ELEC-C1110 Basics of Automation and Systems Engineering

Assignment 3
Spring 2024

Introduction

In the third exercise, the dynamics model is further studied. The assumption in this exercise is that some of the dynamics model parameters are unknown. As a further task the assumption is that parts of the dynamics equation are unknown. Both the parameters and the dynamics model must be learned from data.

For the report, use the report 3 template found in MyCourses. Fill in your student number, name, and group number in the space on the report template. Write down the answers to the tasks in the relevant sections. The total scope of task 3 report 3 is approximately 3 pages or less when responding to all the points requested in the assignments. Return the finished report in pdf format. In addition to the report, be sure to return the Python template that you have completed.

Tasks

In this exercise the goal is to 1) learn model parameters and 2) parts of the dynamics equation using general models. The system used in this exercise is same as the arm robot used in Project 2. The tasks revolve around estimating the parameters or modelling the rotational movement of the shoulder joint with pulsed motor torque. The robot is initially at rest and the angle of the shoulder joint is zero. The angle of the elbow joint is kept as constant and unknown. The dynamics equation of the system is as follows:

$$J\ddot{\phi} = T - b\dot{\phi}$$

Task 1: Use least squares method to find the best estimate of the parameters of the above system (b and J). The noisy samples of angular velocity, angular acceleration and applied torque input are provided to you in python template. Report the estimated system parameters.

Task 2: Using the learned parameters from Task 1, plot the output (joint angle curve) for an input signal T = 0.01 u(t), where u(t) is step function. Run the simulation for 750 s. Compare the plot with the actual response curve generated using the dynamics equations with true parameters provided to you in Python script already.

Task 3: In this task, assume that we do not have any prior info about the dynamics of the robot system. Given the measurements of the system (angular velocity, angular acceleration, torque) at a time instant **t**, the task is to build a neural network that predicts the difference between shoulder angle at time instant **t+1** and **t.** This change in shoulder angle (delta) will be your target vector, and it is provided to you in the python script. The noisy samples of angular velocity, angular acceleration and applied torque are also provided to you which needs to be used as the input to the neural network. Attach the plot of model predictions curve. Finally, report the mean-squared error between your model predictions and the target vector.

Task 4: The task is to combine a known and an unknown model. For the robot system explained in this project, consider that there is an unknown external torque acting and the system follows a new dynamic equation as below:

$$J\ddot{\phi} + b\dot{\phi} + g(\ddot{\phi}, \dot{\phi}) = T$$

where **g** function is the unknown torque function. The task is to model this unknown function using a neural network. The noisy samples of angular velocity, angular acceleration and applied torque input are also provided to you. Plot the unknown function prediction curve using the learned neural network for the given samples. The known system parameters are as follows: J = 10; b = 0.5.

Task 5: How do you think the noises in the samples affect the system parameter estimation using least squares? What could be done to deal with the problems of noisy observations?

Task 6: What are the benefits of modelling only the unknown part of a dynamic equation rather than modelling the entire dynamic equation? Why neural networks are useful in modelling unknown systems?

Tips for tasks

- The samples for each task are pre-loaded and given to you in python scripts. Note that the samples for different tasks are different.
- In Task 3, the system is considered as completely unknown, and the differential equation is not used.
- Refer to Computer Assignment 2 for code templates.