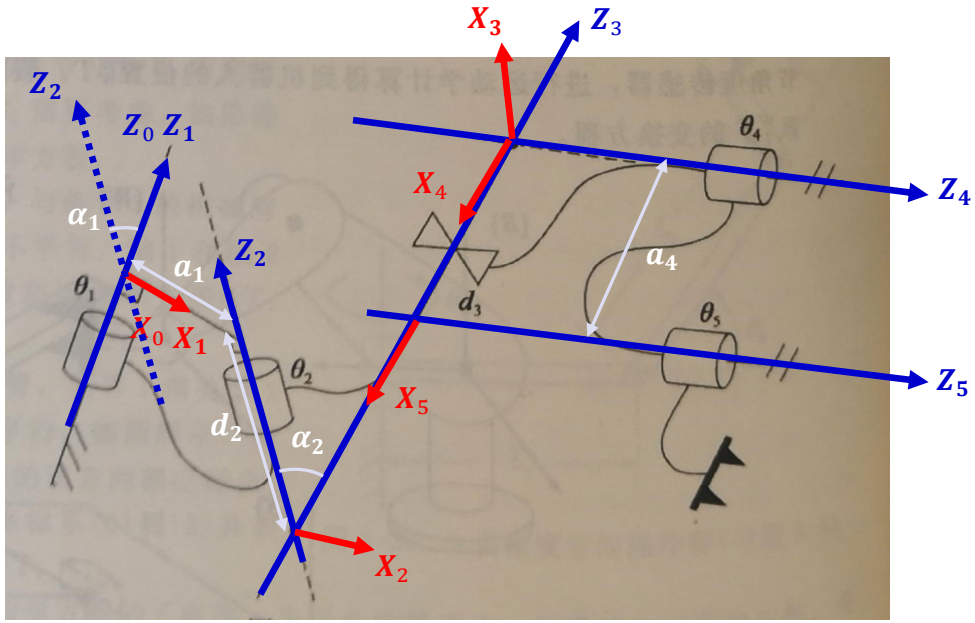
作 业

3.13



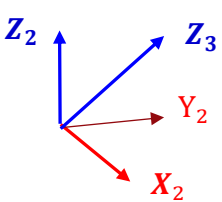
DH参数表

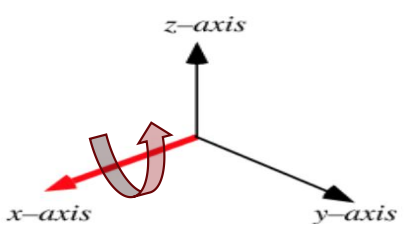
关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	0	θ_1
2	α_1	a_1	$-d_2$	θ_2
3	$-\alpha_2$	0	d_3	$-\theta_3$*
4	$-\alpha_3$	0	0	θ_4
5	0	a_4	0	θ_5

