ME C134 Lab 6b

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Objective:

The objective of this lab was to design and implement an observer in order to reduce the noise of measurements of velocity and angular velocity. The observer controlled system was then compared to a discrete derivative controlled system to contrast the noise and performance.

3 Prelab

3.1 Controllability and Observability

Question 1: Check whether the system is observable and controllable:
Answer: Using the MATLAB in Code Block 1, we found that the state space model created was both observable and controllable.

3.2 Observer Design

Question 1: Given that the size of A-LC must be the same as A, what are the dimensions of L?
Answer: The matrix L must be 4x1 to multiply by the 1x4 C matrix to get a 4x4 equivalent to the size of A.

Question 2: Find the matrix L so that this is achieved.
Answer: MATLAB code in Code Block 1 gives L as

```
L =
   1.0e+05 * [0.0004;    0.0101;   -0.1173;   -1.1509]
```

3.3 Simulation

Question: How does error between xhat and x vary over time?
Answer: Estimation error tends to start large then decreases over time. This is because the controller attempts to reach zero error in order to stabilize the system.

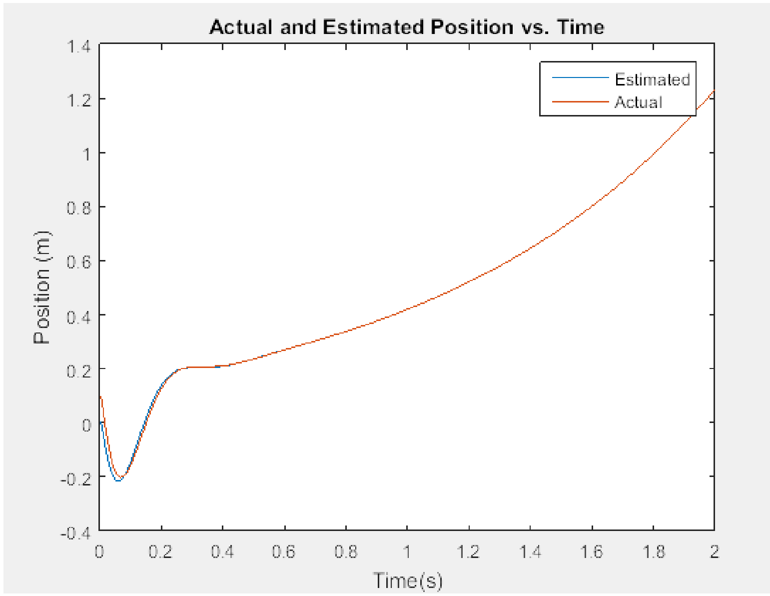

Figure 3.1: Position vs. Time plot of simulated system.

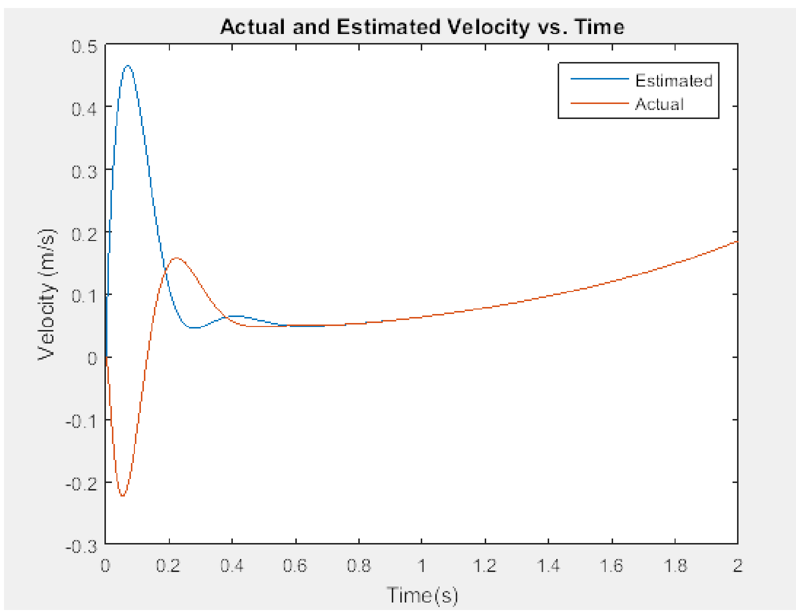

Figure 3.2: Velocity vs. Time plot of simulated system.

