Homework 6, 2025

This homework needs to be done and submitted in groups of 3 to 5 students.

Please note: in this assignment statement the notation of MLS is used a few times (not necessarily always) without explanation where it is used.

Consider a four degree of freedom robotic manipulator schematically shown in figure 1, in its reference configuration. This is exactly the manipulator discussed in MLS example 4.4 p. 177.

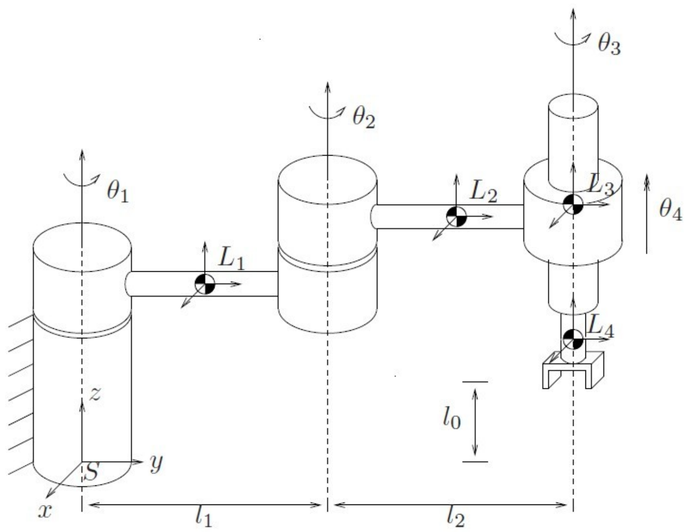

Figure 1: The manipulator in the reference configuration.

Assignment:

(a) Build a SIMULINK model of a computed torque controller controlling the manipulator for tracking a desired joint angle trajectory θ_d, which is in the form of a rounded step function.

The three revolute joints should all track a unit final value (in radians), while the prismatic joint should track a final value of 0.1 m. Since for the computed torque control law θ_d must be twice differentiable, a scalar rounded step function that meets this requirements was generated and stored in a MATLAB '.mat' file, together with its 1st and 2nd time derivatives. The data was stored as a MATLAB time series.

You are given on Moodle a zip file that contains a SIMULINK framework program stored in MATLAB R2024b and MATLAB 2023a versions ('MLS4_4_function_and_input.slx' and 'MLS4_4_function_and_input_R2023a.slx', respectively). You can select which one of these framework programs you would like to use, in which to develop your solution. You may also just copy what you deem necessary and work with your own framework.

The zip file also contains the '.mat' file that contains the rounded step function and the program 'MCandN_init.mlx' that you need to run to initialize the MATLAB workspace, before running either SIMULINK program. All the parameter values that you need to use, are defined in this initialization file. These essentially are the same as were specified in the May 30 tutorial. It also contains various other MATLAB function files that are called by the SIMULINK programs. The given SIMULINK programs will extract the rounded step function and its 1st and 2nd time derivatives and re-package these into three vectors θ_d, $\dot{\theta}_d$ and $\ddot{\theta}_d$, all three at a specific point in time $\in \mathbb{R}^4$. In the process and only for the purposes checking the functions, θ_{d2}, θ_{d3} and θ_{d4}, and their derivatives, are multiplied by factors of 0.8, 0.6 and 0.4, respectively, and then plotted on separate scopes. If you get the correct graphs, it will confirm that your code reads the data for tracking correctly.

The SIMULINK program also contains a MATLAB function block that I have written, to compute $M(\theta)$, $C(\theta, \dot{\theta})$ and $N(\theta, \dot{\theta})$. You may use my function block, but you should preferably write your own. If you wish to write your own but do not know how to create one in SIMULINK, simply double-click on my block, which will open it in a MATLAB editor. Then you can replace all the code inside the function block with your own MATLAB code. My function calculates the same $M(\theta)$ as in the example in MLS, for a set of parameters and variables, but not the same $C(\theta, \dot{\theta})$. I still need to investigate which one is correct, but for the purposes of this assignment my function works well. It will of course render a different result than your function if you write your own and mine happens to be faulty. I shall take this in mind during grading and you will not be penalized for the discrepancies that may result due to this.

(b) Once you are confident that your controller works and the simulation runs well, use your simulation to study the tracking robustness of the computed torque control scheme. To do this, you may for instance reduce or increase all the values in the $\mathcal{M}'$ matrix by 5 or 10 percent **in the plant only**, while keeping the corresponding values in the controller at their nominal values. Report on this investigation.

(c) Also investigate the use of a PD control scheme on this manipulator and report on your findings.

(d) Returning to the computed torque control scheme, with the plant and controller having the same properties: it is observed that the torque values that are required to track the required θ_d trajectory is quite large. Investigate the effect of torque saturation. For this assume that the motor torques are limited to the following values: $|\tau| \leq \begin{bmatrix} 2000 & 1000 & 1000 & 100 \end{bmatrix}^T$ Nm or N.

Include graphs of simulated results in your report, especially to support your arguments or as supporting evidence of observed phenomenon.

You need to upload your report to a Moodle assignment. The details and due date will still be announced.