Contents

Student ID

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

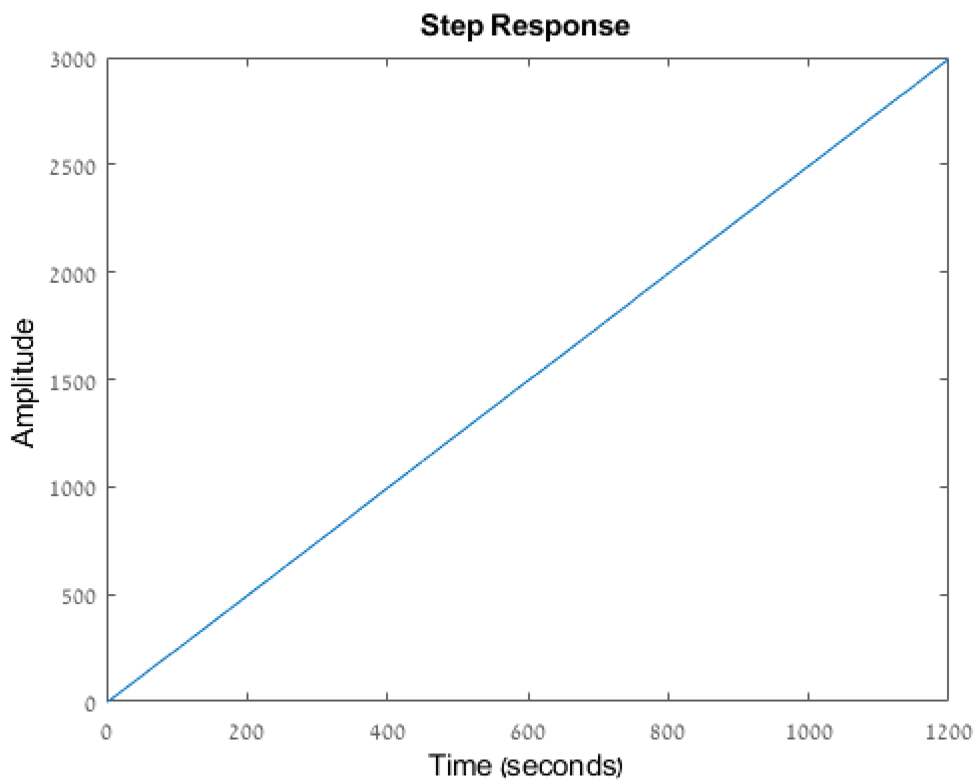
```
316098052
```

1 Manipulator control

2. Response of the closed-loop system to a step input

```
A = [0 1;0 -0.4];
B = [0 1]';
C = [1 0];
D = 0;
sys = ss(A,B,C,D);
test = tf([0 1],[1 0.4 0]);
pzmap(test)
```

```
step(test)
```



4. Response of the state variable feedback system to a step input

```
A_k = [0 1;-18.4 -5.9];
B = [0 1]';
C = [1 0];
D = 0;
sys = ss(A_k,B,C,D);

% pzmap(sys)
step(sys);
stepinfo(sys)
```

```
ans =

  struct with fields:

        RiseTime: 0.4873
    SettlingTime: 1.3984
     SettlingMin: 0.0491
     SettlingMax: 0.0571
       Overshoot: 5.0977
      Undershoot: 0
            Peak: 0.0571
        PeakTime: 1.0147
```

```
syms L1 L2 LAM
A = [0 1;-7 -2];
L = [L1 L2]';
C = [1 4];
O = LAM*eye(2)-A - L*C;
de = det(O);
```

5 Pole-placement algorithm for state-space model

```
clear
check = myPolePlacement(magic(5), [1;2;3;4;5], [-1, -2, -3, -4, -5])
K = place(magic(5), [1;2;3;4;5], [-1, -2, -3, -4, -5])


function [out] =  myPolePlacement(A, B, p)
    s = size(A);
    K  = sym('k',[1 s(1)]);
    A_s = A-B*K;
    p2 = poly(p);
    poli = charpoly(A_s);
    sol = poli == p2;
    sol_k = solve(sol , K)
    A = struct2cell(sol_k);
    out = double(cat(2,A{:}));
end
```

```
sol_k =

  struct with fields:
```

```
    k1: [1×1 sym]
    k2: [1×1 sym]
    k3: [1×1 sym]
    k4: [1×1 sym]
    k5: [1×1 sym]


check =

   10.5062   10.6291    3.5642   -2.7071    9.6742


K =

   10.5062   10.6291    3.5642   -2.7071    9.6742
```

