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CH5120 ASSIGNMENT 11

Question-1

Model Equation: $G(s) = \frac{5}{\tau s+1} e^{-0.15s}$

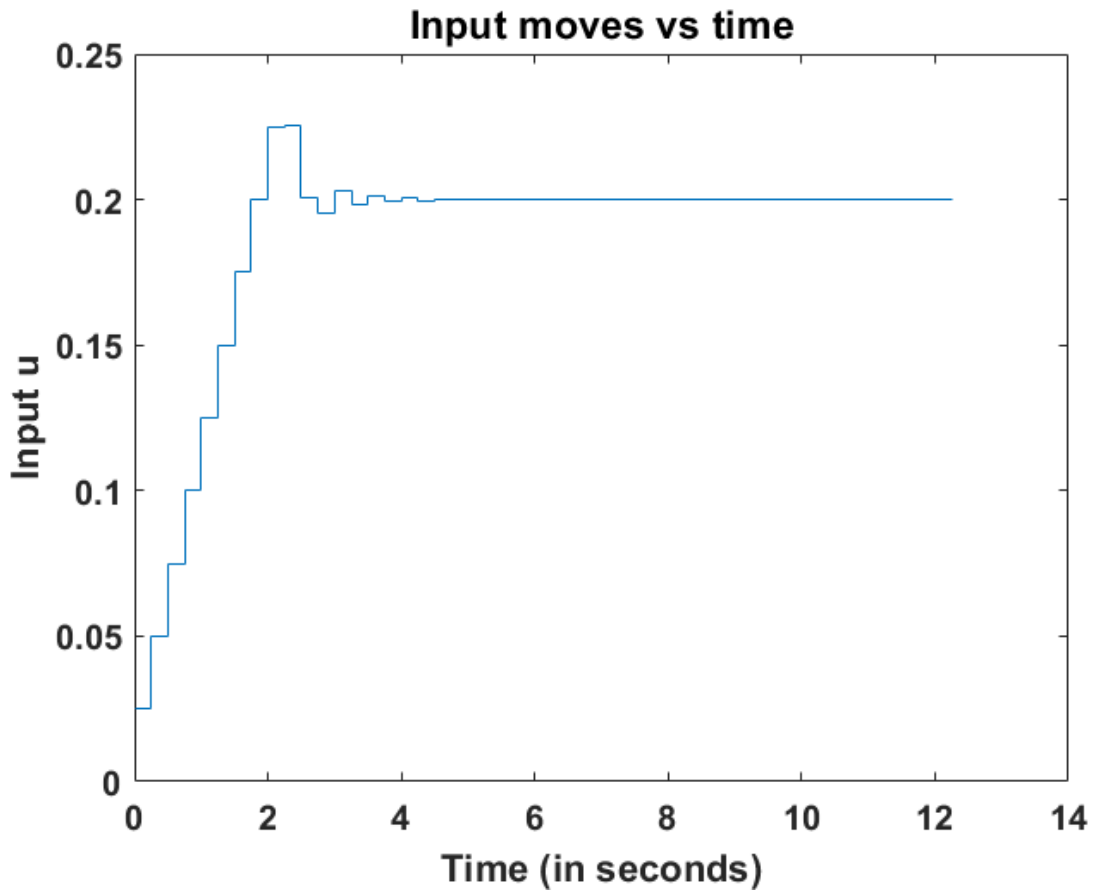
τ = 0.5

```
%% Controller Parameters
ySP=1;        % Setpoint
m=4;          % Control horizon
p=10;         % Prediction horizon
Q=1;          % Output weight
R=0.1;        % Input rate weight
```

Constraints: $-0.4 \leq u(k) \leq 0.4$ and $|\Delta u(k)| < 0.025$

Initial plant state is set to zero by default.

The measurement errors were set to zero using mpcsimopt. (Default is white noise, so we have to explicitly set it to zero)



We can visually see that the input moves satisfy the constraints: $-0.4 \leq u(k) \leq 0.4$.

