ROBOTICS and AUTOMATIONS

Forward Kinematics

Week 5
24/08/2023

Learning outcome: Week 4

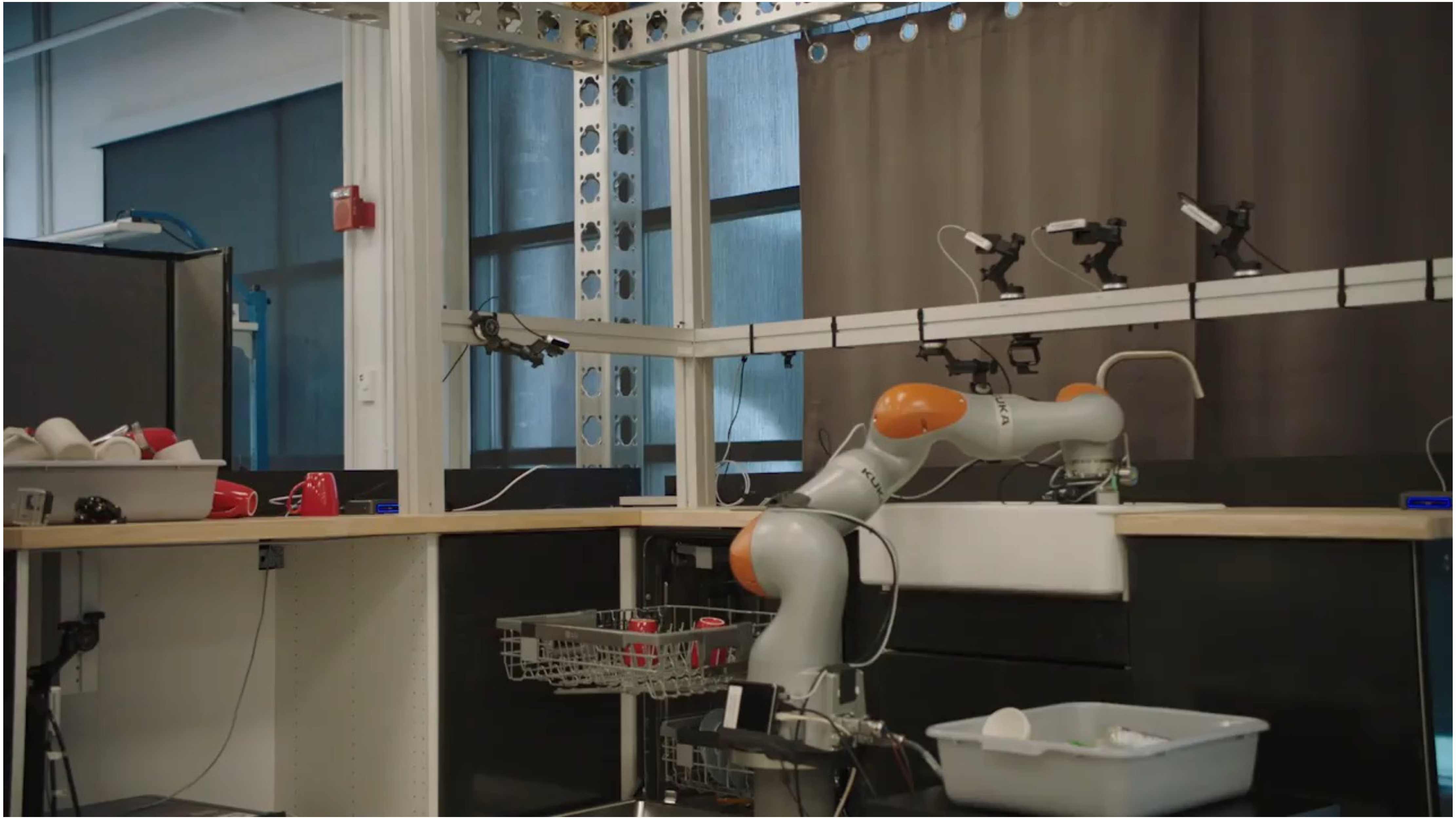
Workshop:

Sensors in industrial Automation

Lecture:

Forward Kinematics

Dish washer robot



https://slides.com/russtedrake/fall21-lec01#/15

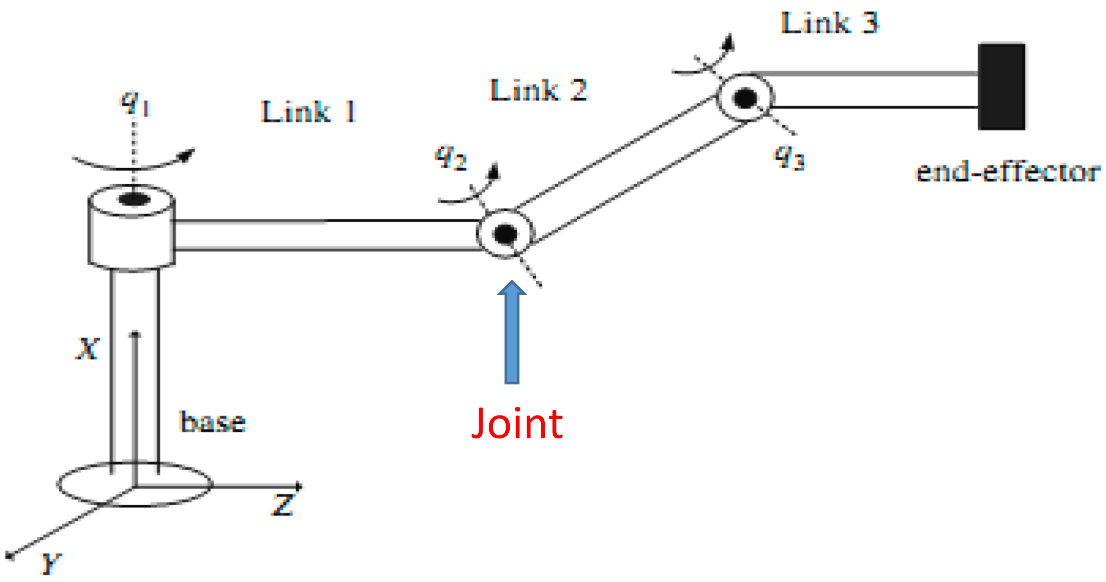

All manipulated objects
in this video have
not been seen before
1x speed

The complexity of grasping in the wild

Kinematics is the science of motion that treats the subject without regard to the forces that cause it.

