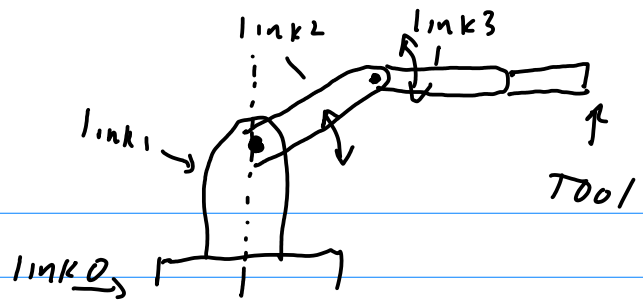


D-H Kinematics

Links & joints

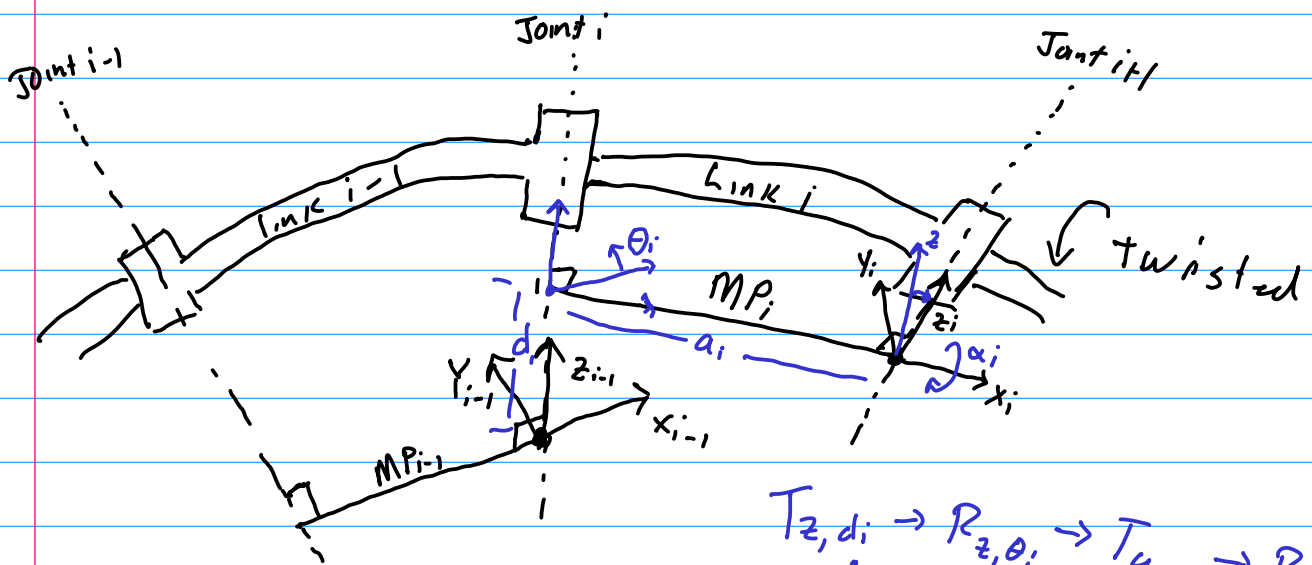
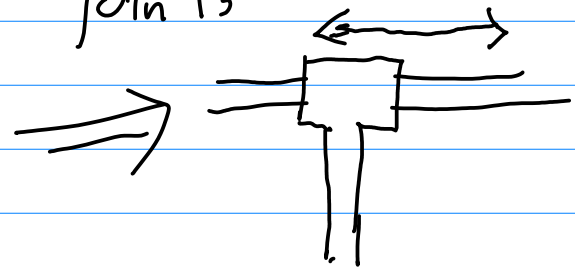


One link-joint pair has one degree of freedom
 Link 0 is the fixed supporting base
 Last link is the tool

Links are numbered outwardly from the base
 Each link is attached to at most two others

