ME 418/518 Data-Based Control

Midterm Exam

Deadline – 18 November 2025, 11.59pm.

Using large language models or any AI assistant or code-generation tools is strictly prohibited, unless they are permitted in the problem statement. You must solve the questions and write your report entirely on your own. Collaboration with other students is not allowed. Submit your solutions as a single pdf file, where the related code must be in the appendix. Also submit your code to Moodle as a single zip file. Name your MATLAB m files using the problem number. Your code must be error-free and create the required plots. Make sure that you add comments to your code explaining each step of the solution.

Please sign the following statement:

`I confirm that I completed this exam completely on my own, without any use of large language models, AI assistants, or code-generation tools.`

Name: Erinç Ada Ceylan
Date: 18.11.2025
Signature:

Problem 1 (25pts). Consider the plant transfer function $\frac{Y(s)}{U(s)} = \frac{5}{s^2+1.2s+5}$. The sampling interval is T=0.01s. The experiment will last 40 seconds, therefore you will obtain N=4000 samples. The control input will be fed to the plant using ZOH. The sensor dynamics is given as $G_s(s) = \frac{1}{0.15s+1}$. Sensor bias is -0.25. Measurement noise is zero-mean Gaussian with s.d. $\sigma = 0.05$ (added after sampling). Insert 25 random spikes to the sampled output. Use a PRBS input u[k] with range [-1,1], with dwell time 0.2 seconds.

For all the questions below, show your code in the appendix of the report, and submit to Moodle.

3.1. Create u[k] and u(t) (using ZOH). Create y[k]. Clearly show these signals in separate figures in your report.

3.2. For this problem, you will clean your data. <u>At the end, show raw and cleaned data in the same plot in your report.</u>

a) First detect, then replace the spikes in y[k] by interpolation. Explain your spike detection method.

b) Detect the bias (you can use zero input for a while for this) and remove it.

c) Filter the noise using a moving average. Explain your method clearly, including the window size. (use the same filter for the input when you identify models in the next problem)

Problem 2 (25pts). In this problem, you will create an FIR model <u>using the cleaned data</u> in the previous problem. You can use MATLAB functions except direct FIR functions. Do not forget to apply to the inputs the same filter you used for the output in the previous problem.

The Model: $\hat{y}[k] = \sum_{1}^{n_b} b_i u[k-i] = \Phi[k]^T b,\ \ \Phi[k] = [u[k],\ u[k-1], \ldots,\ u[k-n_b]]^T$

a) Split the data into two sets: Training (first 35 seconds) and Validation (last 15 seconds). Estimate the model parameters for $n_b = 40$ and $n_b = 120$.

b) Using the validation data generate $\hat{y}[k]$ for each model and plot $\hat{y}[k]$ and the measured $y[k]$ on the same plot. Notice that you will create two plots, one for each model.

c) Using the validation data, report RMSE and fit percentage for both models.

Problem 3 (25pts). Using the same input-output data and the data split, obtain an ARX model. Try 3 different pairs (n_a, n_b), where n_a is number of output history and n_b is the number of input history, and determine the best pair based on the FIT percentage.

Problem 4 (25pts). Consider the following plant dynamics

$x_{k+1} = 0.9x_k + 2u_k,\ \ y_k = x_k.$

We know that the actuator has the following saturation limits: $|u| < 0.55,\ \ |\Delta u| < 0.3$

a) Design an MPC controller to track a step reference of magnitude 2. You are free to choose your prediction and control horizons. Assuming an 0.05 sampling interval, simulate the system for 6 seconds and show the tracking and control signal curves in separate figures. (Do not use MPC toolbox in MATLAB. You can use "quadprog".)

b) Add measurement noise to your system and repeat "a)". You are free to choose the noise structure. Make sure that the noise amplitude you choose makes the noise visible in the plots. Discuss the results by comparing them with "a)".

c) Repeat "b)" with the same noise structure but this time the reference is a sine wave given as $r[k] = \sin\left(\frac{0.1\pi}{3}k\right)$.