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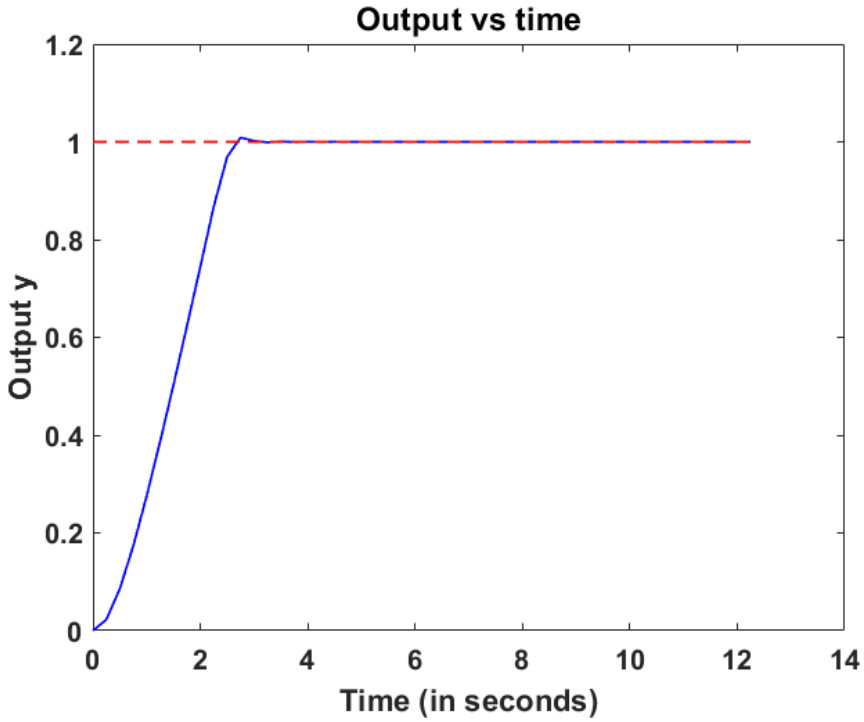

As expected the controller is able to smoothly increase the output the set-point.

Time (in s)	Input move	Time (in s)	Input move
0	0.0250	6.2500	0.2000
0.25	0.0500	6.5000	0.2000
0.50	0.0750	6.7500	0.2000
0.75	0.1000	7.0000	0.2000
1	0.1250	7.2500	0.2000
1.25	0.1500	7.5000	0.2000
1.50	0.1750	7.7500	0.2000
1.75	0.2000	8.0000	0.2000
2	0.2250	8.2500	0.2000
2.25	0.2255	8.5000	0.2000
2.50	0.2005	8.7500	0.2000
2.75	0.1955	9.0000	0.2000
3	0.2028	9.2500	0.2000
3.25	0.1983	9.5000	0.2000
3.50	0.2011	9.7500	0.2000
3.75	0.1993	10.0000	0.2000
4	0.2004	10.2500	0.2000
4.25	0.1997	10.5000	0.2000
4.50	0.2002	10.7500	0.2000
4.75	0.1999	11.0000	0.2000
5	0.2001	11.2500	0.2000
5.25	0.2000	11.5000	0.2000
5.50	0.2000	11.7500	0.2000
5.75	0.2000	12.0000	0.2000
6	0.2000	12.2500	0.2000

