Final Exam

ENPM662: Introduction to Robot Modeling

Deadline : 11:30 pm, December 12, 2022

Instructions

1. Your submissions must contain 3 individual files, **do not** compress them and upload as a single zip file.
2. Your report named as **YourDirectoryID.pdf**, Code for problem 2 named as **transform.py**, instructions to run the code **README.md**.
3. Please use your **directory ID** not your 9 digit **UID**.
4. You are not allowed to discuss your solutions with your classmates. Please cite all the references you have used for your work.

1 Workspace & Velocity Kinematics

Given the DH diagram for the three joint manipulator in Fig.1. Note that d_1 is fixed but d_2 is variable.

1. Specify the set of points reachable by the endpoint of the manipulator (point A in the Fig.1) when both rotary joints can rotate unconstrained and the prismatic joint must satisfy $0 \leq d_2 \leq d_{2max}$.
2. Workspace of this manipulator can be partitioned into regions based on no. of ways a point in that region can be reached by the robot. These regions can be identified by certain geometric conditions. Specify all such regions in the workspace with its conditions and no. of ways a point can be reached in that region.
3. Derive the analytical jacobian for point A.

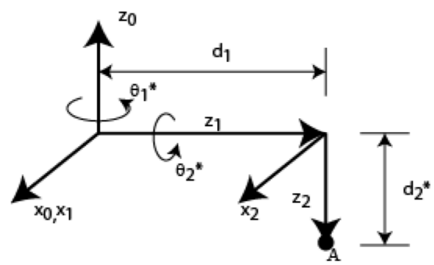

Figure 1: 3-link serial manipulator

2 3D-3D Registration

The process of estimating the 3D rigid transform between two set of 3D points that can optimally align these set of points is called 3D-3D registration. It has diverse applications in the field of robotics such as TCP calibration and hand-eye calibration. You are given 3 such sets with known correspondences. Write a python code to estimate the 3D rigid transform that will optimally align the corresponding points in a set.

- Briefly describe your steps in the report
- Tabulate each of these transforms H, along with the mean error after aligning the point clouds i.e., $\frac{1}{N}\sum_{i=1}^{N}||x'_i - Hx_i||$.
- You **cannot** use any off-the-shelf functions which estimates this transformation. Numpy functions for computing norm, inverse, svd are allowed.

1. Dataset 1
2. Dataset 2
3. Dataset 3

3 Dynamics

3.1 Part 1

Consider a rigid body undergoing a pure rotation with no external forces acting on it. Prove that

$$I_{xx}\dot{\omega}_x + (I_{zz} - I_{yy})\omega_y\omega_z = 0$$
$$I_{yy}\dot{\omega}_y + (I_{xx} - I_{zz})\omega_z\omega_x = 0$$
$$I_{zz}\dot{\omega}_z + (I_{yy} - I_{xx})\omega_x\omega_y = 0$$

Where, I_{xx}, I_{yy}, I_{zz} are principal moments of inertia of the body and $\omega_x, \omega_y, \omega_z$ are components of angular velocity expressed in the frame attached to the body.

3.2 Part 2

Derive the Euler-Langrage equations for the 3-link planar RPR robots as Fig.2. Bottom part of the figure depicts the manipulator when all joint values are zero. (Do not neglect gravity)

- a_1: the length of the first link
- a_{1c}: the length from joint 1 to the center of mass of the first link
- a_2: the length of the second link
- a_{2c}: the length from joint 2 to the center of mass of the second link
- a_{3c}: the length from joint 3 to the center of mass of the third link

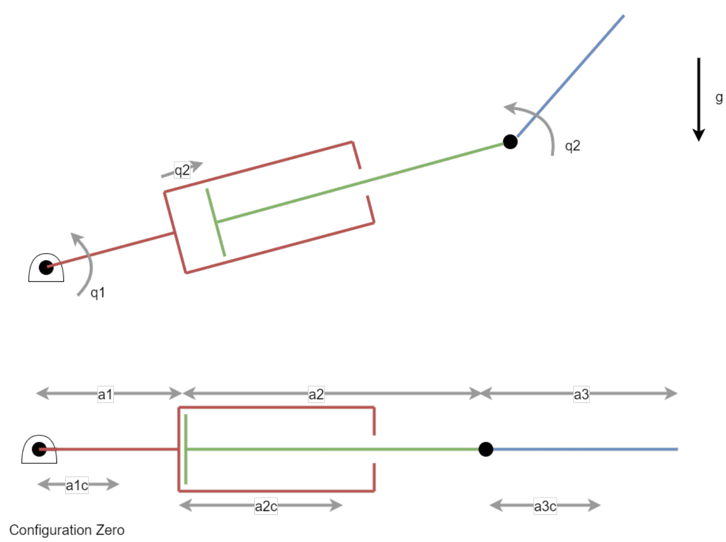

Figure 2: RPR Manipulator

4 Paper Review

Please write a brief review of the following research articles. A 500 words summary for each paper should be sufficient, you can choose to elaborate more (including figures) if you wish. Make sure your summary covers following aspects.

1. Motivation, along with two applications of this work
2. Scientific Contribution
3. Approach
4. Limitations
5. Existing extensions of this work

a Dynamic Identification of the KUKA LBR iiwa Robot With Retrieval of Physical Parameters Using Global Optimization

b Improving the Absolute Positioning Accuracy of Robot Manipulators