问题1：

第3个关节α_{i-1}：绕X_2轴，从Z_2旋转到Z_3

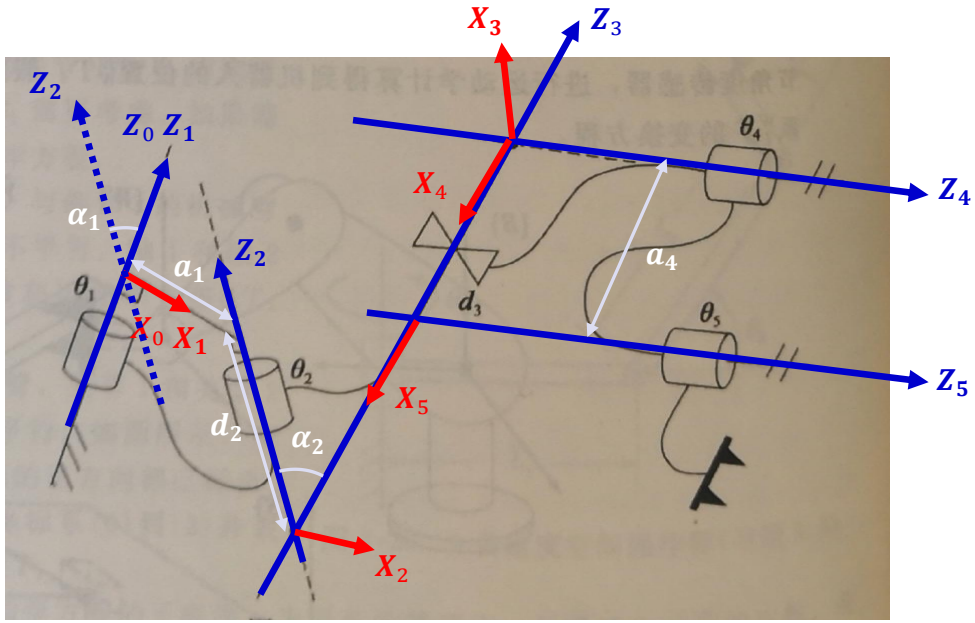
$-\alpha_2$





作 业

3.13



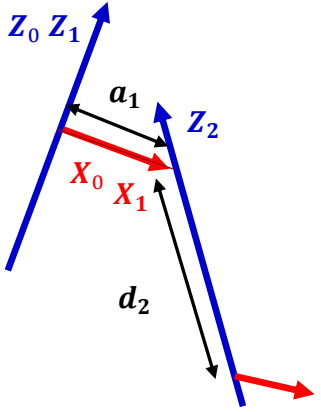
DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	0	θ_1
2	α_1	a_1	$-d_2$	θ_2
3	$-\alpha_2$	0	d_3	$-\theta_3*$
4	$-\alpha_3$	0	0	θ_4
5	0	a_4	0	θ_5

问题2：

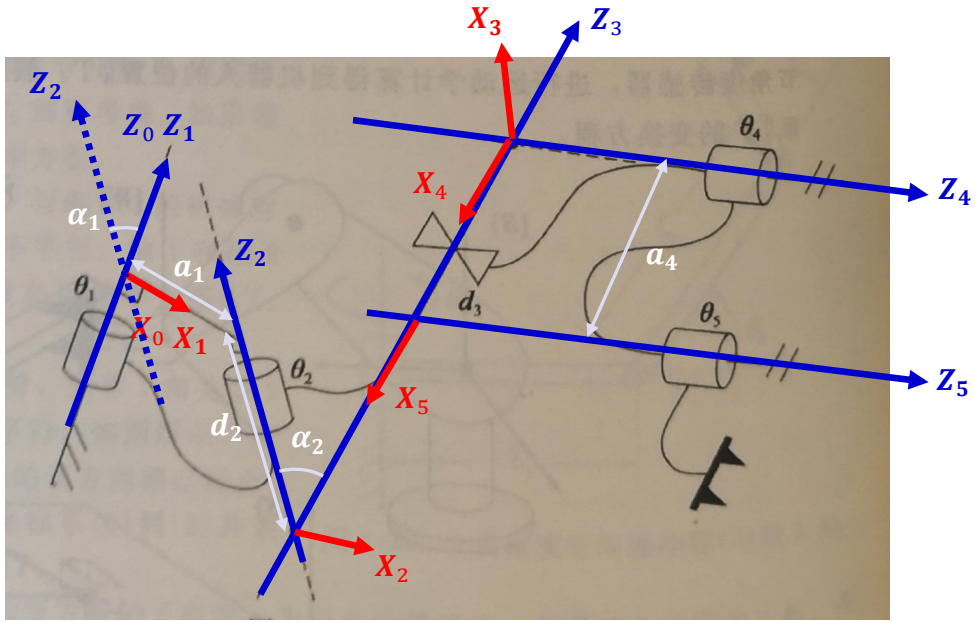
第2个关节d_i：绕Z_2轴，从X_1移动到X_2

$-d_2$



作 业

3.13



DH参数表

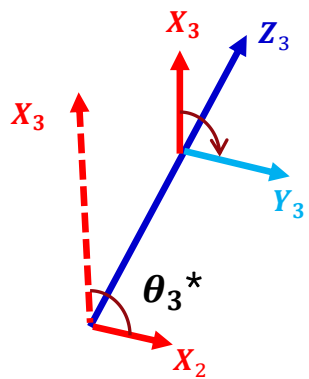
关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	0	θ_1
2	α_1	a_1	$-d_2$	θ_2
3	$-\alpha_2$	0	d_3	$-\theta_3^*$
4	$-\alpha_3$	0	0	θ_4
5	0	a_4	0	θ_5

