2

```
G0=tf([0 1 -1.3],[1 -1.5 0.8],1); H0=tf([1 -1.8 1.2],[1 -1.5 0.8],1);
N=4096; u=sign(randn(N,1)); e=randn(N,1);
y=lsim(G0,u) + lsim(H0,e);
PHI = [u(3:N) u(2:N-1) u(1:N-2) -y(2:N-1) -y(1:N-2)];
Y = y(3:N);
disp('Problem 2 Least Squares Estimate:');
theta = PHI\Y

for i = 1:100
G0=tf([0 1 -1.3],[1 -1.5 0.8],1); H0=tf([1 -1.8 1.2],[1 -1.5 0.8],1);
N=4096; u=sign(randn(N,1)); e=randn(N,1);
y=lsim(G0,u) + lsim(H0,e);
PHI = [u(5:N) u(4:N-1) u(3:N-2) -y(4:N-1) -y(3:N-2)];
XI = [u(5:N) u(4:N-1) u(3:N-2) u(2:N-3) u(1:N-4)];
Y = y(5:N);
theta(:,i) = (XI'*PHI)\(XI'*Y);
end

disp('Problem 2 Instrumental Variable Least Squares Estimate:');
mean(theta')'
```

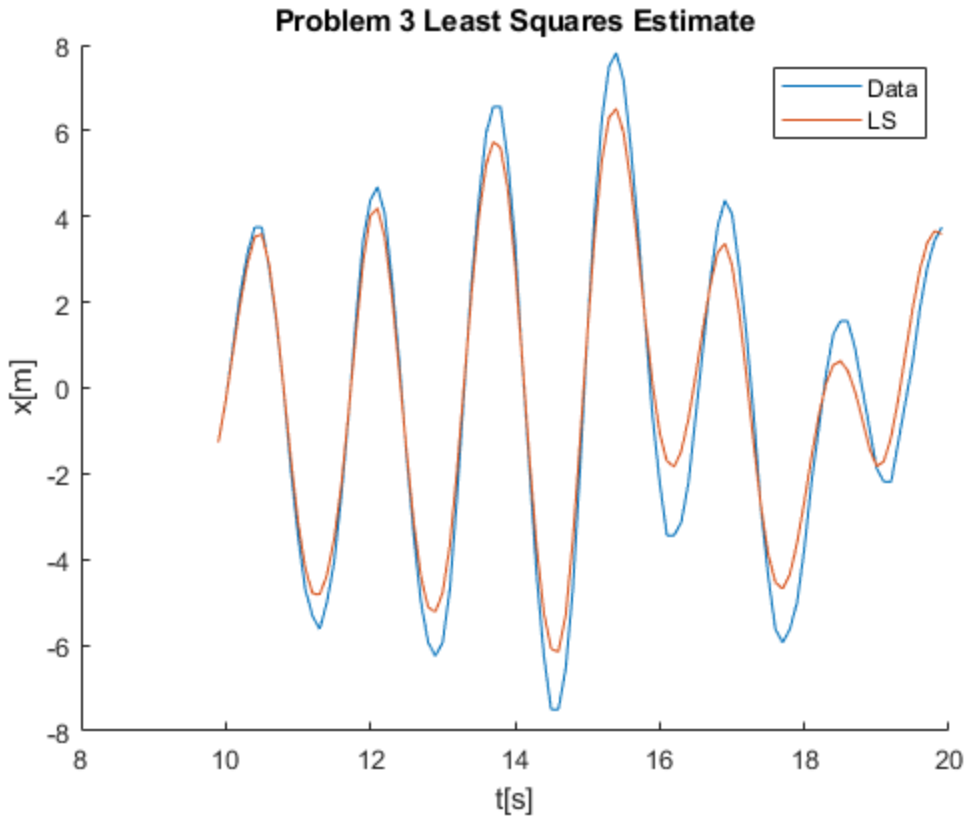
```
Problem 2 Least Squares Estimate:

theta =

    0.0153
    0.9752
   -0.5018
   -0.6907
    0.1741

Problem 2 Instrumental Variable Least Squares Estimate:

ans =

    0.0012
    0.9996
   -1.3011
   -1.5019
    0.8008
```

