Forward and Inverse Kinematics

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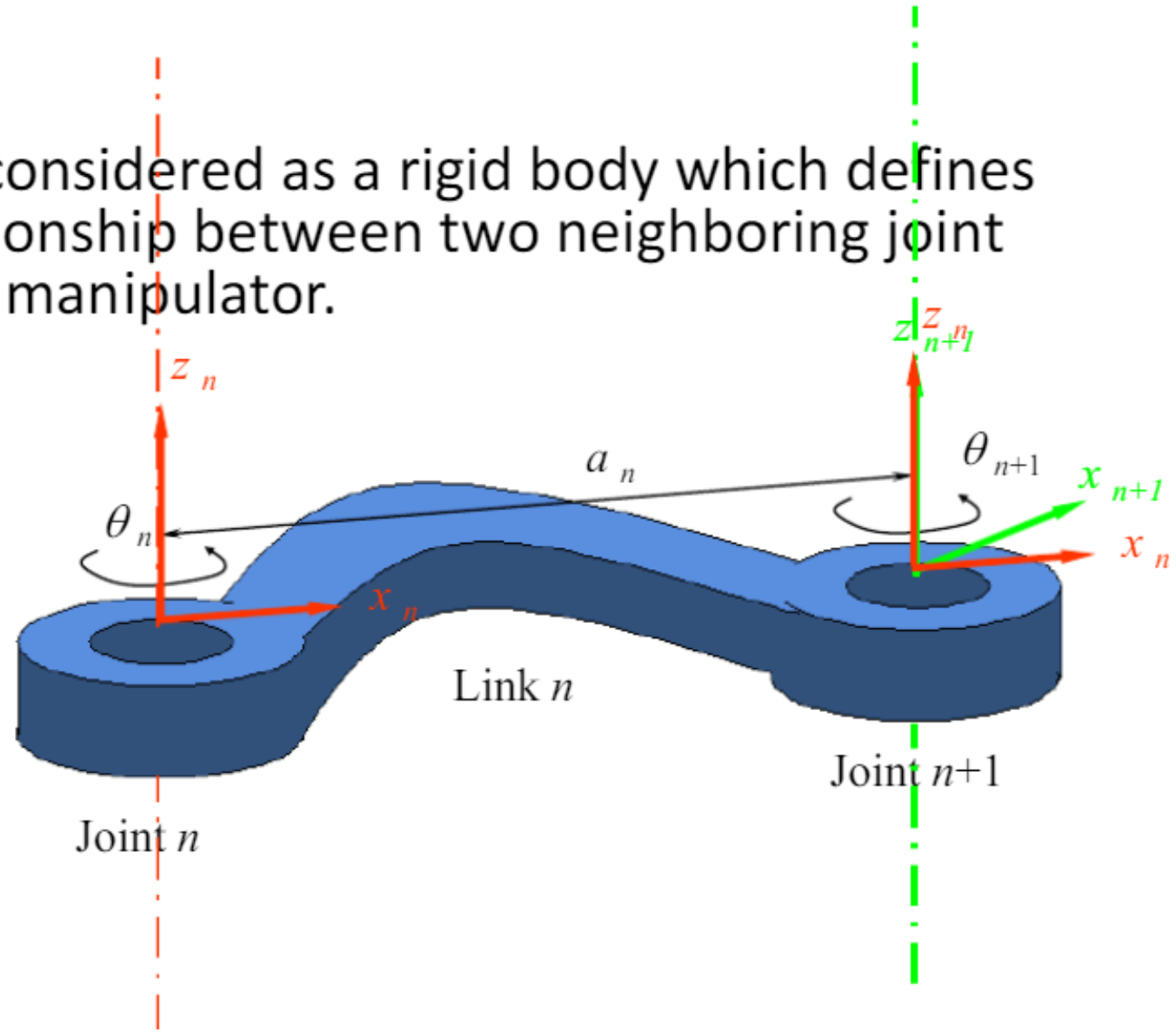
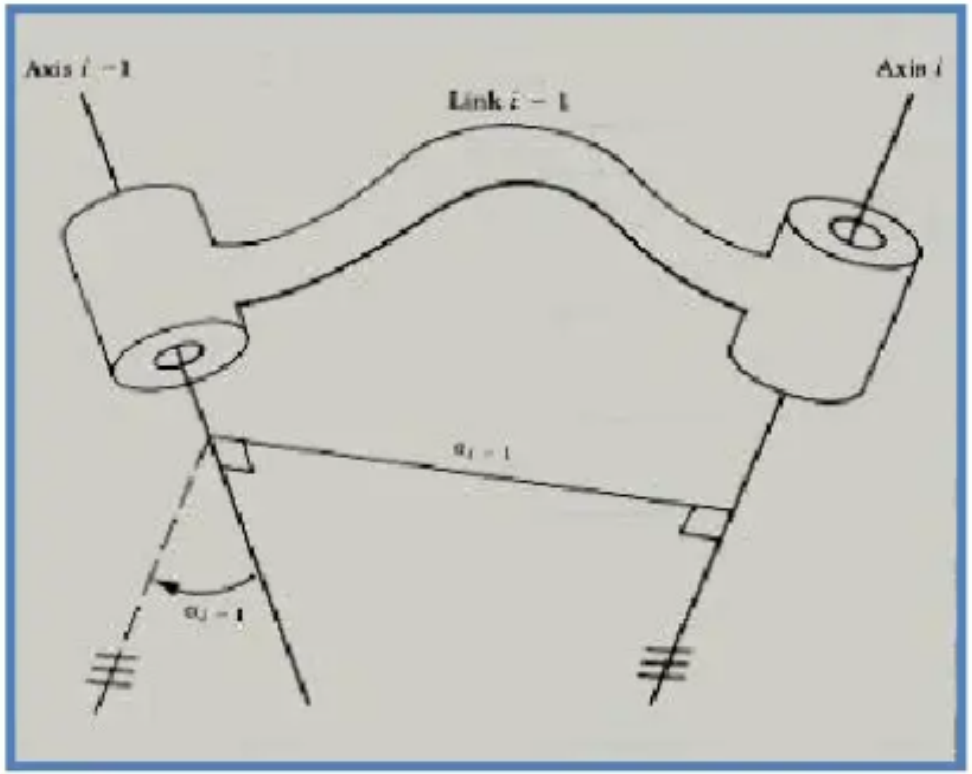
Link