问题3：

第3个关节是平动关节，d_3是变量

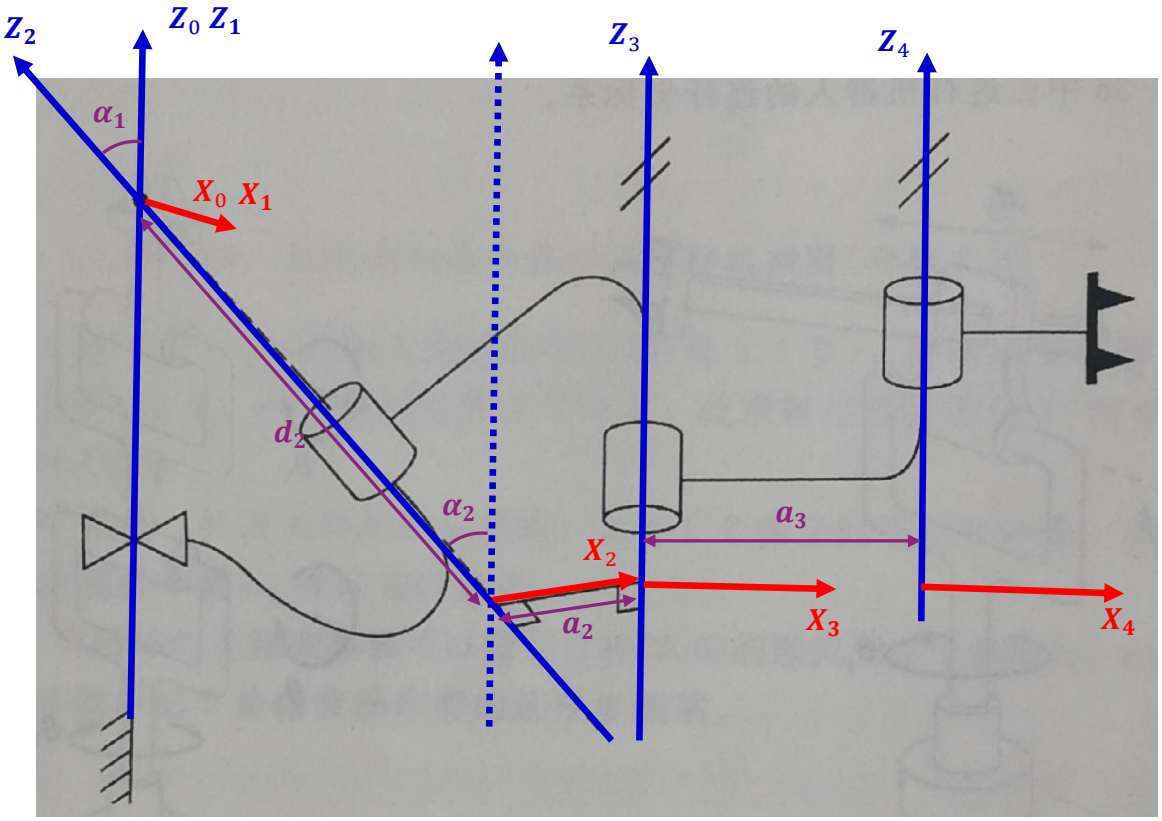
第3个关节θ_3：绕Z_3轴，从X_2旋转到X_3

定值$-\theta_3^*$



作 业

3.22



DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	d_1	0
2	α_1	0	$-d_2$	θ_2
3	α_2	a_2	0	θ_3
4	0	a_3	0	θ_4

