EML ~~5~~ 5311

Control System Theory

HW-7

Problem 1- Given-

$$A=\begin{bmatrix}1 & 0 & 2\\ 0 & 1 & -3\\ 0 & 1 & 0\end{bmatrix} \quad B=\begin{bmatrix}1\\0\\-1\end{bmatrix} \quad C=\begin{bmatrix}0 & 1 & 1\\ 0 & -1 & -1\end{bmatrix}$$

$n=3.$

$$\mathcal{C}=[B \quad AB \quad A^2B].$$

$$AB=\begin{bmatrix}1 & 0 & 2\\ 0 & 1 & -3\\ 0 & 1 & 0\end{bmatrix}\begin{bmatrix}1\\0\\-1\end{bmatrix}=\begin{bmatrix}1-2\\3\\0\end{bmatrix}=\begin{bmatrix}-1\\3\\0\end{bmatrix}$$

$$A^2B=\begin{bmatrix}1 & 0 & 2\\ 0 & 1 & -3\\ 0 & 1 & 0\end{bmatrix}\begin{bmatrix}-1\\3\\0\end{bmatrix}=\begin{bmatrix}-1\\3\\3\end{bmatrix}$$

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

Finding Row-echelon form of C.

$R_3 \to \cancel{R_3}\ R_3+\frac{1}{3}R_2 \qquad R_3 \to R_3+R_1$

$$\mathcal{C}=\begin{bmatrix}1 & -1 & -1\\ 0 & 3 & 3\\ 0 & 0 & 3\end{bmatrix} \qquad \text{Rank}(\mathcal{C})=3$$ (The system is controllable).

The controllability subspace has a dimension 2.

Observability matrix $= \mathcal{O} = \begin{bmatrix} C \\ CA \\ CA^2 \\ \vdots \\ CA^{n-1} \end{bmatrix}$

$$CA = \begin{bmatrix} 0 & 1 & 1 \\ 0 & -1 & -1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & -3 \\ 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 2 & -3 \\ 0 & -2 & 3 \end{bmatrix}$$

$$CA^2 = \begin{bmatrix} 0 & 2 & -3 \\ 0 & -2 & 3 \end{bmatrix} \begin{bmatrix} 1 & 0 & 2 \\ 0 & 1 & -3 \\ 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 0 & -1 & -6 \\ 0 & 1 & 6 \end{bmatrix}.$$

$$\mathcal{O} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1 & -1 \\ 0 & 2 & -3 \\ 0 & -2 & 3 \\ 0 & -1 & -6 \\ 0 & 1 & 6 \end{bmatrix} \qquad \mathcal{O}^T = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 2 & -2 & -1 & 1 \\ 0 & -1 & -3 & 3 & -6 & 6 \end{bmatrix}$$

Calculating the row-echelon form of $\mathcal{O}^T$

$R_1 \leftrightarrow R_2$; $R_2 \leftrightarrow R_3$.

$$\mathcal{O}^T = \begin{bmatrix} 1 & -1 & 2 & -2 & -1 & 1 \\ 0 & -1 & -3 & 3 & -6 & 6 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$R_2 \rightarrow -R_2$; $R_1 \rightarrow R_1 + R_2$.

$$\mathcal{O}^T = \begin{bmatrix} 1 & 0 & 5 & -5 & 5 & -5 \\ 0 & 1 & 3 & -1 & 6 & -6 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$\text{Rank}(\mathcal{O}) = \text{Rank}(\mathcal{O}^T) = 2 \neq n$. (system is not observable).

The system has a 2 dimensional ~~&~~ observable subspace and a one dimensional unobservable subspace.

2. Since the system has 3 inputs equal to the ~~number of~~ dimension n of matrix A the system is controllable. But since the number of output is not equal to the value of n, the system is not stable.

Problem 2 –

1) The given system is not observable when.

$$[c_1, c_2 \ c_3] = [10 \ a \ 5]$$

2) The system is observable when.

$$[c_1 \ c_2 \ c_3] = [10 \ 2 \ 5].$$

3). p: c's do not take up the eigen values of A.
q: the system is observable.
$p \Rightarrow q$.
p is the sufficient condition for q. and q is a necessary condition for p.

Problem -3 –

Given – $\dot{\hat{x}} = A\hat{x} + Bu + L(y - (C\hat{x} + Du))$

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1. $\Rightarrow \dot{\hat{x}} = A\hat{x} - LC\hat{x} + Ly + Bu - LDu.$

$$= (A-LC)\hat{x} + Ly + (B-LD)u.$$

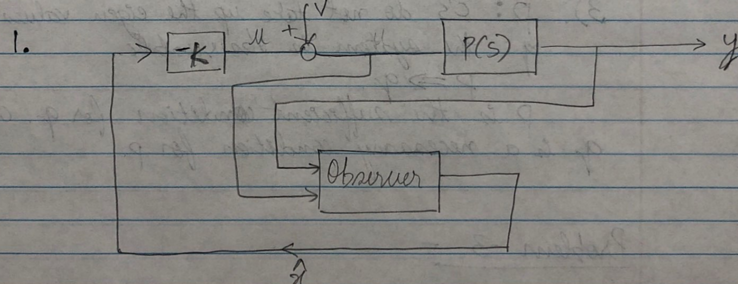
$$\dot{\hat{x}} = (A-LC)\hat{x} + \begin{bmatrix} L & B-LD \end{bmatrix} \begin{bmatrix} y \\ u \end{bmatrix}$$

2. MATLAB problem.

3. The Observer poles have to be faster than Controller poles.
If the eigenvalues of A-LC are chosen so that the poles of observer are further away from the controller poles, the transient state of the system increases ~~&~~ hence, the system reaches steady state slower.

Problem -4

1.



2. We know that,

$$e \triangleq x - \hat{x}$$

$$\Rightarrow \dot{e} = \dot{x} - \dot{\hat{x}}$$

$$= Ax + \cancel{Bu} - [A\hat{x} + \cancel{Bu} + L(y - C\hat{x} - Du)].$$

$$= Ax - A\hat{x} - L[(Cx + \cancel{Du}) - C\hat{x} - \cancel{Du}]$$

$$\dot{e} = Ae - LCe$$

$$\dot{e} = (A - LC)e.$$

and

$$\dot{x} = Ax + B(-K\hat{x}) + Bv$$

$$= Ax - BK\hat{x} + Bv$$

$$= Ax - BK(x - e) + Bv$$

$$= (A - BK)x + BKe + Bv.$$

$$\Rightarrow \begin{bmatrix} \dot{x} \\ \dot{e} \end{bmatrix} = \begin{bmatrix} A-BK & BK \\ 0 & A-LC \end{bmatrix} \begin{bmatrix} x \\ e \end{bmatrix} + \begin{bmatrix} B \\ 0 \end{bmatrix} v.$$

$$y = Cx + \cancel{Du}^{\,0}.$$

$$y = \begin{bmatrix} C & 0 \end{bmatrix} \begin{bmatrix} x \\ e \end{bmatrix}$$ //.

