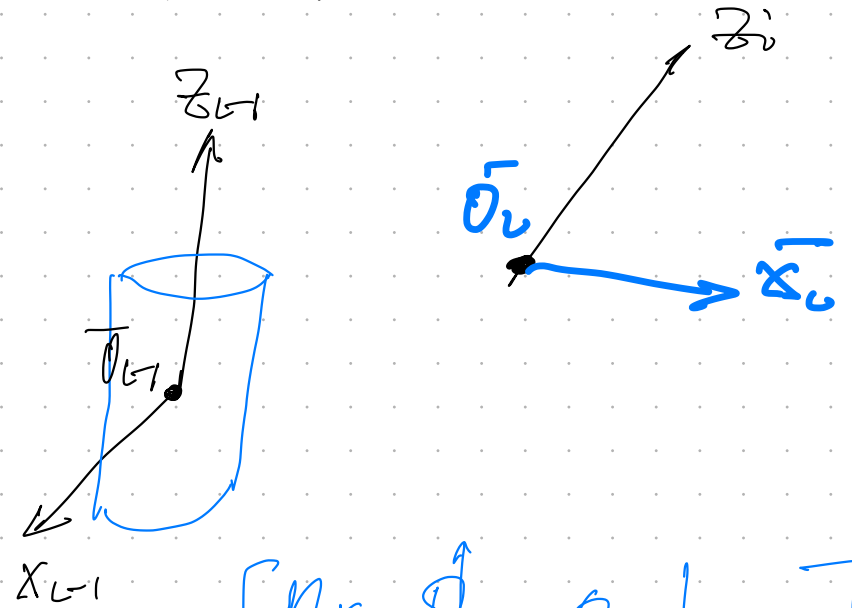


KINEMATICS

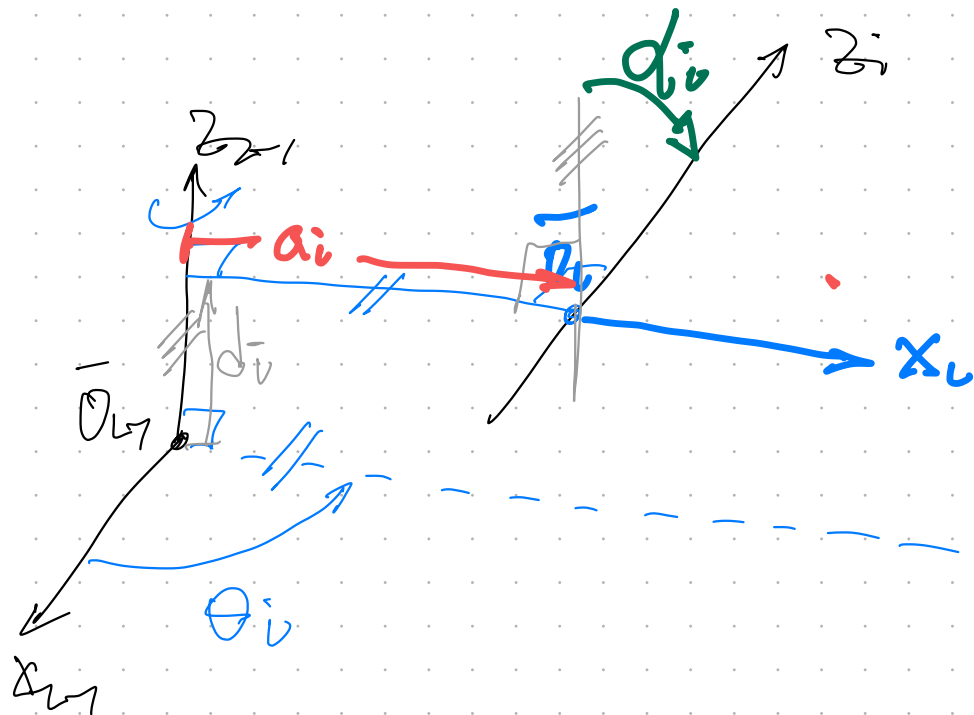


$$T = \left[\begin{array}{ccc|c} n_x & 0_x & 0_x & p_x \\ n_y & 0_y & 0_y & p_y \\ n_z & 0_z & 0_z & p_z \\ \hline 0 & 0 & 0 & 1 \end{array} \right]$$