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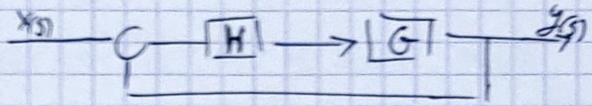
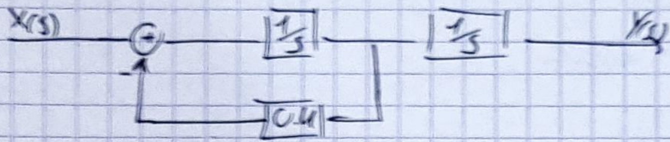
1) Manipulator control

$$G(s) = \frac{1}{s(s+0.4)}$$





$\dot{X} = AX + BU$

$\ddot{x}(t) + 0.4\dot{x}(t) = u(t)$ $\qquad \frac{Y(s)}{X(s)} = \frac{1}{s(s+0.4)}$

$x_1 = x \quad x_2 = \dot{x}$

$$\dot{X} = \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix}, \quad A = \begin{bmatrix} 0 & 1 \\ 0 & -0.4 \end{bmatrix}, \quad X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$G_{CL} = \frac{h \cdot \frac{1}{s^2+0.4s}}{1 + \frac{h}{s^2+0.4s}} = \frac{h}{s^2+0.4s+h}$$

$h = \omega_n^2 \quad , \quad \zeta = \frac{0.2}{\omega_n} = \frac{0.2}{\sqrt{h}}$

$T_{st} \approx \frac{4}{\zeta\omega_n} \leq 1.35$

$O.S = 100\, EXP\left[-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}\right] \leq 5$

$\zeta \geq 0.69$

$\frac{4}{0.69 \cdot 1.35} \leq \omega_n \Rightarrow \omega_n \geq 4.29$

$$\begin{pmatrix} 0 & 1 \\ 0 & -0.4 \end{pmatrix} - \begin{pmatrix} 0 \\ 1 \end{pmatrix}(K_1, K_2) = \begin{pmatrix} 0 & 1 \\ 0 & -0.4 \end{pmatrix} - \begin{pmatrix} 0 & 0 \\ K_1 & K_2 \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -K_1 & -0.4-K_2 \end{pmatrix}$$

$$|\lambda I - \tilde{A}| = \begin{vmatrix} \lambda & -1 \\ K_1 & \lambda+0.4+K_2 \end{vmatrix} = \lambda^2 + \lambda(0.4+K_2) + K_1 = 0$$

$K_1 = \omega_n^2 = 18.4$

$2\omega_n\zeta = 5.92$

$K_2 + 0.4 = 5.92 \Rightarrow K_2 = 5.52$

2) <u>Pole-placement full-state feedback control</u>:

$$A = \begin{pmatrix} -2 & -3 & 1 \\ 5 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}, \quad B = \begin{pmatrix} 5 \\ 0 \\ 0 \end{pmatrix}$$

$$\Delta_d(s) = (s+6)(s+7)(s+8) = (s^2+13s+42)(s+8) =$$
$$= s^3+13s^2+42s+8s^2+104s+336 = s^3+21s^2+146s+336$$

$$\hat{A} = A-BK = \begin{pmatrix} -2 & -3 & 1 \\ 5 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} - \begin{pmatrix} 5 \\ 0 \\ 0 \end{pmatrix} (K_1, K_2, K_3) = \begin{pmatrix} -2 & -3 & 1 \\ 5 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} - \begin{pmatrix} 5K_1 & 5K_2 & 5K_3 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} =$$

$$= \begin{pmatrix} -2-5K_1 & -3-5K_2 & 1-5K_3 \\ 5 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