3. Rise Time = 0.0974.

(MATLAB)

4. (MATLAB & SIMULINK).

Initially I started out by defining the (A, B, C, D) matrices and then by computing the eigenvalues of A I was able to determine the controller poles as

slow as possible. (ie very close to the origin).
Then I made the observer poles 5-10 times slower than my controller poles. From this I was able to calculate K and L required to ~~design the~~ determine the (A, B, C, D) matrices ~~to~~ of the closed loop. And along with the given initial conditions the desired result was reached.

Problem-5

Given - $\ddot{y} + 2\dot{y} + 5y = f(t)$, $y(0) = -4$, $\dot{y}(0) = 5$.

Let $y = x_1$
$\dot{y} = x_2$

$\dot{x}_1 = x_2$
$\dot{x}_2 = u - 2x_2 - 5x_1$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -5 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u.$$

$$y = Cx + Du.$$

1. (MATLAB).

2. (MATLAB).

3. It is clear from the previous ~~examp~~ problem that the predicted solutions ~~fit~~ accurately to the state of the actual system when the sampling period (T_s) are small. Hence, my advise to the engineers would be ~~to~~ ~~make~~ have a small sampling period.

Problem-6

1. Given - $A = \begin{bmatrix} 0 & 1 \\ 3 & 2 \end{bmatrix}$ $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$ $C = \begin{bmatrix} -3 & 1 \end{bmatrix}$ $D = 0$.

$$H(s) = C(sI - A)^{-1}B + D.$$

$$= \begin{bmatrix} -3 & 1 \end{bmatrix} \left[\begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ 3 & 2 \end{bmatrix} \right]^{-1} \begin{bmatrix} 0 \\ 1 \end{bmatrix} + 0.$$

$$= \begin{bmatrix} -3 & 1 \end{bmatrix} \begin{bmatrix} s & -1 \\ -3 & s-2 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} -3 & 1 \end{bmatrix} \frac{1}{(s(s-2)-3)} \begin{bmatrix} s-2 & 1 \\ 3 & s \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix}.$$

$$H(s) = \begin{bmatrix} -3 & 1 \end{bmatrix} \left(\frac{1}{s(s-2)-3} \right) \begin{bmatrix} 1 \\ s \end{bmatrix} = \left[\frac{1}{s^2-2s-3} \right] (-3+s).$$

$$\Rightarrow H(s) = \frac{s-3}{s^2-2s-3} = \frac{s-3}{(s-3)(s+1)}.$$

$$H(s) = \frac{1}{s+1}$$

2. Finding eigen values of A.
Characteristic equation = $\det(A - \lambda I) = 0$.

$$\det\left(\begin{bmatrix} 0 & 1 \\ 3 & 2 \end{bmatrix} - \begin{bmatrix} \lambda & 0 \\ 0 & \lambda \end{bmatrix} \right) = -2\lambda + \lambda^2 - 3.$$

$$\Rightarrow -2\lambda + \lambda^2 - 3 = 0 \quad \Rightarrow \lambda = 3 \text{ and } -1.$$

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Hence, the eigen value of A is the same as the pole of the transfer function.

(3) The system is ~~not B~~ BIBO stable as all it's poles are in SLHP.

ie $s+1 \Rightarrow s = -1$.

But the system is unstable in the sense of Lyapunov since the eigen value of matrix A. ie $\lambda = 3$ is not ~~s~~ in SLHP.

Problem-7

float a11= 0.9397
float a12= 0
float a21 = 0.06034
float a22 = 1
float b11 = 1.931
float b21 = 0.0607
float c11 = 13.75
float c12 = 7.813
float d = 10.

(MATLAB).

Problem - 8

Given - $P(s) = \dfrac{0.5}{(s+0.5)(s-1)}$.

$C(s) = \dfrac{s-1}{s+2}$.

(a) $H_{zR} = \dfrac{CP}{1+CP}$.

$$= \frac{\dfrac{(s-1)(0.5)}{(s+2)(s+0.5)(s-1)}}{1+\dfrac{(s-1)(0.5)}{(s+2)(s+0.5)(s-1)}}$$

$$= \frac{(s-1)(0.5)}{(s+2)(s+0.5)(s-1)+(s-1)(0.5)}$$

$$= \frac{\cancel{(s-1)}(0.5)}{\cancel{(s-1)}\{(s+2)(s+0.5)+0.5\}} = \frac{0.5}{(s+2)(s+0.5)+0.5}.$$

Since, all the poles are in SLHP it is BIBO stable.

(b). $H_{YR} = \dfrac{PC}{1+PC}$

since $H_{YR}(s) = H_{zR}(s)$

$H_{YR}(s)$ is BIBO stable as all its poles are in SLHP.

(c) $H_{zW} = \dfrac{P}{1+CP} = \dfrac{\dfrac{0.5}{(s+0.5)(s-1)}}{1+\dfrac{(s-1)(0.5)}{(s+2)(s+0.5)(s-1)}}$.

$$H_{zW} = \frac{0.5(s+2)}{(s+0.5)(s-1)(s+2)+0.5(s-1)}.$$

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$$H_{2w} = \frac{0.5(s+2)}{(s-1)((s+0.5)(s+2)+0.5)}$$

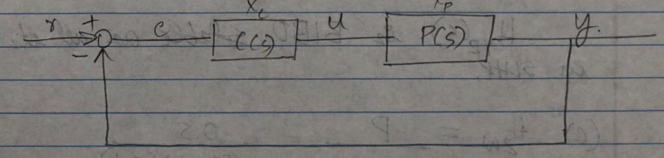
$H_{2w}(s)$ is not BIBO stable as it ~~has~~ does not have poles in the SLHP. (ie it has positive poles).

(d) $$H_{UR} = \frac{C(s)}{1+C(s)P(s)} = \frac{\frac{(s-1)}{(s+2)}}{1+\frac{0.5(s-1)}{(s+0.5)(s-1)(s+2)}} = \frac{(s-1)^2(s+0.5)}{(s+0.5)(s-1)(s+2)+0.5(s-1)}$$

$$H_{UR}(s) = \frac{(s-1)(s+0.5)}{(s+0.5)(s+2)+0.5}$$

$H_{UR}(s)$ is BIBO stable as all the poles are in SLHP.

