Model Predictive Control: Theory and Applications

Assignment 6

DMC Codes Uploaded on Course Website (Download Link Here)

In the class, we developed step-response MPC (i.e., classical DMC algorithm) for control of the following SISO system (with sampling time *h*=5 and *n*=24 step):

$$Y(s) = \frac{2.5e^{-7s}}{20s+1}U(s)$$

We developed DMC algorithm to control the system at the setpoint of $r = 1$. Controller tuning parameters were: $m = 4,\ p = 10,\ Q = 1,\ R = 0.04$ and the following constraints were implemented: $-0.5 \le u(k) \le 0.5$ and $|\Delta u(k)| \le 0.05$.

In this assignment, you will repeat the simulations for *your* SISO system. This will be followed by an analysis of the effect of tuning parameters. Finally, we will extend it to the case of measured disturbance. The link for DMC codes for this assignment:
https://drive.google.com/file/d/1dyyHuH874wUA2RAIkesfsRtEihbR8SGq/

Problem 1: SISO DMC **(3 marks)**

We considered the following FOPTD system in the previous assignments:

$$G = \frac{1.25e^{-1.4s}}{5s+1}$$

with sampling interval of $\Delta t = 1$ and $n = 25$. In this assignment, develop the Dynamic Matrix Control (DMC) algorithm to control this system at the **setpoint of $r = 0.8$**.

The input constraints are $-1 \le u(k) \le 1$ and $|\Delta u(k)| \le 0.1$.

Please use the following tuning parameters: $m = 4,\ p = 10,\ Q = 1,\ R = 0.1$

1. Please include the MATLAB code as well as input and output profiles (u vs. t and y vs. t plots) for this problem.

Problem-2: Effect of Tuning Parameters **(3 marks)**

2. Effect of weight parameters: Repeat the above simulations with a higher input weight value of $R = 100$. Keep the other parameters at the same values as that in Problem 1. Compare with results of Problem 1.

3. Effect of prediction horizon: Repeat the simulations of Problem-1, but with p=4. Note that the other parameters are kept same as those of Problem-1. In this case, the control and prediction horizons have the same value of $m = p = 4$.

4. Effect of control horizon: Repeat the simulations of Problem-1, but with m=1, and with other parameters same as those in Problem-1.

Please compare the results with those of Problem-1 to see the effect of these parameters.

Problem-3: Extension to Measured Disturbance Case **(4 marks)**

Modify the uploaded SISO system code to simulate the case of measured disturbance:

$$y(s) = \frac{1.25e^{-1.4s}}{5s+1}u(s) + \frac{0.2e^{-0.7s}}{6s+1}d(s)$$

Modify the code to handle a step change of $d(t) = 0.5$ in the measured disturbance. Use the same setpoint, constraints and tuning parameters as in Problem-1.

Hint for handling measured disturbances: Consider a model: $y = G_p u + G_d d$.

As we have seen in previous assignments, we can obtain step response coefficient matrices S and S_d from G_p and G_d. The model formulation, thus, becomes:

$$\tilde{Y}(k+1) = M\tilde{Y}(k) + S\,\Delta u(k) + \boldsymbol{S_d}\,\boldsymbol{\Delta d(k)}$$

whereas, the p-step prediction equation becomes:

$$\mathcal{Y}_p(k+1) = \mathcal{M}\tilde{Y}(k) + \mathcal{S}^U \Delta\mathcal{U}_m(k) + \boldsymbol{\mathcal{S}^d \Delta d(k)}$$

As discussed in the course videos, the Hessian remains same, whereas gradient becomes:

$$g^T = [\mathcal{S}^u]^T \Gamma^y \{\mathcal{M}\tilde{Y}(k) + \boldsymbol{\mathcal{S}^d \Delta d(k)} - \mathcal{R}\}$$

You only need to focus on the two highlighted equations. Other equations remain unchanged. The uploaded code does not have the bolded term involving $\Delta d(k)$. You need to edit the code at only the appropriate locations to:

(i) Obtain S_d and $\mathcal{S}^d$ matrices of size $(n.n_y) \times n_d$ and $(p.n_y) \times n_d$;

(ii) edit plant behavior and model predictions to include the effect of $d(k)$; and

(iii) edit the gradient calculation required for obtaining the input moves.

These are the main changes required in the code. Other than these, the idea remains the same.