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Question-2

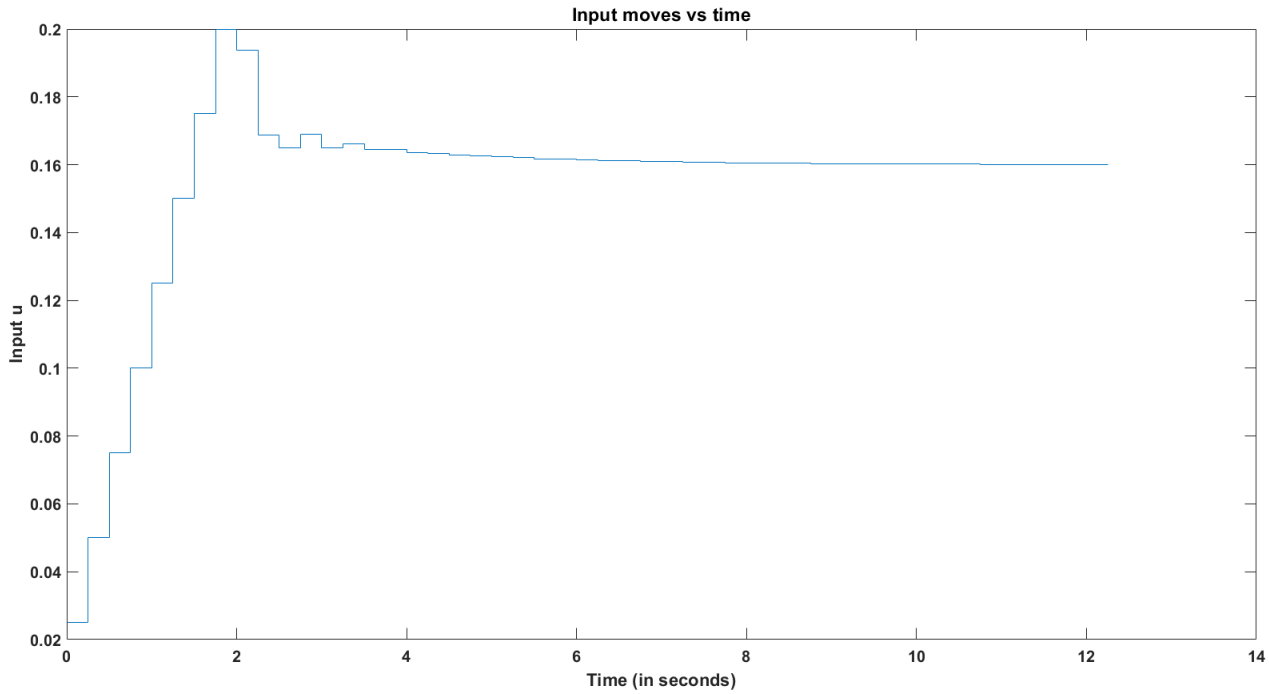
Model Equation:

$$y(s) = \frac{5}{\tau s + 1} e^{-0.15s} u(s) + \frac{0.4}{2s + 1} e^{-0.1s} d(s)$$

```
%% Controller Parameters
ySP=1;      % Setpoint
m=4;        % Control horizon
p=10;       % Prediction horizon
Q=1;        % Output weight
R=0.04;     % Input rate weight
```

Constraints: $-0.4 \leq u(k) \leq 0.4$ and $|\Delta u(k)| < 0.025$

- Disturbance is simply a step change given at t=0. The value of the disturbance is given as a vector to the **sim** function. (d(k) = 0.5)
    - This is done in MATLAB by declaring the model incorporating the measured disturbance along with the manipulated input as a **2-input 1-output** model.
    - Then using **setmpcsignals**, the input corresponding to the transfer function of the disturbance model, is termed as the 'Measured Disturbance'.
- Once again, the measurement errors are set to zero.