Problem 9 -



Plant

$$\dot{x}_p = A_p x_p + B_p u$$
$$y = C_p x_p + D_p u$$

Controller

$$\dot{x}_c = A_c x_c + B_c e$$
$$u = C_c x_c + D_c e$$

$$y = C_p x_p + D_p (C_c x_c + D_c e)$$
$$= C_p x_p + D_p (C_c x_c + D_c (r - y))$$
$$= C_p x_p + D_p (C_c x_c + D_c r - D_c y)$$
$$y = C_p x_p + D_p C_c x_c + D_p D_c r - D_p D_c y$$
$$y(1 + D_p D_c) = C_p x_p + D_p C_c x_c + D_p D_c r$$
$$y = \underbrace{\begin{bmatrix} \frac{C_p}{1 + D_c D_p} & \frac{D_p C_c}{1 + D_c D_p} \end{bmatrix}}_{C_{cl}} \begin{bmatrix} x_p \\ x_c \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{D_p D_c}{1 + D_c D_p} \end{bmatrix}}_{D_{cl}} r(t)$$

$$\dot{x}_p = A_p x_p + B_p (C_c x_c + D_c (r - y))$$
$$= A_p x_p + B_p C_c x_c + B_p D_c r - B_p D_c y$$
$$= \begin{bmatrix} A_p & B_p C_c \end{bmatrix} \begin{bmatrix} x_p \\ x_c \end{bmatrix} + B_p D_c r - B_p D_c \left(\begin{bmatrix} \frac{C_p}{1 + D_c D_p} & \frac{D_p C_c}{1 + D_c D_p} \end{bmatrix} \begin{bmatrix} x_p \\ x_c \end{bmatrix} + \begin{bmatrix} \frac{D_p D_c}{1 + D_c D_p} \end{bmatrix} r(t) \right)$$

$$\dot{x}_p = \begin{bmatrix} A_p - \frac{B_p D_c C_p}{1 + D_c D_p} & B_p C_c - \frac{B_p D_c D_p C_c}{1 + D_c D_p} \end{bmatrix} \begin{bmatrix} x_p \\ x_c \end{bmatrix} + \begin{bmatrix} B_p D_c + \frac{D_p D_c}{1 + D_c D_p} \end{bmatrix} r(t)$$

$$\dot{x}_c = A_c x_c + B_c(r-y).$$

$$= A_c x_c + B_c r - B_c y. \quad \cancel{= A_c x_c + B_c r - B_c}$$

$$= A_c x_c + B_c r - B_c\left(\begin{bmatrix} \frac{C_p}{1+D_cD_p} & \frac{D_pC_c}{1+D_cD_p}\end{bmatrix}\begin{bmatrix} x_p \\ x_c\end{bmatrix} + \left[\frac{D_pD_c}{1+D_cD_p}\right] r(t)\right).$$

$$\dot{x}_c = \begin{bmatrix} \frac{-B_cC_p}{1+D_cD_p} & \frac{A_c - B_cD_pC_c}{1+D_cD_p}\end{bmatrix}\begin{bmatrix} x_p \\ x_c\end{bmatrix} + \left[B_c + \frac{D_pD_c}{1+D_cD_p}\right] r(t).$$

Assuming $(1+D_cD_p)$ is invertible.

$$\alpha = (1+D_pD_c)^{-1}.$$

$$\begin{bmatrix} \dot{x}_p \\ \dot{x}_c\end{bmatrix} = \begin{bmatrix} A_p - \alpha B_pC_pD_c & \alpha B_pC_c \\ -\alpha B_cC_p & A_c - \alpha B_cC_cD_p\end{bmatrix}\begin{bmatrix} x_p \\ x_c\end{bmatrix} + \begin{bmatrix} \alpha B_pD_c \\ -\alpha B_c\end{bmatrix} r.$$

$$y = \begin{bmatrix} \alpha C_p & \alpha D_pC_c\end{bmatrix}\begin{bmatrix} x_p \\ x_c\end{bmatrix} + \alpha D_cD_p r.$$

$$z = [x_p^T, x_c^T]^T.$$

$$\Rightarrow \dot{z} = \begin{bmatrix} A_p - \frac{B_pD_cC_p}{1+D_pD_c} & B_pC_c - \frac{B_pD_cD_pC_c}{1+D_pD_c} \\ \frac{-B_cC_p}{(1+D_pD_c)} & A_c - \frac{B_cD_pC_c}{1+D_pD_c}\end{bmatrix} z + \begin{bmatrix} B_pD_c - \frac{B_pD_cD_pD_c}{(1+D_pD_c)} \\ B_c - \frac{B_cD_pD_c}{(1+D_pD_c)}\end{bmatrix} r$$

$$\Rightarrow y = \begin{bmatrix} \frac{C_p}{(1+D_pD_c)} & \frac{D_pC_c}{(1+D_pD_c)}\end{bmatrix} z + \frac{D_pD_c}{1+D_pD_c} r.$$

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Problem -10

Given :- $P(s) = \dfrac{0.5}{(s+0.5)(s-1)}$ $\qquad C(s) = \dfrac{s-1}{s+2)}$

$$P(s) = \frac{0.5}{s^2+0.5s-s-0.5} = \underline{\underline{\frac{0.5}{s^2-0.5s-0.5}}}$$

$$R(s) \longrightarrow \boxed{\frac{0.5}{s^2-0.5s-0.5}} \longrightarrow C(s)$$

$$(s^2-0.5s-0.5)\,C(s) = 0.5\,R(s).$$

with zero initial conditions.

we have,

$$\ddot{c} - 0.5\dot{c} - 0.5c = 0.5r$$

Let $c = x_1$

$\dot{c} = x_2$.

$$\dot{x}_1 = x_2.$$

$$\dot{x}_2 = 0.5r + 0.5x_1 + 0.5x_2.$$

$$\Rightarrow \begin{vmatrix} \dot{x}_1 \\ \dot{x}_2 \end{vmatrix} = \begin{bmatrix} 0 & 1 \\ 0.5 & 0.5 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \end{bmatrix} r$$ //

1. The closed loop is not stable in the sense of Lyapunov as the eigen values of A are not in SLHP.

2. Problem 8 showed that some of the external properties of the system were not BIBO stable. And Lyapunov stability is a indication or a form of internal stability of the system. This result shows that zero-pole cancellation of an unstable pole only hides the fact that the system has internal instability.

```
n=5;
m=1;
p=2;
A=[-14.5 -59.5 -149.5 -38.5 65
    1 0 0 0 0
    0 1 0 0 0
    0 0 1 0 0
    0 0 0 1 0];
B=[ 1; 0; 0; 0; 0];
C=[ 0 0 0 100 500];
D=zeros(size(C,1), size(B,2));
OB=obsv(A,C);
rank_OB=rank(OB);
j=sqrt(-1);
cont_poles=[-15 -30 -50 -15+3j -15-3j];
obsv_poles =[-15+0j -7+3j -7-3j -6+0j 5.5+0j];
K2=place(A',C',obsv_poles);
K1=place(A,B,cont_poles);
L=K2';
A_obs = (A-L*C);
B_obs = [L (B - L*D)];
C_obs = eye(n); %why?
D_obs = zeros(size(C_obs,1),size(B_obs,2));

A_cl=[A-(B*K1) (B*K1)
    zeros(size(A)) A-L*C];
B_cl=[B; zeros(size(B))];
C_cl=[C zeros(size(C))];
D_cl=zeros(size(C_cl,1),size(B_cl,2));

x0=[1 1 1 1 1]';
x0_hat=[0 0 0 0 0]';
SYS=ss(A_cl,B_cl,C_cl,D_cl);
figure(1)
step(SYS)
hold on;
% figure(2)
stepinfo(SYS,'SettlingTimeThreshold',0.02)
Ts = 0.1;
t_final = 15;
time = [0:Ts:t_final]';

% sim('observer1')
```