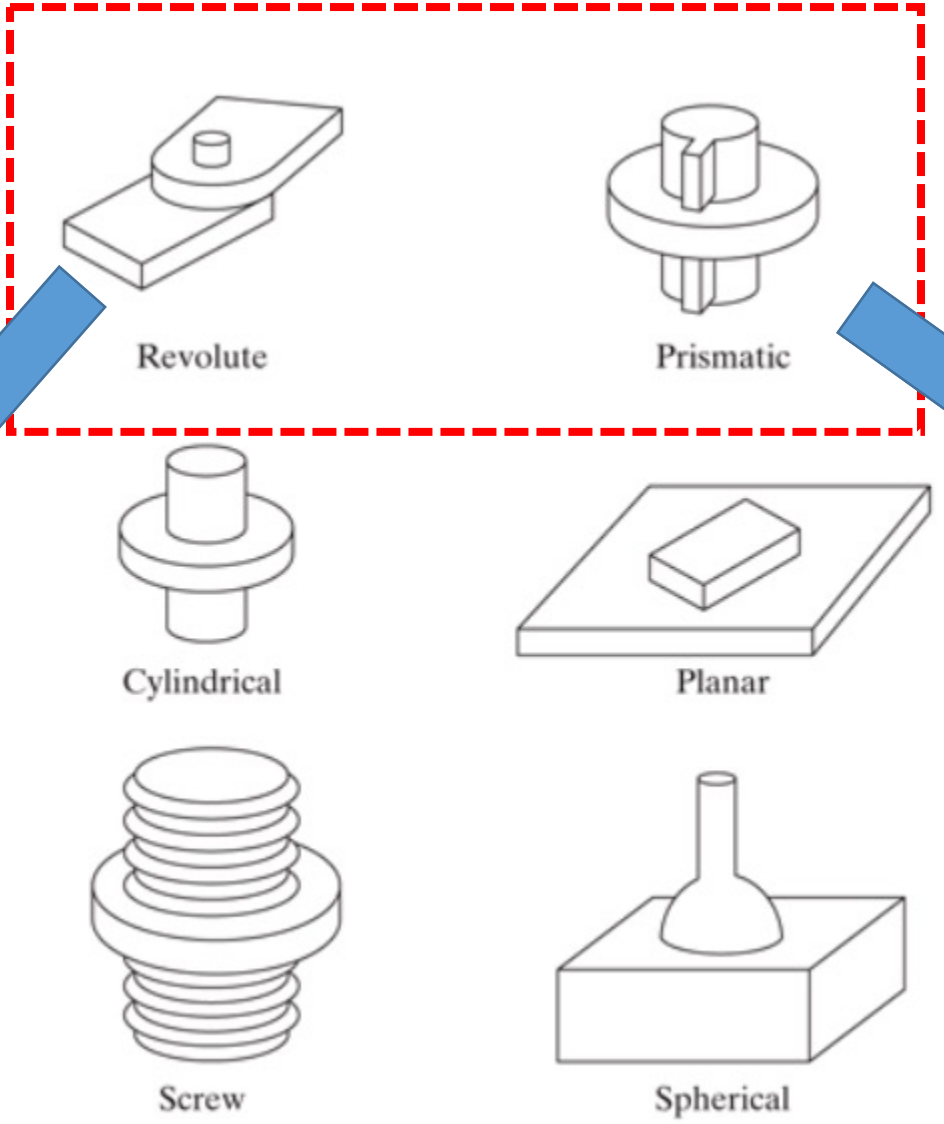
Within the science of kinematics, one studies the position, the velocity, the acceleration, and all higher order derivatives of the position variables [with respect to time or any other variable(s)]. Hence, the study of the kinematics of manipulators refers to all the geometrical and time-based properties of the motion.

The central topic in kinematic is a method to compute the position and orientation of the manipulator's end-effector relative to the base of the manipulator as a function of the joint variables.



In-class assignment, Submit in ilearn

Joint types

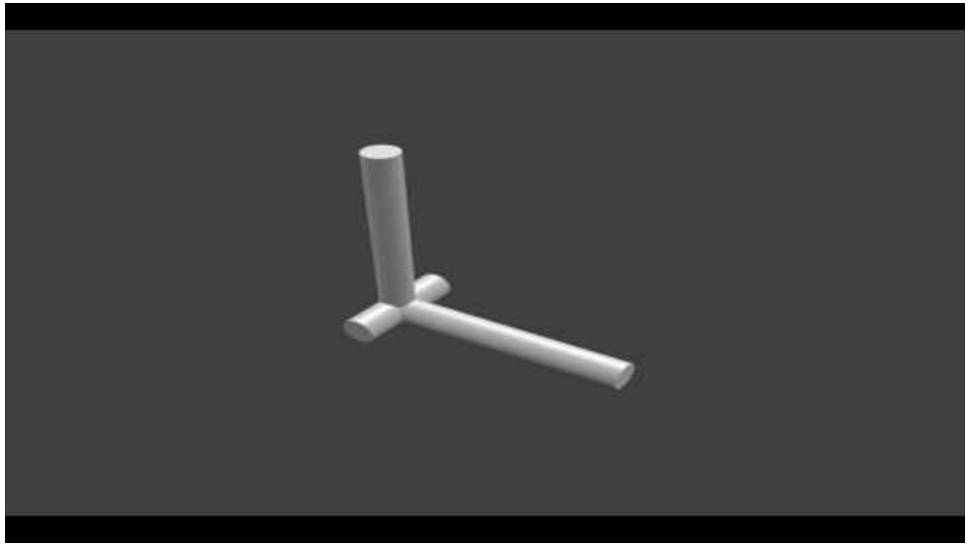


Single-axis rotational joints that connect two rigid links together

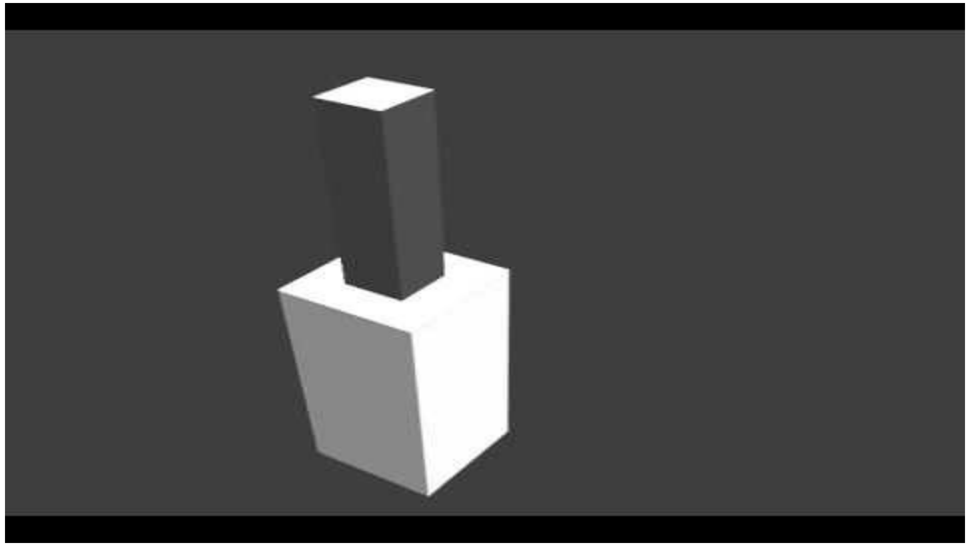
Single-axis translational joints that connect two rigid links together

The six possible lower-pair joints.