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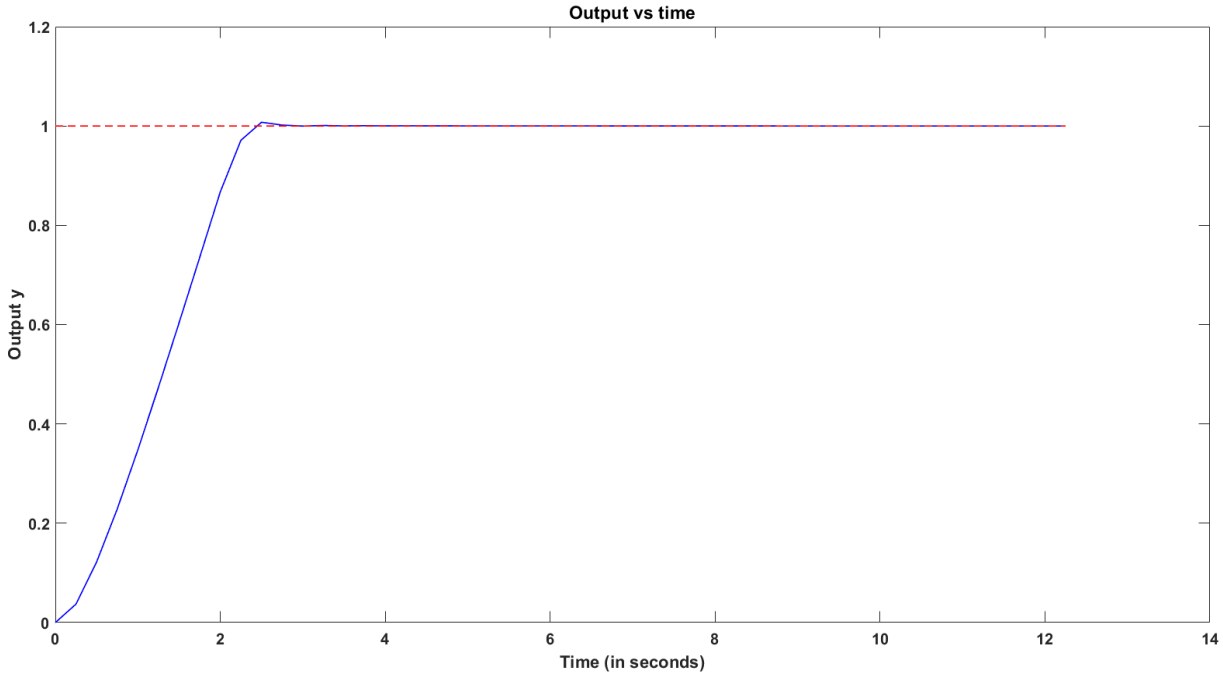

Time (in s)	Input move	Time (in s)	Input move
0	0.0250	6.2500	0.1612
0.25	0.0500	6.5000	0.1611
0.50	0.0750	6.7500	0.1610
0.75	0.1000	7.0000	0.1608
1	0.1250	7.2500	0.1607
1.25	0.1500	7.5000	0.1607
1.50	0.1750	7.7500	0.1606
1.75	0.2000	8.0000	0.1605
2	0.1938	8.2500	0.1605
2.25	0.1688	8.5000	0.1604
2.50	0.1650	8.7500	0.1604
2.75	0.1689	9.0000	0.1603
3	0.1651	9.2500	0.1603
3.25	0.1662	9.5000	0.1602
3.50	0.1644	9.7500	0.1602
3.75	0.1645	10.0000	0.1602
4	0.1636	10.2500	0.1602
4.25	0.1634	10.5000	0.1601
4.50	0.1629	10.7500	0.1601
4.75	0.1626	11.0000	0.1601
5	0.1623	11.2500	0.1601
5.25	0.1620	11.5000	0.1601
5.50	0.1618	11.7500	0.1601
5.75	0.1616	12.0000	0.1601
6	0.1614	12.2500	0.1601