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```
clc;
clear;
A=[0 1;-5 -2];
B=[ 0; 1];
C=rand(1,2);
D=zeros(size(C,1),size(B,2));
SS=ss(A,B,C,D);
t=[0:0.25:5];
x0=[-4 5];
U=2*sin(2*t)+5;
lsim(SS,U,t,x0);
```

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```
clc;
clear;
A=[0 1;-5 -2];
B=[0; 1];
C=[1 0];
D=zeros(size(C,1),size(B,2));
SS=ss(A,B,C,D);
% time=[0:0.25:10];

Ts = 0.5;%time step
time = [0:Ts:10];%array of time points

x_init=[-4; 5];

U=2*sin(2*time)+5;
junk = find(time>=1); index1sec = junk(1);

u  = zeros(1,length(time));
u(index1sec:end) = 2*sin(2*time(index1sec:end))+5;
x_euler = zeros(2,length(time)+1);%intialize for storage
x_euler(:,1) = x_init;
x_now = x_init;
x_euler(:,1) = x_init;
for t_index = 1:length(time)
    u_now = u(t_index); %read u(t)
x_next = (eye(2)+Ts*A)*x_now + Ts*B*u_now; % Euler approx
x_euler(:,t_index+1) = x_next; %store state
x_now = x_next; %update state
end;
y_euler = C*x_euler(:,1:length(time)); % y = Cx+Du
figure
h=lsim(SS,U,time,x_init);
plot(time,h,'go:')

hold on;

plot(time,y_euler,'bo:');
```

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```
TF=tf([10 450 250],[1 1 0])
SYS=ss(TF)
TS=1.25*exp(-3)
SYSD=c2d(SYS,TS,'zoh')
```

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```matlab

%% this is the part that you have to do!
% ----------------------------------------
% design observer gain L
j=sqrt(-1);
obsv_poles =[-5+2j -5-2j -6+0j -5.2+0j];
K=place(A',C',obsv_poles);
L=K';%choose eigenvalues of A-LC
%compute L by using 'place' command here

% initialize state of the observer
xhat_init = randn(4,1); %or use something else if you prefer

%define system matrices for the observer
A_obs = (A-L*C);
B_obs = [L (B - L*D)];
C_obs = eye(n); %why?
D_obs = zeros(size(C_obs,1),size(B_obs,2));
% ----------------------------------------




%% define plant inputs - right now I am choosing it arbitrarily:
% you are welcome to change this to something else
```

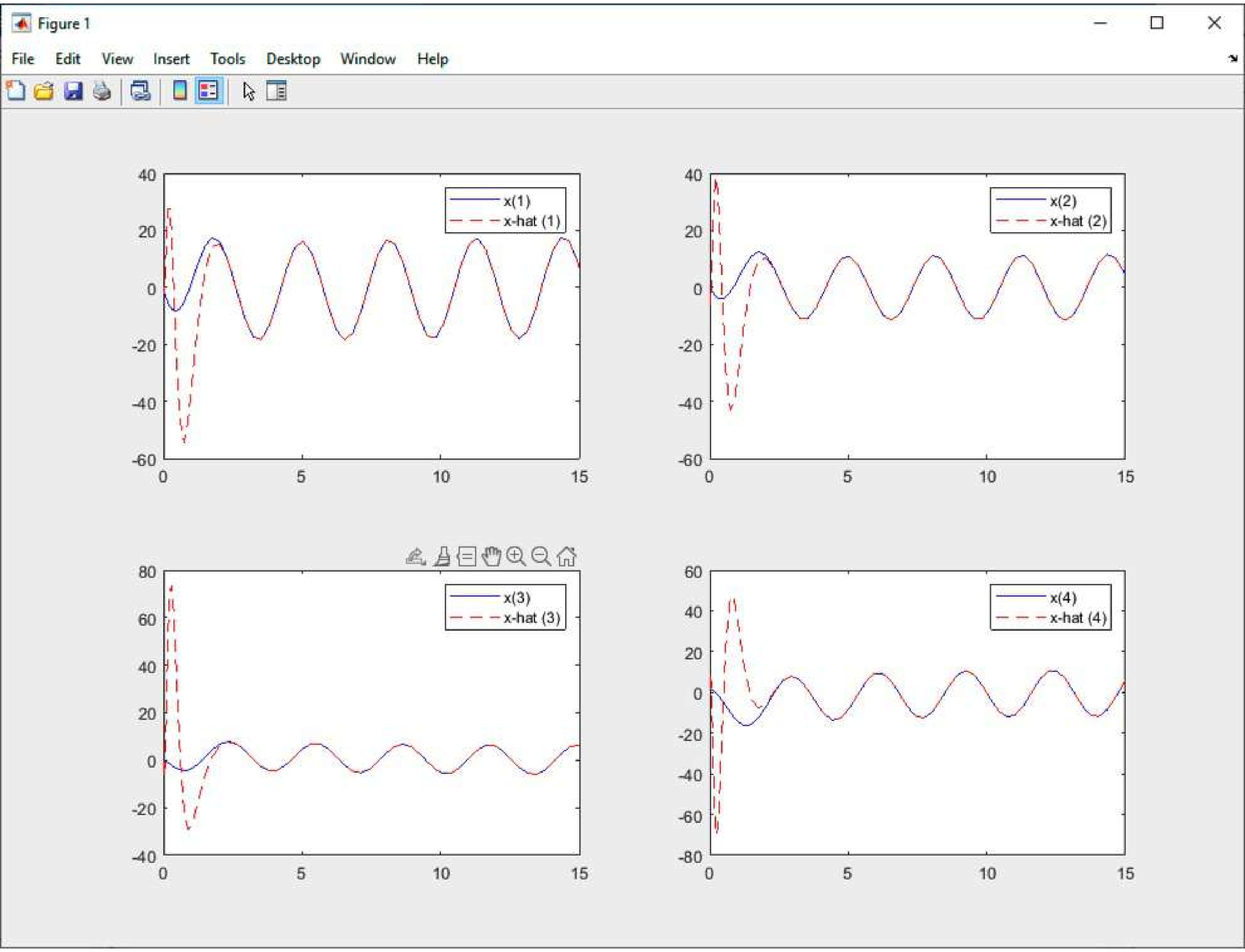


Figure 1
File Edit View Insert Tools Desktop Window Help
x(1)
x-hat (1)
x(2)
x-hat (2)
x(3)
x-hat (3)
x(4)
x-hat (4)