Link Description



https://www.youtube.com/watch?v=wwyJS9X3WvE

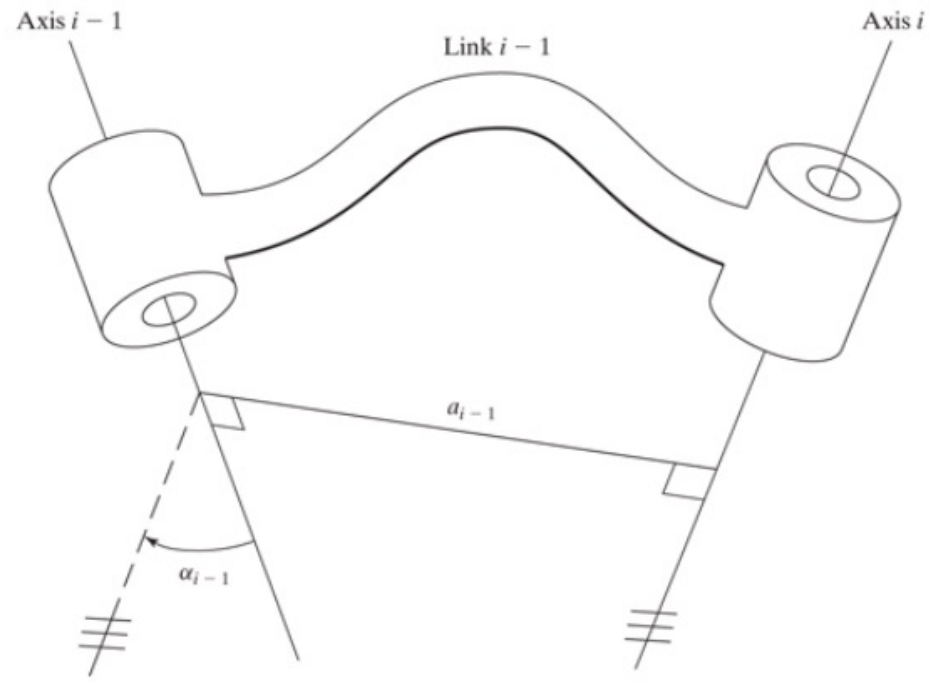


https://www.youtube.com/watch?v=ih3oXigeY-U

Link-Joint Description

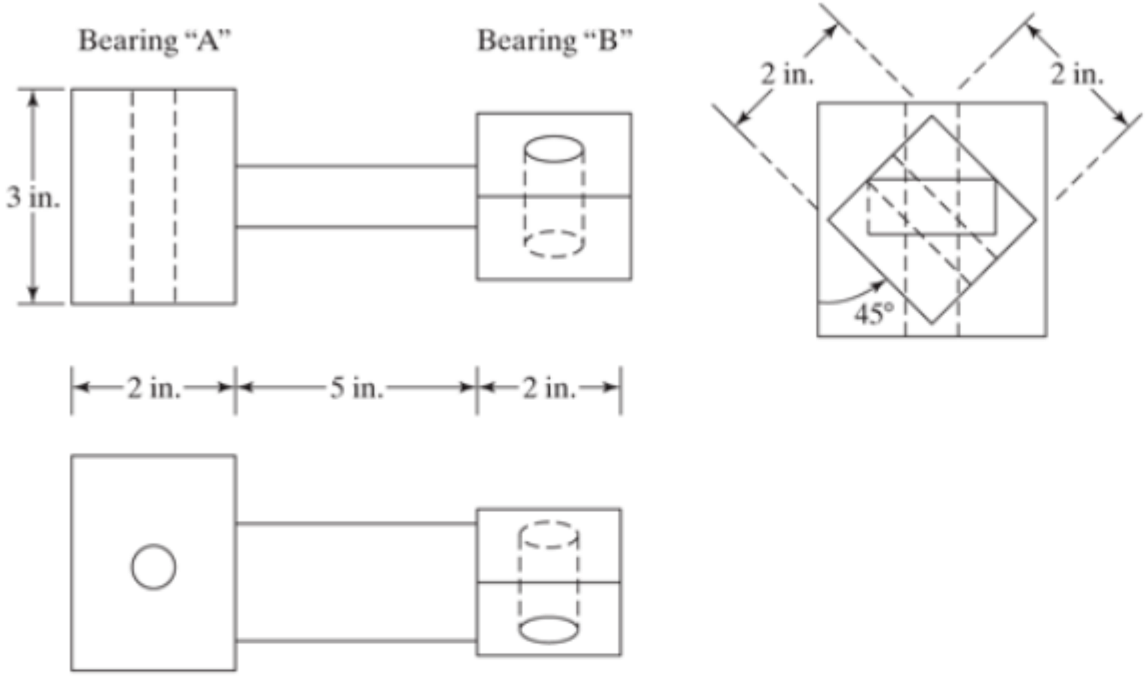
Link-joint pair can be described using four parameters, two that describe the link, and two that describe the joint.

For any two axes in 3-space, there exists a well-defined measure of distance between them. This distance is measured along a line that is mutually perpendicular to both axes. This mutual perpendicular always exists; it is unique except when both axes are parallel, in which case there are many mutual perpendiculars of equal length.



Link-Joint Description

shows the mechanical drawings of a robot link. If this link is used in a robot, with bearing “A” used for the lower-numbered joint, give the length and twist of this link. Assume that holes are centered in each bearing.



Joint description: A robotic manipulator can contain one or more joints. Joints are described using two parameters.

Neighbouring links have a common joint axis between them. One parameter of interconnection has to do with the distance along this common axis from one link to the next. This parameter is called the **joint offset**. The offset at joint axis i is called d_i.