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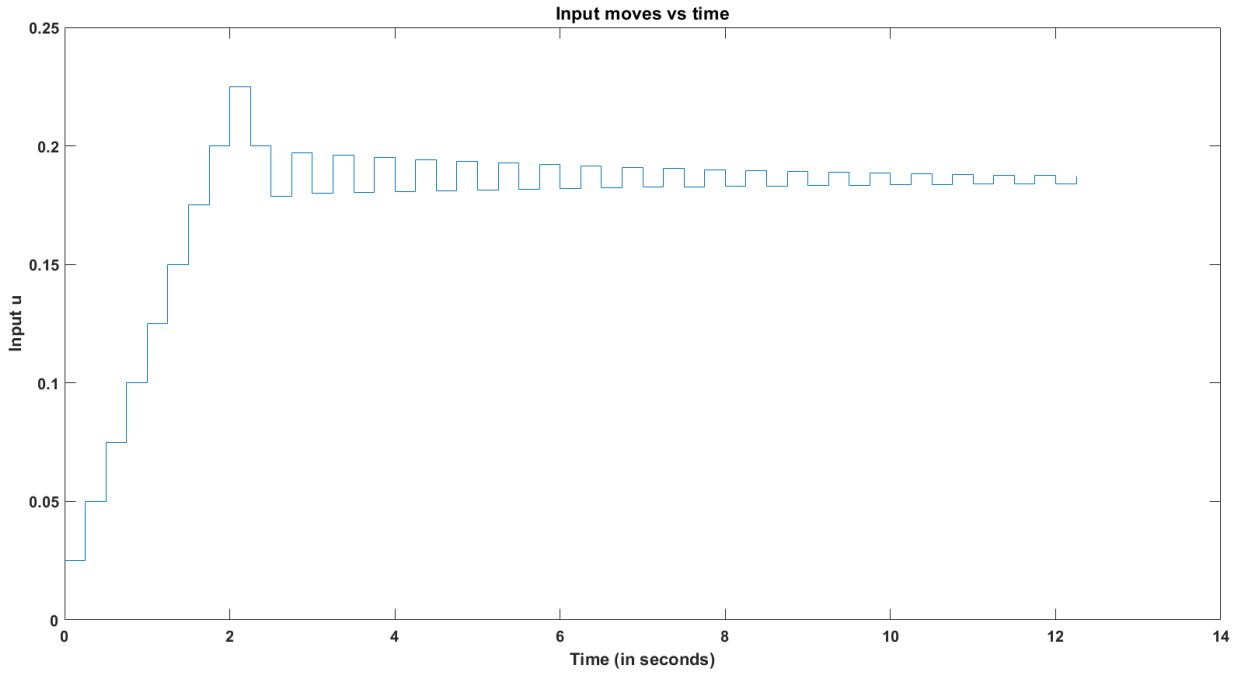
Question-3

Here the tuning parameters remain the same and we remove the disturbance effects. Instead, this question deals with **model-plant mismatch**.

Model: $y(s) = \frac{5}{\tau s+1} e^{-0.15s} u(s)$

True Plant: $y(s) = \frac{5.4}{\tau s+1} e^{-0.12s} u(s)$

- The constraints and tuning parameters are same as in that of previous cases.
- The time taken to get reasonably close to the set-point value (~0 error) is more for the case with mismatch. This extra time is needed to incorporate the effects of the mismatch (bias in the model).
- The mismatch effect was implemented in MATLAB by updating the plant model in the options structure created using mpcsimopt().
- The measurement errors were set to zero.



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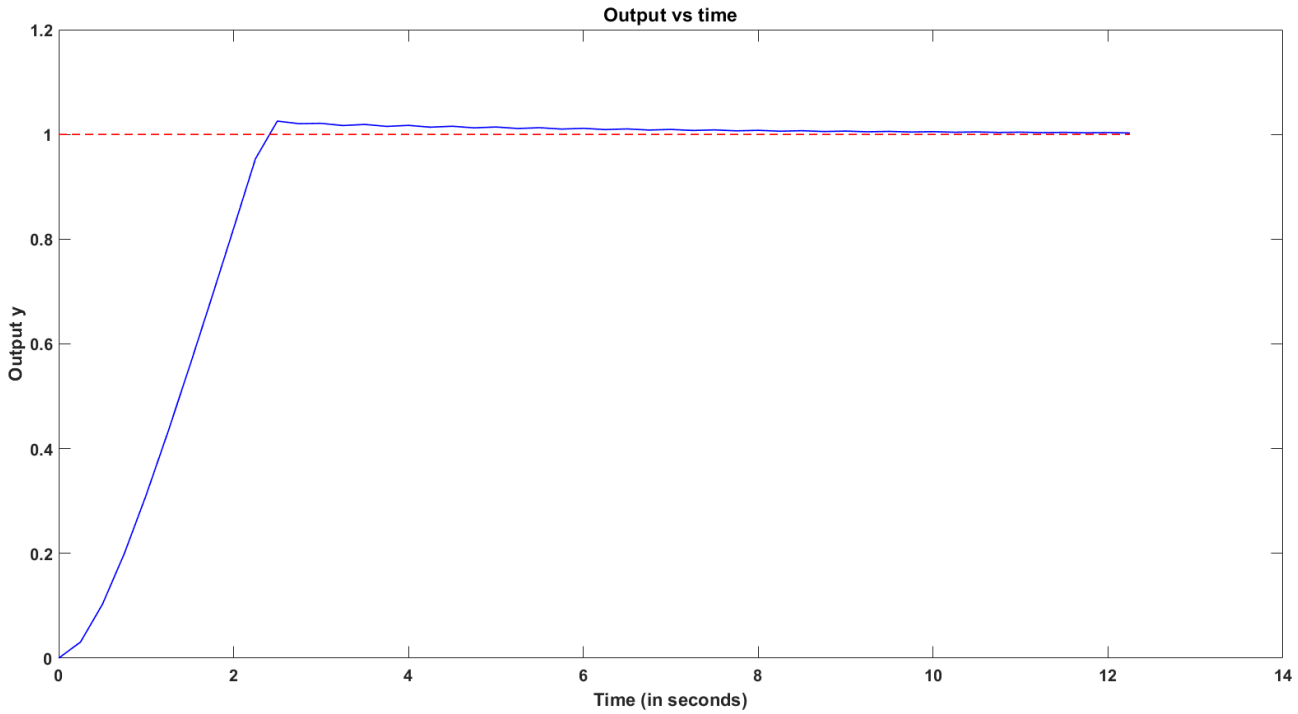