We consider two types of joints

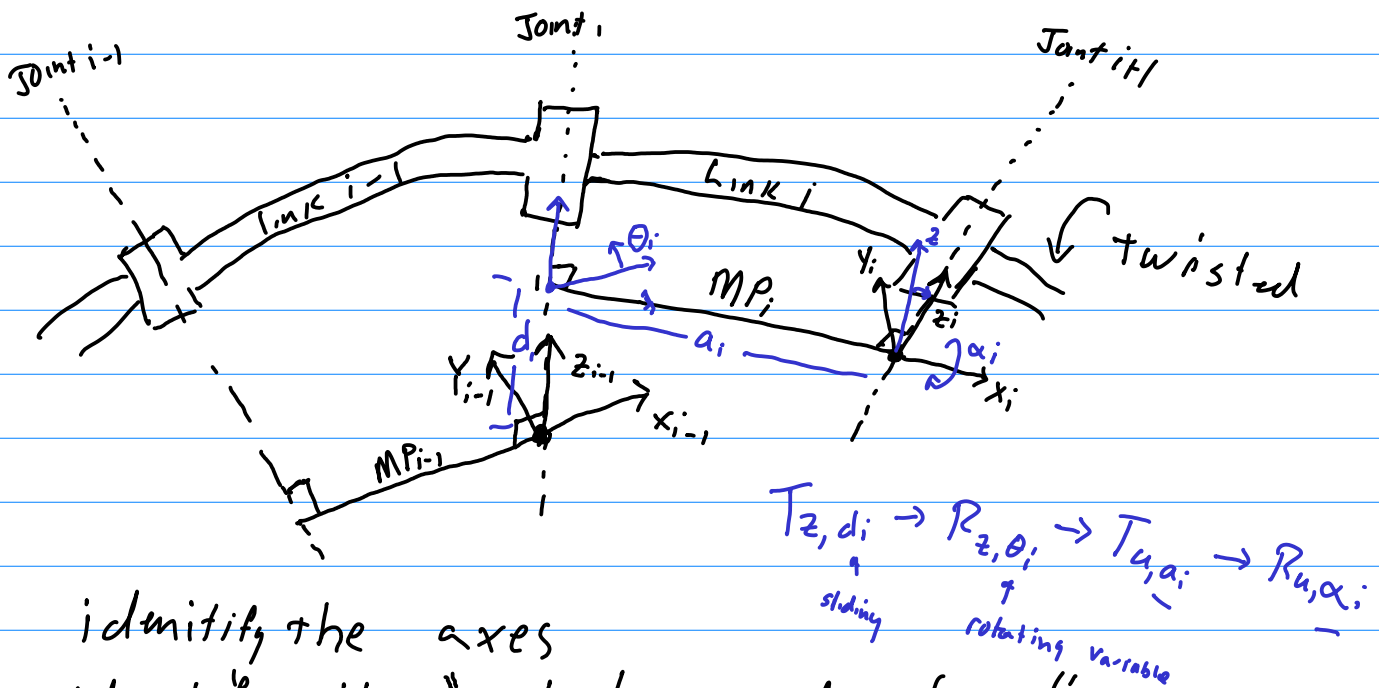
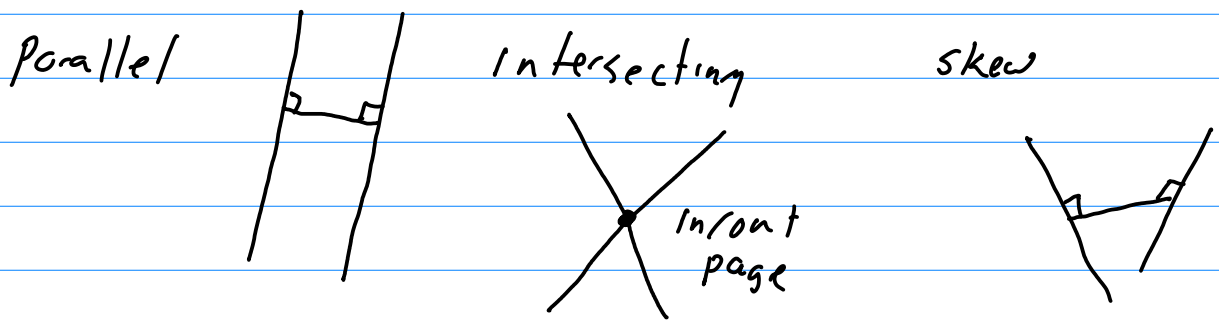
- (1) Revolute (rotating)
- (2) Prismatic (sliding)



