Assignment 5 (GE22M019)

Discretized state-space model of a system is represented below.

Am = [2 0; 6 1]

Bm = [-1; -3]

Cm = [0 -1]

Dm = [0]

x0 (initial states) = [0 0]

The closed loop poles for the initial values of the discretized system

Control move penalty: 5, Prediction horizon: 4, Control horizon: 1 are 0.0017,0.8845 ± 0.1957i

The set point of the system is 1.5.

```
% Discrete model input parameters
clear
Am = [2 0; 6 1];
Bm = [-1; -3];
Cm = [0 -1];
Dm = [0];
% Initial State
xm=[0;0];
N_sim = 100;
r=1.5*ones(N_sim,1);
u=0;                % All previous u are zero
y=0;

% % Initial parameters to verify eigenvalues
% Np = 4;     % Prediction Horizon
% Nc = 1;     % Control Horizon
% R = 5;      % Control move penalty or input weight

% Parameters to tune for optimality
Np = 20;    % Prediction Horizon
Nc = 4;     % Control Horizon
R = 0.05;   % Control move penalty or input weight
```

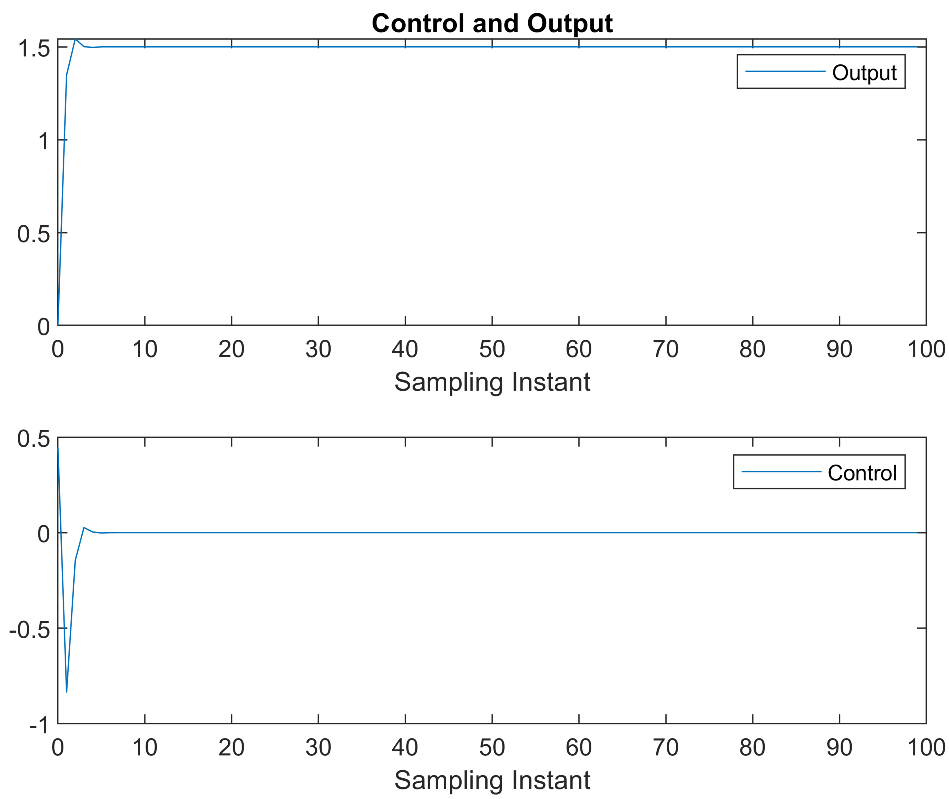
```
%% Create augmented model for MPC design using input parameters
% Code refered from MPC Design and Implementation - Wang
[m1,n1]=size(Cm);
[n1,n_in]=size(Bm);
A=eye(n1+m1,n1+m1);
A(1:n1,1:n1)=Am;
A(n1+1:n1+m1,1:n1)=Cm*Am;
B=zeros(n1+m1,n_in);
B(1:n1,:)=Bm;
```

```
B(n1+1:n1+m1,:)=Cm*Bm;
C=zeros(m1,n1+m1);
C(:,n1+1:n1+m1)=eye(m1,m1);

% Find the quantities required for optimal control move
n=n1+m1;
Xf=zeros(n,1); % initial state feedback variable
h(1,:)=C;
F(1,:)=C*A;
for kk=2:Np
h(kk,:)=h(kk-1,:)*A;
F(kk,:)= F(kk-1,:)*A;
end
v=h*B;
Phi=zeros(Np,Nc);   % declare the dimension of Phi
Phi(:,1)=v;         % first column of Phi
for i=2:Nc
Phi(:,i)=[zeros(i-1,1);v(1:Np-i+1,1)]; %Toeplitz matrix
end
BarRs=ones(Np,1);
Phi_Phi= Phi'*Phi;
Phi_F= Phi'*F;
Phi_R=Phi'*BarRs;
```

```
[n,x]=size(B);
Xf=zeros(n,1);      % initial state feedback variable

% Optimal control move calculation
for kk=1:N_sim
DeltaU=inv(Phi_Phi+R*eye(Nc,Nc))*(Phi_R*r(kk)-Phi_F*Xf);
deltau=DeltaU(1,1);
deltau_values(kk) = deltau;
u=u+deltau;
u1(kk)=u;
y1(kk)=y;
xm_old=xm;
xm=Am*xm+Bm*u;
y=Cm*xm;
Xf=[xm-xm_old;y];
end
```

```
% Plot the Control Move and corresponding Output
k=0:(N_sim-1);
figure
subplot(211)
plot(k,y1)
title("Control and Output")
xlabel('Sampling Instant')
legend('Output')
```

```
subplot(212)
plot(k,u1)
xlabel('Sampling Instant')
legend('Control')
```




```
% Closed loop poles calculation
Kmpc = inv((Phi_Phi+R*eye(Nc,Nc)))*Phi_F;
kmpc = Kmpc(1,:);
cloop_poles = eig(A-B*kmpc)
```

```
cloop_poles = 3×1 complex
   0.1078 + 0.0000i
   0.0189 + 0.2120i
   0.0189 - 0.2120i
```

```
disp("The closed loop radius is:")
```

```
The closed loop radius is:
```

