3.4

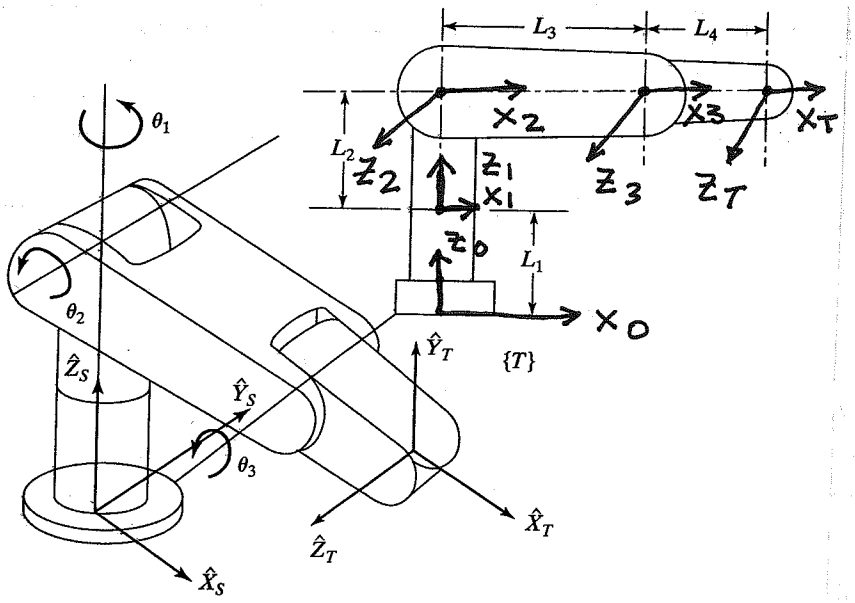


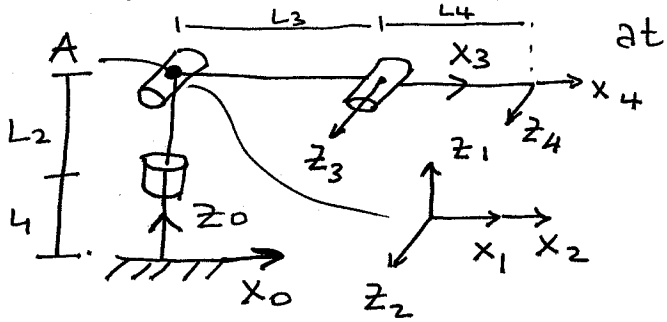
FIGURE 3.30: Two views of a 3*R* manipulator (Exercise 3.4).

If this frame assignment is used, we observe that L_2 is not included in the MDH table.

How to accomodate include L_2 in the MDH table?

Two approaches:

Approach 1 Assign the origins for joints 1 & 2 at pt A



$$ {}^{3}_{4}T = \begin{bmatrix} 1 & 0 & 0 & L_4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

MDH TABLE:

FRAME C	FRAME N	JOINT #	JOINT TYPE	JOINT VAR	MDH PARAMETERS α	a	d	θ
0	1	1	R	θ	0	0	L_1+L_2	θ_1
1	2	2	R	θ	90	0	0	θ_2
2	3	3	R	θ	0	L_3	0	θ_3
3	4	—	—	—	0	L_4	0	0

$$ {}^{0}_{1}T = \begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & L_1+L_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^{1}_{2}T = \begin{bmatrix} C_2 & -S_2 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ S_2 & C_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad {}^{2}_{3}T = \begin{bmatrix} C_3 & -S_3 & 0 & L_3 \\ S_3 & C_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

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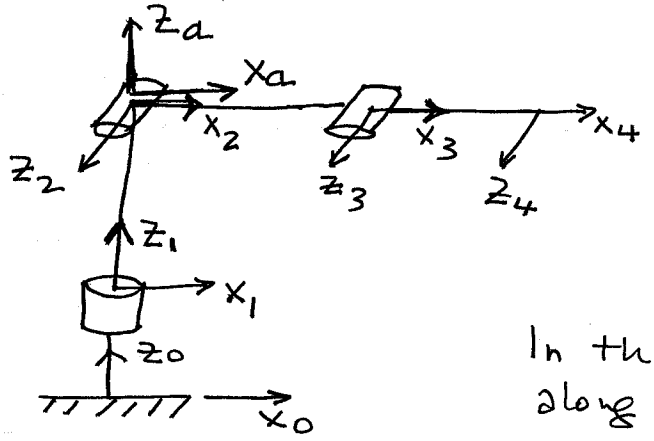
3.4 CONT.

