ภาคผนวก

ภาคผนวก ก. : โปรแกมที่ใช้ในการออกแบบตัวควบคุม และตัวประมาณค่า

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%Inverted Pendulum Control Design

%parameter of inverted pendulum
m=0.25;M=0.3;r=0.011;I=0.51;Km=6*0.0390;Kb=0.02
12;Ra=3;g=9.81;

%state equation     xd=Ax+Bu
%                   y=Cx+Du
A=[0      0         1         0;...
   0      0         0         1;...
   0      -(m*g)/M
-(Km*Kb)/(M*Ra*r^2)          0;...
   0      (M+m)*g/(M*I)
(Km*Kb)/(M*I*Ra*r^2)         0]
B=[0;
   0;
   1.8*Km/(M*Ra*r);
  -1.8*Km/(M*I*Ra*r)]
C=[1      0         0         0;...
   0      1         0         0];
D=[0;0];

%Time response of open loop Inverted pendulum at
%any initial condition
to=0:0.001:0.5;
I=[0,0.1,0,0];
[yo,xo]=initial(A,B,C,D,I,to);
plot(to,yo);grid
title('Time response of Inverted pendulum with initial
condition')
xlabel('Time(seconds)')
ylabel('amplitude')
text(0.21,0.25,'Angle ---------->')
text(0.4,0.01,'<----------y ')

%Impulse response of open loop Inverted Pendulum
ti=0:0.01:0.5;
[yi,xi]=impulse(A,B,C,D,1,ti);
plot(ti,yi);grid
title('Impulse response of open loop system')
xlabel('Time(seconds)')
ylabel('Amplitude')
text(0.22,-4.5,'Angle ---------->')
text(0.25,0.65,'<---------- y')

%Controllability matrix and Observability matrix
Pv=[B A*B A^2*B A^3*B];
rank(Pv);
Qv=[C;C*A;C*A^2;C*A^3];
rank(Qv);

%Design controller by LQR
Q=[800  0  0  0 ;0  800  0  0 ;0  0  1  0 ;0  0  0
1];
R=100;
[K,S,E]=lqr(A,B,Q,R)
At=A-B*K;
t=0:0.001:3;
X0=[0.1;0.1;0;0];
[y,x]=initial(At,B,C,D,X0,t);
[y,x]=step(At,B,C,D,1,t);
[y,x]=impulse(At,B,C,D,1,t);
x1=[1 0 0 0]*x';
x2=[0 1 0 0]*x';
x3=[0 0 1 0]*x';
x4=[0 0 0 1]*x';

plot(t,y);grid
title('Time response of Inverted pendulum with initial
condition')
xlabel('Time(seconds)')
ylabel('amplitude')
text(0.6,-0.08,'<---------- Angle')
text(0.8,0.25,'<----------y ')

plot(t,x1);grid
title('Position of cart versus time')
xlabel('Time (seconds)')
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ylabel('meters')

plot(t,x2);grid
title('Angle of pendulum versus time')
xlabel('Time (seconds)')
ylabel('radiuses')

plot(t,x3);grid
title('Velocity of cart versus time')
xlabel('Time (seconds)')
ylabel('meter/seconds')

plot(t,x4);grid
title('Velocity of pendulum versus time')
xlabel('Time (seconds)')
ylabel('rad/seconds')

u=-K*x';
plot(t,u);grid
umax=max(u);
umin=min(u);
title('Control signal versus time')
xlabel('Time (seconds)')
ylabel('Volts')

%design observer
T=[0 0 1 0 ;0 0 0 1];
E=[C;T];
Ei=inv(E);
[mm,nn]=size(C);
Pi=Ei(:,1:mm)
Mi=Ei(:,mm+1:nn)
A11=C*A*Pi
A12=C*A*Mi
A21=T*A*Pi
A22=T*A*Mi
B1=C*B
B2=T*B
Qo=[500  0;0  1000];
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```
Ro=[1  0;0  1];
L=lqr(A22',A12',Qo,Ro)
F=A22-L*A12
eig(F)
Do=F*L+(A21-L*A11)
G=B2-L*B1
Mo=[0  0;0  0;1  0;0  1]
Po=[1  0;0  1;0  0;0  0]
N=Po+Mo*L
u2=-K*Mo
u1=-K*N

%Connection of controller and observer
O=[0;0];
Ok=[0 0;0 0];
Ak=[A-B*K*N*C  -B*K*Mo;Do*C-G*K*N*C  F-
G*K*Mo];
Bk=[B;G];
Ck=[C Ok];
Dk=D;
[yc,xc]=initial(Ak,Bk,Ck,Dk,1,t);
[yc,xc]=impulse(Ak,Bk,Ck,D,1,t);
plot(t,yc);grid
xc1=[1 0 0 0 0 0]*xc';
plot(t,yc);grid
title('Impulse response of Inverted pendulum after
connection')
xlabel('Time(seconds)')
ylabel('Amplitude')
text(1.25,-0.16,'<---------- y')
text(0.7,0.1,'<---------- Angle')

%combining the closed loop system and error system
 Oe=[0 0 0 0;0 0 0 0];
Ae=[A-B*K  B*K*Mo;Oe  A22-L*A12];
Be=[B;G];
Ce=[C Ok];
De=D;
Ie=[0;0;0;0;1;1];
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```
[yc,xe]=initial(Ae,Be,Ce,De,Ie,t);
[ye,xe]=impulse(Ae,Be,Ce,De,1,t);
plot(t,yc);grid
xe3=[0 0 1 0 0 0]*xe';
xe4=[0 0 0 1 0 0]*xe';
xe1=[0 0 0 0 1 0]*xe';
xe2=[0 0 0 0 0 1]*xe';
subplot(2,1,1);
plot(t,xe1);grid
title('Error for vilocity of cart')
ylabel('m/s')

subplot(2,1,2)
plot(t,xe2);grid
title('Error for vilocity of pendulum')
ylabel('rad/s')
xlabel('Time(Sec)')
```