracy & Repeatability of movement (mm).

Terminologies :

Reach & Stroke.

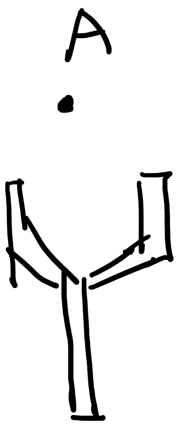
(1) Horizontal Reach
(2) " Stroke
(3) Vertical Reach
(4) Vertical Stroke.

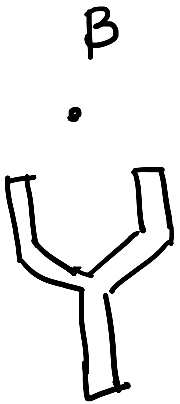


Motor, Step, Servo, Arm Configuaration.

Terminologies

Speed:





10 cm = 100 mm

$$= \frac{\text{Distance}}{\text{Time}} = \frac{100\text{ mm}}{10\text{ sec}} = 10\text{ mm/sec.}$$

① Min Speed, ② Maximum Speed.

(Devient - Harterberg) Parameters.

D-H parameters

① Link length
② Link twist

③ Joint Distance.
④ Joint Angle.

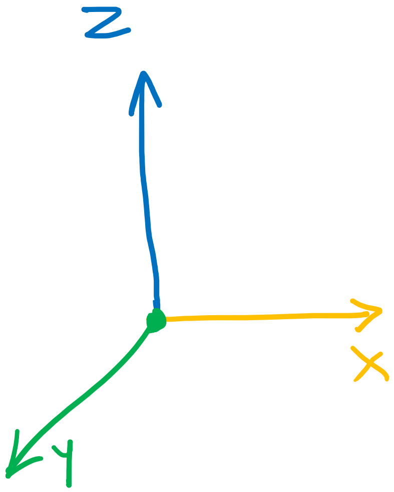
Link