- A link is considered as a rigid body which defines the relationship between two neighboring joint axes of a manipulator.



The Kinematics Function of a Link

- The kinematics function of a link is to maintain a fixed relationship between the two joint axes it supports.
- This relationship can be described with two parameters: the link length a, the link twist α



Link Length

- Is measured along a line which is ***mutually perpendicular*** to both axes.

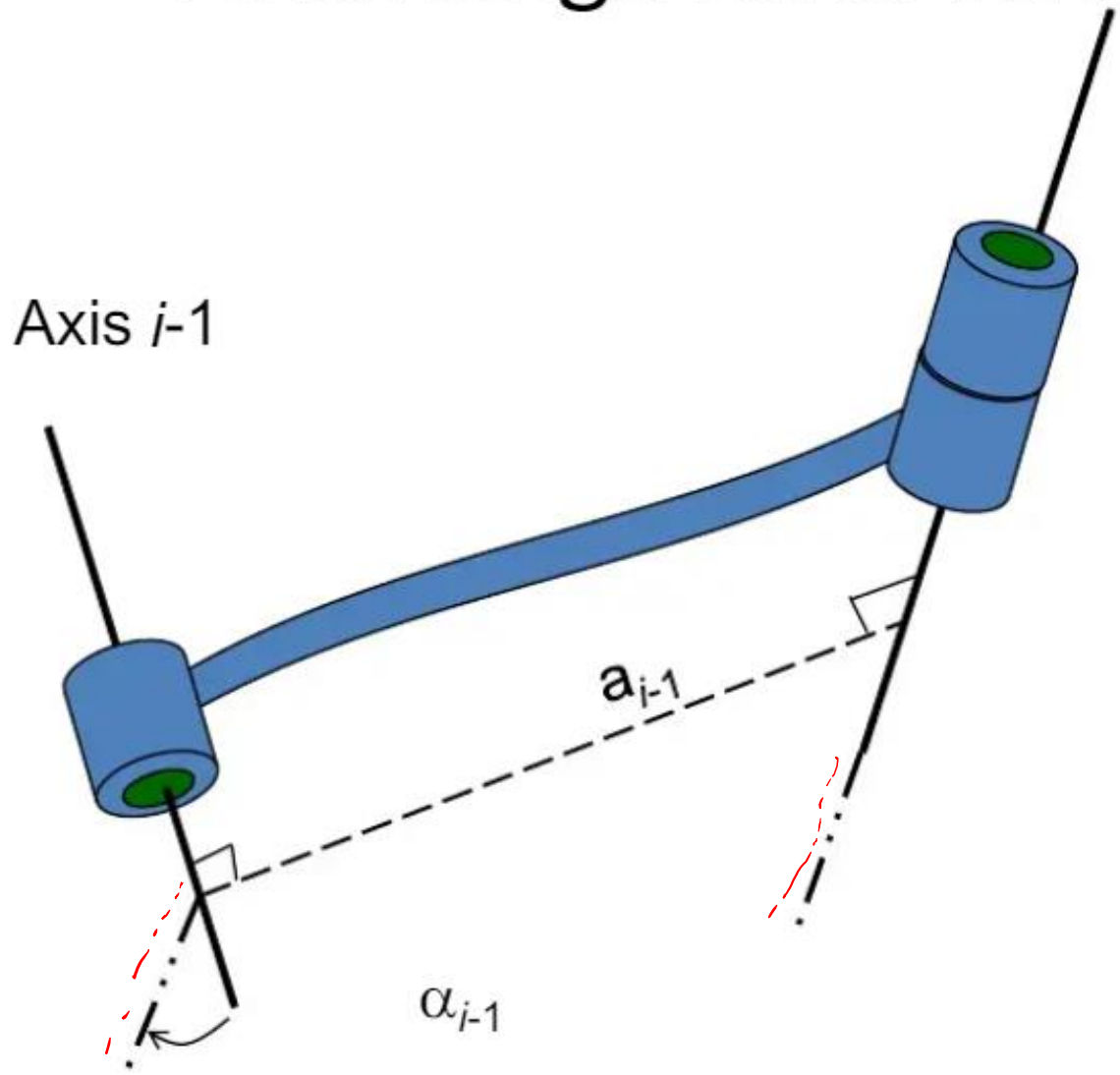
- The mutually perpendicular ***always exists and is unique*** except when both axes are parallel.

Link twist

- Project both axes *i-1* and *i* onto *the plane whose normal is the mutually perpendicular line*, and measure the angle between them

- Right-hand sense

Link Length and Twist



a_{i-1} is measured along the line mutually perpendicular to both axes.

α_{i-1} Project both axes onto the plane which normal is mutually perpendicular line and measure angle.

