Problem 1: Take Care of the Obstacle!

In this problem a planar 4-DOF robotic manipulator to follows a specified trajectory while avoiding a predefined obstacle. The robot's trajectory is parameterized in terms of time, and inverse kinematics is used to compute the necessary joint angles. An animation visualizes the movement of the robot and demonstrates collision avoidance.

We know that forward kinematic problem's equations are:

$$x = L_1 \cos(\theta_1) + L_2 \cos(\theta_1 + \theta_2) + L_3 \cos(\theta_1 + \theta_2 + \theta_3) + L_4 \cos(\theta_1 + \theta_2 + \theta_3 + \theta_4)$$

$$y = L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2) + L_3 \sin(\theta_1 + \theta_2 + \theta_3) + L_4 \sin(\theta_1 + \theta_2 + \theta_3 + \theta_4)$$

$$\phi = \theta_1 + \theta_2 + \theta_3 + \theta_4$$

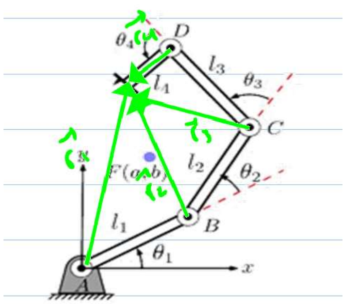

Figure 1: RRRR manipulator

$$J = \begin{bmatrix} 1 & 1 & 1 & 1 \\ E\,\overrightarrow{r_1} & E\,\overrightarrow{r_2} & E\overrightarrow{r_3} & E\overrightarrow{r_4} \end{bmatrix}_{3\times 4}, \text{ m < n redundant robot}$$

$$E = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

$$t = J\dot{\theta} \rightarrow \begin{bmatrix} \dot{\phi} \\ \dot{x} \\ \dot{y} \end{bmatrix} = J_{3\times 4} \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \\ \dot{\theta}_4 \end{bmatrix} \rightarrow \quad J^{-1} t \neq \dot{\theta}$$

I've implemented IKP with Pseudo-Inverse and Redundancy Resolution. Available in MATLAB file.

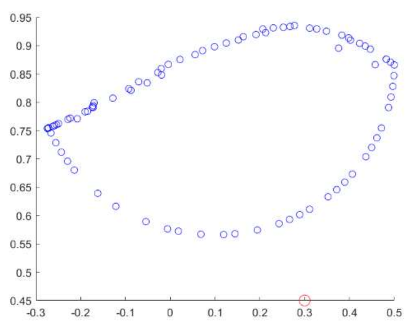

Figure 2: IKP with desired trajectory.

The inverse kinematics problem is solved using the *fmincon* function from MATLAB's Optimization Toolbox, which allows for non-linear constraints and optimization:

Objective Function: Minimize the change in joint angles and penalize configurations that bring the end-effector close to the obstacle.

Constraint Function: Ensure the end-effector reaches the desired position and orientation.

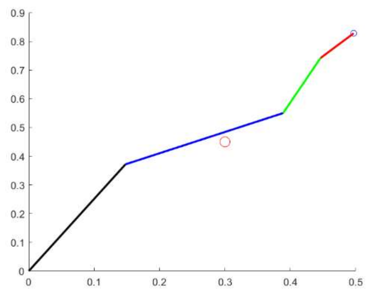

Figure 3: Avoiding the obstacle.

The animation is created by plotting the robot's configuration at each time step:
Links: Represented by lines connecting the joints.
End-Effector: Represented by a blue circle.
Obstacle: Represented by a red circle.

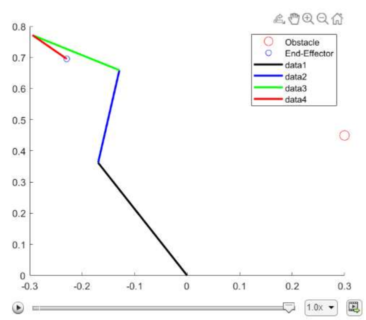

Figure 4: RRRR avoiding the obstacle animation

You can find the code attached named '4DOF_Robotic_Manipulator_Trajectory_Avoidance.mlx'.