

D-H algorithm

Lecture slide-8

Presented by-

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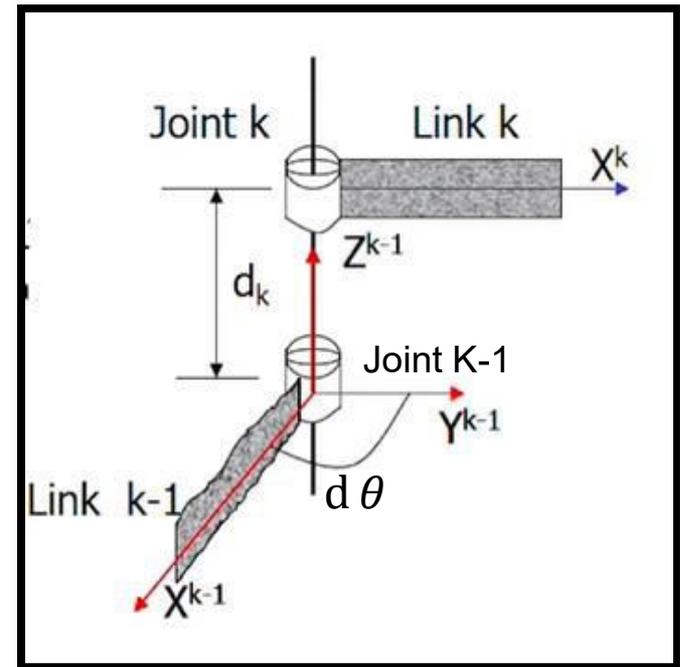
What is DH algorithm?

- ▶ The Denavit-Hartenberg (DH) algorithm is a method for describing the kinematic chains of robotic arms.
- ▶ It uses four parameters to define the transformation between adjacent links.
- ▶ It is used to calculate the kinematics and dynamics of robots.

Joint Parameter

The relative position and orientation of two successive links can be specified by two joint parameter.

Example: In a robotic arm, the rotation of an elbow joint or the extension of a telescopic segment is defined by joint parameters.



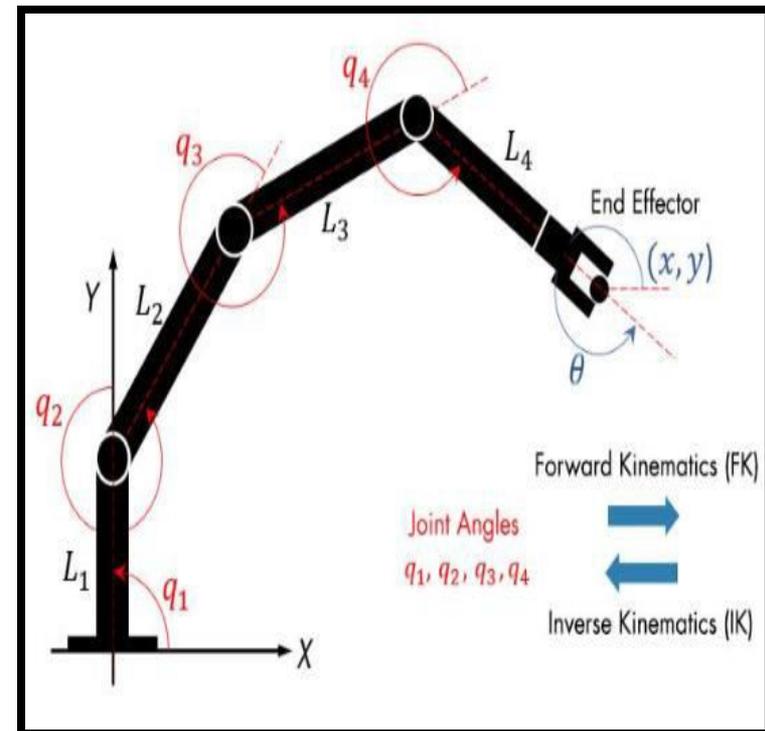
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Joint Parameter

1. Joint Angles: Joint angle represents the angular displacement of a joint from its reference position.

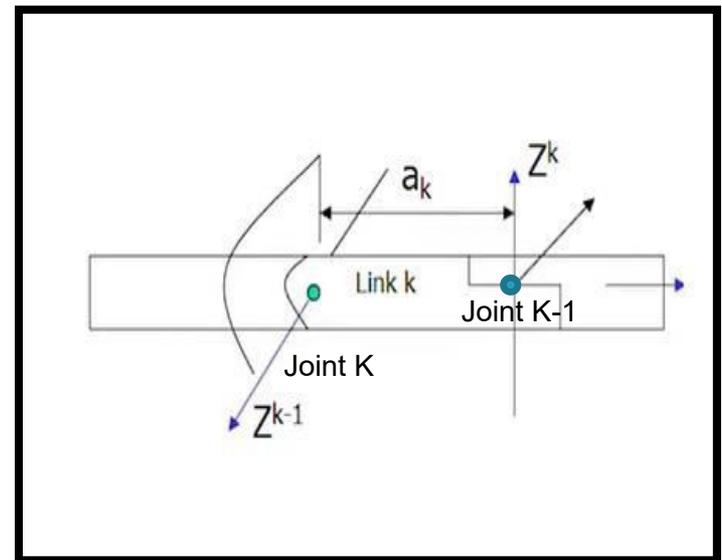
2. joint distance: Joint distance is the distance between the centers of adjacent joints. here, d_k is the joint angle.