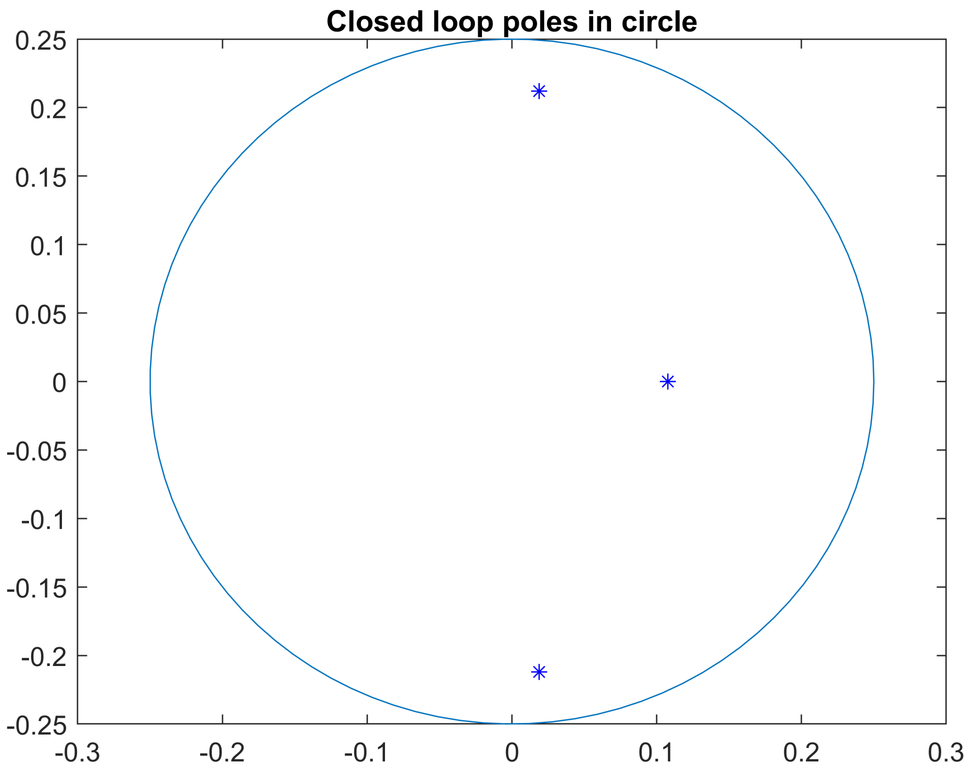
```
cloop_poles_radius = abs(cloop_poles)
```

```
cloop_poles_radius = 3×1
    0.1078
    0.2128
    0.2128
```

```
% Calculate the control energy: delU*R*delU'
control_energy = (deltau_values)*R*deltau_values'
```

```
control_energy = 0.1178
```