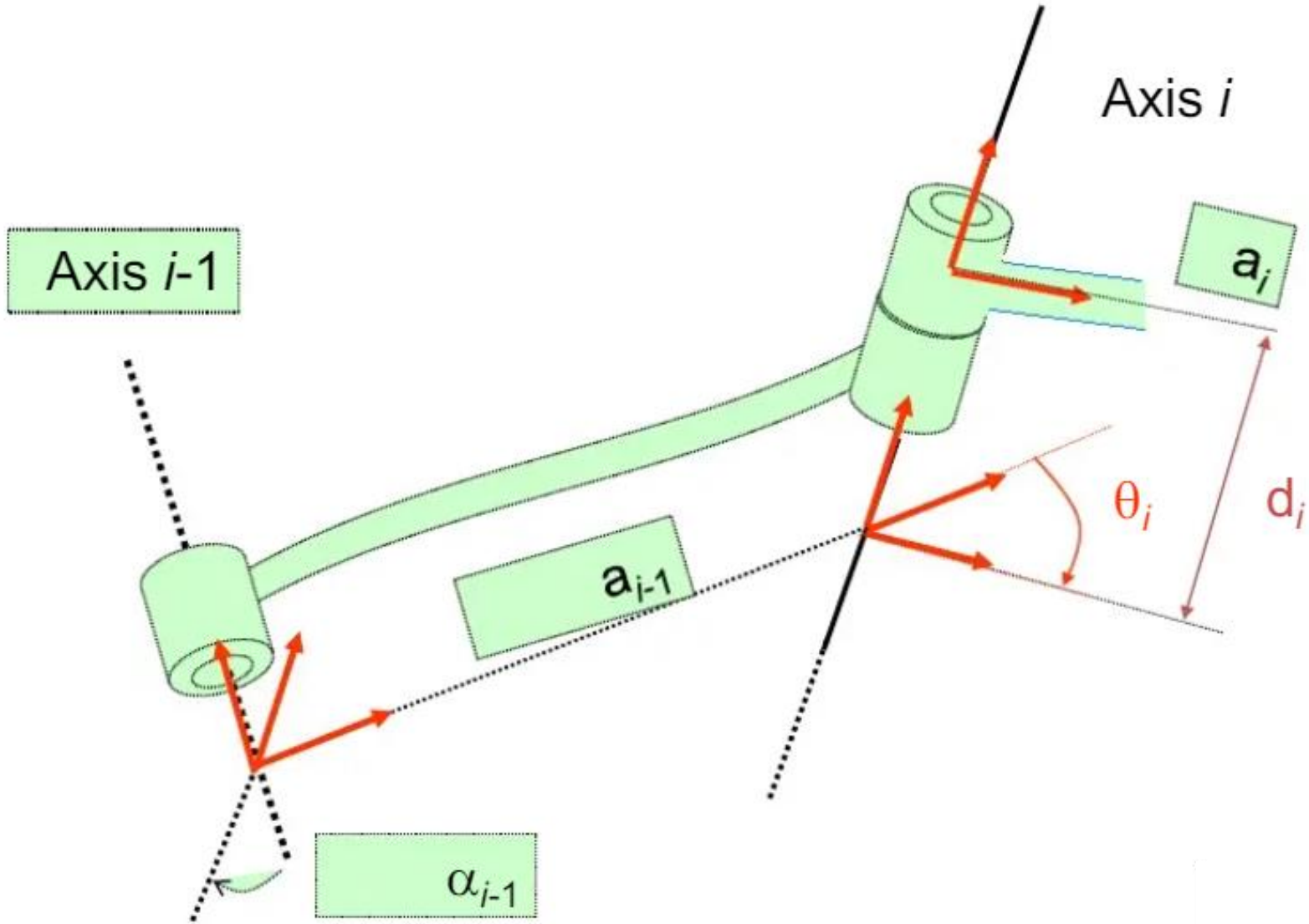
Joint Parameters

A joint axis is established at the connection of two links. This joint will have two normals connected to it one for each of the links.

- The relative position of two links is called *link offset* d_n whish is the distance between the links (the displacement, along the joint axes between the links).

- The *joint angle* θ_n between the normals is measured in a plane normal to the joint axis.

Link and Joint Parameters



Link and Joint Parameters

4 parameters are associated with each link. You can align the two axis using these parameters.

