EENG 428 Introduction to Robotics

Tutorial 2

Question 1

Given a coordinate frame **T** and $\mathbf{T}_{\mathbf{new}}$ which is the new location of the frame after a differential transformation

$$\mathbf{T}_{new} = \begin{bmatrix} -1 & -0.2 & -0.1 & 2 \\ -0.1 & 0 & 1 & -1.5 \\ -0.2 & 1 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{and } \mathbf{T} = \begin{bmatrix} -1 & 0 & 0 & 3 \\ 0 & 0 & 1 & -2 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

a) Determine the differential translation **d** and rotation $\boldsymbol{\delta}$ made with respect to **T**.

b) What is the equivalent translation and rotation with respect to base coordinate frame?

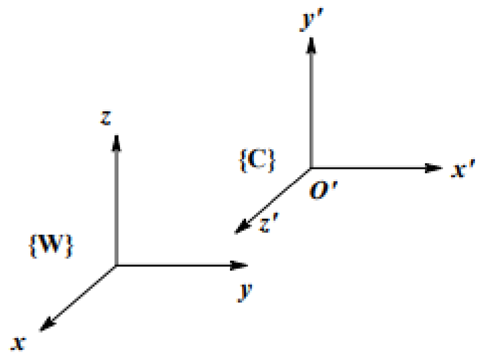
Question 2

The hand frame of a robot and the corresponding Jacobian are given. For the given differential changes of the joints, compute the change in the hand frame, its new location and corresponding Δ.

$$T_4 = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & -1 & 0 & 18.66 \\ 0 & 0 & -1 & -5 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad {}^0J = \begin{bmatrix} -18.66 & -10 & 0 & 0 \\ 5 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & -1 \end{bmatrix}, \quad dq = \begin{bmatrix} 0 \\ 0.1 \\ 0.2 \\ -0.2 \end{bmatrix}$$

Question 3

The world coordinate frame $W(x, y, z)$ and the coordinate frame $C(x', y', z')$ are given as shown below. The origin O' of frame C is given by $O' = [1 \quad 4 \quad 2]^T$ with respect to world coordinate system.



(a) Find the representation of frame C with respect to world coordinate frame W (${}^W\mathbf{T}_C$).

$$
{}^W T_C = \begin{bmatrix} 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 4 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

(b) Calculate ${}^W D$, ${}^W \Delta$, $d\,{}^W\mathbf{T}_C$, ${}^C D$, ${}^C \Delta$, and ${}^C\mathbf{M}_W$ corresponding to a differential translation 0.5 unit in x'-direction, differential rotations 0.2 radians around the y'-axis and –0.1 radian around the z'-axis of the frame C.

Question 4

For a three-link cylindrical manipulator, derive the Jacobian with respect to base coordinate frame.

The link parameters of the manipulator shown in the following table.

Link	a_i	α_i	d_i	θ_i
1	a_1	0	0	θ_1^*
2	a_2	180	0	θ_2^*
3	0	0	d_3^*	0

Question 5

For a two-link planar manipulator, it is given that

$$T_2 = A_1 A_2 \text{ where } A_1 = \begin{bmatrix} C_1 & -S_1 & 0 & \ell_1 C_1 \\ S_1 & C_1 & 0 & \ell_1 S_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } A_2 = \begin{bmatrix} C_2 & -S_2 & 0 & \ell_2 C_2 \\ S_2 & C_2 & 0 & \ell_2 S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

It is desired that at the end of manipulator we have the force and moment vectors given

by $${}^2 f = \begin{bmatrix} f_x \\ f_y \\ 0 \end{bmatrix} \qquad {}^2 M = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Determine the joint torques τ_1 and τ_2 required.

Question 6

A fifth-order polynomial is to be used to control the motions of the joints of a robot in joint-space. Find the coefficients of a fifth-order polynomial that allow a joint to go from initial angle of 30°to a final angle of 90° in 6 seconds, while the initial and final velocities are zero and initial acceleration and final decelerations are 10 degrees/sec2 and plot the position, velocity and acceleration curves for the motion.

Question 7

Joint 1 of a 6-axis robot is to go from an initial angle of $\theta_i = 30°$ to the final angle of $\theta_f = 120°$ in 4 seconds with a cruising velocity of $\omega_1 = 30°/sec$. Find the necessary blending time for a trajectory with linear segments and parabolic blends and plot the joint positions, velocities, and accelerations.