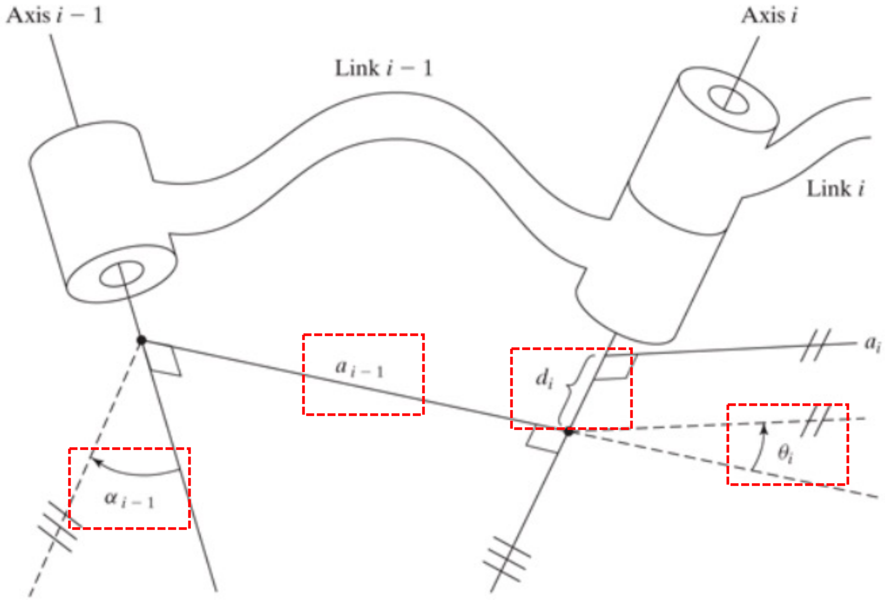
The second parameter describes the amount of rotation about this common axis between one link and its neighbour. This is called the **joint angle**.

For revolute joint, θ is Variable and d is constant.

For prismatic joint, d is variable and θ is constant.

Denavit–Hartenberg notation

any robot can be described kinematically by giving the values of four quantities for each link. Two describe the link itself, and two describe the link's connection to a neighboring link. In the usual case of a revolute joint, θ_i is called the **joint variable**, and the other three quantities would be fixed **link parameters**. For prismatic joints, d_i is the joint variable, and the other three quantities are fixed link parameters. The definition of mechanisms by means of these quantities is a convention usually called the **Denavit–Hartenberg notation** [1].



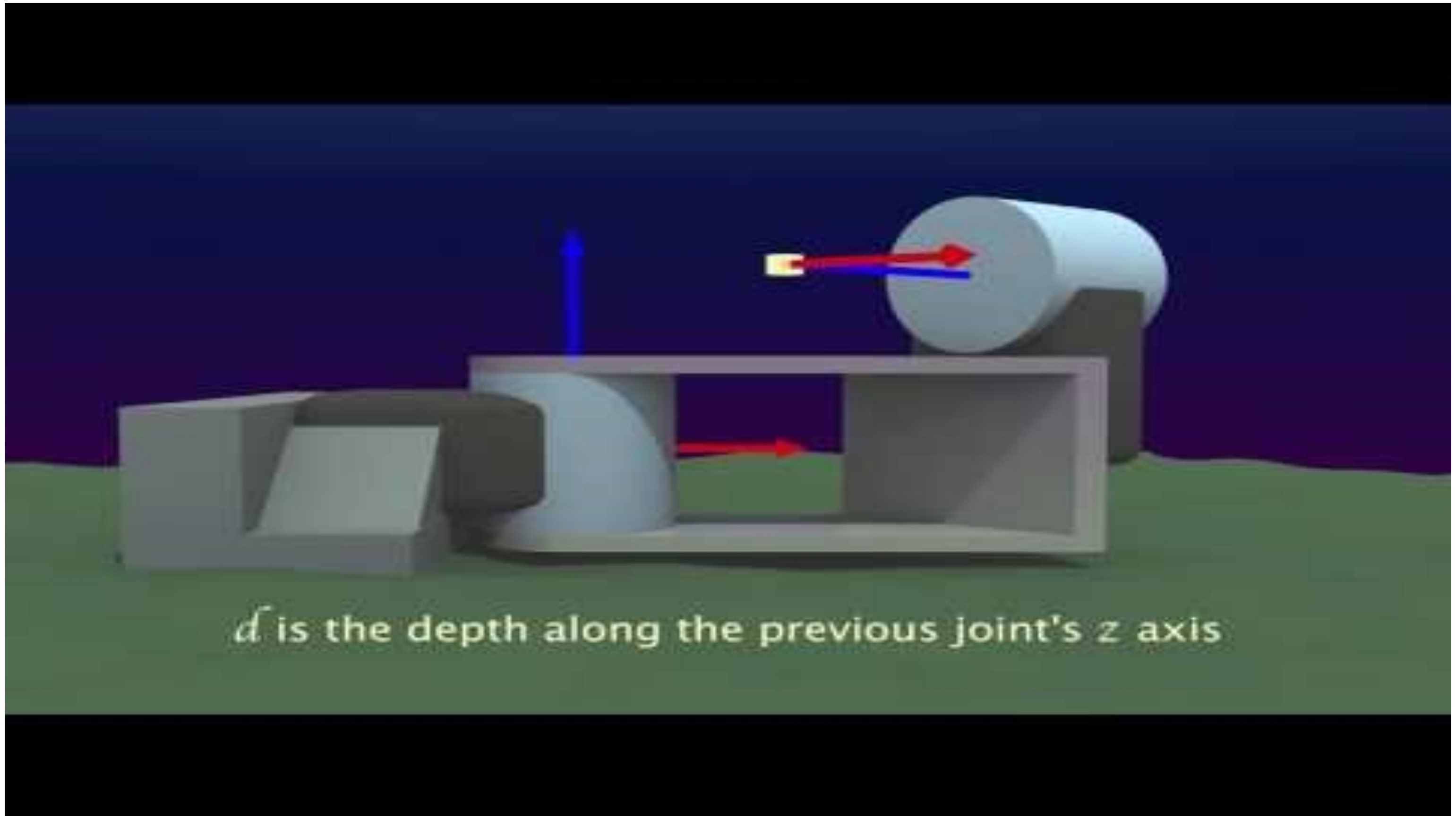
Denavit–Hartenberg notation

For revolute joint, θ is Variable and *d* is constant.