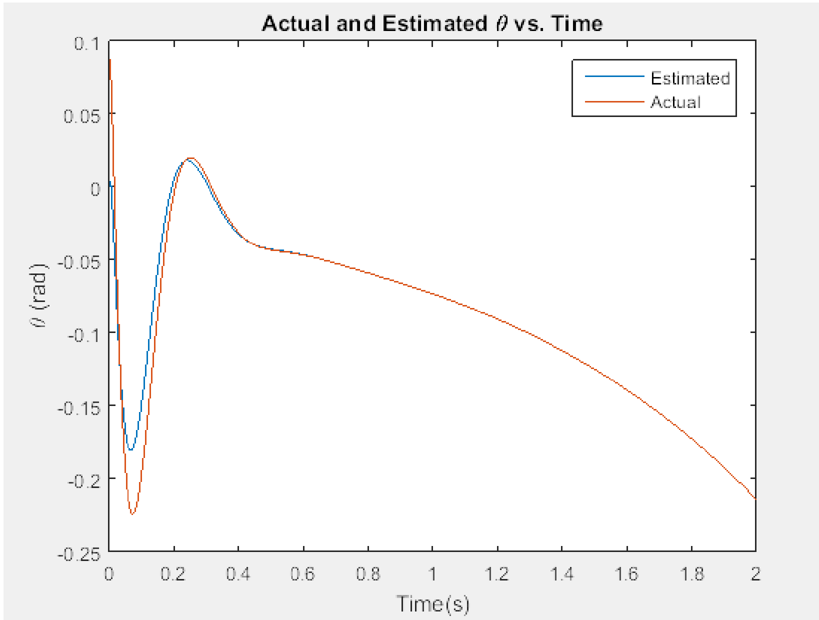

Figure 3.3: Angle vs. Time plot of simulated system.

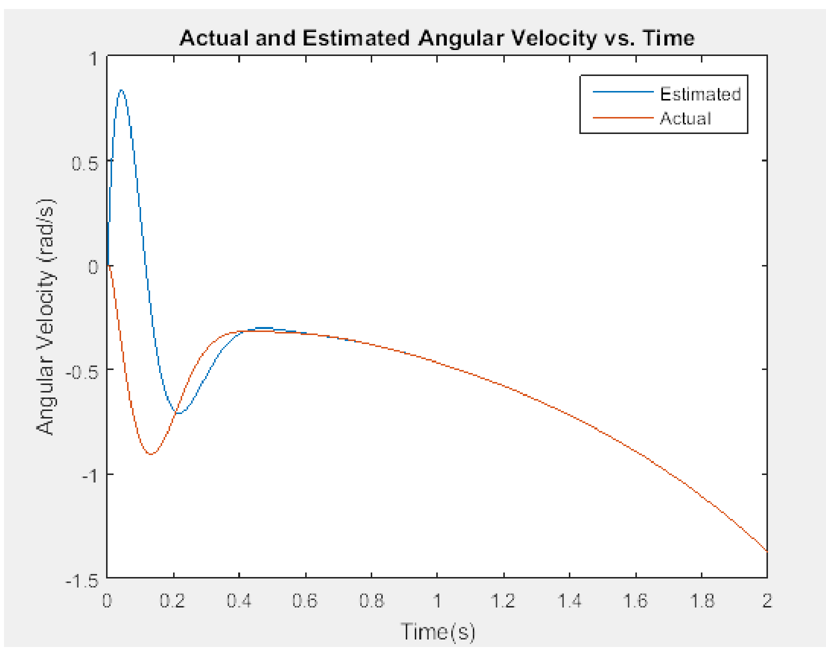

Figure 3.4: Angular Velocity vs. Time plot of simulated system.