Link Parameter

The relative position and orientation of two successive joints can be specified by two link parameter.

Example: The length of a robotic arm segment or the twist angle between two connected segments is defined by link parameters.



Link Parameter

1.Link length: is the translation along X^k needed to make axis Z^{k-1} Intersect Z^k .

2.Twist angle : is the rotation of X^k needed to make axis Z^{k-1} parallel with Z^k .

*****These parameters are constant, as they are determined by the robot's physical structure.**

Kinematics parameter

For **n-axis** robot manipulator, the **4n** kinematic parameters constitute the minimal set needed to specify the kinematic configuration of the robot.

Arm Parameter	Symbol	Revolute Joint (R)	Prismatic Joint (P)
Joint Angle	θ	Variable	Fixed
Joint Distance	d	Fixed	Variable
Link Length	a	Fixed	Fixed
Link Twist angle	α	Fixed	Fixed

Normal, Sliding and Approach vector

Normal vector: Represents the direction perpendicular to the tool's surface (or the x-axis of the end-effector's coordinate frame).

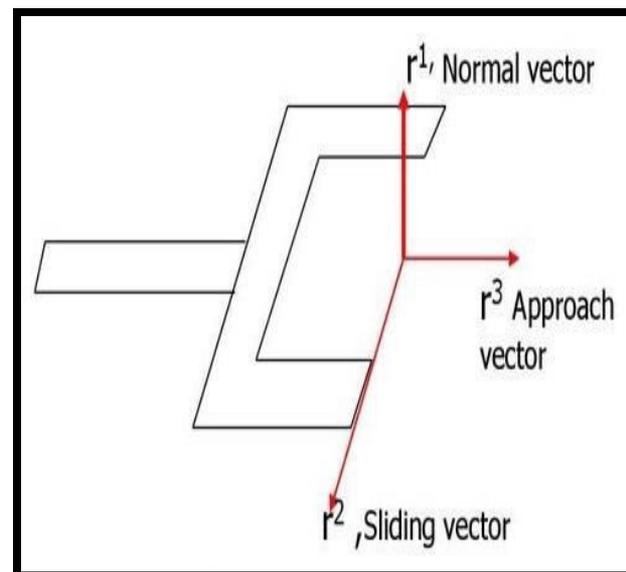
Sliding Vector: Represents the direction parallel to the tool's primary axis of movement (or the y-axis of the end-effector's coordinate frame).

Approach Vector: Represents the direction along which the tool approaches the workpiece or performs operations (or the z-axis of the end-effector's coordinate frame).

$$\begin{pmatrix} N_x & S_x & A_x \\ N_y & S_y & A_y \\ N_z & S_z & A_z \end{pmatrix}$$

Normal, Sliding and Approach vector

- The orientation of a tool can be represented in joint Coordinates by YPR convention.
- In Rectangular or Cartesian coordinates the same can be represented by a rotation matrix $R = [r^1, r^2, r^3]$ where columns of R correspond to the normal, sliding and approach vectors.
- **Yaw, Pitch and Roll motions are rotations about normal, sliding and approach vectors.**



Direct(Forward) Kinematics

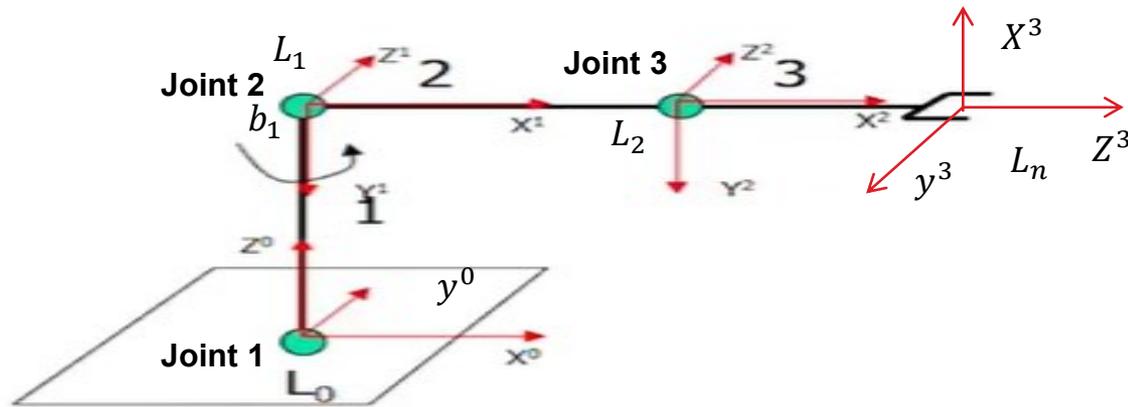
- In order to manipulate objects in space, it is required to control both position and orientation of the tool/end effector in three dimension space.
- A relationship between the joint variables and the position and orientation of the tool id to be formed.