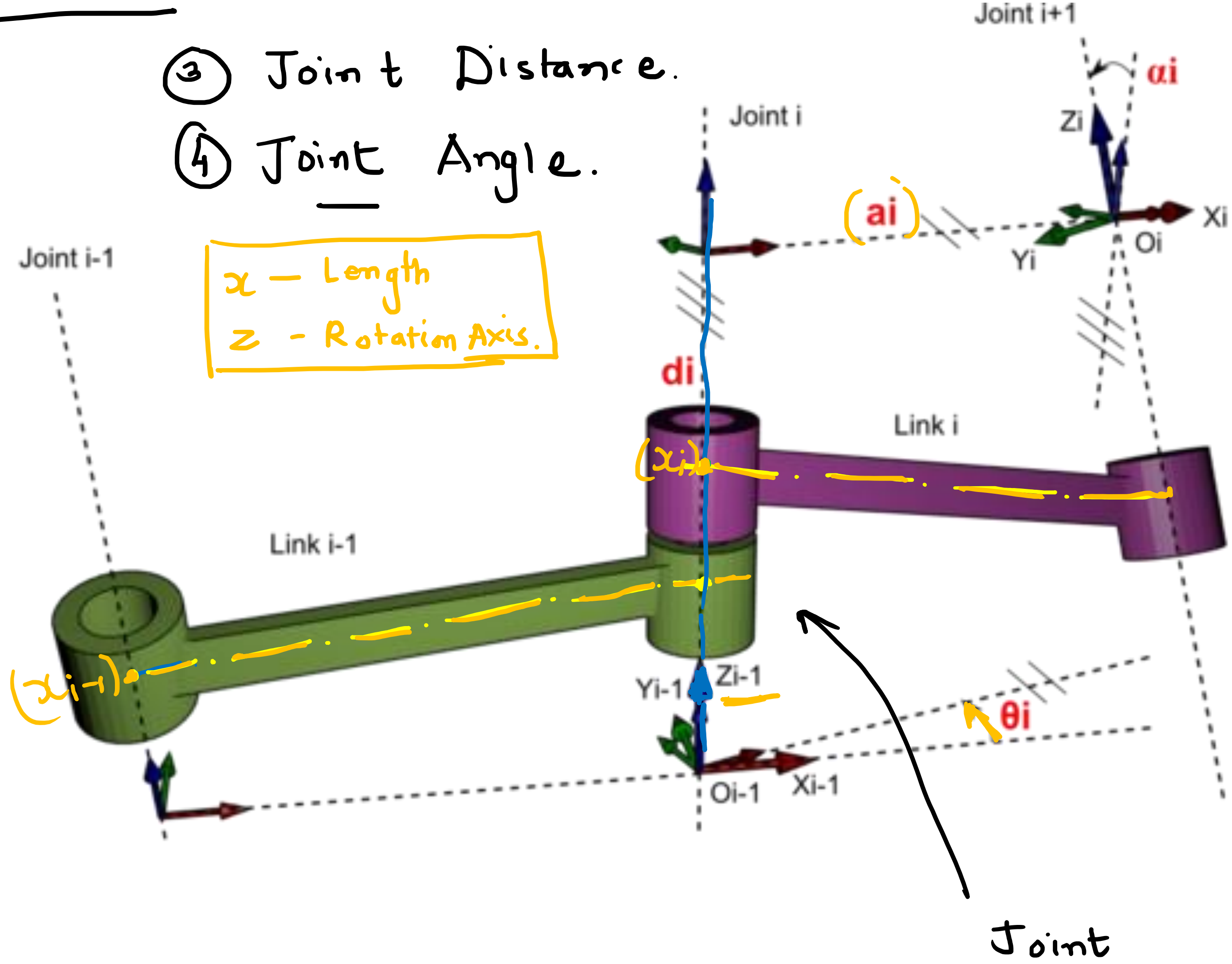
① a_i
② α_i

Joint

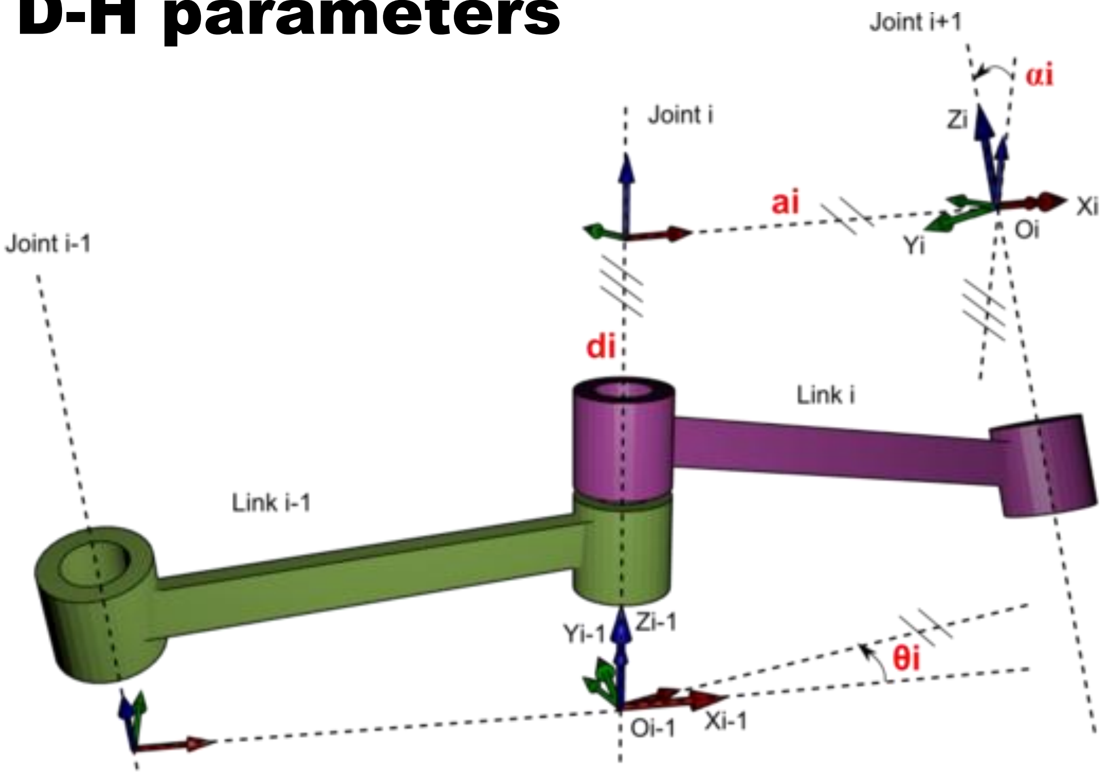
③ d_i -
④ θ_i

$i-1$ = pre-primary
i = primary
$i+1$ = secondary





D-H parameters



The 4 parameters of a DH coordinate frame:

Link length a_i : distance between z_{i-1} and z_i along the x-axis is the *kinematic length* of link i.

Link twist α_i : required rotation of the z_{i-1} axis about the x_i to become parallel to the z_i axis.

Joint distance d_i : distance between x_{i-1} and x_i along the z_{i-1} axis, also called *link offset*.

Joint angle θ_i : required rotation of x_{i-1} about the z_{i-1} axis to become parallel to the x_i axis