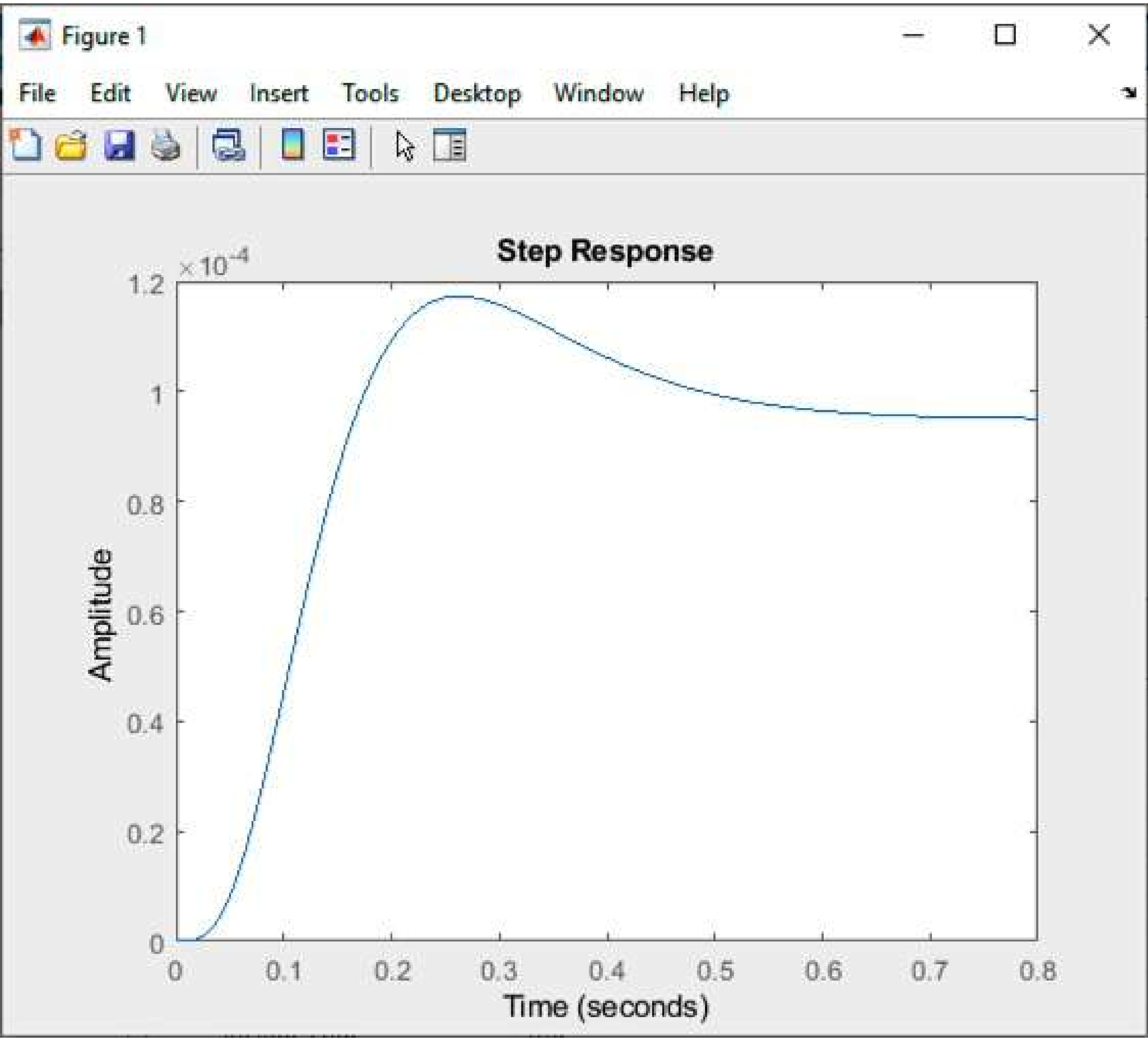
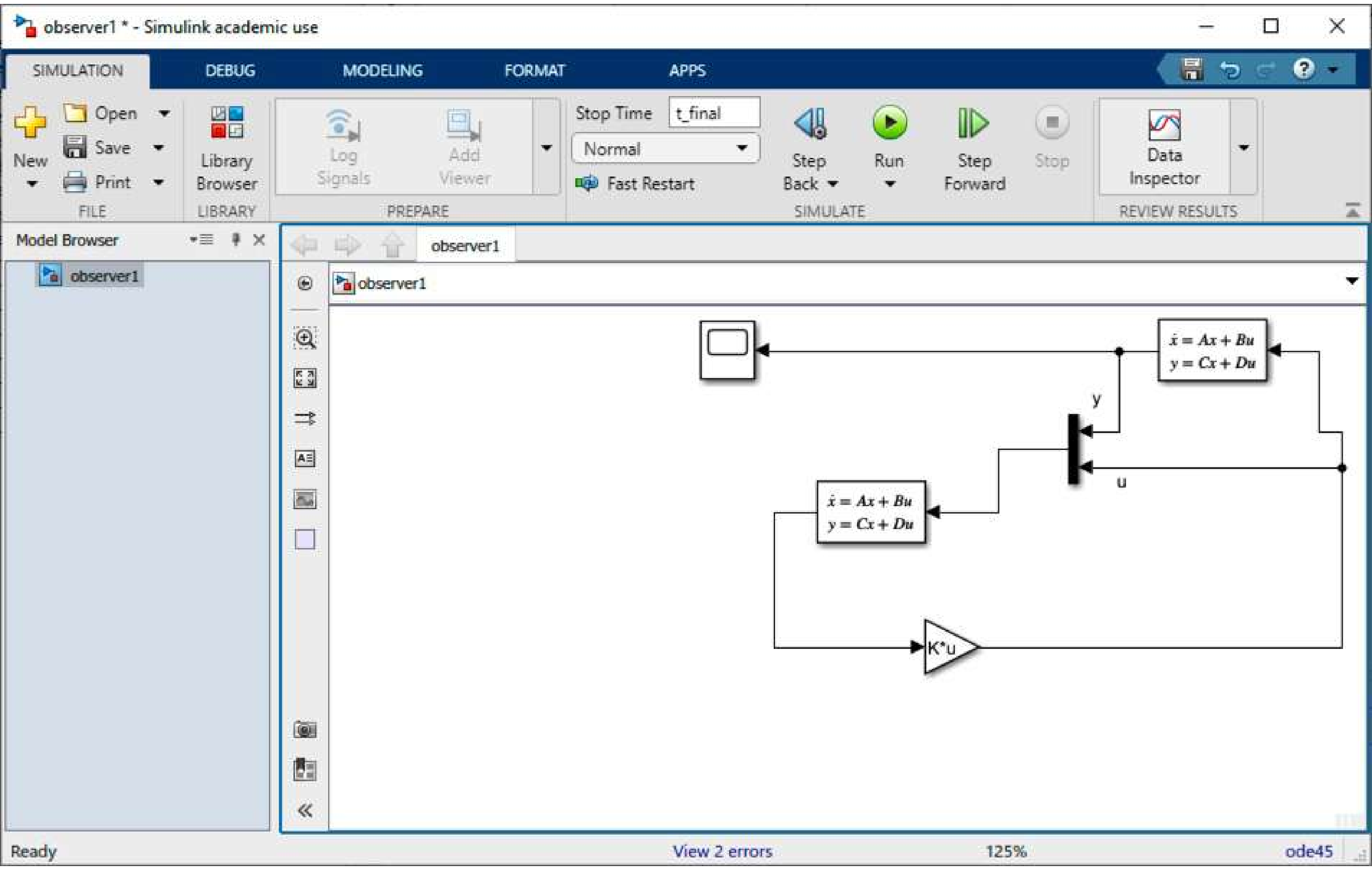
