Kinematic Model of Robot

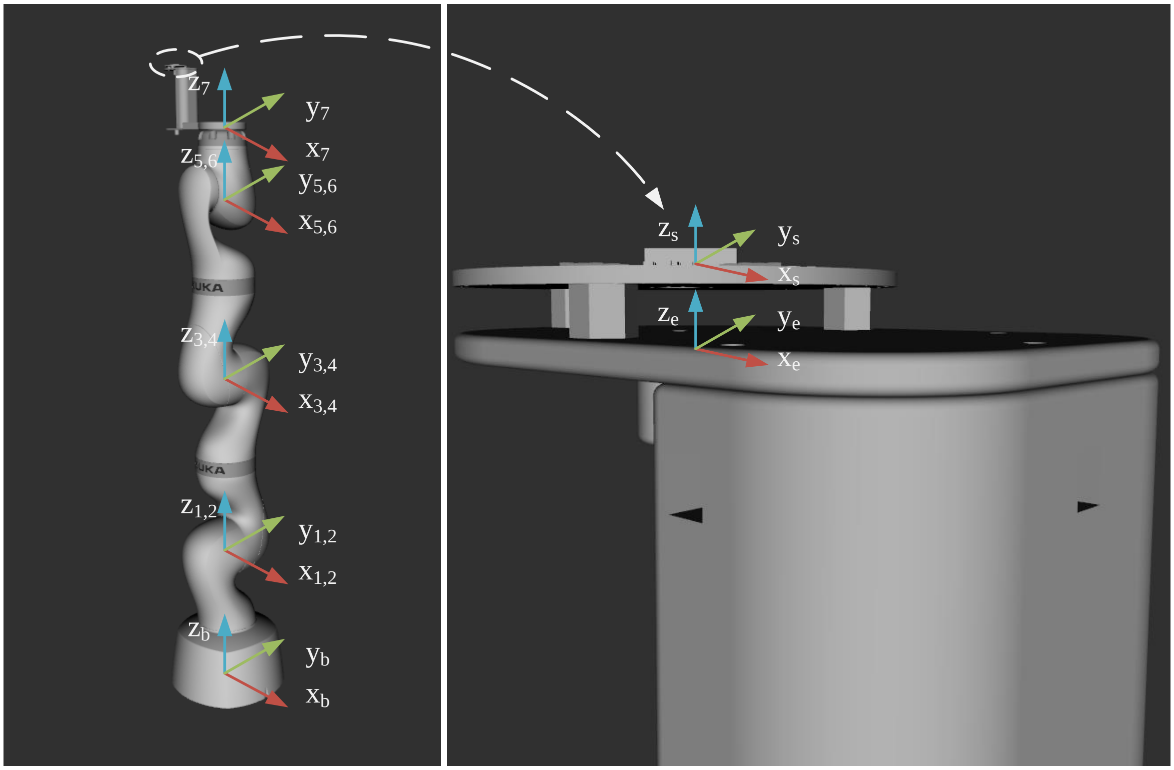

Fig. 1. Kinematic model of the robot.

Kinematic model:

As shown in Fig. 1, the elementary transform sequence (ETS) between the attached frames can be described as follows:

$$ {}^{b}\boldsymbol{T}_1 = \begin{cases} \boldsymbol{E}_1 = \boldsymbol{T}_{\boldsymbol{t}_z}(0.340) \\ \boldsymbol{E}_2 = \boldsymbol{T}_{\boldsymbol{R}_z}(q_1) \end{cases} \tag{1} $$

$$ {}^{1}\boldsymbol{T}_2 = \Big\{ \boldsymbol{E}_3 = \boldsymbol{T}_{\boldsymbol{R}_y}(q_2) \tag{2} $$

$$ {}^{2}\boldsymbol{T}_3 = \begin{cases} \boldsymbol{E}_4 = \boldsymbol{T}_{\boldsymbol{t}_z}(0.400) \\ \boldsymbol{E}_5 = \boldsymbol{T}_{\boldsymbol{R}_z}(q_3) \end{cases} \tag{3} $$

$$ {}^{3}\boldsymbol{T}_4 = \Big\{ \boldsymbol{E}_6 = \boldsymbol{T}_{\boldsymbol{R}_y}(-q_4) \tag{4} $$

$$ {}^{4}\boldsymbol{T}_5 = \begin{cases} \boldsymbol{E}_7 = \boldsymbol{T}_{\boldsymbol{t}_z}(0.400) \\ \boldsymbol{E}_8 = \boldsymbol{T}_{\boldsymbol{R}_z}(q_5) \end{cases} \tag{5} $$

$$ {}^{5}\boldsymbol{T}_6 = \Big\{ \boldsymbol{E}_9 = \boldsymbol{T}_{\boldsymbol{R}_y}(q_6) \tag{6} $$

$$
{}^{6}\boldsymbol{T}_{7} = \begin{cases} \boldsymbol{E}_{10} = \boldsymbol{T}_{\boldsymbol{t}_z}(0.126) \\ \boldsymbol{E}_{11} = \boldsymbol{T}_{\boldsymbol{R}_z}(q_7) \end{cases} \tag{7}
$$

$$
{}^{7}\boldsymbol{T}_{e} = \begin{cases} \boldsymbol{E}_{12} = \boldsymbol{T}_{\boldsymbol{t}_x}(-0.140) \\ \boldsymbol{E}_{13} = \boldsymbol{T}_{\boldsymbol{t}_z}(0.120) \end{cases} \tag{8}
$$

By multiplying the elementary transforms, the forward kinematics of the robot can be obtained:

$$
\begin{aligned}
{}^{b}\boldsymbol{T}_{e} &= \mathcal{FK}(\boldsymbol{q}) \\
&= {}^{b}\boldsymbol{T}_{1}{}^{1}\boldsymbol{T}_{2}\cdots{}^{6}\boldsymbol{T}_{7}{}^{7}\boldsymbol{T}_{e} \\
&= \boldsymbol{E}_{1}\boldsymbol{E}_{2}\cdots\boldsymbol{E}_{12}\boldsymbol{E}_{13}
\end{aligned} \tag{9}
$$

In addition, from design parameter, the kinematic relationship between end-effector frame and sensor frame can be described by:

$$
{}^{e}\boldsymbol{T}_{s} = \boldsymbol{E}_{14} = \boldsymbol{T}_{\boldsymbol{t}_z}(0.058) \tag{10}
$$

Combining (9) and (10), the transformation from robot base frame to sensor frame can be computed:

$$
{}^{b}\boldsymbol{T}_{s} = {}^{b}\boldsymbol{T}_{e}{}^{e}\boldsymbol{T}_{s} \tag{11}
$$