- Link parameters:

a_n the length of the link.

α_n the twist angle between the joint axes.

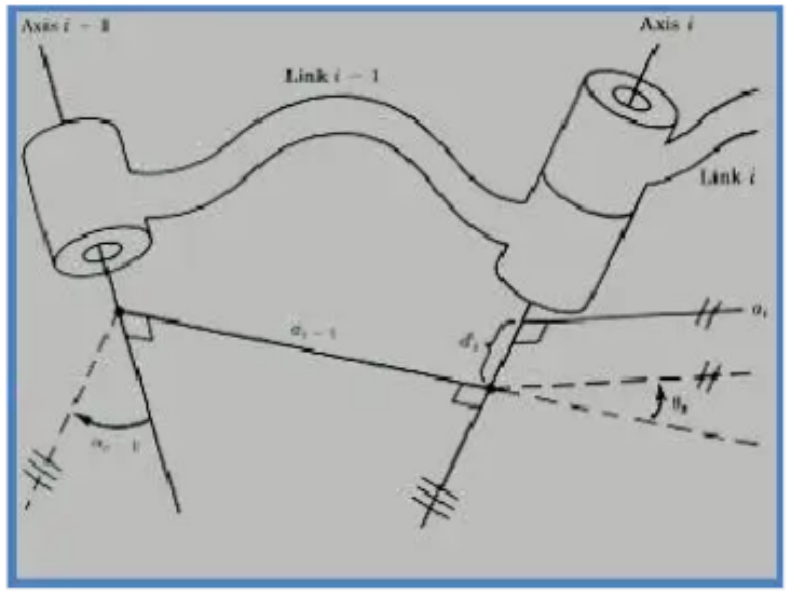
- Joint parameters:

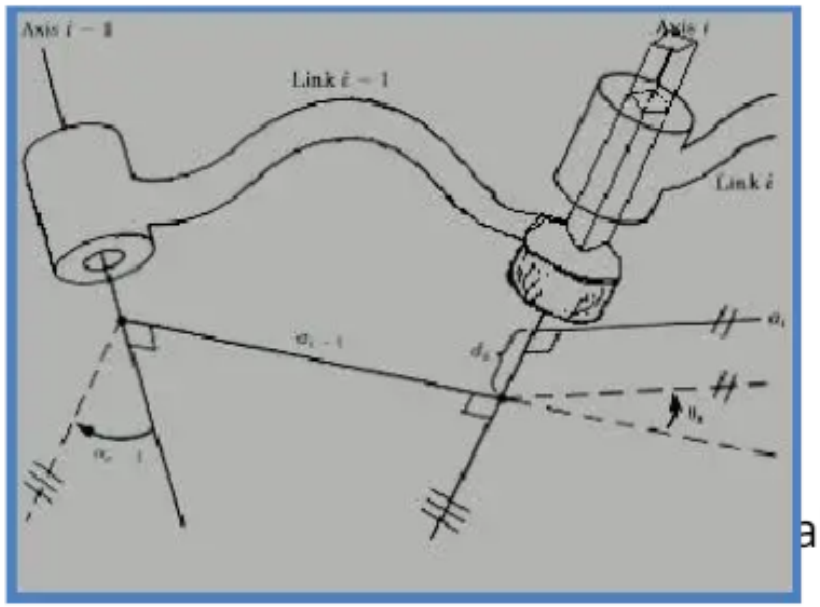
θ_n the angle between the links.

d_n the distance between the links

Link Connection Description:

For Revolute Joints: a, α, and d. are all fixed, then "θ_i" is the. Joint Variable.





For Prismatic Joints: a, α, and θ. all fixed, then "d_i" is the. Joint Variable.

These four parameters: (Link-Length a_{i-1}), (Link-Twist α_{i-1}), (Link-Offset d_i), (Joint-Angle θ_i) are known as the *Denavit-Hartenberg Link Parameters*.