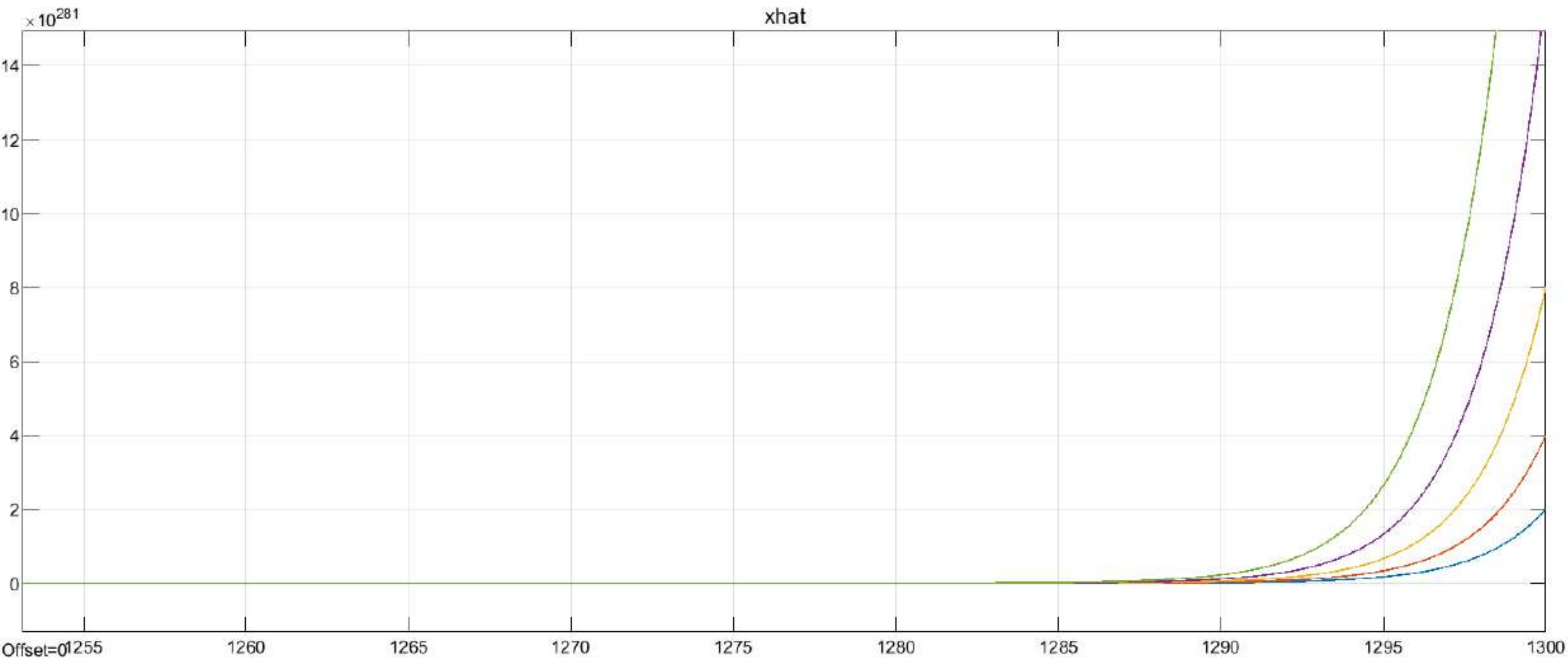


