

Код по лабораторной работе №12

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Задание №1

Сначала придумываем объект управления

```
A1 = [-1 0 0; 0 -3 1; 0 1 -1]
```

```
A1 = 3x3
    -1     0     0
     0    -3     1
     0     1    -1
```

```
B1 = [-1; 1; 0]
```

```
B1 = 3x1
    -1
     1
     0
```

```
B2 = [1 0 0 0; 0 0 0 2; 0 0 1 1]
```

```
B2 = 3x4
     1     0     0     0
     0     0     0     2
     0     0     1     1
```

```
A2 = [0 2 0 0; -2 0 0 0; 0 0 0 3; 0 0 -3 0]
```

```
A2 = 4x4
     0     2     0     0
    -2     0     0     0
     0     0     0     3
     0     0    -3     0
```

```
C2 = [1 0 1]
```

```
C2 = 1x3
     1     0     1
```

```
D2 = [0 0 0 0]
```

```
D2 = 1x4
     0     0     0     0
```

Далее проверяем выполнения условий

```
eig(A1)
```

```
ans = 3x1
    -3.4142
```

```
-1.0000  
-0.5858
```

```
eig(A2)
```

```
ans = 4x1 complex  
0.0000 + 2.0000i  
0.0000 - 2.0000i  
0.0000 + 3.0000i  
0.0000 - 3.0000i
```

```
[B1 A1*B1 A1*A1*B1]
```

```
ans = 3x3  
-1    1    -1  
1    -3   10  
0     1   -4
```

```
rank([B1 A1*B1 A1*A1*B1])
```

```
ans = 3
```

Синтезируем регулятор

```
G = [-3 1 0; 0 -3 1; 0 0 -3]
```

```
G = 3x3  
-3    1    0  
0    -3    1  
0     0   -3
```

```
Y1 = [1 1 1]
```

```
Y1 = 1x3  
1    1    1
```

```
V = [Y1; Y1*G; Y1*G*G]
```

```
V = 3x3  
1    1    1  
-3   -2   -2  
9     3    4
```

```
r=rank(V)%проверяем ранг
```

```
r = 3
```

```
cvx_begin sdp  
variable P1(3,3)  
A1*P1 - P1*G == B1*Y1;  
cvx_end
```

```
Homogeneous problem detected; solution determined analytically.  
Status: Solved  
Optimal value (cvx_optval): +0
```

```
K1 = -Y1*inv(P1)
```

```
K1 = 1×3
    -8.0000  -12.0000  -29.0000
```

Находим K2

```
cvx_begin sdp
variable P2(3,4)
variable Y2(1,4)
P2*A2 - A1*P2 == B1*Y2 + B2;
C2*P2 + D2 == 0;
cvx_end
```

```
Homogeneous problem detected; solution determined analytically.
Status: Solved
Optimal value (cvx_optval): +0
```

Y2

```
Y2 = 1×4
    1.2000  -0.2667    1.8207    1.0483
```

P2

```
P2 = 3×4
    0.0667    0.1333   -0.4966    0.4414
    0.2000   -0.2667    0.8207    0.0483
   -0.0667   -0.1333    0.4966   -0.4414
```

K2 = Y2 - K1*P2

```
K2 = 1×4
    2.2000  -6.2667   22.0966  -7.6414
```

Строим матрицы наблюдаемости и находим их ранги

```
AV = [A1 B2;
      zeros(4,3) A2];
CV = [C2 0 0 0 0];
V1 = [CV;
      CV*AV;
      CV*AV^2;
      CV*AV^3;
      CV*AV^4;
      CV*AV^5;
      CV*AV^6];
rank(V1)
```

```
ans = 7
```

```
AV= [A1+B1*K1 B2+B1*K2;
     zeros(4,3) A2];
CV = [C2 0 0 0 0];
V1 = [CV;
      CV*AV;
```

```
CV*AV^2
CV*AV^3;
CV*AV^4;
CV*AV^5;
CV*AV^6];
rank(V1)
```

```
ans = 3
```