The parameters θ_i and d_i are called *joint parameters,* since they define the relative position of two adjacent links connected at joint *i*. The variable parameter either θi or di is called the *joint variable* (the other parameter is fixed).
The parameters αi and a_i are called *link parameters,* because they define relative positions of joints *i* and *i* + 1 at two ends of link (i).

D-H parameters

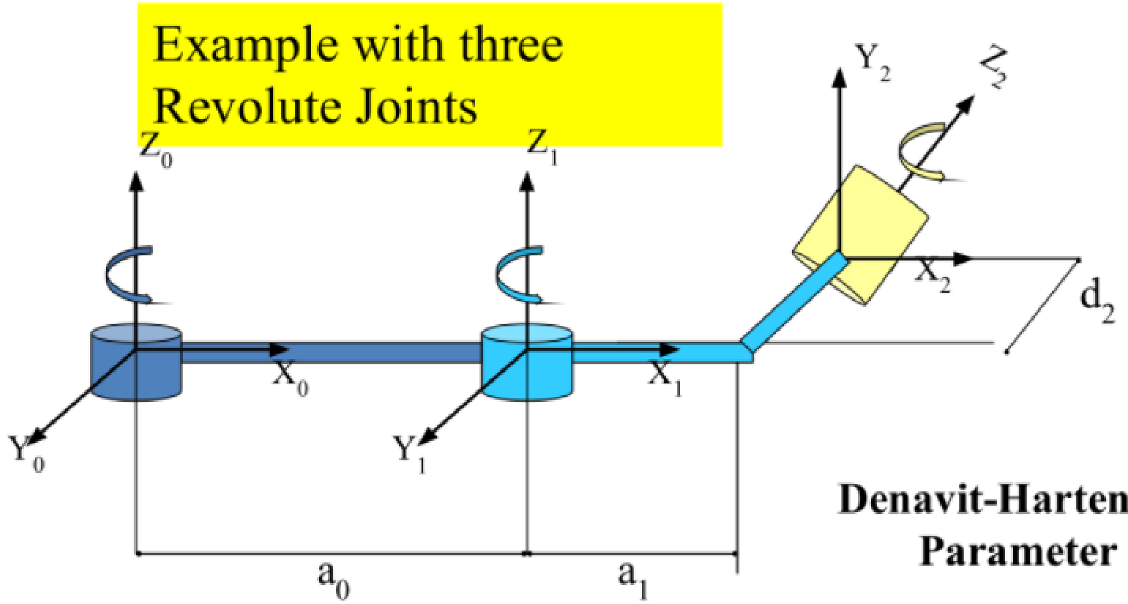
θ : A rotation about the *z*-axis.

d : The distance on the *z*-axis.

a : The length of each common normal (Joint offset).