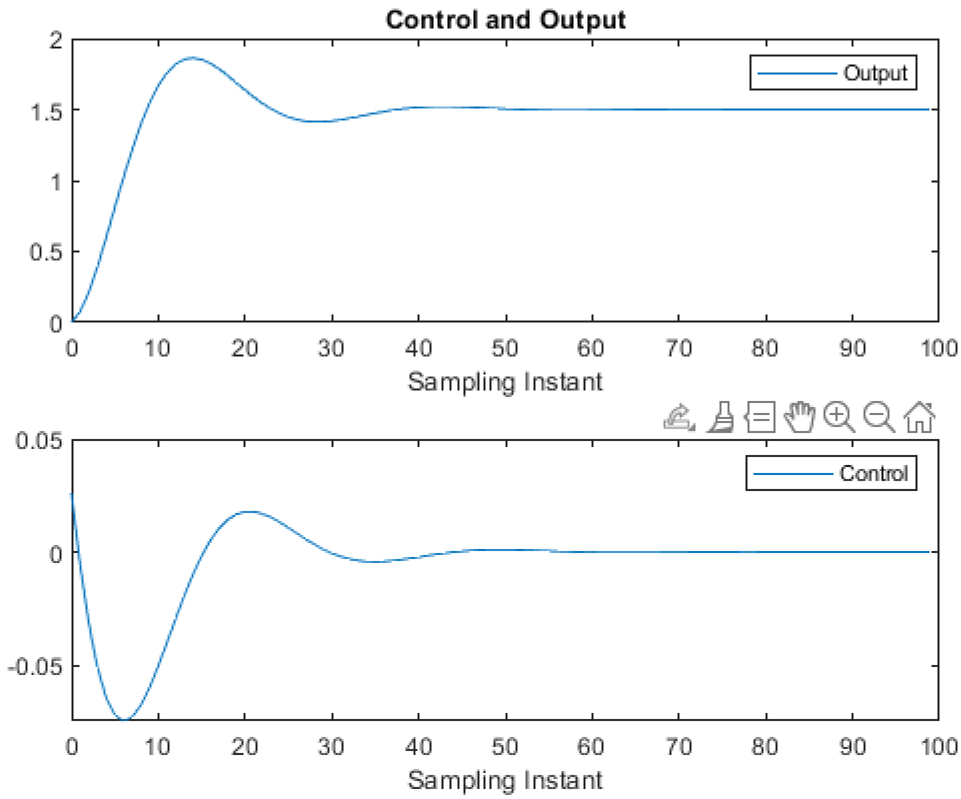
```
% Initial poles plotted in circle
figure;
t = linspace(0,2*pi,100);
x = 0.25*cos(t);
y = 0.25*sin(t);
plot(x,y)

hold on
plot(real(cloop_poles),imag(cloop_poles),'b*')
title("Closed loop poles in circle")
```



With short prediction and control horizons, the closed-loop predictive control system is not necessarily stable, so the process of shifting of poles involved, increasing the prediction horizon and control horizon And reducing the control move penalty, we are not paying attention to how large input move ΔU might be and our goal would be solely to make error (Rs-Y)' (Rs-Y) as small as possible.

Closed loop poles were obtained inside the circle with radius 0.25 by increasing Np to 20, Nc to 4 and reducing input weight(R) to 0.05.

With initial parameters Np = 4;   Nc = 1;   R = 5;




```
cloop_poles = 3×1 complex
     0.0017 + 0.0000i
     0.8845 + 0.1957i
     0.8845 - 0.1957i

The closed loop radius is:
cloop_poles_radius = 3×1
      0.0017
      0.9058
      0.9058

control_energy = 0.0188
```