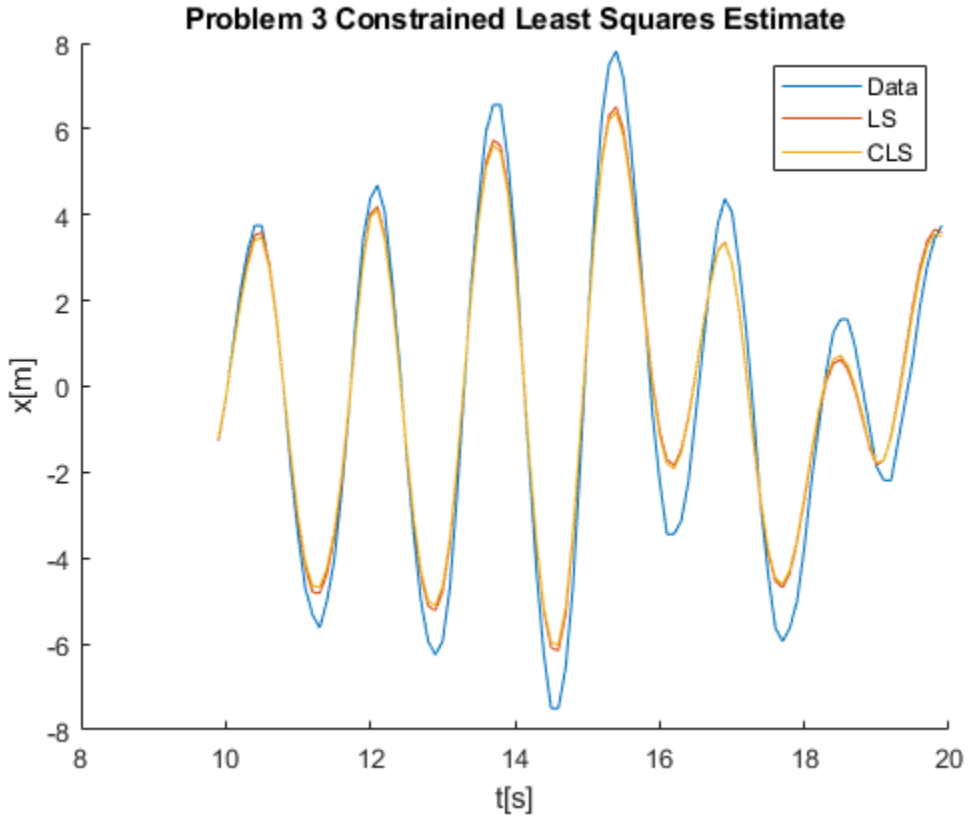
3

```
clear all
load('mass_spring_damper.mat');

N = length(t);
```

```
PHI = [u(2:end-1) u(1:end-2) -y(2:end-1) -y(1:end-2)];
Y = y(3:end);

disp('Problem 3 Least Squares Estimate:');
theta = PHI\Y

A = [2.3 2.3 -1 -1];
b = 1;

R = 1/(N - 1)*PHI'*PHI;

F = 1/(N - 1)*PHI'*Y;

disp('Problem 3 Constrained Least Sqaures Estimate:');
thetacls = [R A'; A 0]\[F;b]

G0=tf([0 theta(1) theta(2)],[1 theta(3) theta(4)],1);
ysim = lsim(G0,u);

G0CLS=tf([0 thetacls(1) thetacls(2)],[1 thetacls(3) thetacls(4)],1);
ysimcls = lsim(G0CLS,u);

figure; hold on; title('Problem 3 Least Squares Estimate');
plot(t(100:200),y(100:200));
plot(t(100:200),ysim(100:200));
legend('Data','LS'); xlabel('t[s]'); ylabel('x[m]');

figure; hold on; title('Problem 3 Constrained Least Squares
 Estimate');
plot(t(100:200),y(100:200));
plot(t(100:200),ysim(100:200));
plot(t(100:200),ysimcls(100:200));
legend('Data','LS','CLS');  xlabel('t[s]'); ylabel('x[m]');
```

```
Problem 3 Least Squares Estimate:

theta =

    0.0327
    0.0344
   -1.7538
    0.9011

Problem 3 Constrained Least Sqaures Estimate:

thetacls =

    0.0312
    0.0329
   -1.7569
    0.9044
    0.0116
```


Problem 3 Least Squares Estimate
Data
LS
x[m]
t[s]
8
6
4
2
0
-2
-4
-6
-8
8
10
12
14
16
18
20


Problem 3 Constrained Least Squares Estimate
Data
LS
CLS
x[m]
t[s]
8
6
4
2
0
-2
-4
-6
-8
8
10
12
14
16
18
20

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