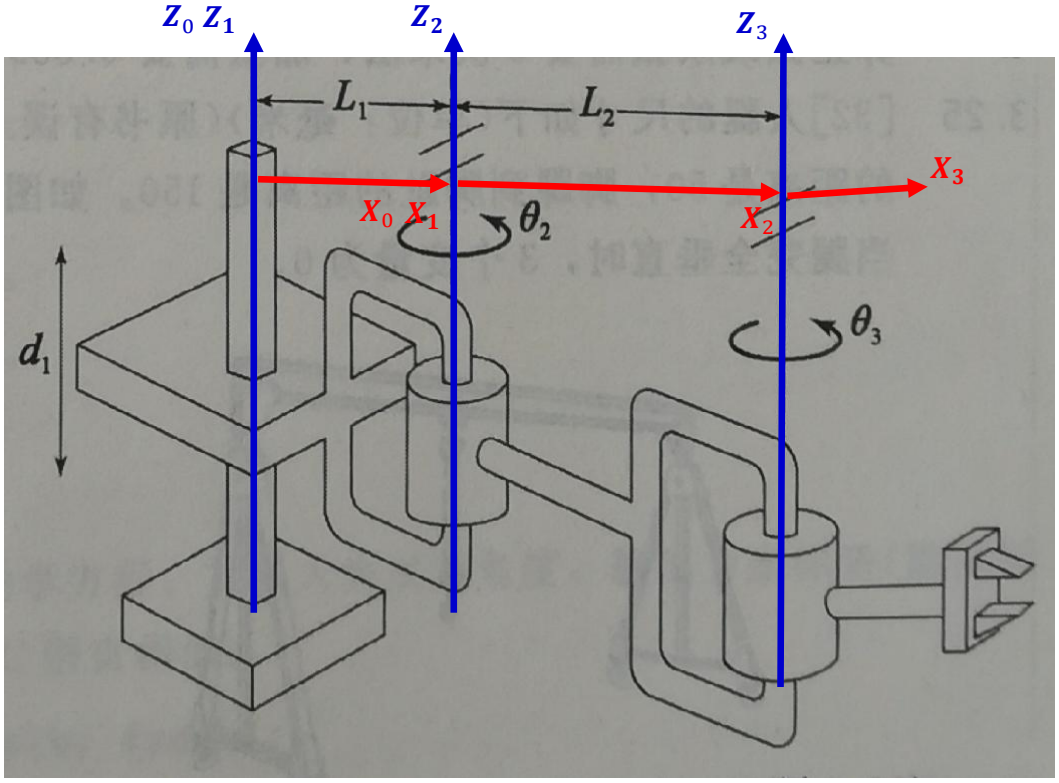
第2个关节d_i：绕Z_2轴，从X_1移动到X_2

问题：

$-d_2$

作 业

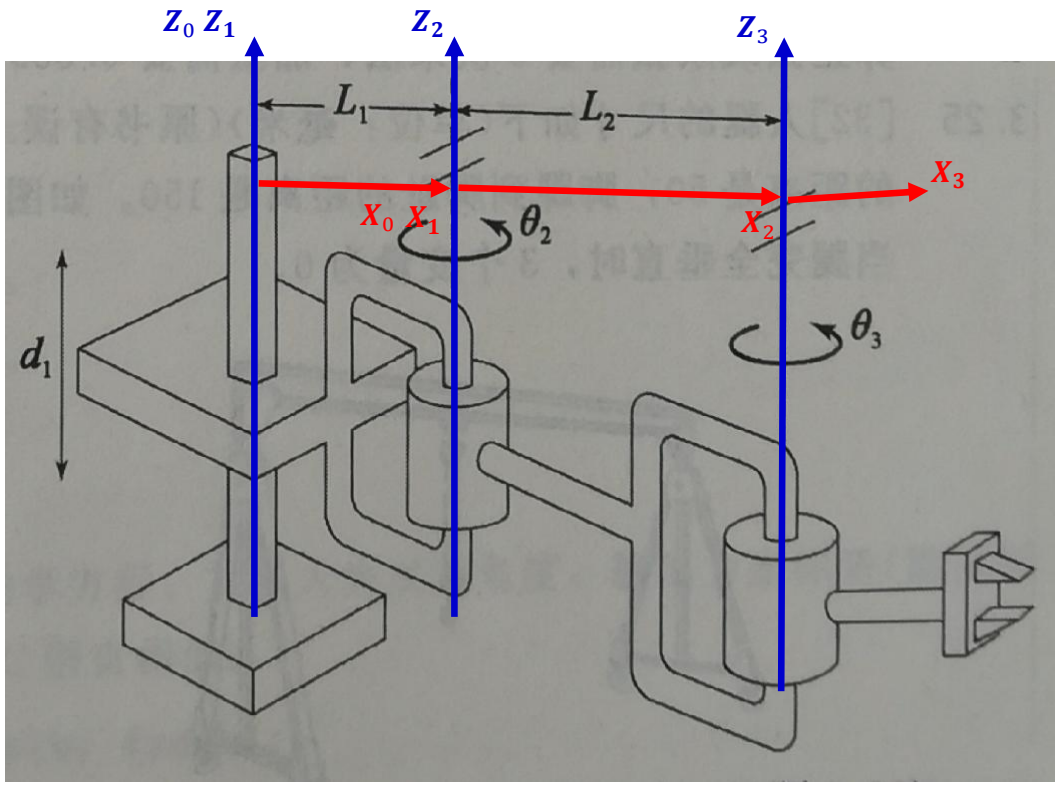
3.17



DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	d_1	0
2	0	L_1	0	θ_2
3	0	L_2	0	θ_3

