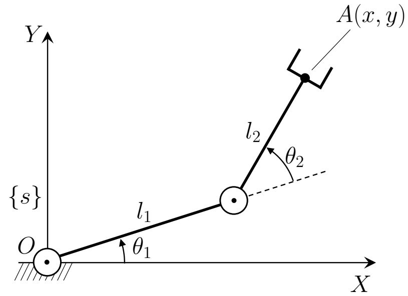
Homework #1

MEC 529: Introduction to Robotics

Spring 2023

Instructor	Amin Fakhari, Ph.D.
Assigned Date	Wednesday, Feb. 1, 2023
Due Date	Tuesday, Feb. 14, 2023

Consider a 2R planar robot as shown in the figure. Let θ_1 and θ_2 be the joint angles of the robot, x and y be the coordinates of the end-effector (i.e., point A) in the fixed base frame $\{s\}$, and l_1 and l_2 be the length of the links. Assume that $l_1 = l_2 = 0.3$ m.



1. The robot forward kinematics map $\mathcal{FK} : \mathbb{R}^2 \to \mathbb{R}^2$ is defined as $\boldsymbol{q} = \mathcal{FK}(\boldsymbol{\theta})$ where $\boldsymbol{\theta} = (\theta_1, \theta_2) \in \mathbb{R}^2$ is the vector of joint angles and $\boldsymbol{q} = (x, y) \in \mathbb{R}^2$ is the position vector of the end-effector. Write a MATLAB function `FK_2R` for the forward kinematics of the robot ($\boldsymbol{q} = \texttt{FK\_2R}(\boldsymbol{\theta})$). Then, write a program that allows the user to determine the joint angles θ_1 and θ_2, and computes the coordinates of the end-effector position (x, y), and also schematically plots the robot configuration (as two line segments). Validate your function using some special configurations of the robot (e.g., $(0, 0)$, $(\pi/4, 0)$, and $(\pi/2, 0)$), and discuss the results (by including proper figures at different configurations of the robot) in your report.

2. The robot inverse kinematics map $\mathcal{IK} : \mathbb{R}^2 \to \mathbb{R}^2$ is defined as $\boldsymbol{\theta} = \mathcal{IK}(\boldsymbol{q})$. Write a MATLAB function `IK_2R` for the inverse kinematics of the robot, which returns all the possible solutions ($\boldsymbol{\theta} = \texttt{IK\_2R}(\boldsymbol{q})$). Then, write a program that allows the user to determine the end-effector position (x, y), and computes the joint angles θ_1 and θ_2, and also schematically plots all the possible robot configurations. Validate your `IK_2R` function using your `FK_2R` function for some arbitrary configurations, and discuss the results (by including proper figures at different configurations of the robot) in your report.

3. Write a MATLAB function `J_2R` to compute the robot Jacobian $\boldsymbol{J}(\boldsymbol{\theta}) \in \mathbb{R}^{2\times 2}$ for any given joint angles θ_1 and θ_2 ($\boldsymbol{J} = \texttt{J\_2R}(\boldsymbol{\theta})$). Then, write a program that allows the user to determine the joint angles θ_1 and θ_2, and plots the robot, velocity manipulability ellipse, and force manipulability ellipse (with different colors) centered at the robot's end-effector (i.e., point A). Choose the proper scaling for the ellipses so that they can be easily visualized (e.g., the ellipse should usually be shorter than the arm but not so small that you cannot easily see it). Discuss the results (by including proper figures at different configurations of the robot) in your report.

4. Plot the robot workspace (the whole region that end-effector can reach) when $\theta_1 \in [0, \pi]$ and $\theta_2 \in [0, 5\pi/6]$.

Notes:

- Your report should include a brief description of your results with supporting figures which are usually output of your code. You do not have to include a screenshot of your code in the report.
- Add proper comments to your code, which detail what each part of the code is doing.
- Submit your report and code files in a single Zip file on Brightspace. Name the Zip file as `HW#N_FullName`, where `N` is the homework number and `FullName` is your full name. A report without its supporting code files and code files without a supporting report are NOT acceptable.
- Make sure to submit all the files/functions required to properly execute your code.