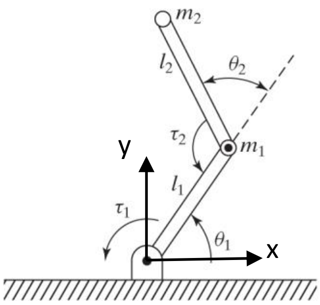
Boğaziçi University
Electrical and Electronics Engineering Department
MECA 513 Robotics and Robot Control
Course Project

The objective of this project is to perform all the stages of modeling and control of a RR robot arm. Consider the planar RR robot arm shown in the figure below.



Link lengths are l_1 and l_2, joint variables are θ_1 and θ_2, mass of the links are assumed to be point mass and concentrated at the distal end of the link and are given by m_1 and m_2 as shown in the figure. g denotes the gravity constant and the direction of the gravity is shown in the figure. Denote with $q = (\theta_1, \theta_2)^T$ the joint space configuration and with $X = (x, y)^T$ the Cartesian space configuration of the robot. The control input to the system is $\tau = (\tau_1, \tau_2)^T$ where τ_1 and τ_2 denote the torques applied to the joints.

1. Define frames at the joints of the robot and determine the corresponding Denavit-Hartenberg parameters. Express the parameters in a table form.
2. Solve the forward kinematics of the robot using the obtained Denavit-Hartenberg parameters. With this respect, find the transformations between all consecutive joint frames and the transformation from all joint frames to the base frame.
3. Solve the inverse kinematics of the robot. Calculate all possible solutions.
4. Find the Jacobian which relates the speed of the tip of the robot to the joint speeds.
5. Derive the dynamic equations of the robot.

   Assume that values of the robot parameters are as follows: $m_1 = m_2 = 1kg$ ve $l_1 = l_2 = 1m$. Also assume that the value of the gravity constant is $g = 9.8m/s^2$.

6. Assume that initially the robot is motionless at configuration $\theta_1(0) = \theta_2(0) = 0$. Plan trajectories both in joint space and task space which will move the tip of the robot (the point where m_2 is located) from the initial configuration to the Cartesian configuration $X = (0m,1m)$. Develop controllers which will achieve the desired motion using
   a. Resolved Motion Rate Control
   b. Joint Space Control (using nonlinear dynamic decoupling)
   c. Task/Operation Space Control (using nonlinear dynamic decoupling)

   Simulate your controller using Matlab and/or Simulink.
7. Assume that initially the robot is motionless at configuration $\theta_1(0) = 30^o, \theta_2(0) = 150^o$. It is required that the tip of the robot (the point where m_2 is located) is required to draw a circle centered at $(0m,1m)$ and radius 0.5m (the motion could be continuous without a need to stop).

Repeat problem 6 (i.e., plan desired trajectories and develop stated controllers) so that the robot achieves the desired objective. Simulate your controller using Matlab and/or Simulink.

Submit your results in a project report. The report should include all the derivations, related discussions (what were the difficulties, how did you overcome them, was everything requested feasible, did you skip any parts and if so why etc.), Matlab/Simulink code, as well as the obtained results. Your plots should be properly labelled. Print screen or scope plots are not acceptable! You should demonstrate a run of your program in class. Please also send your program file and project report by e-mail in a .rar file with the file convention yourname_project.rar.

Due: December 31, 2017