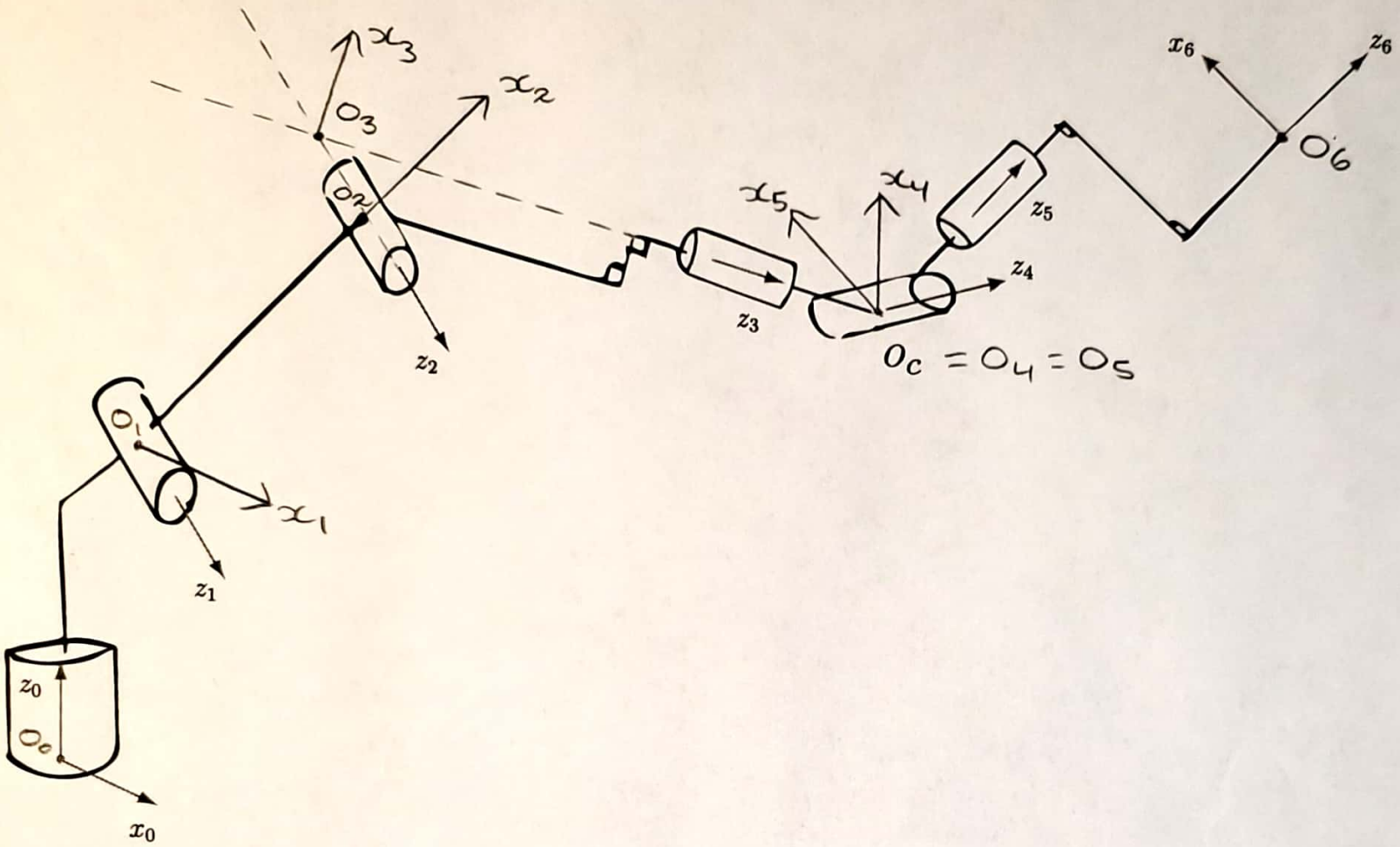

Figure 3: Schematic diagram of KUKA robot arm not at rest.

