CL686 Course Project: Generic Description

Title: Performance Evaluation of PID, LQOC and Linear MPC using Nonlinear System Dynamic Simulation

Submission Deadline: 23:59 on 11 April (Monday), 2022

Total Marks: 20

Marks for MPC and LQOC programs: 10

Marks for report: 10

Controllers to be implemented as part of course project

1. **Linear Quadratic Optimal Controller:** To be implemented using state space realization of ARX model developed in Computing Assignment 4 and innovation bias approach. (You are expected to change your Computing Assignment 3 program for implementing this data driven model based control scheme.)
2. **Model Predictive Controller (MPC):** To be implemented using Kalman predictor developed using discrete linear perturbation model developed from the mechanistic model and used in Computing Assignment 3

Controllers to be evaluated while preparing project report

1. **PID:** Multi-loop PID controllers (used in Computing Assignment 2)
2. **Pole Placement** design based state feedback **controller (PPC)** implemented using Luenberger observer as part of Computing Assignment 3
3. **Linear Quadratic Optimal controller** implemented using ARX model and innovation bias approach
4. **Model Predictive Controller (MPC)** implemented using linearized mechanistic model
5. **Sensitivity Analysis of MPC scheme:** Study effect of one MPC tuning parameter on the closed loop performance. (Each student has been assigned a different parameter for carrying this analysis).

Let M = sum of digits in your roll number.

- Case **M is ODD** number: Use **Innovation Bias Approach** for MPC implementation

- Case **M is EVEN** number: Use **State Augmentation (Input Bias) Approach** for MPC

In other words, if you have used Innovation Bias approach for Computing Assignment 3, then use State Augmentation (Input Bias) Approach for MPC implementation and vice versa.

Control Algorithms: Details of algorithms for Kalman predictor, LQG and MPC controllers are specified in the following files

- Course_Project_Innovation_Bias_Generic_Description.pdf
- Course_Project_State_Augmentation_Generic_Description.pdf
- Course_Project_ARX_LQOC_Innovation_Bias.pdf

Servo and Regulatory control problems and closed loop simulation conditions are specified in the following files

- System1_Specific_Simulation_Parameters.pdf
- System2_Specific_Simulation_Parameters.pdf

Performance Comparison

- Use *randn('seed',0)* at the beginning of each simulation program so that identical sets of random numbers will be generated in each simulation run.
- **Graphical comparison:** Plot results of PID, LQOC and MPC for servo and regulatory problem defined for your system
  - $\mathcal{Y}_i(k)$ v/s k and $\mathcal{R}_i(k)$ v/s k for all 4 controllers in same figure for $i = 1, 2$ where $\mathcal{R}(k) = \mathbf{r}(k) + \mathcal{Y}_s$
  - $\mathcal{U}_i(k)$ v/s k using stairs function for all 4 controllers in same figure for $i = 1, 2$
  - $\mathcal{D}(k)$ v/s k using stairs function
  - **Plot all 3 controller responses in same figure.** Use *legend* command in Matlab to indicate graphs for PID, LQOC and MPC
  - Properly label x and y axes

- **Performance indices based comparison (in table form):** for PID, PPC, LQOC and MPC for the servo and regulatory problems defined for your system
  - **Sum Squared Error (SSE)**

    $$SSE_i = \sum_{k=1}^{N_s} [\mathcal{Y}_i(k) - \mathcal{R}_i(k)]^2$$

    for i = 1,2
  - **Sum Squared Manipulated Variables (SSMV)**

    $$SSMV_i = \sum_{k=1}^{N_s} [\mathcal{U}_i(k) - \mathcal{U}_s]^2$$

    for i = 1,2

What to Submit?

1. Program files for LQOC and MPC
2. A presentation (ppt or pdf) or a report consisting of following details:
   (a) Aim of the project
   (b) System Model
   (c) Control relevant discrete linear models,
   (d) Controller tuning parameters
   (e) Tables of performance indices for PID, PPC, LQOC and MPC for the servo and regulatory problems defined for your system
   (f) Comparative figures for PID, LQOC and MPC for the servo and regulatory problems defined for your system
   (g) Sensitivity Analysis of MPC: Study effect of the **allotted parameter variation** on MPC performance (using Tables and figures) while keeping other parameteters constant. Depending the paremeter alloted to you
      i. change W_x (or W_y) as $\rho \times [W_x]_{\text{nominal}}$ (or $\rho \times [W_y]_{\text{nominal}}$) where $\rho > 0$
      ii. change W_u as $\rho \times [W_u]_{\text{nominal}}$ where $\rho > 0$
      iii. change q (control horizon) from specified value to $q = p$
      iv. increase and decrease prediction horizon p
      Report the effect on MPC perfrmance using tables and figures or performance indices v/s the parameter changed.
   (h) Analysis of simulation results (based on Tables and Figures) and conclusions.