Direct Kinematics Problem:

Given the vector of joint variables of a robotic manipulator, determine the position and orientation of the tool with respect to a coordinate frame attached to the robot base.

1. Number the joints from 1 to n starting with the base and ending with the tool yaw, pitch, and roll in that order.
2. Assign a right-handed orthonormal coordinate frame (L_0) to the robot base, making sure that Z^0 aligns with the axis of joint 1. Set $k=1$.

Direct(Forward) Kinematics



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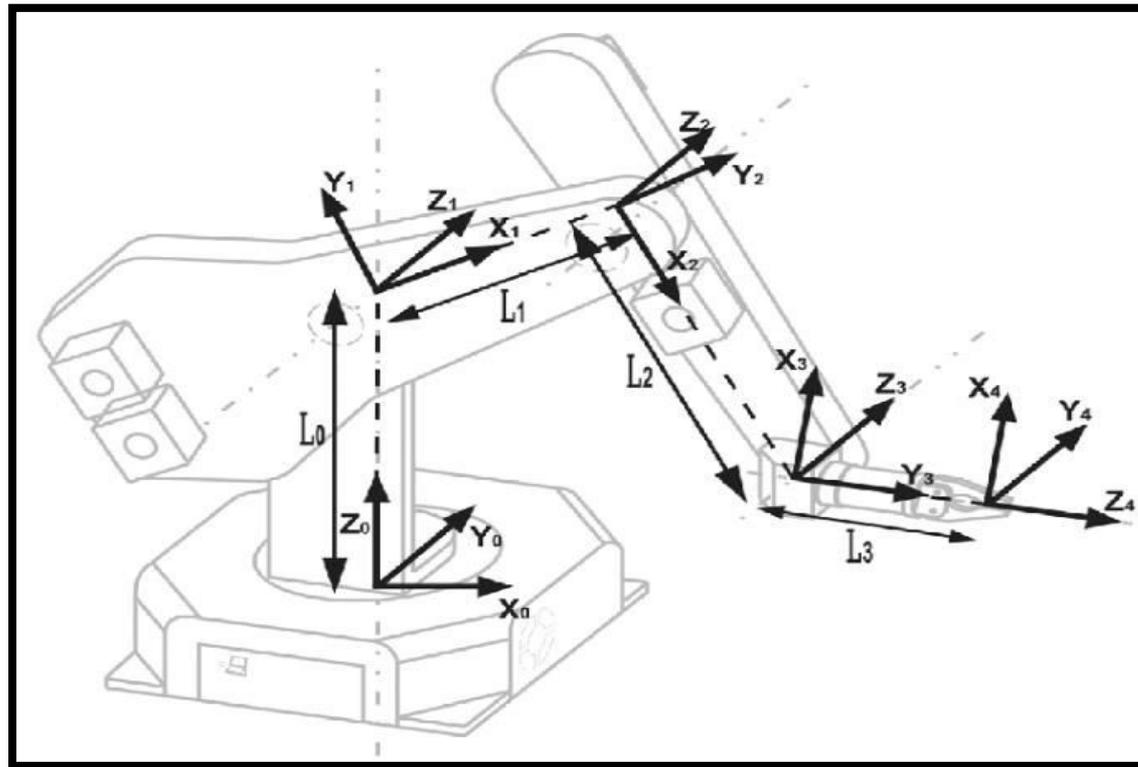
Direct(Forward) Kinematics

3. Align Z^k with the axis of joint $k+1$.
4. Locate origin of L_k at the intersection of the Z^k and Z^{k-1} .
5. Select X^k to be orthogonal to both Z^k and Z^{k-1} . If Z^k and Z^{k-1} are parallel, point X^k away from Z^{k-1} .
6. Select y^k to form a right handed coordinate frame L_k .
7. Set $k = k+1$, if $k < n$ then go to step 2, else continue.
8. Set the origin of L_n at the tool tip. Align Z^n with the approach vector, y^n with the sliding vector, and x^n with the normal vector of the tool. Set $k=1$.
9. Locate point b_k at the intersection of X^k and Z^{k-1} axes. If they do not intersect, use the intersection of X^k with a common normal between X^k and Z^{k-1} .

Direct(Forward) Kinematics

10. Compute θ_k as the angle of rotation from x^{k-1} to X^k measured about Z^{k-1} .
11. Compute d_k as the distance from the origin of frame L_k to point b_k measured along Z^{k-1} .
12. Compute a_k as the distance from the point b_k to the origin of frame L_k measured along X^k .
13. Compute α_k as the angle of rotation from Z^{k-1} to Z^k measured about X^k .
14. Set $k = k+1$, if $k \leq n$, go to step 9; else stop.

Direct(Forward) Kinematics



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Thank you Everyone!

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