Links Numbering Convention

Base of the arm: Link-0
1st moving link: Link-1

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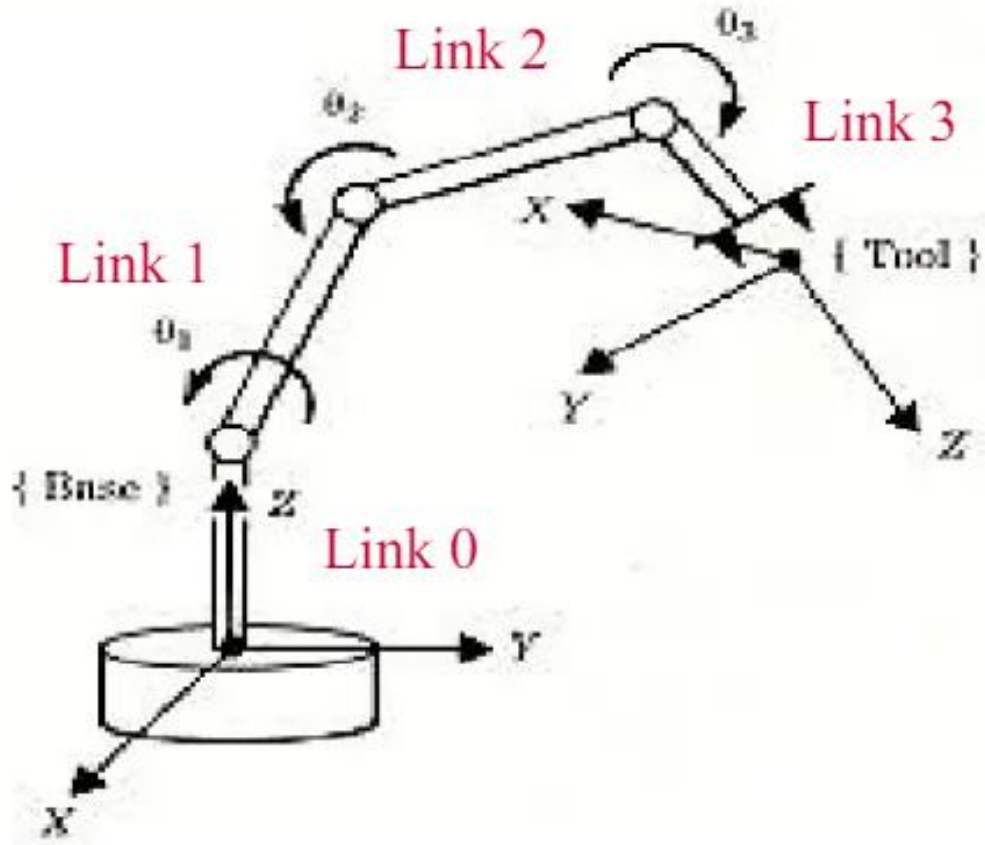
.

Last moving link Link-n



A 3-DOF Manipulator Arm

First and Last Links in the Chain

- $a_{0=}\ \alpha_{n=0.0}$
- $\alpha_{0=}\ \alpha_{n=0.0}$
- *If joint 1 is revolute:* $d_{0=}\ 0$ *and* θ_1 *is arbitrary*
- *If joint 1 is prismatic:* $d_{0=}$ *arbitrary and* $\theta_{1\ =}\ 0$

We are interested in two kinematics topics

Forward Kinematics (angles to position)

What you are given: The length of each link
The angle of each joint

What you can find: The position of any point
(i.e. it's (x, y, z) coordinates

position of end effector/gripper

Inverse Kinematics (position to angles)

What you are given: The length of each link
The position of some point on the robot

position of end effector/gripper

What you can find: The angles of each joint needed to obtain that position

Animation of Forward and Inverse Kinematics

- https://www.youtube.com/watch?v=rIurtdGVQCk