12 parameters \rightarrow 9 parameters

Denevit - Hartenberg
(4 D-H parameters)

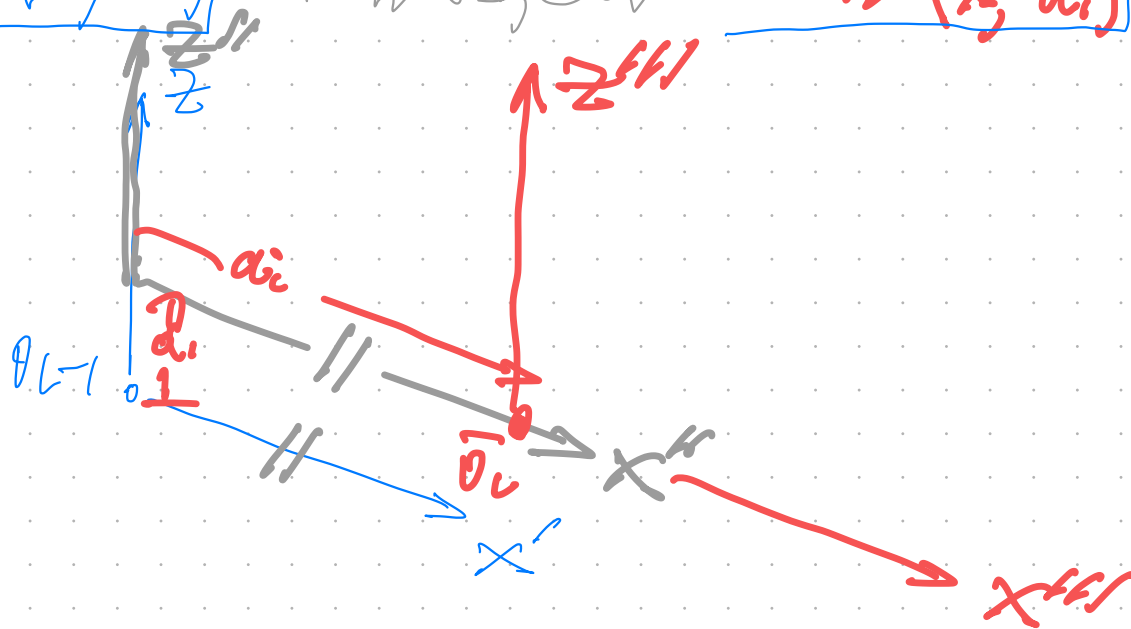
Common normal



D-H parameters

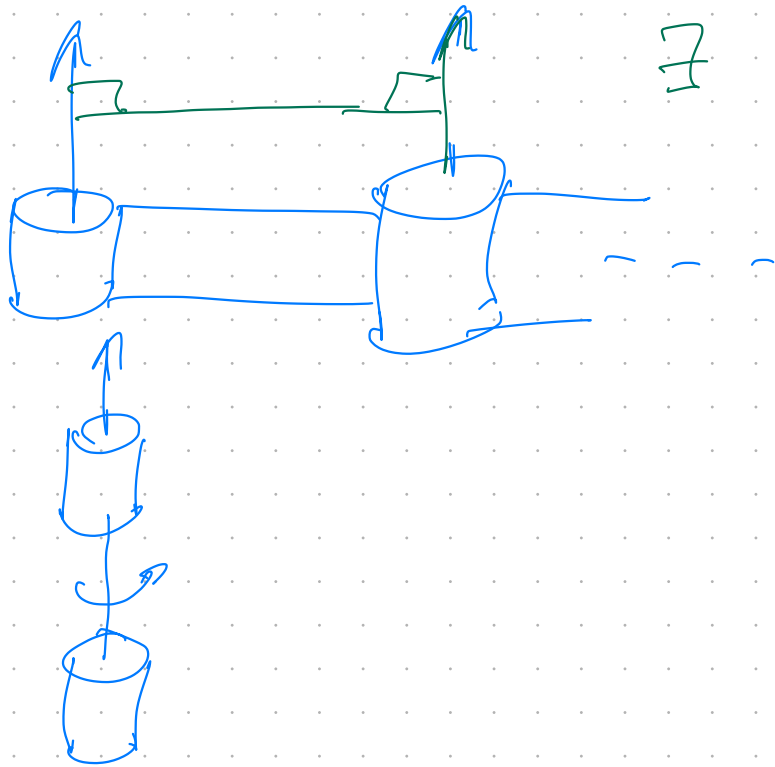
$\theta_i, d_i, \boxed{a_i, d_i}$ constant