APPROACH 2 Use auxiliary frame from 1 → 2



$0 \to 1$
$1 \to a$
$a \to 2$
$2 \to 3$
$3 \to 4$

REMEMBER

TRANSLATION
- ALONG CURRENT X-AXIS OR
- ALONG NEXT Z-AXIS

In this example, we are transl. along next Z i.e. Za.

FRAME		JOINT			MDH PARAMETERS			
C	N	#	TYP	VAR	α	a	d	θ
0	1	1	R	θ	0	0	L_1	θ_1
1	a	—	—	—	0	0	L_2	0
a	2	2	R	θ	90	0	0	θ_2
2	3	3	R	θ	0	L_3	0	θ_3
3	4	—	—	—	0	L_4	0	0

You can use MATLAB or some other software package to find the H.T. and ${}^{0}_{4}T$.

3.8 [13] In Fig. 3.31, the location of the tool, ${}^{W}_{T}T$, is not accurately known. Using force control, the robot feels around with the tool tip until it inserts it into the socket (or Goal) at location ${}^{S}_{G}T$. Once in this "calibration" configuration (in which $\{G\}$ and $\{T\}$ are coincident), the position of the robot, ${}^{B}_{W}T$, is figured out by reading the joint angle sensors and computing the kinematics. Assuming ${}^{B}_{S}T$ and ${}^{S}_{G}T$ are known, give the transform equation to compute the unknown tool frame, ${}^{W}_{T}T$.

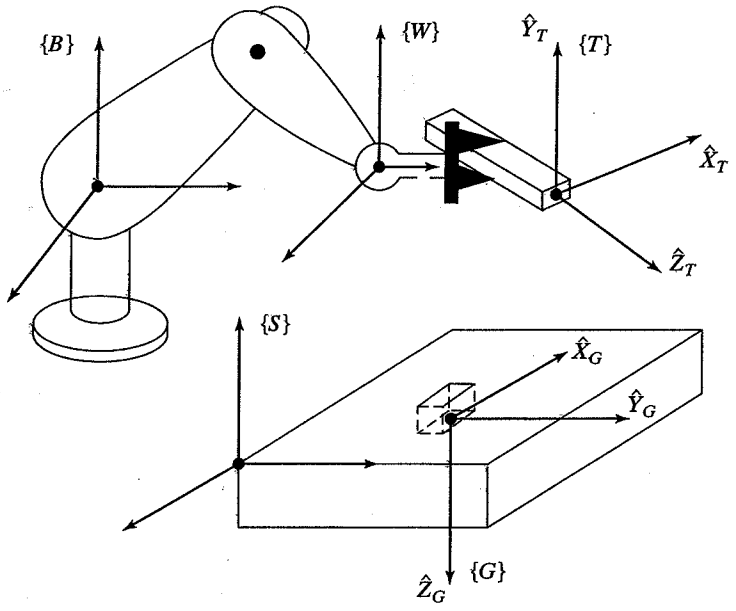


FIGURE 3.31: Determination of the tool frame (Exercise 3.8).

KNOWN: ${}^{B}_{W}T$; ${}^{S}_{G}T$; $\left({}^{B}_{S}T\right)$ FIND: ${}^{W}_{T}T$

when $[G] = [T]$ i.e. frames are coincident we have

$${}^{B}_{W}T\ {}^{W}_{T}T = {}^{B}_{S}T\ {}^{S}_{G}T \Rightarrow$$

$${}^{W}_{T}T = \left({}^{B}_{W}T\right)^{-1}\ {}^{B}_{S}T\ {}^{S}_{G}T$$

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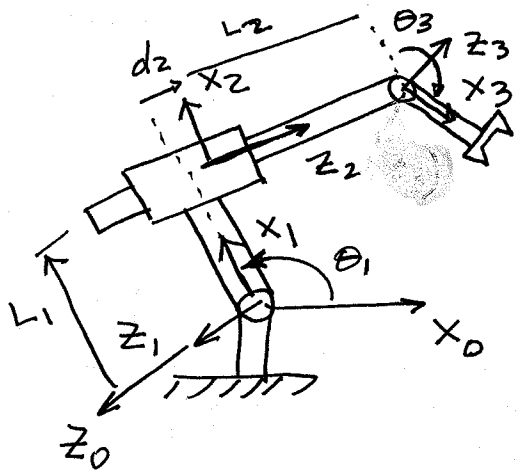
3.16 RPR Manipulator