Time (in s)	Input move	Time (in s)	Input move
0	0.0250	6.2500	0.1914
0.25	0.0500	6.5000	0.1823
0.50	0.0750	6.7500	0.1909
0.75	0.1000	7.0000	0.1825
1	0.1250	7.2500	0.1904
1.25	0.1500	7.5000	0.1827
1.50	0.1750	7.7500	0.1899
1.75	0.2000	8.0000	0.1829
2	0.2250	8.2500	0.1895
2.25	0.2000	8.5000	0.1831
2.50	0.1786	8.7500	0.1891
2.75	0.1970	9.0000	0.1833
3	0.1800	9.2500	0.1888
3.25	0.1960	9.5000	0.1834
3.50	0.1804	9.7500	0.1885
3.75	0.1951	10.0000	0.1836
4	0.1808	10.2500	0.1882
4.25	0.1942	10.5000	0.1837
4.50	0.1811	10.7500	0.1879
4.75	0.1934	11.0000	0.1838
5	0.1815	11.2500	0.1877
5.25	0.1927	11.5000	0.1839
5.50	0.1818	11.7500	0.1875
5.75	0.1920	12.0000	0.1840
6	0.1820	12.2500	0.1873

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Codes

Q1)

```
% DMC SISO with no disturbances and measurement errors
clear; close all;
%% Model
a = 0;
tau = (a+1)/2;
G = tf(5,[tau,1],'inputdelay',0.15);
sys = ss(G);
sampling_time = 0.25;
model = c2d(sys,sampling_time);
%% Setting up the Controller
p = 10; % Prediction horizon
m = 4; % Control Horizon
Q = 1; % Output weight
R = 0.1; % Input rate weight
Weights.ManipulatedVariablesRate = R;
Weights.OutputVariables = Q;
Weights.ManipulatedVariables = 0;
mp1 = mpc(model,sampling_time,p,m,Weights);
mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;
mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;
%% Running the controller
ySP = 1; % Setpoint
T = 50; % Number of simulation steps
options = mpcsimopt();
options.InputNoise = 0;
options.OutputNoise = 0;
[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,options);
%% Plotting the results
plot(t,y,'-b',...              % Plots the output
   t,ones(size(t)),'--r','linewidth',1);  % Plots  set-point
set(gca,'fontsize',12,'fontweight','bold');
title('Output vs time','fontsize',14,'fontweight','bold');
xlabel('Time (in seconds)');ylabel('Output y');
figure();
stairs(t,u); % Plots the input
set(gca,'fontsize',12,'fontweight','bold');
title('Input moves vs time','fontsize',14,'fontweight','bold')
xlabel('Time (in seconds)');ylabel('Input u');
```