For prismatic joint, *d* is variable and θ is constant.

For convenience and to reduce calculations, it is preferred to set the following parameters to zero (to avoid extra calculations) $a_0=a_n=\alpha_0=\alpha_n=0$ and for revolute joints $d_1=0$, and for prismatic joints $\theta_1=0$

Forward Kinematics

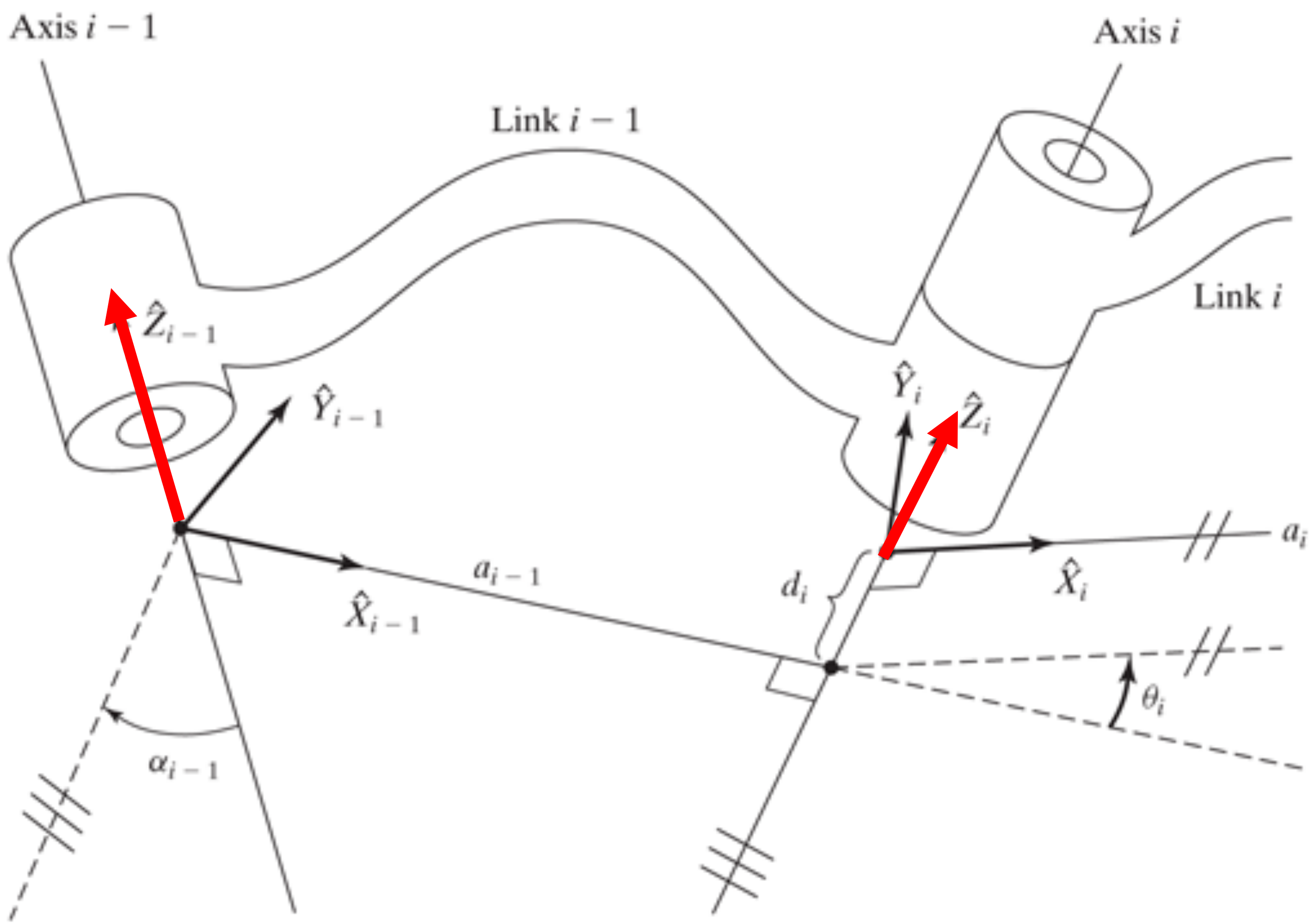


https://www.youtube.com/watch?v=rA9tm0gTln8&t=100s&ab_channel=TekkotsuRobotics

Also see https://blog.robotiq.com/how-to-calculate-a-robots-forward-kinematics-in-5-easy-steps

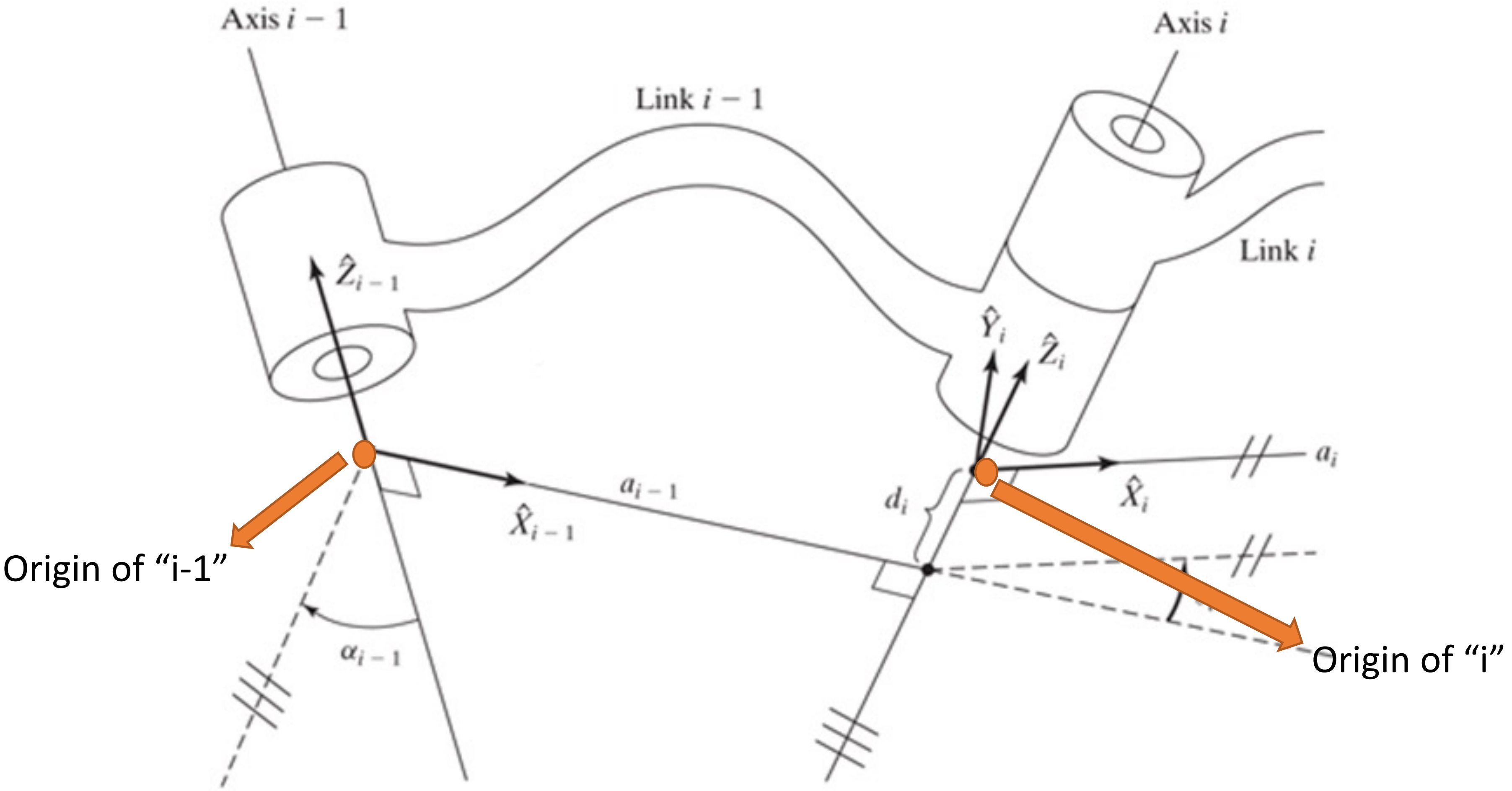
Procedure for frame assignment: (attach frame {i} to link "i")