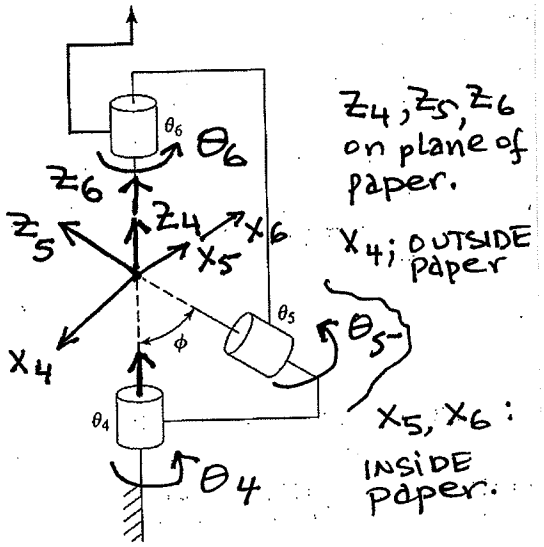
FRAME		JOINT		MDH PARAMS.			
C	N	#	T	V	α	a	d	θ
0	1	1	R	θ	0	0	0	θ_1
1	2	2	P	d	90	L_1	d_2	0
2	3	3	R	θ	90	0	0	θ_3

Note L_2 is not included in the analysis. How can we include L_2?

a) Use auxiliary frame from joint 2 → aux → 3 or

b) Include it in the motion of joint 2 (Prismatic). So $d_2 = d_{2\,MOTION} + L_2$.

3.11



Z_4, Z_5, Z_6 on plane of paper.

X_4: OUTSIDE paper

X_5, X_6: INSIDE paper.

FIGURE 3.33: 3*R* nonorthogonal-axis robot (Exercise 3.11).

Schematic of a wrist with 3-intersecting axes — non-orthogonal. Assign Link frames to this wrist.

C	N	#	T	R	α	a	d	θ
–	4	4	R	θ	–	–	–	θ_4
4	5	5	R	θ	ϕ	0	0	θ_5
5	6	6	R	θ	ϕ	0	0	θ_6

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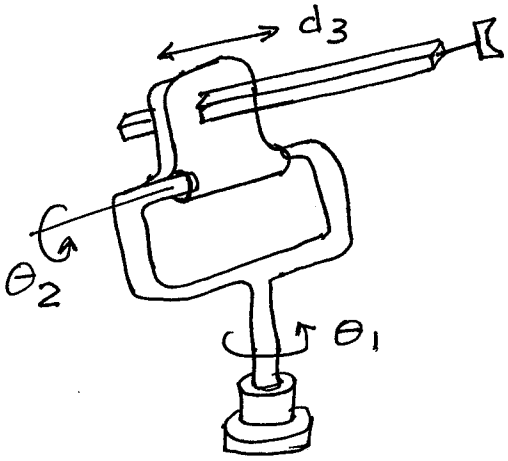
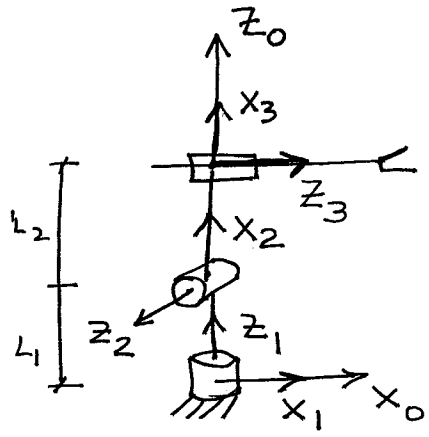
3.17 RRP



Equivalent Schematic



C	N	#	T	V	α	a	d	θ
0	1	1	R	θ	0	0	0	θ_1
1	2	2	R	θ	90	0	0	θ_2
2	3	3	P	d	90	L_2	d_3	0

- Again note that L_1 is not included in the analysis
- The two choices are to put joints 1 & 2 at same origin (at joint 2) or to include an auxiliary frame. We discussed the aux. frame extensively in class, so I will let you decide where to assign it and how to orient it.