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Q2)

```
% DMC SISO with no disturbances and measurement errors
clear; close all;
%% Models
a = 0;
tau = (a+1)/2;
% Plant model
G = tf(5,[tau,1],'inputdelay',0.15);
sys = ss(G);
sampling_time = 0.25;
plant_model = c2d(sys,sampling_time);
% Disturbance model
Gdist = tf(0.4,[2,1],'inputdelay',0.1);
dist = ss(Gdist);
dist_model = c2d(dist,sampling_time);
%Combined Model
tf_model = [G Gdist];
ss_model = ss(tf_model);
model = c2d(ss_model,sampling_time);
%% Setting up the Controller
p = 10; % Prediction horizon
m = 4; % Control Horizon
Q = 1; % Output weight
R = 0.1; % Input rate weight
Weights.ManipulatedVariablesRate = R;
Weights.OutputVariables = Q;
Weights.ManipulatedVariables = 0;
model2 = setmpcsignals(model,'MD',2);
mp1 = mpc(model2,sampling_time,p,m,Weights);
mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;
mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;
% Dist.Name = 'd';
% Dist.Units = 1;
% mp1.DisturbanceVariables = Dist;
% mp1.Disturbance = dist_model;
%% Running the controller
ySP = 1; % Setpoint
T = 50; % Number of simulation steps
d = 0.5*ones(T,1);  % Measured Disturbance
options = mpcsimopt();
options.InputNoise = 0;
options.OutputNoise = 0;
[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,d,options);
%% Plotting the results
plot(t,y,'-b',...            % Plots the output
   t,ones(size(t)),'--r','linewidth',1);  % Plots  set-point
```

```
set(gca,'fontsize',12,'fontweight','bold');
title('Output vs time','fontsize',14,'fontweight','bold');
xlabel('Time (in seconds)');ylabel('Output y');
figure();
stairs(t,u); % Plots the input
set(gca,'fontsize',12,'fontweight','bold');
title('Input moves vs time','fontsize',14,'fontweight','bold')
xlabel('Time (in seconds)');ylabel('Input u');
```

Q3)

```
% DMC SISO with no disturbances and measurement errors
clear; close all;
%% Model
a = 0;
tau = (a+1)/2;
% Plant Model
G = tf(5,[tau,1],'inputdelay',0.15);
sys = ss(G);
sampling_time = 0.25;
model = c2d(sys,sampling_time);
% Actual Plant
Gplant = tf(5.4,[tau 1],'inputdelay',0.12);
p = ss(Gplant);
plant = c2d(p,sampling_time);
%% Setting up the Controller
p = 10; % Prediction horizon
m = 4; % Control Horizon
Q = 1; % Output weight
R = 0.1; % Input rate weight
Weights.ManipulatedVariablesRate = R;
Weights.OutputVariables = Q;
Weights.ManipulatedVariables = 0;
mp1 = mpc(model,sampling_time,p,m,Weights);
mp1.ManipulatedVariables.Min = -0.4;mp1.ManipulatedVariables.Max = 0.4;
mp1.ManipulatedVariables.RateMin = -0.025; mp1.ManipulatedVariables.RateMax = 0.025;
%% Running the controller
ySP = 1; % Setpoint
T = 50; % Number of simulation steps
options = mpcsimopt();
options.Model = plant;
options.InputNoise = 0;
options.OutputNoise = 0;
[y,t,u,xp,xmpc,SimOptions,status] = sim(mp1,T,ySP,options);
%% Plotting the results
plot(t,y,'-b',...            % Plots the output
   t,ones(size(t)),'--r','linewidth',1);  % Plots  set-point
```

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```
set(gca,'fontsize',12,'fontweight','bold');
title('Output vs time','fontsize',14,'fontweight','bold');
xlabel('Time (in seconds)');ylabel('Output y');
figure();
stairs(t,u); % Plots the input
set(gca,'fontsize',12,'fontweight','bold');
title('Input moves vs time','fontsize',14,'fontweight','bold')
xlabel('Time (in seconds)');ylabel('Input u');
```