$\boxed{\text{Rot}(z, \theta_i)} \quad \boxed{\text{Trans}(z, d_i)} \quad \boxed{\text{Trans}(x, a_i)} \quad \boxed{\text{Rot}(x, d_i)}$



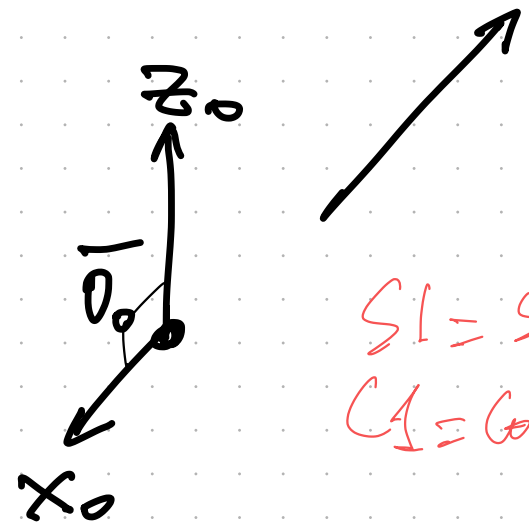
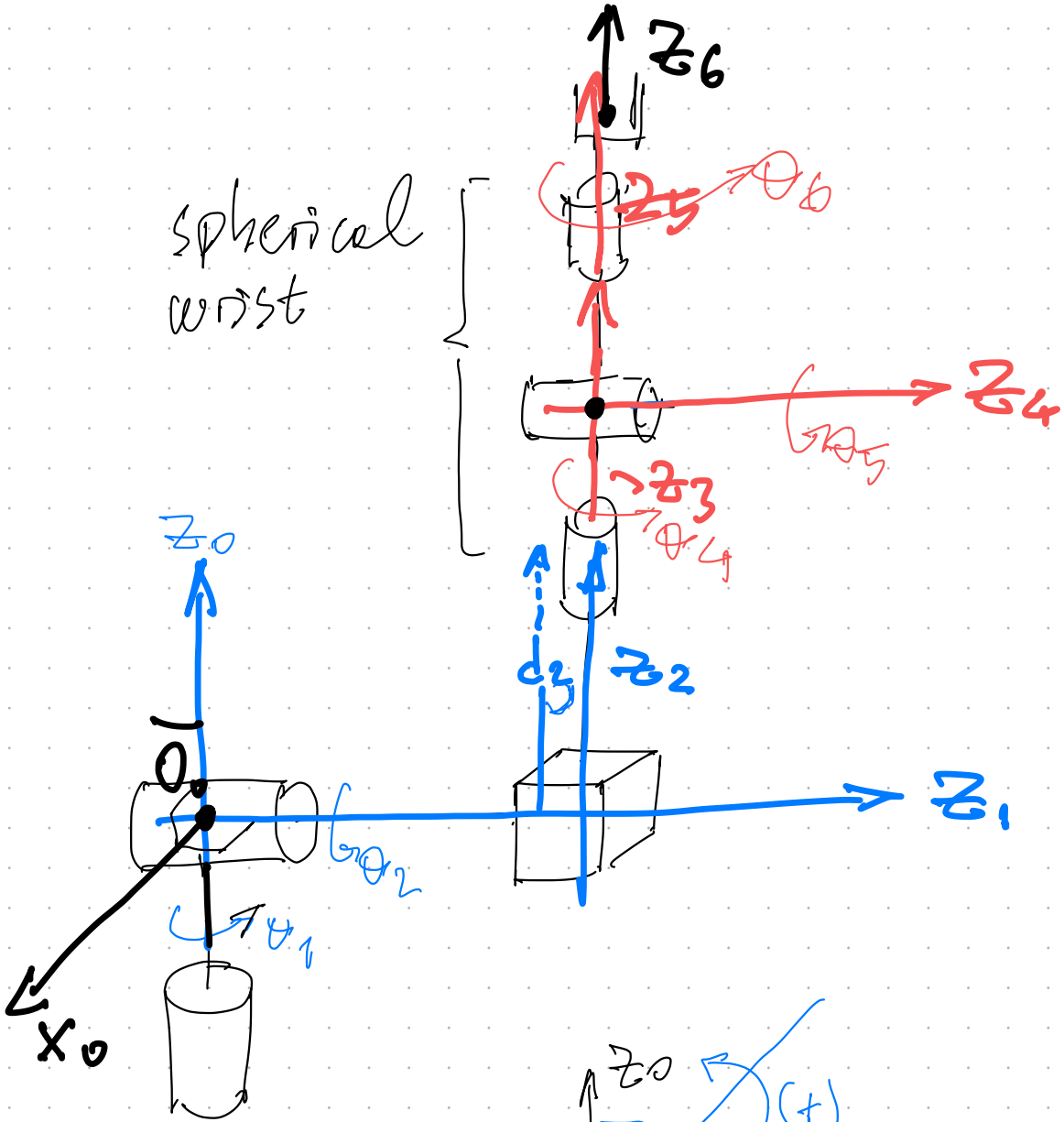
$$A_i \rightarrow \left[\begin{array}{cc|c} c\theta & -s\theta & 0 \\ s\theta & c\theta & 0 \\ \hline & & 1 \end{array} \right] \left[\begin{array}{c|c} 1 & 0 \\ & 1 \\ \hline & d_i \end{array} \right] \left[\begin{array}{c|c} 1 & d_i \\ & 0 \\ \hline & 1 \end{array} \right] \left[\begin{array}{cc|c} 1 & c d_i - s d_i & 0 \\ & s d_i & c d_i \\ \hline & & 1 \end{array} \right]$$