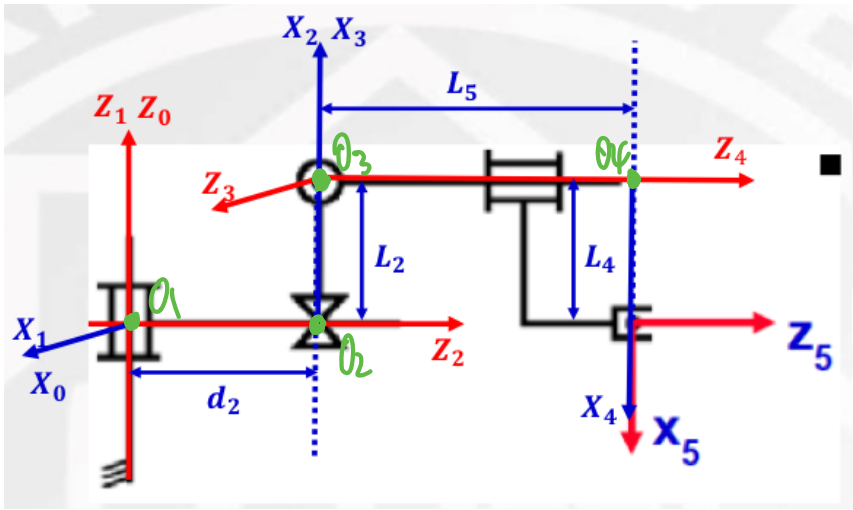
3.20



DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	d_1	0
2	0	L_1	0	θ_2
3	0	L_2	0	θ_3

例2 空间RP2R四关节机器人正运动学



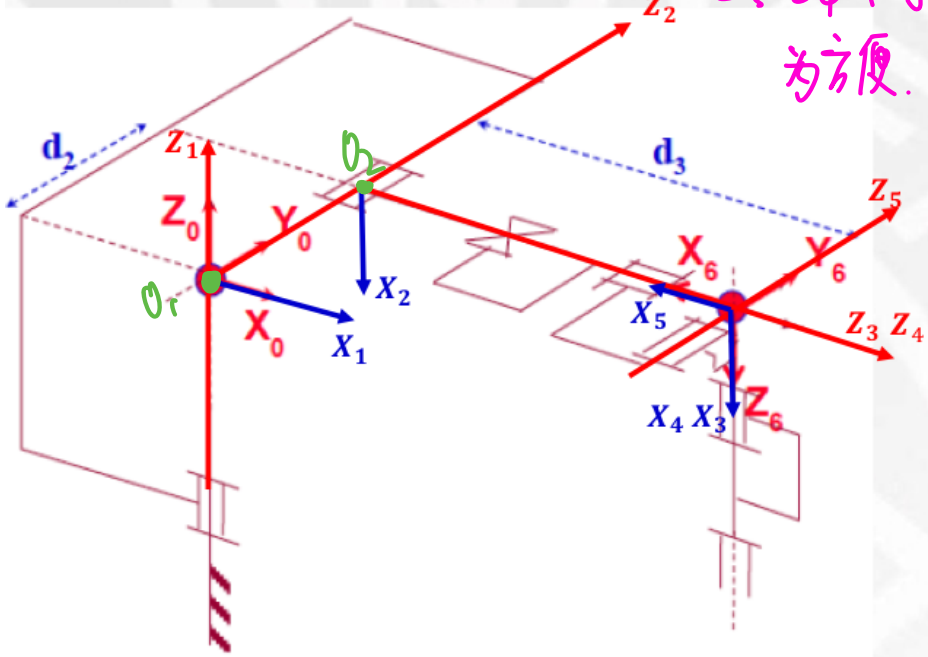
DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	0	θ_1
2	-90^0	0	d_2	-90^0
3	-90^0	L_2	0	θ_3
4	90^0	0	L_5	θ_4
5	0	L_4	0	0