$$T_{z, d_i} \xrightarrow{\text{sliding}} R_{z, \theta_i} \xrightarrow{\text{rotating variable}} T_{x, a_i} \xrightarrow{\text{rotating variable}} R_{x, \alpha_i}$$

Identify the axes
 Identify the "mutual perpendiculars"

possibilities for mutual perpendiculars



identifying the axes

identifying the "mutual perpendiculars"

Put origin of frame i at the intersection of MP_i & $J_{int i}$

z_i along $J_{int i}$

x_i extends MP_i

y_i by right-hand rule

Frame 0 origin anywhere on J_1 , x_0 & y_0 wherever

Joint Parameter

Table

	d_i	θ_i	a_i	α_i
1	0	θ_1	20	90
2	10	θ_2	20	180
3	d_i	0	15	90
4				
5				

$$T_{z,d_i} \rightarrow R_{w,\theta_i} \rightarrow T_{u,a_i} \rightarrow R_{u,\alpha_i}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} c\theta_i & -s\theta_i & 0 & 0 \\ s\theta_i & c\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & c\alpha_i & -s\alpha_i & 0 \\ 0 & s\alpha_i & c\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

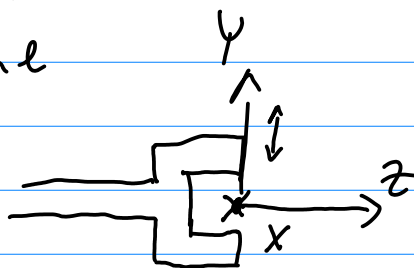
T_{z,d_i} R_{w,θ_i} T_{u,a_i} R_{u,α_i}

$$\begin{bmatrix} c\theta_i & -s\theta_i & 0 & 0 \\ s\theta_i & c\theta_i & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & c\alpha_i & -s\alpha_i & 0 \\ 0 & s\alpha_i & c\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i c\alpha_i & s\theta_i s\alpha_i & a_i c\theta_i \\ s\theta_i & c\theta_i c\alpha_i & -c\theta_i s\alpha_i & a_i s\theta_i \\ 0 & s\alpha_i & c\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End-effector frame