Figure 1
File Edit View Insert Tools Desktop Window Help
Step Response
×10^-4
1.2
1
0.8
0.6
0.4
0.2
0
Amplitude
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Time (seconds)


observer1 * - Simulink academic use
SIMULATION
DEBUG
MODELING
FORMAT
APPS
Open
Save
Print
New
FILE
Library
Browser
LIBRARY
Log
Signals
Add
Viewer
PREPARE
Stop Time
t_final
Normal
Fast Restart
Step
Back
Run
Step
Forward
Stop
SIMULATE
Data
Inspector
REVIEW RESULTS
Model Browser
observer1
observer1
observer1
$\dot{x} = Ax + Bu$
$y = Cx + Du$
y
u
$\dot{x} = Ax + Bu$
$y = Cx + Du$
K*u
Ready
View 2 errors
125%
ode45


xhat
×10^281
Offset=0

```
ans =

  struct with fields:

        RiseTime: 0.0974
    SettlingTime: 0.5784
     SettlingMin: 8.5781e-05
     SettlingMax: 1.1732e-04
       Overshoot: 23.5373
      Undershoot: 0
            Peak: 1.1732e-04
        PeakTime: 0.2640
```

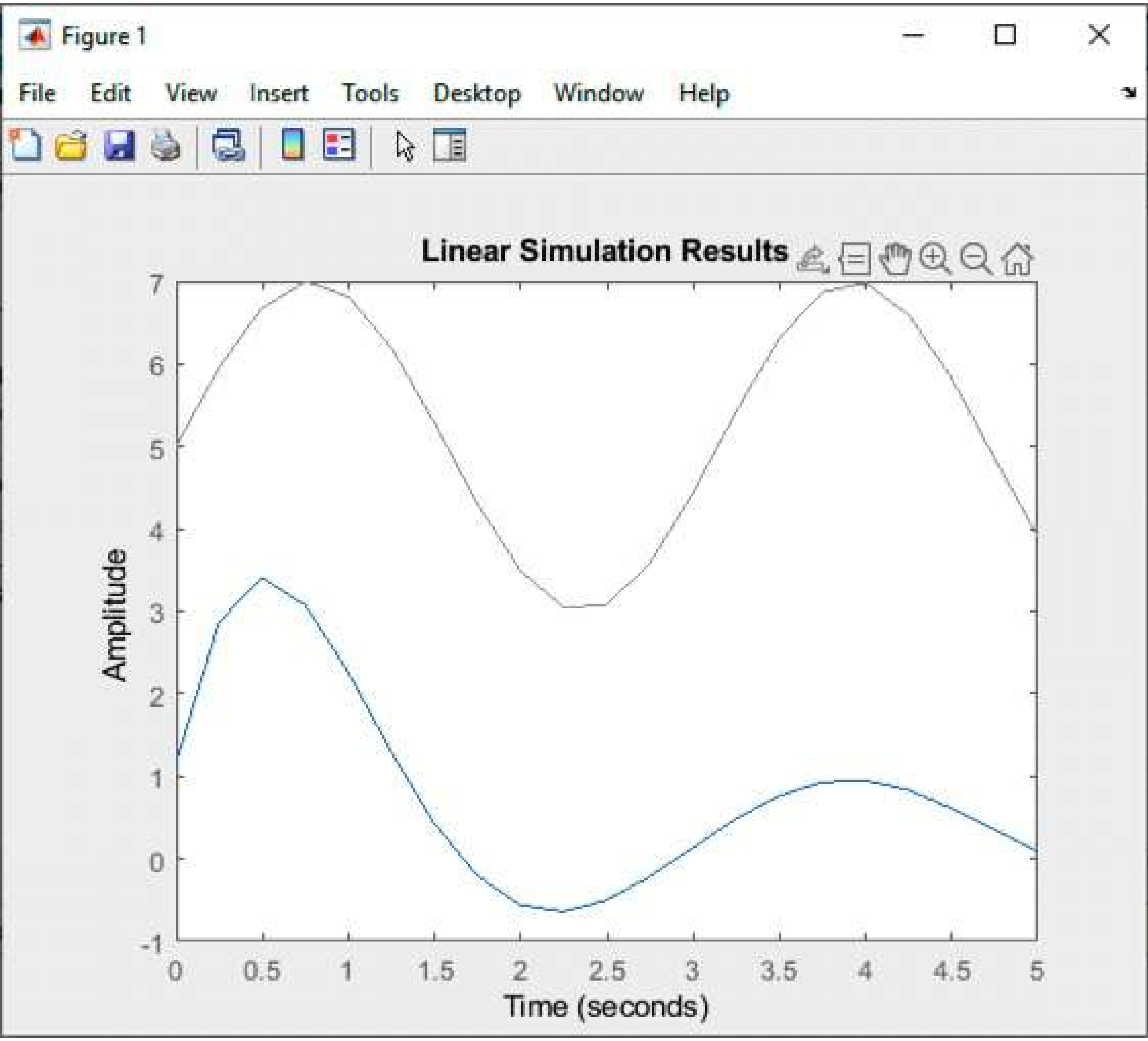


Figure 1
File Edit View Insert Tools Desktop Window Help
Linear Simulation Results
7
6
5
4
3
2
1
0
-1
Amplitude
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Time (seconds)

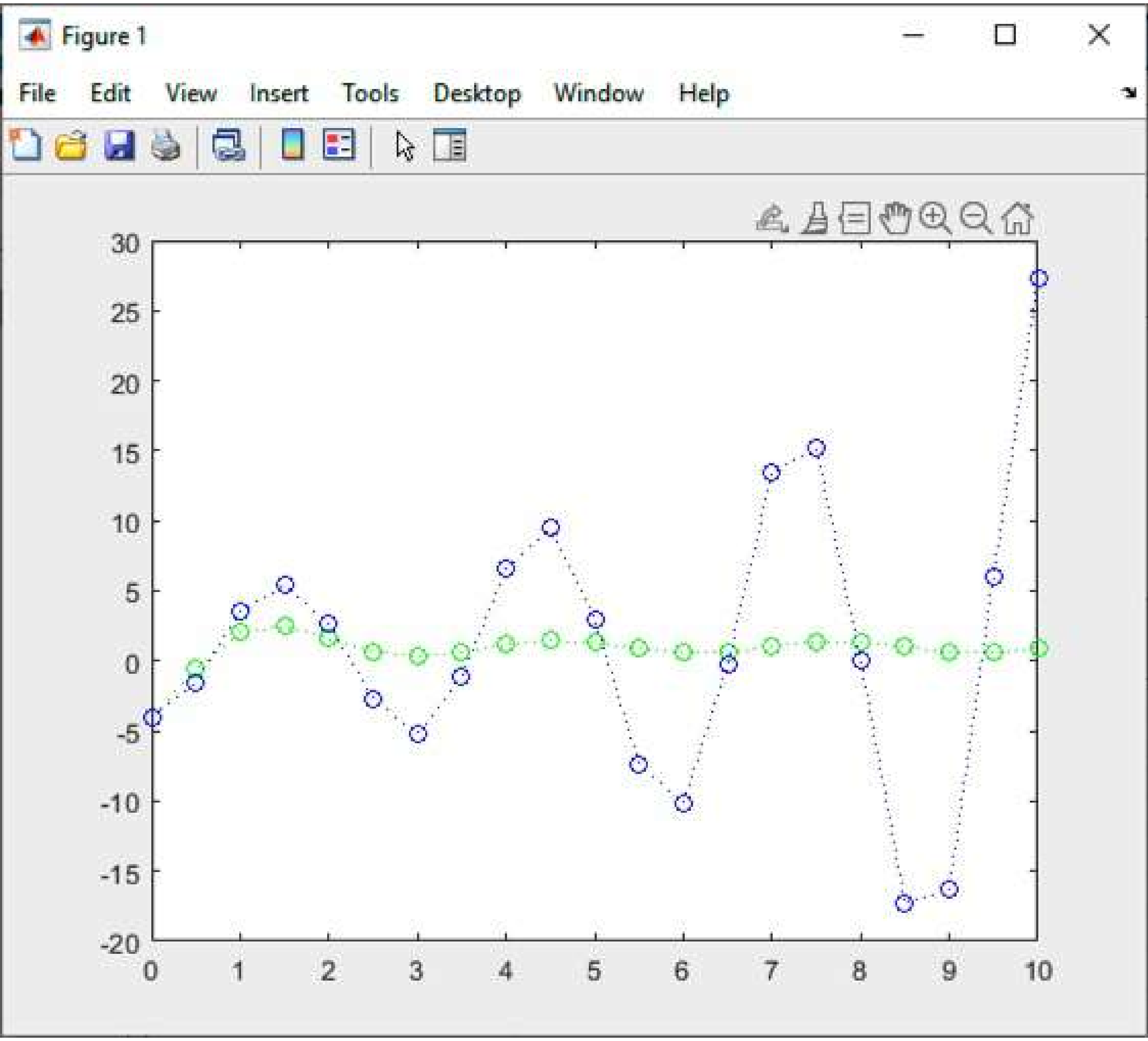


Figure 1
File Edit View Insert Tools Desktop Window Help
30
25
20
15
10
5
0
-5
-10
-15
-20
0 1 2 3 4 5 6 7 8 9 10

