**LAB # 7(Open Ended)**

**OBJECTIVE**

Generate a Matlab code to find the state space model from the transfer function of a system and vice versa. Also find the transition matrix.

**THEORY**

**State Space Model**

This model is a differential equation model, but the equations are always written in a specific format so for the conversion of the transfer function to state variable model use inverse Laplace transform. The state variable model, or state space model, is expressed as n first order coupled differential equations. These equations preserve the system’s input-output relationships (that of the transfer function).

**Y1**

**U1**

**X1**

**SYSTEM**

**X2**

**U2**  **Y2**

**Nth order system**

**X1, X2 are state variables**

The standard form of the State Equation of a LTI system is

**Ẋ(t) = AX(t) + BU(t)**

**Y(t) = CX(t) + DU(t)**

**Ẋ(t) =** Time derivative of X(t)

**X(t) =** State variable

**U(t) =** Input vector

**Y(t) =** Output vector

**A =** System matrix

**B =** Input matrix

**C =** Output matrix

**D =** Transition matrix(usually zero)

There are two matrix equations: the first equation is the state equation and the second equation is the output equation.

To perform this lab we need the following commands:

* eye
* Syms
* Pretty
* tf2ss
* ss2tf
* ilaplace
* inv

**EXERCISE**

**Task 1:** Find state space model matrices ABCD.

T.F=

**Coding:**

N=[10 5]

De=[2 5 6]

[A,B,C,D]=tf2ss(N,De)

**Result:**

A =

-2.5000 -3.0000

1.0000 0

B =

1

0

C =

5.0000 2.5000

D =

0

**Task 2:** Verify numerator & denominator of the previous t.f.

**Coding:**

A=[-2.5 -3;1 0]

B=[1;0]

C=[5 2.5]

D=[0]

[N,De]=ss2tf(A,B,C,D)

**Result:**

N =

0 5.0000 2.5000

De =

1.0000 2.5000 3.0000

**Task 3:** Find state transition matrix of previous t.f.

FORMULA:

L-1 (SI-A)-1

**Coding:**

Syms s

A=[-2.5 -3;1 0]

I=eye(2)

R=I\*s

R1=R-A

R2=inv(R1)

Y=ilaplace(R2)

**Result:**

Y =

[ exp(-(5\*t)/4)\*(cos((23^(1/2)\*t)/4) - (5\*23^(1/2)\*sin((23^(1/2)\*t)/4))/23), -(12\*23^(1/2)\*exp(-(5\*t)/4)\*sin((23^(1/2)\*t)/4))/23]

[ (4\*23^(1/2)\*exp(-(5\*t)/4)\*sin((23^(1/2)\*t)/4))/23, exp(-(5\*t)/4)\*(cos((23^(1/2)\*t)/4) + (5\*23^(1/2)\*sin((23^(1/2)\*t)/4))/23)]

**Task 4:** Find t.f by formula .

FORMULA:

C(SI-A)-1B+D

**Coding:**

syms s

A=[-2.5 -3;1 0]

B=[1;0]

C=[5 2.5]

D=[0]

I=eye(2)

G=inv (s\*I-A)

K=C\*G\*B+D

pretty(K)

**Result:**

I =

1 0

0 1

G =

[ (2\*s)/(2\*s^2 + 5\*s + 6), -6/(2\*s^2 + 5\*s + 6)]

[ 2/(2\*s^2 + 5\*s + 6), (2\*s + 5)/(2\*s^2 + 5\*s + 6)]

K =

(10\*s)/(2\*s^2 + 5\*s + 6) + 5/(2\*s^2 + 5\*s + 6)

10 s 5

-------------- + --------------

2 2

2 s + 5 s + 6 2 s + 5 s + 6

**Task 5:** Find state space model matrices ABCD.

T.F=

**Coding:**

N=[4]

De=[1 -3 2]

[A,B,C,D]=tf2ss(N,De)

**Result:**

A =

3 -2

1 0

B =

1

0

C =

0 4

D =

0

**Task 6:** Verify numerator & denominator of the previous t.f.

**Coding:**

A=[3 -2;1 0]

B=[1;0]

C=[0 4]

D=[0]

[N,De]=ss2tf(A,B,C,D)

**Result:**

N =

0 0 4

De =

1 -3 2

**Task 7:** Find state transition matrix of previous t.f.

FORMULA:

L-1 (SI-A)-1

**Coding:**

syms s

A=[3 -2;1 0]

I=eye(2)

R=I\*s

R1=R-A

R2=inv(R1)

Y=ilaplace(R2)

**Result:**

Y =

[ 2\*exp(2\*t) - exp(t), 2\*exp(t) - 2\*exp(2\*t)]

[ exp(2\*t) - exp(t), 2\*exp(t) - exp(2\*t)]

**Task 8:** Find t.f by formula .

FORMULA:

C(SI-A)-1B+D

**Coding:**

syms s

A=[3 -2;1 0]

B=[1;0]

C=[0 4]

D=[0]

I=eye(2)

G=inv (s\*I-A)

K=C\*G\*B+D

pretty(K)

**Result:**

I =

1 0

0 1

G =

[ s/(s^2 - 3\*s + 2), -2/(s^2 - 3\*s + 2)]

[ 1/(s^2 - 3\*s + 2), (s - 3)/(s^2 - 3\*s + 2)]

K =

4/(s^2 - 3\*s + 2)

4

------------

2

s - 3 s + 2

**Task 9:** Find state space model matrices ABCD.

T.F=

**Coding:**

N=[9 0]

De=[4 3 -1]

[A,B,C,D]=tf2ss(N,De)

**Result:**

A =

-0.7500 0.2500

1.0000 0

B =

1

0

C =

0 2.2500

D =

0

**Task 10:** Verify numerator & denominator of the previous t.f.

**Coding:**

A=[-0.7500 0.2500;1 0]

B=[1;0]

C=[0 2.2500]

D=[0]

[N,De]=ss2tf(A,B,C,D)

**Result:**

N =

0 2.2500 0

De =

1.0000 0.7500 -0.2500

**Task 11:** Find state transition matrix of previous t.f.

FORMULA:

L-1 (SI-A)-1

**Coding:**

syms s

A=[-0.7500 0.2500;1 0]

I=eye(2)

R=I\*s

R1=R-A

R2=inv(R1)

Y=ilaplace(R2)

**Result:**

Y =

[ (4\*exp(-t))/5 + exp(t/4)/5, exp(t/4)/5 - exp(-t)/5]

[ (4\*exp(t/4))/5 - (4\*exp(-t))/5, exp(-t)/5 + (4\*exp(t/4))/5]

**Task 12:** Find t.f by formula .

FORMULA:

C(SI-A)-1B+D

**Coding:**

syms s

A=[-0.7500 0.2500;1 0]

B=[1;0]

C=[0 2.2500]

D=[0]

I=eye(2)

G=inv (s\*I-A)

K=C\*G\*B+D

pretty(K)

**Result:**

I =

1 0

0 1

G =

[ (4\*s)/(4\*s^2 + 3\*s - 1), 1/(4\*s^2 + 3\*s - 1)]

[ 4/(4\*s^2 + 3\*s - 1), (4\*s + 3)/(4\*s^2 + 3\*s - 1)]

K =

9/(4\*s^2 + 3\*s - 1)

9

--------------

2

4 s + 3 s - 1

**CONCLUSION:**

In this lab we find the state space model from the transfer function of a system and vice versa. Also find the transition matrix. By using **syms, Solve, Pretty & Simplify, tf2ss, ss2tf, ilaplace, inv.**