Задание №2

```
A1 = [-1 0 0; 0 -3 1; 0 1 -1]
```

```
A1 = 3×3
    -1     0     0
     0    -3     1
     0     1    -1
```

```
B1 = [-1; 1; 0]
```

```
B1 = 3×1
    -1
     1
     0
```

```
B2 = [1 0 0 0; 0 0 0 2; 0 0 1 1]
```

```
B2 = 3×4
     1     0     0     0
     0     0     0     2
     0     0     1     1
```

```
A2 = [0 2 0 0; -2 0 0 0; 0 0 0 3; 0 0 -3 0]
```

```
A2 = 4×4
     0     2     0     0
    -2     0     0     0
     0     0     0     3
     0     0    -3     0
```

```
C2 = [1 0 1]
```

```
C2 = 1×3
     1     0     1
```

```
D2 = [1 -1 0 2]
```

```
D2 = 1×4
     1    -1     0     2
```

```
eig(A1)
```

```
ans = 3×1
   -3.4142
   -1.0000
   -0.5858
```

```
eig(A2)
```

```
ans = 4×1 complex
    0.0000 + 2.0000i
    0.0000 - 2.0000i
    0.0000 + 3.0000i
    0.0000 - 3.0000i
```

```
[B1 A1*B1 A1*A1*B1]
```

```
ans = 3×3
    -1     1     -1
     1    -3    10
     0     1     -4
```

```
rank([B1 A1*B1 A1*A1*B1])
```

```
ans = 3
```

```
G = [-3 1 0; 0 -3 1; 0 0 -3]
```

```
G = 3×3
    -3     1     0
     0    -3     1
     0     0    -3
```

```
Y1 = [1 1 1]
```

```
Y1 = 1×3
     1     1     1
```

```
V = [Y1; Y1*G; Y1*G*G]
```

```
V = 3×3
     1     1     1
    -3    -2    -2
     9     3     4
```

```
cvx_begin sdp
variable P1(3,3)
A1*P1 - P1*G == B1*Y1;
cvx_end
```

Homogeneous problem detected; solution determined analytically.
 Status: Solved
 Optimal value (cvx_optval): +0

```
K1 = -Y1*inv(P1)
```

```
K1 = 1×3
   -8.0000  -12.0000  -29.0000
```

```
cvx_begin sdp
variable P2(3,4)
variable Y2(1,4)
P2*A2 - A1*P2 == B1*Y2 + B2;
C2*P2 + D2 == 0;
cvx_end
```

Homogeneous problem detected; solution determined analytically.
 Status: Solved
 Optimal value (cvx_optval): +0

Y2

Y2 = 1×4
 5.0667 0.1333 -4.5103 4.6759

P2

P2 = 3×4
 -0.8667 1.6000 -0.9517 -1.8207
 1.0667 -0.8667 0.4897 1.6759
 -0.1333 -0.6000 0.9517 -0.1793

K2 = Y2 - K1*P2

K2 = 1×4
 7.0667 -14.8667 21.3517 5.0207

AV = [A1 B2;
 zeros(4,3) A2]

AV = 7×7
 -1 0 0 1 0 0 0
 0 -3 1 0 0 0 2
 0 1 -1 0 0 1 1
 0 0 0 0 2 0 0
 0 0 0 -2 0 0 0
 0 0 0 0 0 0 3
 0 0 0 0 0 -3 0

CV = [C2 D2];

V1 = [CV;
 CV*AV;
 CV*AV^2
 CV*AV^3;
 CV*AV^4;
 CV*AV^5;
 CV*AV^6];

rank(V1)

ans = 7

AV= [A1+B1*K1 B2+B1*K2;
 zeros(4,3) A2];

CV = [C2 D2];

V1 = [CV;
 CV*AV;
 CV*AV^2
 CV*AV^3;
 CV*AV^4;
 CV*AV^5;
 CV*AV^6];

```
rank(V1)
```

```
ans = 3
```

Задание №3

Матрицы для уравнений

```
A1 = [-1 0 0; 0 -3 1; 0 1 -1]
```

A1 = 3×3

-1	0	0
0	-3	1
0	1	-1

```
B1 = [-1; 1; 0]
```

B1 = 3×1

-1
1
0

```
B2 = [1 0 0 0; 0 0 0 2; 0 0 1 1]
```

B2 = 3×4

1	0	0	0
0	0	0	2
0	0	1	1

```
A2 = [0 2 0 0; -2 0 0 0; 0 0 0 3; 0 0 -3 0]
```

A2 = 4×4

0	2	0	0
-2	0	0	0
0	0	0	3
0	0	-3	0

```
C2 = [1 0 1]
```

C2 = 1×3

1	0	1
---	---	---

```
D2 = [1 -1 0 2]
```

D2 = 1×4

1	-1	0	2
---	----	---	---

```
C1 = [2 1 0]
```

C1 = 1×3

2	1	0
---	---	---

```
D1 = [0 0 1 0]
```

D1 = 1×4

0	0	1	0
---	---	---	---

Определяем собственные числа матриц A1, A2

```
eig(A1)
```

```
ans = 3×1
-3.4142
-1.0000
-0.5858
```

```
eig(A2)
```

```
ans = 4×1 complex
0.0000 + 2.0000i
0.0000 - 2.0000i
0.0000 + 3.0000i
0.0000 - 3.0000i
```