α : The angle between two successive *z*-axes (Joint twist)

D-H parameters



Denavit-Hartenberg Link Parameter Table

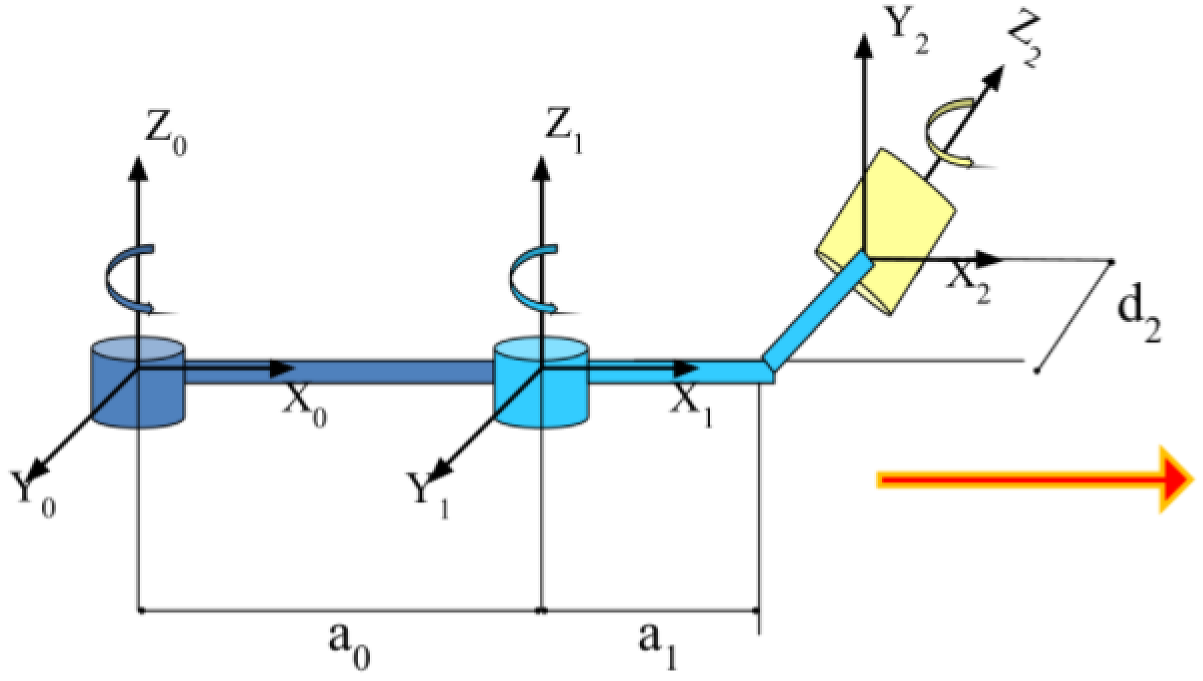
Notice that the table has two uses:

1) To describe the robot with its variables and parameters.

2) To describe some state of the robot by having a numerical values for the variables.

i	$\alpha_{(i-1)}$	$a_{(i-1)}$	d_i	θ_i
0	0	0	0	θ_0
1	0	a_0	0	θ_1
2	-90	a_1	d_2	θ_2

DH parameter



i	$\alpha_{(i-1)}$	$a_{(i-1)}$	d_i	θ_i
0	0	0	0	θ_0
1	0	a_0	0	θ_1
2	-90	a_1	d_2	θ_2

1 , 1.5 , 1

Joint Angle	Link lenght	Link twist	Joint distance
Theta 0	1	0	0
Theta 1	1.5	0	0
Theta 2	1	0	0