为何要给末端执行器建⑦

$\theta_5=0$ 表示末端执行器不转⑦

例3 Stanford Scheinman机器人正运动学



■ 根据关节类型，先填入变量

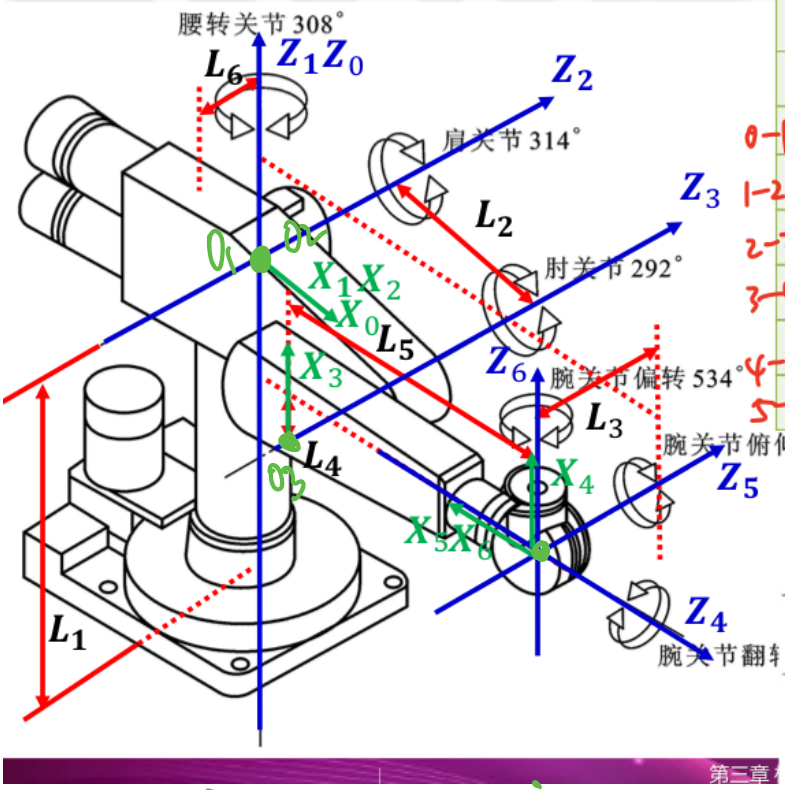
DH参数表

关节	α_{i-1}	$\vec{a}_{i-1}$	d_i	θ_i
1	0	0	0	θ_1
2	-90^0	0	变量d_2	θ_2
3	90^0	0	变量d_3	0
4	0	0	0	θ_4
5	-90^0	0	0	θ_5
6	90^0	0	0	θ_6