Определяем стабилизируемость системы

```
u=[B1 A1*B1 A1*A1*B1 A1*A1*A1*B1]
```

```
u = 3×4
-1    1    -1    1
 1   -3   10  -34
 0    1   -4   14
```

```
rank(u)
```

```
ans = 3
```

Проверим пару (CV, AV) на обнаруживаемость

```
CV=[C1 D1]
```

```
CV = 1×7
 2    1    0    0    0    1    0
```

```
AV = [A1 B2;
zeros(4,3) A2]
```

```
AV = 7×7
-1    0    0    1    0    0    0
 0   -3    1    0    0    0    2
 0    1   -1    0    0    1    1
 0    0    0    0    2    0    0
 0    0    0   -2    0    0    0
 0    0    0    0    0    0    3
 0    0    0    0    0   -3    0
```

```
V1 =[CV;
CV*AV;
CV*AV^2
CV*AV^3;
CV*AV^4;
CV*AV^5;
CV*AV^6]
```

```
V1 = 7×7
 2    1    0    0    0    1 ...
-2   -3    1    2    0    0
 2   10   -4   -2    4   -14
-2  -34   14   -6   -4   11
 2   116  -48    6  -12   92
```


-2	-396	164	26	12	15
2	1352	-560	-26	52	-1216

```
rank(V1)
```

```
ans = 7
```

Синтезируем регулятор

```
G = [-3 1 0; 0 -3 1; 0 0 -3]
```

```
G = 3x3
    -3     1     0
     0    -3     1
     0     0    -3
```

```
Y1 = [1 1 1]
```

```
Y1 = 1x3
     1     1     1
```

```
V = [Y1; Y1*G; Y1*G*G]
```

```
V = 3x3
     1     1     1
    -3    -2    -2
     9     3     4
```

```
if rank(V) == 3
    cvx_begin sdp
        variable P1(3,3)
        variable Q1(3,3)
        A1*P1 - P1*G == B1*Y1;

        cvx_end
        K1 = -Y1*inv(P1);
end
```

Homogeneous problem detected; solution determined analytically.
Status: Solved
Optimal value (cvx_optval): +0

```
K1
```

```
K1 = 1x3
    -8.0000  -12.0000  -29.0000
```

Задаем матрицу G

```
G = [-3 1 0 0 0 0 0;
     0 -3 1 0 0 0 0;
     0 0 -3 0 0 0 0;
     0 0 0 -0.5 0 0 0;
     0 0 0 0 -2 0 0;
     0 0 0 0 0 -0.4 1;
     0 0 0 0 0 0 -0.4];
```

```
C = [C1 D1]
```

```
C = 1×7  
    2    1    0    0    0    1    0
```

```
A = [A1 B2; zeros(4,3) A2]
```

```
A = 7×7  
   -1    0    0    1    0    0    0  
    0   -3    1    0    0    0    2  
    0    1   -1    0    0    1    1  
    0    0    0    0    2    0    0  
    0    0    0   -2    0    0    0  
    0    0    0    0    0    0    3  
    0    0    0    0    0   -3    0
```

```
eig(A)
```

```
ans = 7×1  
   -1.0000  
   -3.4142  
   -0.5858  
    0.0000  
    0.0000  
    0.0000  
    0.0000
```

```
y = [1; 1; 1; 1; 1; 1; 1];
```

Проверяем управляемость

```
u = rank([y G*y (G^2)*y (G^3)*y (G^4)*y (G^5)*y (G^6)*y])
```

```
u = 7
```

Вычисляем матрицы L1, L2

```
cvx_begin sdp  
    variable p(7,7)  
    G*p - p*A == y*C;  
cvx_end
```

```
Homogeneous problem detected; solution determined analytically.  
Status: Solved  
Optimal value (cvx_optval): +0
```

```
l = inv(p)*y;  
L1 = l(1:3)
```

```
L1 = 3×1  
    1.6168  
   -3.5187  
   -2.1361
```

```
L2 = l(4:7)
```

```
L2 = 4×1  
    6.8635
```

-0.6461
-7.0148
-4.6547

Находим K2

```
cvx_begin sdp
    variable P(3,4)
    variable Y(1,4)
    P*A2 - A1*P == B1*Y + B2;
    C2*P + D2 == 0;
cvx_end
```

Homogeneous problem detected; solution determined analytically.
Status: Solved
Optimal value (cvx_optval): +0

