Course Mini-Project

Due: Saturday, 2nd January 2021 at 10 pm

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Instructions

- Submit your MATLAB codes on MATLAB Grader before the deadline
- Please ignore any automated tests.
- Note that the project is evaluated manually by myself and the TAs. There are no tests on the Grader because each student is given a separate assignment.
- Please type your roll number in the first line of your answers in MATLAB grader
- Please ensure that the question paper you received is the one that carries your roll number

Problem 1 **(6 points)**

Consider the state space model, $x(k+1) = Ax(k) + Bu(k)$; $y(k) = Cx(k)$, where

```
A=[ 2.700  2   0     0
   -1.230  0   1     0
    0.436  0   0  0.25
   -0.192  0   0     0];
B=[0; 0.5; -0.35; 0.2];
C=[1     0     0    0];
```

Please use MATLAB Grader to answer the following questions

- Compute the eigenvalues to confirm whether the above system stable or not
- Compute the controllability matrix (also called controllability grammian). Is the above system controllable?
- Please compute the **uncontrollable** subspace.
  If the entire system is controllable, then the uncontrollable subspace is an empty matrix.
- Please use the Hautus condition in MATLAB to confirm if the system stabilizable
- Is the system observable?
- Compute and report the **unobservable** subspace

Problem 2 **(6 points)**

Consider the system:

$$y = \frac{2.5}{40s^2 + 16s + 1}u + \frac{0.8}{24s + 1}\varepsilon$$

where $\varepsilon(k)$ is zero-mean Gaussian white noise with covariance 0.25. $\Delta t = 5$ is the sampling time.

- Using `ss` and `c2d` commands in MATLAB (or any other method of your choice), please express the above in the form: $x(k+1) = Ax(k) + Bu(k) + B_e\varepsilon(k), \quad y(k) = Cx(k) + \nu(k)$.
  Please report these in matrices `A`, `B`, `Be` and `C`.

- With covariance of $\nu(k)$ as 0.1, please compute the Kalman filter and predictor gains K_∞ and $\overline{K}_\infty$

Problem 3 **(12 points)**

Consider the following SISO system:

$$Y(s) = \frac{4\,e^{-6s}}{40s+1}U(s) \;+\; \frac{0.8\,e^{-4s}}{24s+1}D(s)$$

Let $\Delta t = 5$ be the sampling interval. Starting at origin, the aim of the DMC control is to take the system to the setpoint of $r = 0.6$. Choose appropriate size *n* for the step-response coefficients. Let the horizons be $p = 12$ and $m = 5$. Let the output weight be Q = 1 and input-rate weight be R = 0.2. The constraints are $-1 \le u(k) \le 1$ and $-0.2 \le \Delta u(k) \le 0.2$.

Problem 3a: Measured Disturbance Case

Starting with the system at origin, a step change of $d(k) = 0.2$ is observed starting at the initial time. Please simulate step-response-based DMC algorithm to take the system to the desired setpoint of $r = 0.6$. Note that $d(k)$ is measured.

Problem 3b: Effect of Tuning Parameters

Repeat the same problem as Problem 3a, but for the following cases for the effect of *p* and *m*:

- Modify the prediction horizon so that $m = p = 5$. Run the simulation and compare.
- Modify the control horizon so that $m = 1$ and $p = 12$.