1) Z-axis: Assign all z-axis along the axis of the rotation (for revolute joints) or axis of translation (for prismatic joints). Choose either of the two directions.



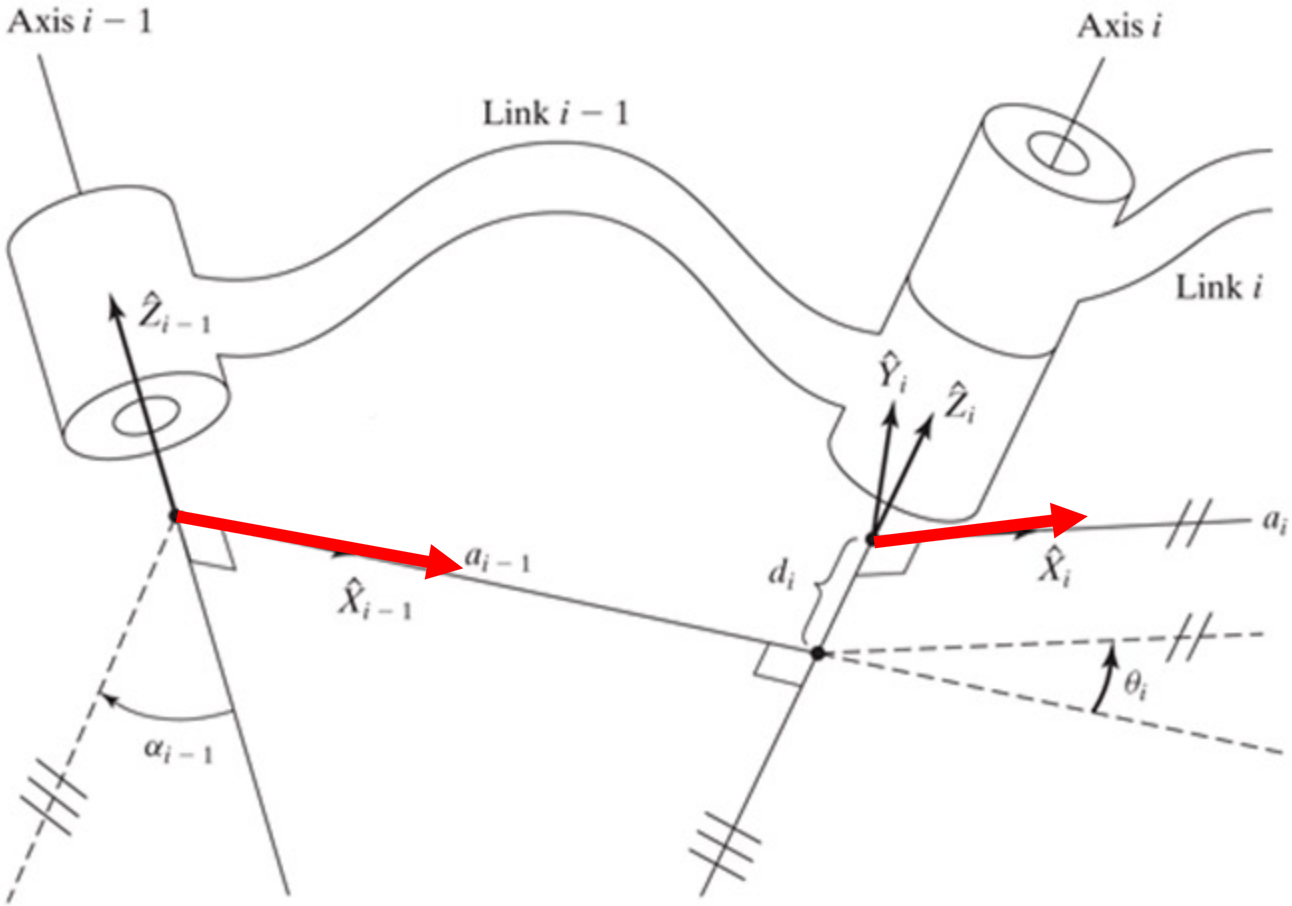
Procedure for frame assignment: (attach frame {i} to link “i”)

2) Frame origins. Identify the common perpendicular between z-axis, or the point of intersection between them. These intersections will be the frame origins.