注意：各个关节的零点位置

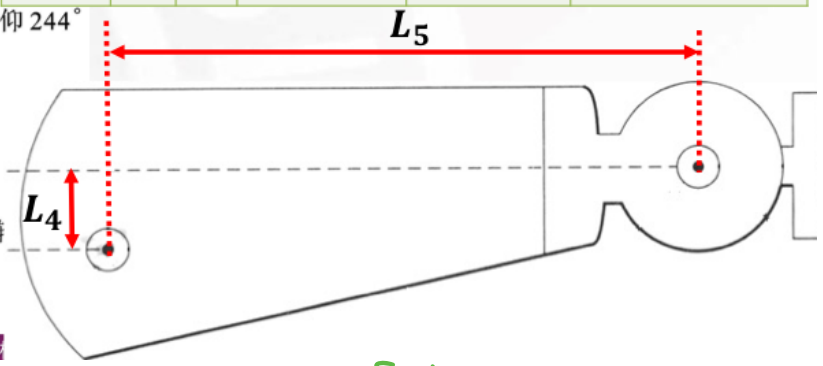
Stanford Scheinman机器人：空间2RP3R机器人

3.5 PUMA机器人正运动学建模



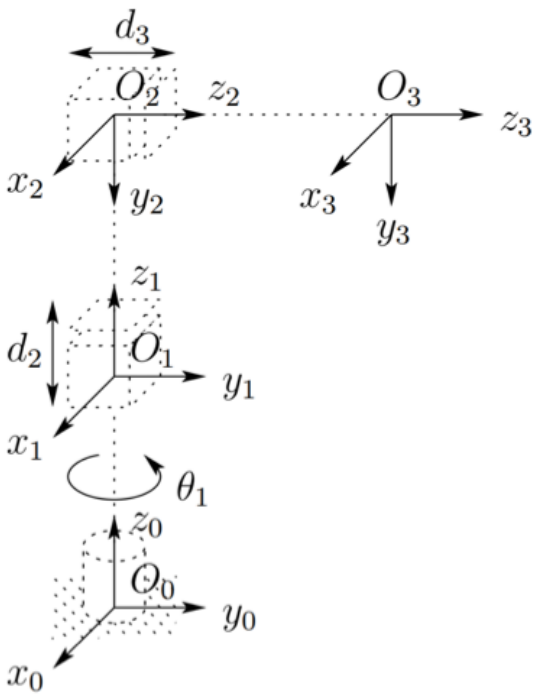
PUMA robot arm link coordinate parameters

	Joint i	θ_i	α_{i-1}	a_{i-1}	d_i	Joint range
0-1	1	θ_1	0	0	0	-160 to 160
1-2	2	θ_2	-90	0	0	-225 to 45
2-3	3	θ_3	0	L_2	L_3	-45+180 to 225+180
3-4	4	θ_4	-90	L_4	L_5	-110 to 170
4-5	5	θ_5	90	0	0	-100 to 100
5-6	6	θ_6	-90	0	0	-266 to 266



3.5 举例：3DOF 圆柱机械臂

《机器人学导论》



Three-link cylindrical manipulator

Link parameters for 3-link cylindrical manipulator

Link	a_i	α_i	d_i	θ_i
1	0	0	d_1	θ_1^*
2	0	-90	d_2^*	0
3	0	0	d_3^*	0

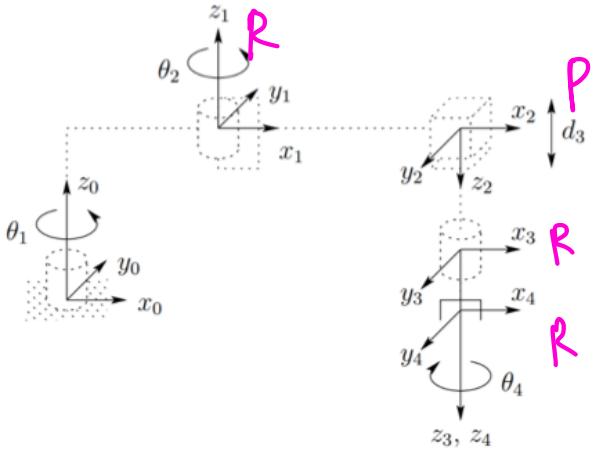
* variable

$$A_1 = \begin{bmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_3^0 = A_1 A_2 A_3 = \begin{bmatrix} c_1 & 0 & -s_1 & -s_1 d_3 \\ s_1 & 0 & c_1 & c_1 d_3 \\ 0 & -1 & 0 & d_1 + d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



DH coordinate frame assignment for the SCARA manipulator

Joint parameters for SCARA.

Link	a_i	α_i	d_i	θ_i
1	a_1	0	0	$\star$
2	a_2	180	0	$\star$
3	0	0	$\star$	0
4	0	0	d_4	$\star$

* joint variable

$$A_1 = \begin{bmatrix} c_1 & -s_1 & 0 & a_1c_1 \\ s_1 & c_1 & 0 & a_1s_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} c_2 & s_2 & 0 & a_2c_2 \\ s_2 & -c_2 & 0 & a_2s_2 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_4 = \begin{bmatrix} c_4 & -s_4 & 0 & 0 \\ s_4 & c_4 & 0 & 0 \\ 0 & 0 & 1 & d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

$$T_4^0 = A_1 \cdots A_4 = \begin{bmatrix} c_{12}c_4 + s_{12}s_4 & -c_{12}s_4 + s_{12}c_4 & 0 & a_1c_1 + a_2c_{12} \\ s_{12}c_4 - c_{12}s_4 & -s_{12}s_4 - c_{12}c_4 & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & -1 & -d_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$