NYU ROB-UY 2004
Robotics Locomotion and Manipulation
Spring Semester 2026

Due on BrightSpace, Midnight, Monday, February 23rd, 2026.

Assignment 2: Transformations and Forward Kinematics

This assignment is to be completed by yourself, without help from the internet, LLMs including ChatGPT, etc. Your class notes should be sufficient.

Question 1 - 10 marks

The answers to this question are to be done with pencil and pen on paper (or stylus on an iPad screen). It should be submitted as a jpeg or pdf.

a) Given there are two frames in the world $\{S\}$ and $\{B\}$, write out the homogeneous transformation matrix T_{SB}, such that going from frame $\{S\}$ to frame $\{B\}$ there is a translation of 4 units in the positive y_S direction, and then a rotation about z_S of $\pi/4$ rad.

b) Given there are two frames in the world $\{S\}$ and $\{B\}$, write out the homogeneous transformation matrix T_{SB}, such that going from frame $\{S\}$ to frame $\{B\}$ there is a translation of 7 units in the positive y_B direction, a translation of 9 units in the positive z_B direction, and there is also a rotation about x_S of $\pi/2$ rad.

c) Two engineers, named engineer A and engineer B, each design a coordinate frame system for a 4 DOF robot arm. Both engineers come up with the same final transformation for the Forward Kinematics transformation $T_{0EE}(\theta_1, \theta_2, \theta_3, \theta_4)$ from which the final column yields the position of the end effector with respect to coordinate frame $\{0\}$. Will engineer A's transformation T_{01} necessarily be identical to engineer B's transformation T_{01}?

d) If a 5 DOF robotic arm with a reach of 1.2m has transformation matrix $T_{0EE}(\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$ $= T_{01}(\theta_1)T_{12}(\theta_2)T_{23}(\theta_3)T_{34}(\theta_4)T_{45}(\theta_5)T_{5EE}()$, what is the physical interpretation of $T_{0EE} = I$ for a specific set of joint angles $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$? Draw a picture to help explain the physical interpretation.

Question 2 - 10 marks

The answers to this question are to be coded in python. Note that all angles are in radians. Please refer to Figure 1 for an illustration of the Puma 560 manipulator robot. To note, there are three motor controlled joints such that frame 1 rotates relative to frame 0 a controlled angle θ_1 rad, frame 2 rotates relative to frame 1 a controlled angle θ_2 rad, and frame 3 rotates relative to frame 2 a controlled angle θ_3 rad. Also, there is a distance of 0.3 m between the origins of frames 1 and 2, a distance of 0.4 meters between the origins of the frames 2 and 3, and a distance of 0.3 m between the origins of frames 3 and 4. Assume that for each pair of consecutive frames, one axis from each of the frame pairs are parallel. Assume Right hand rule conventions. Make other reasonable assumptions from the diagram.

a) In a file called `my_asignment_2.py`, write python functions that output 4x4 `numpy` arrays. You may want to write support functions. Make sure these functions pass all unit tests provided in the file `assignment_2_unit_test_2a.py`. You can place your file `my_asignment_2.py` within the same folder as the unit test file, and type python3 `assignment_2_unit_test_2a.py` to make sure your function passes the available tests. These are the python functions to write:

- `get_T01(theta_1)` - which inputs scalar θ_1 and outputs the homogeneous transformation matrix between coordinate frame 0 and coordinate frame 1.
- `get_T12(theta_2)` - which inputs scalar θ_2 and outputs the homogeneous transformation matrix between coordinate frame 1 and coordinate frame 2.
- `get_T23(theta_3)` - which inputs scalar θ_3 and outputs the homogeneous transformation matrix between coordinate frame 2 and coordinate frame 3.
- `get_T34()` - which has no inputs arguments and outputs the homogeneous transformation matrix between coordinate frame 3 and coordinate frame 4.
- `get_FK(theta_1, theta_2, theta_3)` - which inputs the three scalar rotation angles θ_1, θ_2, θ_3 and outputs the homogeneous transformation matrix between coordinate frame 0 and coordinate frame 4. We will ignore coordinate frames 5 and 6 in this exercise.

b) In the same file called `my_asignment_2.py,` write a python function called `ee_in_collision` that takes in three input arguments: a list including the three scalar angles `theta_1, theta_2, theta_3`, a 3x1 `numpy` array called `p_point,` and a scalar value `tolerance`. The function should return the a boolean value True if the distance between the end effector pose position and point `p_point` is less than `tolerance` m.

c) In the same file called `my_asignment_2.py,` write a python function called `path_in_collision` that takes in two input arguments. The first input `path` is a list of tuples, where each tuple contains three scalar joint angles. The second input `object_list` is a list of spherical objects, each being a two element tuple. Each tuple in `object_list` has a 3x1 `numpy` array defining its position wrt the zero coordinate frame, and a scalar `object_radius` in meters.

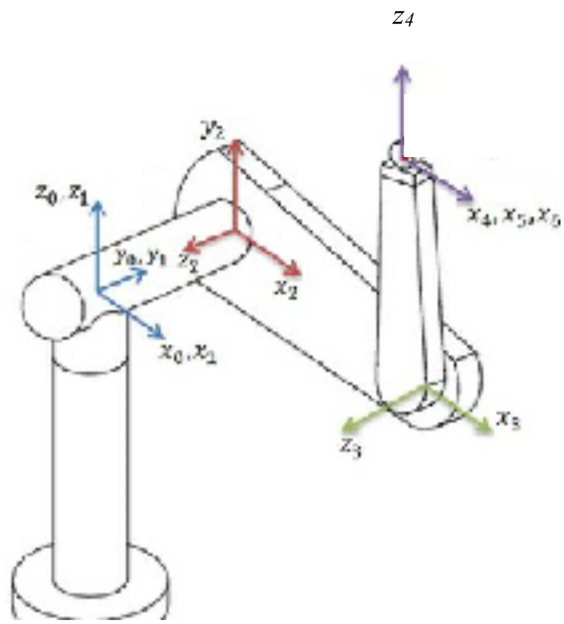

Figure 1: The Puma 560 (from “A Random Matrix Approach to Manipulator Jacobian”, 2013 ASME)

Question 3 - 10 marks

Without changing any code from question 2, you will be graded upon how well your functions from question 2 pass other, undisclosed test functions.