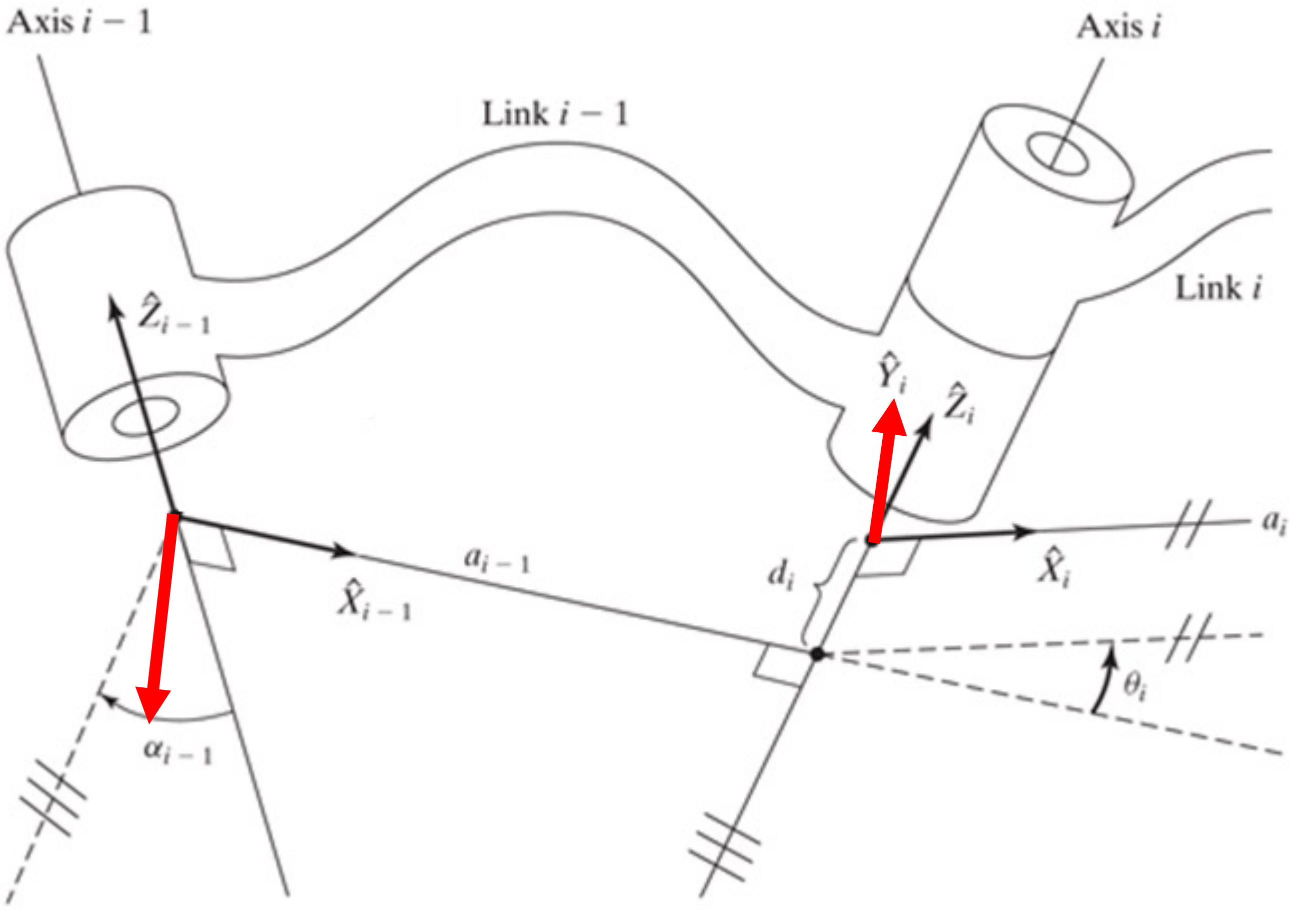
Procedure for frame assignment: (attach frame {i} to link "i")

3) X-axes: Assign all x-axes starting from the frame origin and pointing towards the next joint along the common perpendicular.



Procedure for frame assignment: (attach frame {i} to link "i")

4) Y-axes: Assign all y-axes to complete the right-hand rule (when the hand is flat open, the thumb is pointing towards the z-axis, the four fingers are pointing towards the x-axis, then moving the four fingers 90 degrees will indicate the direction of the y-axis).



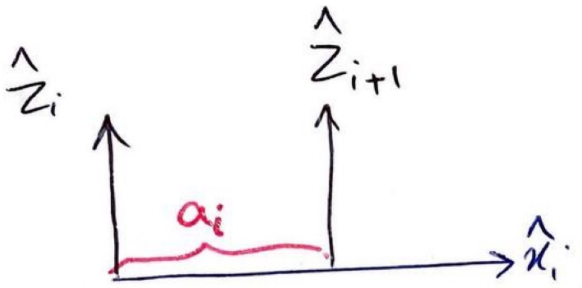
Procedure for frame assignment: (attach frame {i} to link "i")

5) Frame {0} (ground frame-does not move): Assign frame {0} to match frame {1} when the first joint variable is zero. This is recommended for convenience so that some DH parameters can be set to zero to reduce calculations. Otherwise, frame {0} can be assigned arbitrarily.

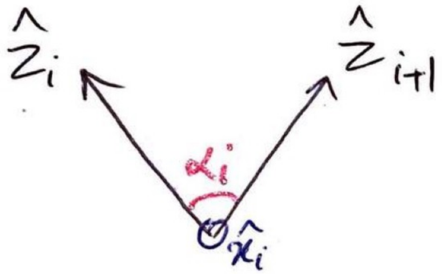
6) Frame {n}-or frame gripper: Assign frame {n} such that as many DH parameters as possible can be set to zero.

Procedure for Extracting the DH parameters:

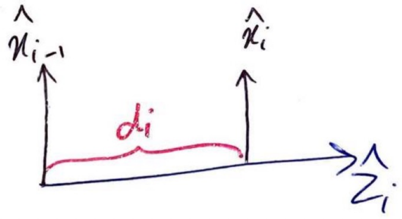
a_i: The distance from z_i and z_{i+1} along x_i



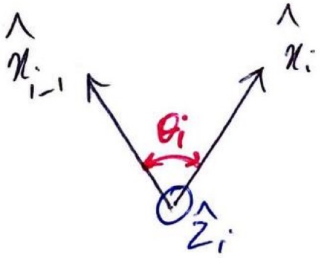
α_i: The angle from z_i and z_{i+1} about x_i



d_i: The distance from x_{i-1} and x_i along z_i



θ_i: The angle from x_{i-1} and x_i about z_i



$$a_i = \textit{the distance from } \widehat{Z}_i \textit{ to } \widehat{Z}_{i+1} \textit{ measured along } \widehat{X}_i;$$