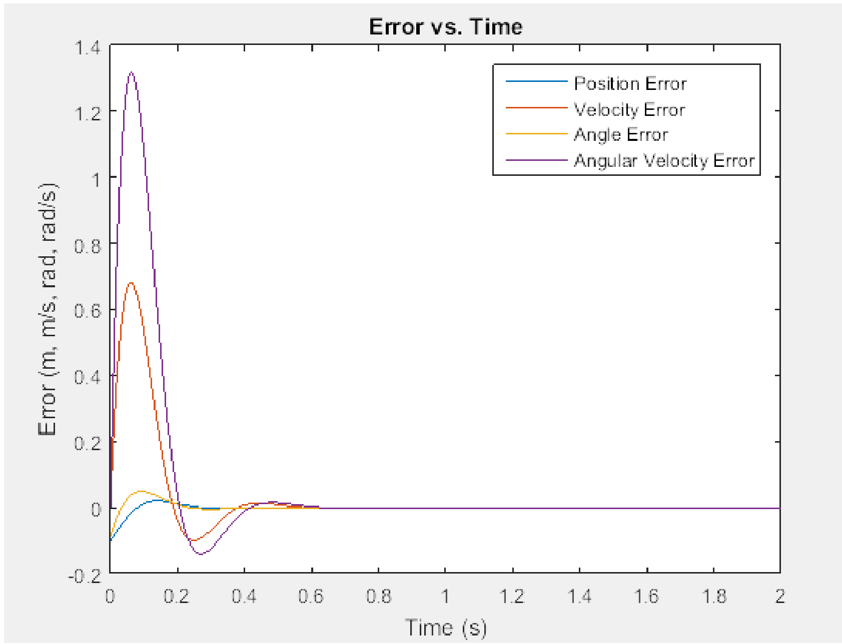

Figure 3.5: Error vs. Time of all state variables in simulated system.