if possible

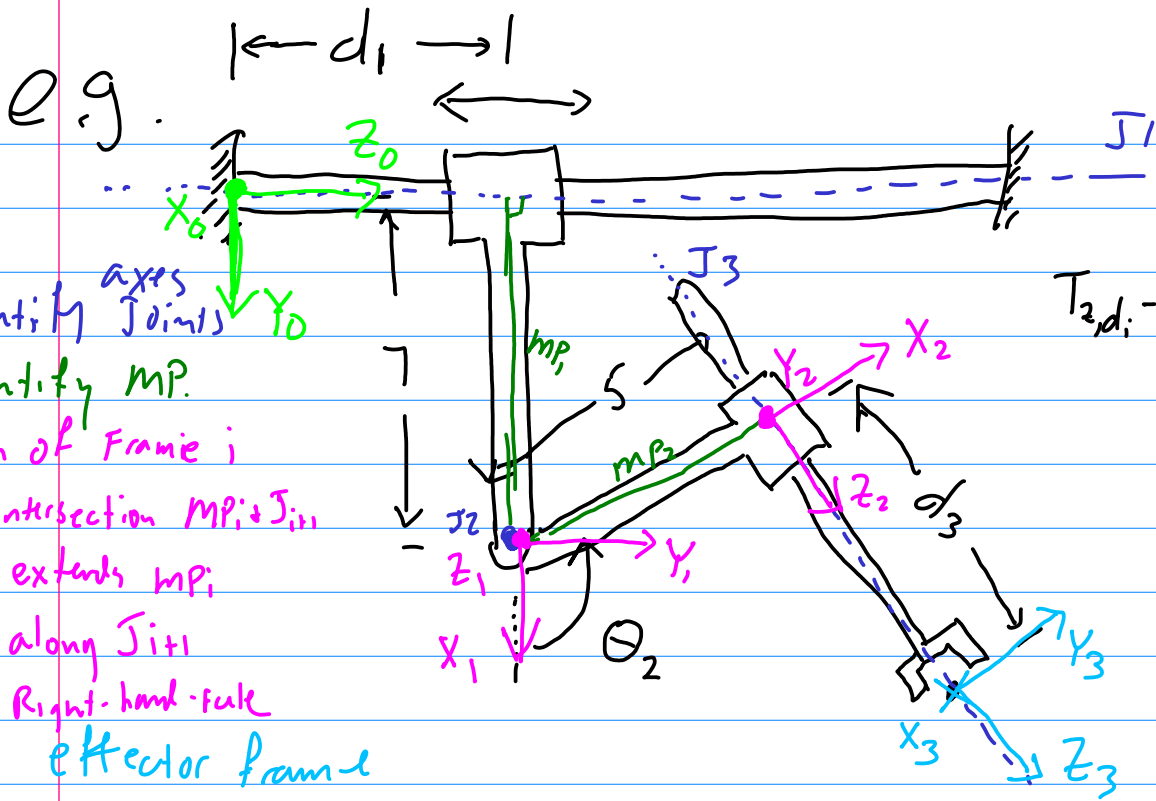


Origin at "finger tips"

z-out

x - towards "palm"

y - direction of finger motion



$$T_{2,d_1} \rightarrow R_{z,\theta_1} \rightarrow T_{1,a_1} \rightarrow R_{x,\alpha_1}$$

Identify axes
Identify Joints

Identify MP.

Origin of Frame i

@ intersection $MP_i + J_{i+1}$

x_i extends MP_i

z_i along J_{i+1}

y_i Right-hand-rule

End effector frame

follow convention

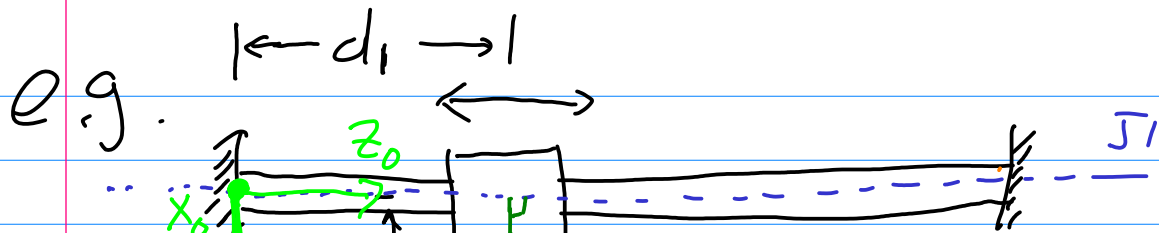
if possible

Frame 0

Origin on J_1

XY - mutually perpendicular

	d_i	θ_i	a_i	α_i
1	d_1	90	7	90
2	0	θ_2	5	90
3	d_3	-90	0	0



Identity axes
Identity Joints

Identity MP.

Origin of Frame i

@ intersection $MP_i + J_{i+1}$

X_i extends MP_i

Z_i along J_{i+1}

Y_i Right-hand-rule

End effector frame

follow convention

if possible

Frame 0

Origin on J_1

XY - mutually perpendicular

$$T_{2,d_1} \rightarrow R_{2,\theta_1} \rightarrow T_{3,a_2} \rightarrow R_{3,\alpha_2}$$

	d_i	θ_i	a_i	α_i
1	d_1	90	7	90
2	0	$\theta_2 + 90^\circ$	5	90
3	d_3	-90	0	0

