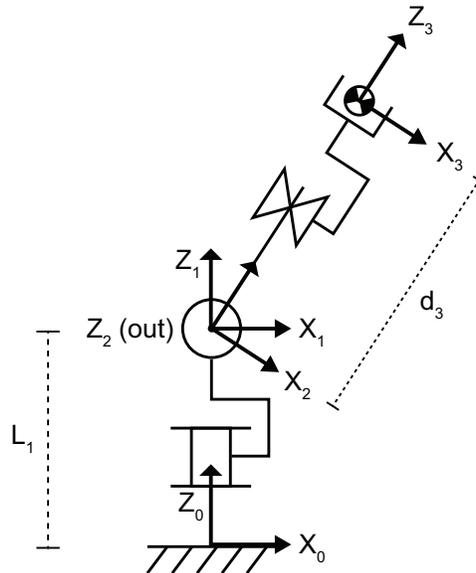   In this homework assignment, we will review kinematics and dynamics concepts from CS223A and then set up the simulation environment (SAI) that will be used for subsequent homework assignments and the final project.

1. Consider the RRP manipulator below. Assume this robot is massless except for the end effector, which is a mass point $m_3 = 1\,\text{kg}$.

   (a) Find the position $^0P_3$ of the end effector expressed in frame $\{0\}$. *Hint:* Avoid DH parameters and use geometric intuition instead. Break up the projections by finding $^1P_3$ before $^0P_3$. Alternatively, you may use a symbolic calculator.

   (b) Find the linear Jacobian ^0J_v of the end effector expressed in frame $\{0\}$.

   (c) Find the linear singularity of this robot. Draw the robot in a singular configuration and specify the singular direction. *Hint:* Avoid taking the determinant and use intuition to identify the singularity.

   (d) Write out ^0J_v for the singular configuration you drew above. What joint loses the ability to produce velocities at the end effector? What is the singular direction expressed in frame $\{0\}$ when $\theta_1 = 0°$? When $\theta_1 = 90°$?

   (e) Find the joint space mass matrix M for this manipulator.

   (f) Find the gravity vector G. Assume acceleration due to gravity is $[0, 0, -g]^T$, where $g = 9.8\,\text{m s}^{-2}$.

2. Now, we will run this robot in simulation. Follow the setup instructions from the repository (`https://github.com/tmigimatsu/cs225a-dist`) to get SAI installed on your system.

   (a) Find the simulated Jacobian ^0J_v for the two configurations considered in 1 (d). Are the results consistent with your hand computations? What is different?

   (b) For the following plots, output the desired mass matrix values to a file and use a program like MATLAB or Excel for plotting [1]. For each, compare your results to 1 (e) and explain physically why each configuration sweep produces your results.

      i. Set $\theta_1 = 0°$ and $d_3 = 0.1$ m. Plot m_{11}, m_{22}, and m_{33} as θ_2 varies from $-90°$ to $90°$.

      ii. Set $\theta_1 = 0°$ and $\theta_2 = 0°$. Plot m_{11}, m_{22}, and m_{33} as d_3 varies from 0.0 m to 0.2 m.

      iii. Set $\theta_1 = 0°$ and $\theta_2 = 90°$. Plot m_{11}, m_{22}, and m_{33} as d_3 varies from 0.0 m to 0.2 m.

   (c) Now, produce the same plots for G. For each, compare your results to 1 (f) and explain physically why each configuration sweep produces your results.

      i. Set $\theta_1 = 0°$ and $d_3 = 0.1$ m. Plot G as θ_2 varies from $-90°$ to $90°$.

      ii. Set $\theta_1 = 0°$ and $\theta_2 = 0°$. Plot G as d_3 varies from 0 m to 0.2 m.

      iii. Set $\theta_1 = 0°$ and $\theta_2 = 90°$. Plot G as d_3 varies from 0 m to 0.2 m.

3. Attach your SAI code here.

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[1] If you're feeling ambitious, you can output the keys to Redis and create a Python script to catch the keys and plot them with Matplotlib. We will be using Redis heavily later in the course, so it'll be good to familiarize yourself with it.