$$= \begin{bmatrix} c\theta_c & -s\theta_c c d_c & s\theta_c s d_c & d_c c\theta_c \\ s\theta_c & c\theta_c c d_c & -c\theta_c s d_c & d_c s\theta_c \\ 0 & s d_c & c d_c & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2.37) \text{ @ pp. 53}$$



\exists infinite common normals

spherical wrist



$$S1 = \sin(\theta_1)$$

$$C1 = \cos(\theta_1)$$

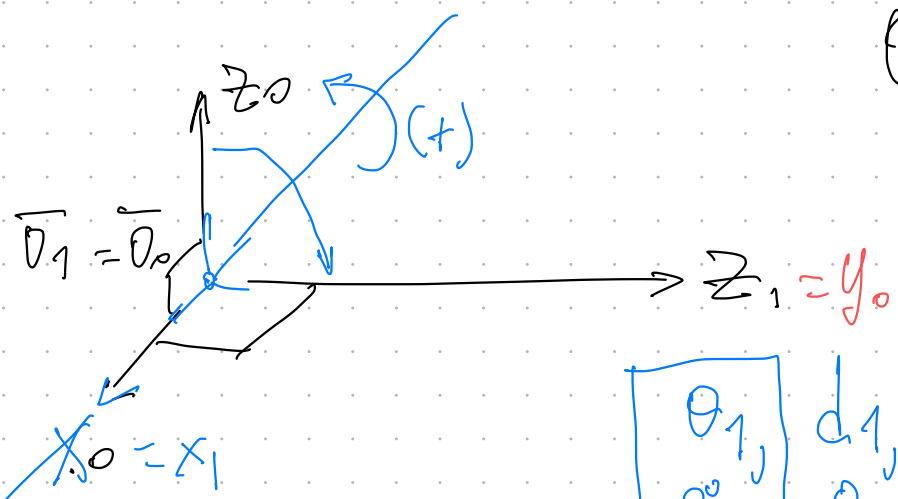
$$A_0^1 = \begin{bmatrix} C1 & 0 & S1 & 0 \\ S1 & 0 & C1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