DH Table of robot :

Link	a_i/mm	α_i/radians	d_i/mm	θ_i/radians
1	25	$\pi/2$	400	θ_1
2	315	0	0	θ_2
3	35	$\pi/2$	0	θ_3
4	0	$-\pi/2$	365	θ_4
5	0	$\pi/2$	0	θ_5
6	-296.23	0	161.44	θ_6

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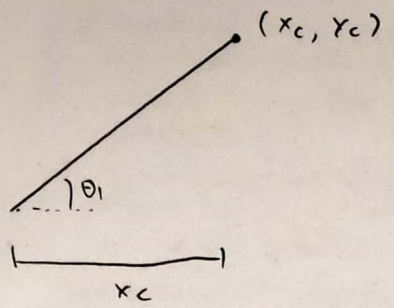
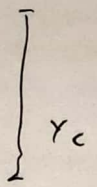
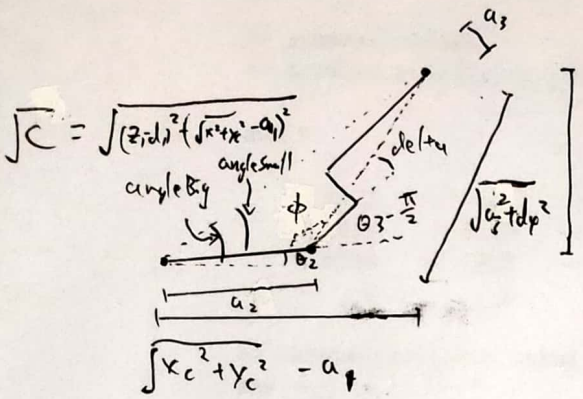
Find x_c, y_c, z_c using $o_d^0 - R_d \begin{bmatrix} -a_6 \\ 0 \\ d_6 \end{bmatrix}$





$$\theta_1 = \operatorname{atan2}(y_c, x_c)$$



$$\text{angle Big} = \operatorname{atan2}\left(z_c - d_1, \sqrt{x_c^2+y_c^2} - a_1\right)$$

$$\cos(\text{angle Small}) = \frac{a_3^2 + d_\varphi^2 - a_2^2 - C}{-2(\sqrt{C})\, a_2}$$

$$\sin(\text{angle Small}) = \sqrt{1 - \cos(\text{angle Small})^2}$$

$$\text{angle Small} = \operatorname{atan2}(-\sin(\text{angle Small}), \cos(\text{angle Small}))$$

$$\theta_2 = \text{angle Big} - \text{angle Small}$$

$$\text{delta} = \operatorname{atan2}(a_3, d_\varphi)$$

$$\phi + \text{delta} + \theta_3 - \frac{\pi}{2} = \pi$$

$$\sin(\beta) = \frac{C - a_2^2 - a_3^2 - d_\varphi^2}{2\sqrt{a_3^2+d_\varphi^2}\; a_2}$$

$$\beta = \theta_3 + \text{delta} = \frac{3\pi}{2} - \phi$$

$$\cos(\beta) = \sqrt{1 - \sin(\beta)^2}$$

$$\theta_3 = \beta - \text{delta}$$

$$\beta = \operatorname{atan2}(\sin(\beta), \cos(\beta))$$

$$\theta_3 = \beta - \text{delta}$$

Consider $R_6^3 = \begin{bmatrix} * & * & c_4 \cdot s_5 \\ * & * & s_4 \cdot s_5 \\ -s_5 \cdot c_6 & s_5 \cdot s_6 & c_5 \end{bmatrix} \equiv M$

$\theta_4 = \text{atan2}(m_{23}, m_{13})$ or $\theta_4 = \text{atan2}(-m_{23}, -m_{13})$

$\theta_5 = \text{atan2}(\sqrt{1-m_{33}^2}, m_{33})$ or $\theta_5 = \text{atan2}(-\sqrt{1-m_{33}^2}, m_{33})$

$\theta_6 = \text{atan2}(m_{32}, -m_{13})$ or $\theta_6 = \text{atan}(-m_{32}, -m_{31})$

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