Robotics Examination （2018-Fall semester） 1/29/2019 (4th period）

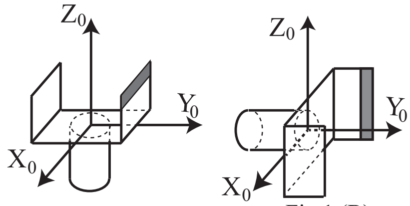

Fig.1 (A) Fig.1 (B)

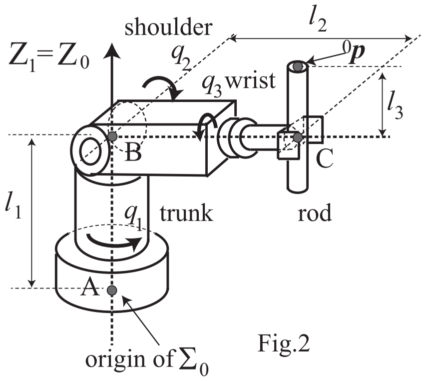

Fig.2

(1) Original orientation of a hand is given in Fig.1 (A). After some rotations, we have an another orientation of the hand shown in Fig.1 (B). Show the rotation matrix ${}^0R$ which represents the orientation of the hand in Fig.1 (B).

(2) For a robotic arm having trunk q_1, shoulder q_2 and wrist q_3 joints in Fig.2 (the figure shows the case of $q_1 = q_2 = q_3 = 0$),
(2-1) show the geometrical relationship of the coordinate frames $\Sigma_0 \sim \Sigma_3$ using the points A,B,C in Fig.2 by following Denaviet-Hartenberg (D-H) method and the recommendation in the textbook.
(2-2) Find the D-H parameters $(a_i, \alpha_i, d_i, \theta_i)$ for the robotic arm. Note that the origin of Σ_0 is specified, arrow symbol represents the positive direction and follow the recommendations in the textbook on some free setting parameters.
(2-3) Represent the vector ${}^0\boldsymbol{p}$ in Σ_0 using homogenous transfer matrix ${}^0T_3 = {}^0T_1{}^1T_2{}^2T_3$. Where you do not need to calculate the actual elements of ${}^0T_3$ but need to show each element for ${}^0T_1, {}^1T_2, {}^2T_3$.

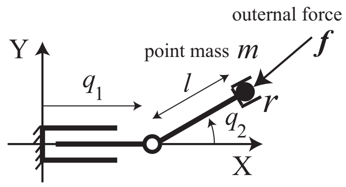

Fig. 3

(3) A planar 2-DOF robotic arm has two joints (q_1 = translational joint and q_2 = rotational joint) shown in Fig.3 where each link has no mass and only has point mass m at the tip point $\boldsymbol{r}$.
(3-1) Describe the tip point $\boldsymbol{r} = [x, y]^T$ using q_1, q_2 and l.
(3-2) Calculate the velocity $\boldsymbol{v}$ for $\boldsymbol{r}$ and show the Jacobian $J(\boldsymbol{q})$ for it.
(3-3) Calculate inertia moment matrix $M(\boldsymbol{q})$ for the arm.
(3-4) When an outernal force $\boldsymbol{f} = [f_x, f_y]^T$ is added at $\boldsymbol{r}$, calculate the holding joint force/torque $\boldsymbol{\tau}$ for it.