from

$$\bar{O}_1 = z_0$$

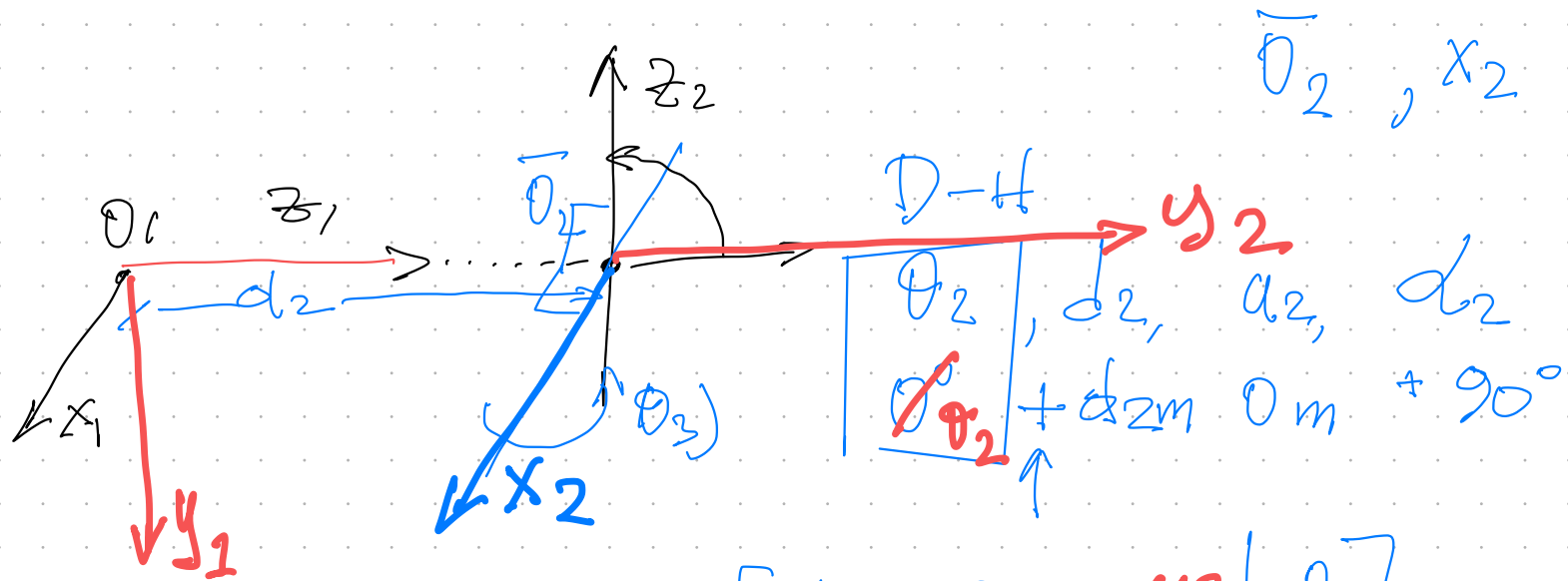
$$\bar{x}_1 = \bar{x}_0$$

$$A_0^1(\theta_1)$$



$$\begin{bmatrix} \theta_1 \\ 0 \end{bmatrix} \quad d_1, a_1, d_1$$

$$0_m, 0_m, -90^\circ$$



$$A^2_{(0)} = \begin{bmatrix} \cancel{c\theta_2} & 0 & s\theta_2 & 0 \\ s\theta_2 & 0 & -c\theta_2 & 0 \\ 0 & 1 & 0 & d_2 \\ \hline & & & 1 \end{bmatrix}$$

$$A^2_{(0)} = A^1_{(0)}(\theta_1) A^2_{(1)}(\theta_2)$$

$$\vdots$$

$$A^6_{(0)}$$