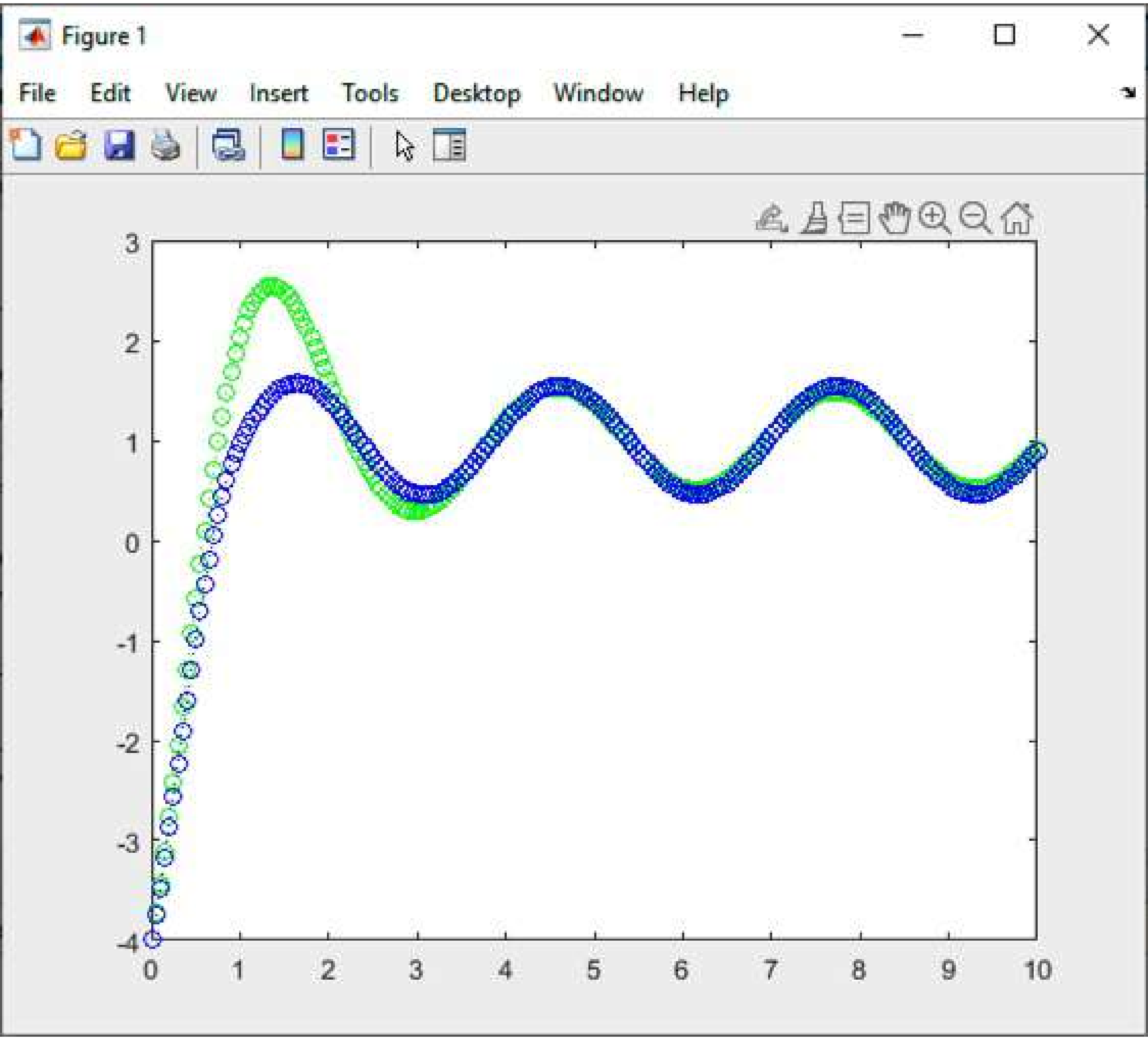


Figure 1
File Edit View Insert Tools Desktop Window Help
3
2
1
0
-1
-2
-3
-4
0 1 2 3 4 5 6 7 8 9 10

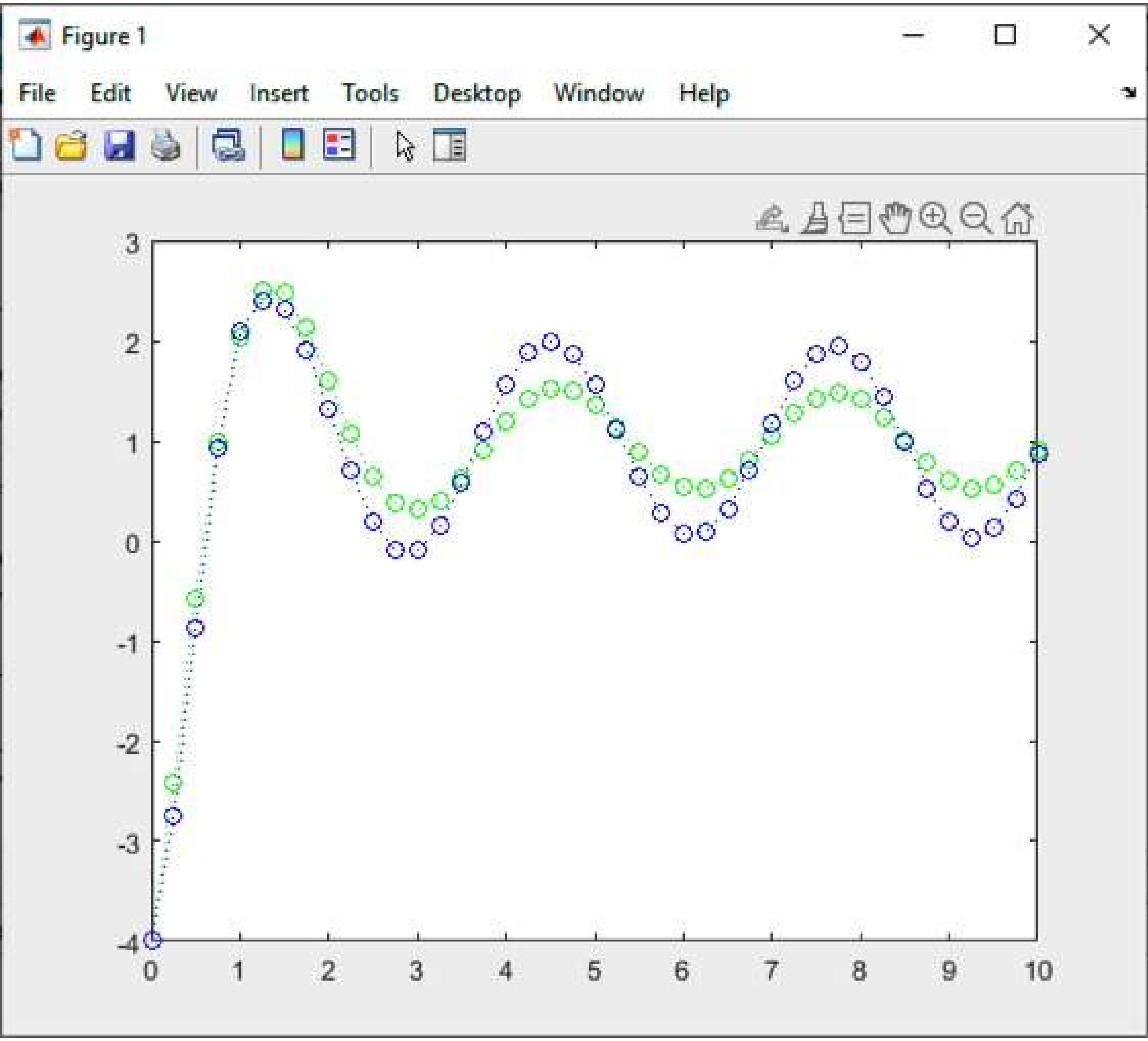


Figure 1
File Edit View Insert Tools Desktop Window Help
3
2
1
0
-1
-2
-3
-4
0 1 2 3 4 5 6 7 8 9 10