Contents

Student ID

```
ID = 316098052;
disp(ID)
```

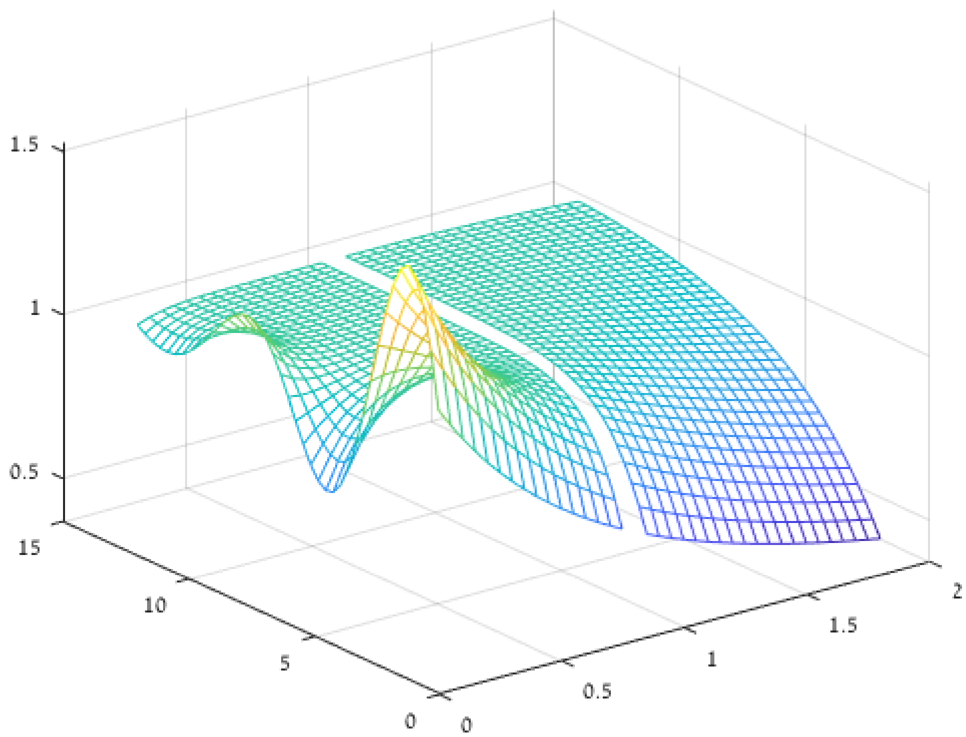
```
316098052
```

1 Second-order system mesh plot

```
zeta = 0.2:0.05:2;
omega_t = 2:0.3:14;
[ZETA,OMEGA_T] = meshgrid(zeta,omega_t);

beta = (1-ZETA.^2).^(1/2);
tetha = acos(ZETA);
Y_T = 1-(1./beta).*exp(-1.*ZETA.*OMEGA_T).*sin(OMEGA_T.*beta+tetha);

mesh(ZETA,OMEGA_T,Y_T)
```



2 Inverted pendulum on a cart

2. State-space equations.

The linearized model of the system:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{-mg}{M} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & \frac{Mg}{Ml} & 0 \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{M} \\ 0 \\ \frac{1}{-Ml} \end{bmatrix} \cdot u(t)$$

3. Controlable and observable.

The matrix cont is full rank and therefore the system is contorlable.

The matrix obs is full rank and therefore the system is observable.

```
syms m g l M
C = [1 0 0 0; 0 1 0 0];
A = [0 1 0 0; 0 0 (-m*g)/M 0;0 0 0 1; 0 0 (g/l) 0];
B = [0; 1/M; 0; -1/(M*l)];

cont = [B A*B  A^2*B  A^3*B]
rank(cont)
obs = [C ; C*A ; C*(A^2) ; C*(A^3)]
rank(obs)
```

```
cont =

[        0,      1/M,              0, (g*m)/(M^2*l)]
[      1/M,        0, (g*m)/(M^2*l),             0]
[        0, -1/(M*l),              0,    -g/(M*l^2)]
[ -1/(M*l),        0,     -g/(M*l^2),             0]


ans =

     4


obs =

[ 1, 0,              0,        0]
[ 0, 1,              0,        0]
[ 0, 1,              0,        0]
[ 0, 0,       -(g*m)/M,        0]
[ 0, 0,       -(g*m)/M,        0]
[ 0, 0,              0, -(g*m)/M]
[ 0, 0,              0, -(g*m)/M]
[ 0, 0, -(g^2*m)/(M*l),        0]


ans =

     4
```

4 DC motor control

1.Steady state error:

The system's error function in laplace domain:

$$E(s) = \frac{s(s + 0.02 + k_b k_m)}{(kk_m + sk_b + s(s + 0.02))}$$

The error's steady state response to a ramp unit using the final value theorem:

$$e_{ss} = lim\ (t \to \infty)\ e(t) = lim\ (s \to 0)\, sE(s)\, \frac{1}{s^2} = \frac{0.02 + k_b k_m}{kk_m}$$

2. Required K calculation:

For $k_m = 10$ and $k_b = 0.05$.

$k = 10^{-3}$

```
syms k k_m k_b

k = 10^-3;
k_m = 10;
k_b = 0.02;
s =tf('s')

H = (k*k_m+s*k_b*(1-k_m))/(k*k_m+s*k_b+s*(s+0.02))

ramp = H*(1/s);

figure(1)
step(H,20)
figure(2)
step(ramp,20)
```

```
s =

  s

Continuous-time transfer function.


H =

    -0.18 s + 0.01
  -------------------
  s^2 + 0.04 s + 0.01

Continuous-time transfer function.
```

The two plots are acceptable by the derivative link between them.

```
function [zeros,poles] = pzplot2(a,b)

    poles = complex(roots(b));
    max_pole = max(real(poles));
    zeros = complex(roots(a));
    axe = max([max(abs(zeros)) max(abs(poles))]);
```

```
    figure(1)

    plot(zeros,'o','MarkerEdgeColor','red','MarkerSize',10)
    hold on
    plot(poles, 'x','MarkerEdgeColor','blue','MarkerSize',10)
    grid, axis([-axe-1 axe+1 -axe-1 axe+1])
    hold on
    xL = xlim;
    yL = ylim;
    line([0 0], yL);  %x-axis
    line(xL, [0 0]);  %y-axis
    hold on
    patch_x = [max_pole; max_pole; axe+1; axe+1];
    patch_y = [-axe-1; axe+1; axe+1; -axe-1];
    patch(patch_x,patch_y,[0,0.8,0.8],'edgeAlpha',0.1);
    alpha(0.3)
    hold off

    title('Pole-Zero map')
    xlabel('Real Part (\sigma)')
    ylabel('Imaginary Part (jw)')

end
```

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