$$|\lambda I - A| = \begin{vmatrix} \lambda+(2+5K_1) & 3+5K_2 & -1+5K_3 \\ -5 & \lambda & 0 \\ 0 & -1 & \lambda \end{vmatrix} = (\lambda+(2+5K_1))\lambda^2+5(\lambda(3+5K_2))+(-1+5K_3)) =$$

$$= \lambda^3+\lambda^2(2+5K_1)+\lambda(5(3+4K_2))+5(-1+5K_3)$$

$$2+5K1 = 21 \Rightarrow K_1 = 19/5$$

$$5(3+4K_2) = 146 \Rightarrow K_2 = \left(\frac{146}{5}-3\right)\frac{1}{5}$$

$$5(-1+5K_3) = 336 \Rightarrow K_3 = \frac{1}{5}\left(\frac{336}{5}+1\right)$$

3) Observer design:

$e(s)$ - אחרי המחבר , A - אחרי $\frac{1}{s}$ הראשון , B - אחרי $\frac{1}{s}$ השני.

$u - 7B - 2A = e \quad , A = \frac{e}{s} \quad , B = \frac{1}{s}A \quad , Y = 4A + B$

$Y = 4A + \frac{1}{s}A = \frac{4}{s}e + \frac{1}{s^2}e = e\left(\frac{4}{s} + \frac{1}{s^2}\right)$

$u - \frac{1}{s}7A - 2A = e \Rightarrow u - \frac{1}{s}7 \cdot e\frac{1}{s} - 2e\frac{1}{s} = e$

$u = e\left(1 + \frac{2}{s} + \frac{7}{s^2}\right)$

$$\frac{Y}{u} = \frac{\frac{4s+1}{s^2}}{\frac{s^2+2s+7}{s^2}} = \frac{4s+1}{s^2+2s+7}$$

$\Delta d = s^2 + 2\zeta\omega_n + \omega_n^2$

$(s-(-10+10j))(s-(-10-10j)) = s^2 - (-10-10j)s - (-10+10j)s + (-10+10j)(-10-10j)$

$s^2 + 20s + 200 \Rightarrow \omega_n = \sqrt{200}$

$2\zeta\omega_n = 20 \Rightarrow \zeta = \frac{10}{\sqrt{2} \cdot 10} = \frac{1}{\sqrt{2}}$

$\ddot{y} + 2\dot{y} + 7y = 4\dot{x} + 1$

$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \qquad x_1 = y \ , \ x_2 = \dot{y} \quad , \ u = 4\dot{x} + 1$

$\dot{x} = \begin{pmatrix} 0 & 1 \\ -7 & -2 \end{pmatrix} x + \begin{pmatrix} 0 \\ 1 \end{pmatrix} u \qquad y = [1 \ 4] \ x$

$\Theta = \begin{bmatrix} C \\ CA \end{bmatrix} = \begin{pmatrix} 1 & 4 \\ -28 & -7 \end{pmatrix}$

$\det(\Theta) = -7 + 4 \cdot 28 = 105 \neq 0$ - לכן המע' אובזרבבילית.

$\det(\lambda I(A - LC)) = \det\left(\lambda I \cdot \begin{pmatrix} 0 & 1 \\ -7 & -2 \end{pmatrix} - \begin{pmatrix} L_1 & 4L_1 \\ L_2 & 4L_2 \end{pmatrix}\right) =$

$= \left|\lambda I - \begin{pmatrix} -L_1 & 1-4L_1 \\ -7-L_2 & -2-4L_2 \end{pmatrix}\right| = \begin{vmatrix} \lambda + L_1 & -1+4L_1 \\ 7+L_2 & \lambda+2+4L_2 \end{vmatrix} =$

$= \lambda^2 + \lambda(2 - L_1 - 4L_2) + 7 - L_2 + 26L_1$

$-L_1 - 4L_2 = 18$

$-L_2 + 26L_1 = 193$

$-L_2 + 26(-4L_2 - 18) = 193$

$L_2 = -6.29 \quad , L_1 = 7.16$