$K2 = Y - K1*P$

$K2 = 1 \times 4$
7.0667 -14.8667 21.3517 5.0207

Определяем собственные числа уравнения регулятора

```
eig([A1+B1*K1+L1*C1 B2+B1*K2+L1*D1; L2*C1 A2+L2*D1])
```

ans = 7×1
-11.6627
0.8978
0.8978
-5.4788
-0.5498
-0.2022
-0.2022

Задание №4

$A1 = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -3 & 1 \\ 0 & 1 & -1 \end{bmatrix}$

$A1 = 3 \times 3$
-1 0 0
0 -3 1
0 1 -1

$B1 = \begin{bmatrix} -1 \\ 1 \\ 0 \end{bmatrix}$

$B1 = 3 \times 1$
-1
1
0

$B2 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2 \\ 0 & 0 & 1 & 1 \end{bmatrix}$

$B2 = 3 \times 4$
1 0 0 0
0 0 0 2
0 0 1 1

```
A2 = [0 2 0 0; -2 0 0 0; 0 0 0 3; 0 0 -3 0]
```

A2 = 4x4

```
0    2    0    0
-2   0    0    0
0    0    0    3
0    0   -3    0
```

```
C = [2 1 0]
```

C = 1x3

```
2    1    0
```

```
D = [0 0 1 0]
```

D = 1x4

```
0    0    1    0
```

```
C1=C
```

C1 = 1x3

```
2    1    0
```

```
C2=C
```

C2 = 1x3

```
2    1    0
```

```
D1=D
```

D1 = 1x4

```
0    0    1    0
```

```
D2=D
```

D2 = 1x4

```
0    0    1    0
```

```
G = [-3 1 0; 0 -3 1; 0 0 -3]
```

G = 3x3

```
-3    1    0
0   -3    1
0    0   -3
```

```
Y1 = [1 1 1]
```

Y1 = 1x3

```
1    1    1
```

```
V = [Y1; Y1*G; Y1*G*G]
```

V = 3x3

```
1    1    1
-3   -2   -2
9     3     4
```

```
if rank(V) == 3
    cvx_begin sdp
        variable P1(3,3)
```

```

    variable Q1(3,3)
    A1*P1 - P1*G == B1*Y1;

    cvx_end
    K1 = -Y1*inv(P1);
end

```

Homogeneous problem detected; solution determined analytically.
 Status: Solved
 Optimal value (cvx_optval): +0

K1

```

K1 = 1x3
    -8.0000  -12.0000  -29.0000

```

```

G = [-3 1 0 0 0 0 0;
      0 -3 1 0 0 0 0;
      0 0 -3 0 0 0 0;
      0 0 0 -0.5 0 0 0;
      0 0 0 0 -2 0 0;
      0 0 0 0 0 -0.4 1;
      0 0 0 0 0 0 -0.4];
C = [C1 D1]

```

```

C = 1x7
      2      1      0      0      0      1      0

```

```

A = [A1 B2; zeros(4,3) A2]

```

```

A = 7x7
    -1      0      0      1      0      0      0
      0     -3      1      0      0      0      2
      0      1     -1      0      0      1      1
      0      0      0      0      2      0      0
      0      0      0     -2      0      0      0
      0      0      0      0      0      0      3
      0      0      0      0      0     -3      0

```

eig(A)

```

ans = 7x1
    -1.0000
    -3.4142
    -0.5858
     0.0000
     0.0000
     0.0000
     0.0000

```

```

y = [1; 1; 1; 1; 1; 1; 1];
u = rank([y G*y (G^2)*y (G^3)*y (G^4)*y (G^5)*y (G^6)*y])

```

```

u = 7

```

```

cvx_begin sdp

```

```

    variable p(7,7)
    G*p - p*A == y*C;
cvx_end

```

Homogeneous problem detected; solution determined analytically.
 Status: Solved
 Optimal value (cvx_optval): +0

```

l = inv(p)*y;
L1 = l(1:3)

```

```

L1 = 3×1
    1.6168
   -3.5187
   -2.1361

```

```

L2 = l(4:7)

```

```

L2 = 4×1
    6.8635
   -0.6461
   -7.0148
   -4.6547

```

```

cvx_begin sdp
    variable P(3,4)
    variable Y(1,4)
    P*A2 - A1*P == B1*Y + B2;
    C2*P + D2 == 0;
cvx_end

```

Homogeneous problem detected; solution determined analytically.
 Status: Solved
 Optimal value (cvx_optval): +0

```

K2 = Y - K1*P

