ME 418/518 Data-Based Control
Midterm Exam Report

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Problem 1 – Data Generation and Cleaning

A PRBS input with dwell time of 0.2 seconds was generated and applied to the continuous-time plant using a zero-order hold. The experiment duration was 40 seconds, producing 4000 samples. The plant output was passed through the given sensor dynamics, and bias, Gaussian noise, and 25 random spikes were added. The raw signals exhibit clear noise and spikes. Spike detection was performed using a Median Absolute Deviation (MAD)–based thresholding. Detected spikes were replaced via linear interpolation. Sensor bias was estimated from the initial zero-input segment and removed. A moving-average filter with window size $M = 5$ was applied to both $u[k]$ and $y[k]$ to reduce noise without distorting the dynamics.

Figures included show:

- PRBS input $u[k]$ and ZOH signal $u(t)$,
- Raw output $y[k]$ with bias, noise, and spikes,
- Final cleaned output after spike removal, bias correction, and filtering.

Problem 2 – FIR Model Identification

The cleaned dataset was split into a 25-second training set and a 15-second validation set. Two FIR models were identified with $n_b = 40$ and $n_b = 120$. The smaller model ($n_b = 40$) fails to capture system dynamics and produces poor validation performance. Increasing the model order to $n_b = 120$ significantly improves the prediction quality.

Validation metrics obtained:

- RMSE improves from 0.6163 to 0.2726,
- Fit improves from 3.61% to 57.37%.

Both validation plots are included in the report.

Problem 3 – ARX Model Identification

Using the same training/validation split, three ARX models were tested with different (n_a, n_b) values:

$$(1, 40),\ (2, 40),\ (2, 80)$$

All ARX models perform significantly better than FIR due to the inclusion of output history. The best validation fit was obtained with:

$$(n_a,\ n_b) = (2,\ 80)$$

achieving approximately 97% fit.

Validation plots for all three structures are included.

Problem 4 – Model Predictive Control

The discrete-time plant

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

was controlled using MPC with constraints

$$|u_k| \leq 0.55, \qquad |\Delta u_k| \leq 0.30.$$

Prediction and control horizons were chosen as $N_p = 8$, $N_c = 4$. Quadratic programs were solved using `quadprog`.

(a) Step Reference Tracking

The MPC controller successfully tracks the reference of magnitude 2 within one second. The control signal respects the saturation and rate constraints. Plots of the tracking performance and control input are included.

(b) Tracking with Measurement Noise

Zero-mean Gaussian measurement noise was added. The tracking performance remains stable, but the control signal becomes more active due to noisy feedback, as expected. Plots of the noisy output and corresponding control input are included.

(c) Sine-Wave Reference Tracking

The same noise structure was applied while tracking

$$r[k] = \sin\left(\frac{0.1\pi}{3}k\right).$$

The controller successfully follows the sinusoidal reference while satisfying constraints. Tracking, control input, and predicted outputs are included.

Appendix

The following appendix contains:

- All MATLAB code for Problems 1–4,
- All figures required in the exam,