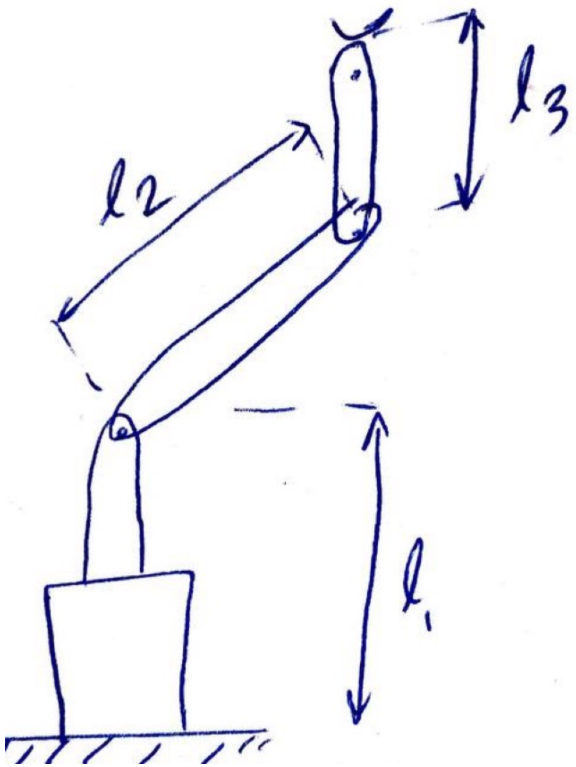
$$\alpha_i = \textit{the angle from } \widehat{Z}_i \textit{ to } \widehat{Z}_{i+1} \textit{ measured about } \widehat{X}_i;$$

$$d_i = \textit{the distance from } \widehat{X}_{i-1} \textit{ to } \widehat{X}_i \textit{ measured along } \widehat{Z}_i; \text{ and}$$

$$\theta_i = \textit{the angle from } \widehat{X}_{i-1} \textit{ to } \widehat{X}_i \textit{ measured about } \widehat{Z}_i.$$

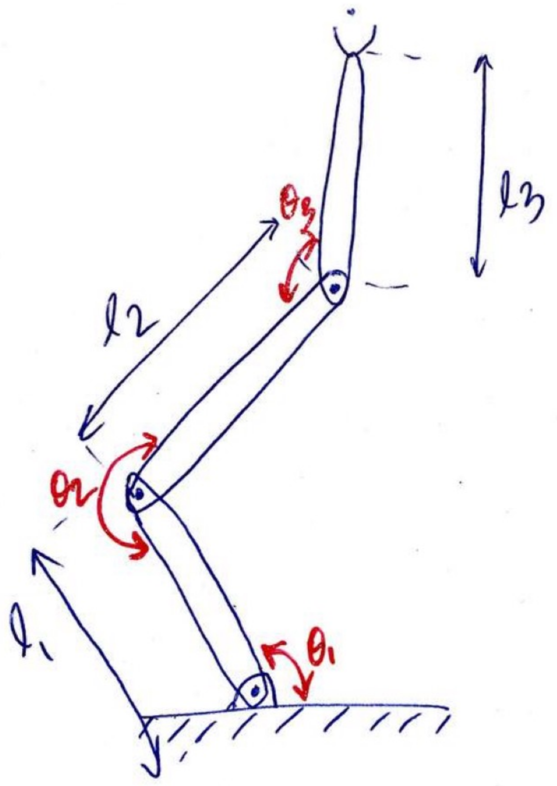
Example 1:

Assign frames {0} to {4} for the shown non-planar 3R robotic manipulator, then find the DH parameters table



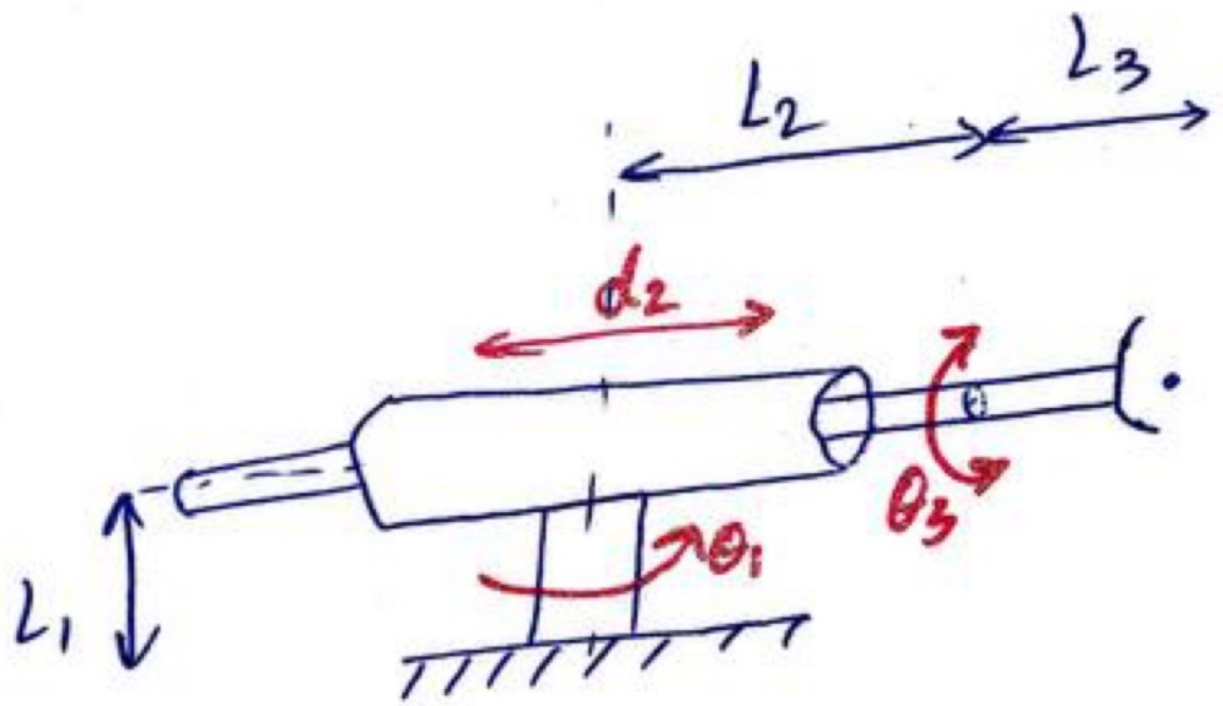
Example 2:

Assign frames {0} to {4} for the shown non-planar 3R robotic manipulator, then find the DH parameters table



Example 3:

Assign frames {0} to {4} for the shown non-planar RPR robotic manipulator, then find the DH parameters table



End of week 5