```

```

K2 = 1×4
    3.4897   -6.1241   23.4000   -2.8000

```

```

eig([A1+B1*K1+L1*C1 B2+B1*K2+L1*D1; L2*C1 A2+L2*D1])

```

```

ans = 7×1
   -10.2343
    -5.5193
     0.0000
     0.0000
    -0.0000
    -0.0000
    -0.5464

```

Задание №5

```

A1 = [0 1; 0 0]

```

```

A1 = 2×2
     0     1

```

0 0

B2 = [0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0]

B2 = 2×8

0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

A2 = [0 1 0 0 0 0 0 0; -1 0 0 0 0 0 0 0; 0 0 0 3 0 0 0 0; 0 0 -3 0 0 0 0 0;
0 0 0 0 0 5 0 0; 0 0 0 0 -5 0 0 0; 0 0 0 0 0 0 0 7; 0 0 0 0 0 0 -7 0;]

A2 = 8×8

0	1	0	0	0	0	0	0
-1	0	0	0	0	0	0	0
0	0	0	3	0	0	0	0
0	0	-3	0	0	0	0	0
0	0	0	0	0	5	0	0
0	0	0	0	-5	0	0	0
0	0	0	0	0	0	0	7
0	0	0	0	0	0	-7	0

B1 = [0; 1]

B1 = 2×1

0
1

C1 = [1 0]

C1 = 1×2

1 0

C2 = -C1

C2 = 1×2

-1 0

D1 = [1 1 2 0 2 0 0 1]

D1 = 1×8

1 1 2 0 2 0 0 1

D2 = [1 0 1/3 0 1/5 0 1/7 0];

Находим K1

```
G = [-2 2; -2 -2];
y = [1 1];
V = [y; y*G];
if rank(V) == 2
    cvx_begin sdp
        variable p(2,2)
        A1*p - p*G == B1*y;
    cvx_end
    K1 = -y*inv(p)
end
```

Homogeneous problem detected; solution determined analytically.

Status: Solved

Optimal value (cvx_optval): +0

```
K1 = 1x2
    -8    -4
```

```
G = [-3 1 0 0 0 0 0 0 0 0;
      0 -3 1 0 0 0 0 0 0 0;
      0 0 -3 0 0 0 0 0 0 0;
      0 0 0 -0.5 0 0 0 0 0 0;
      0 0 0 0 -2 0 0 0 0 0;
      0 0 0 0 0 -0.4 1 0 0 0;
      0 0 0 0 0 0 -0.4 0 0 0;
      0 0 0 0 0 0 0 -1.5 0 0;
      0 0 0 0 0 0 0 0 -1.2 0;
      0 0 0 0 0 0 0 0 0 -1.6]
```

```
G = 10x10
   -3.0000    1.0000         0         0         0         0         0         0 ...
         0   -3.0000    1.0000         0         0         0         0         0
         0         0   -3.0000         0         0         0         0         0
         0         0         0   -0.5000         0         0         0         0
         0         0         0         0   -2.0000         0         0         0
         0         0         0         0         0   -0.4000    1.0000         0
         0         0         0         0         0         0   -0.4000         0
         0         0         0         0         0         0         0   -1.5000
         0         0         0         0         0         0         0         0
         0         0         0         0         0         0         0         0
```

```
C = [C1 D1];
A = [A1 B2; zeros(8,2) A2];
y = [1; 1; 1; 1; 1; 1; 1; 1; 1; 1];
u = rank([y G*y (G^2)*y (G^3)*y (G^4)*y (G^5)*y (G^6)*y (G^7)*y (G^8)*y (G^9)*y]);
cvx_begin sdp
    variable p(10,10)
    G*p - p*A == y*C;
cvx_end
```

Homogeneous problem detected; solution determined analytically.

Status: Solved

Optimal value (cvx_optval): +0

```
l = inv(p)*y;
L1 = l(1:2)
```

```
L1 = 2x1
   -0.0120
   -0.0011
```

```
L2 = l(3:10)
```

```
L2 = 8x1
   -0.0114
```



```
0.0356
1.0223
-0.0039
0.3614
8.2473
16.7665
-19.3796
```

```
cvx_begin sdp
    variable P(2,8)
    variable Y(1,8)
    P*A2 - A1*P == B1*Y + B2;
    C2*P + D2 == 0;
cvx_end
```

Homogeneous problem detected; solution determined analytically.
Status: Solved
Optimal value (cvx_optval): +0

```
K2 = Y - K1*P
```

```
K2 = 1x8
    7.0000    4.0000   -0.3333    4.0000   -3.4000    4.0000   -5.8571    4.0000
```