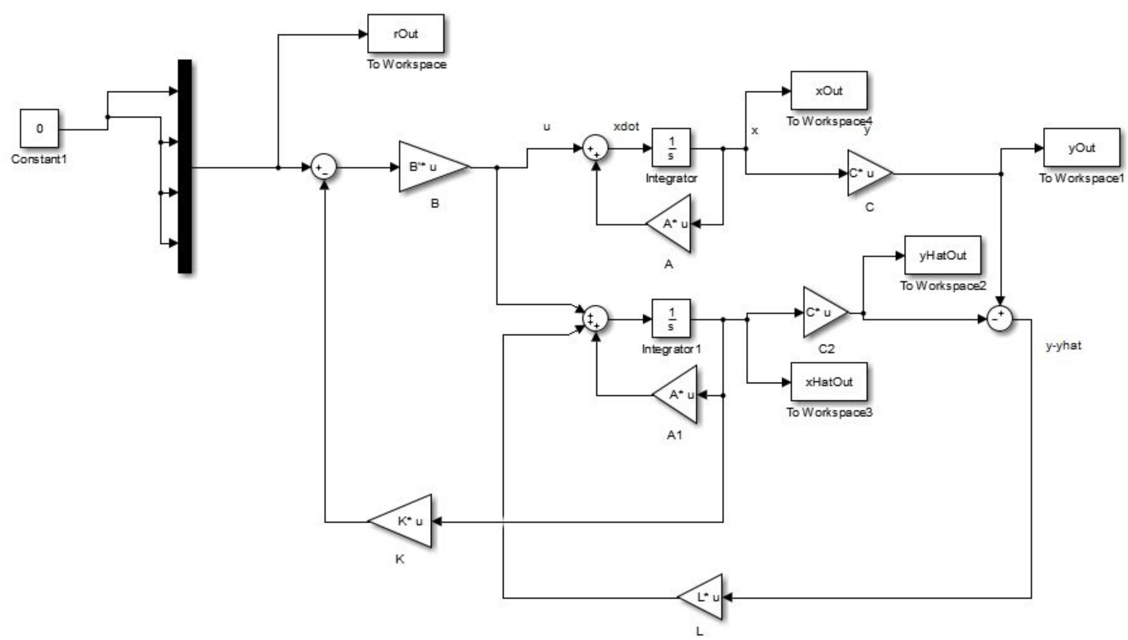

Figure 3.6: Simulink model used to model system.

4 Lab:

Task 1:

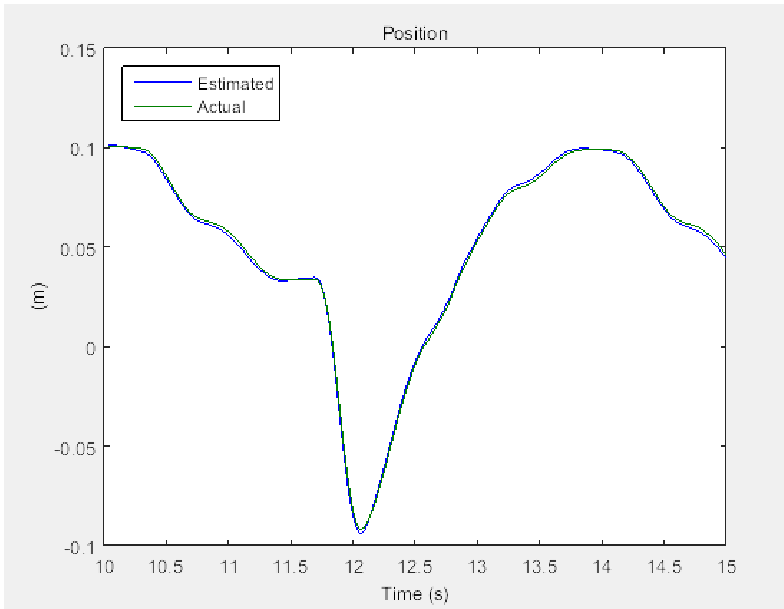

Figure 4.1.1:

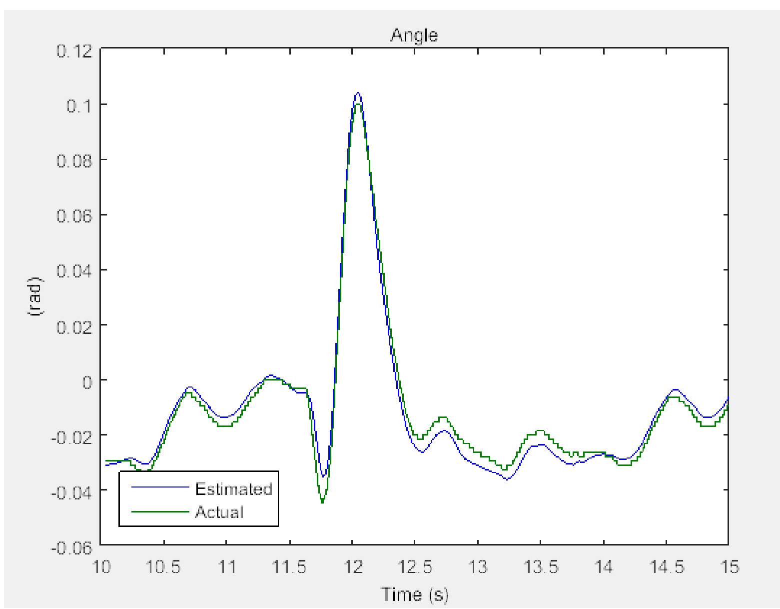

Figure 4.1.2:

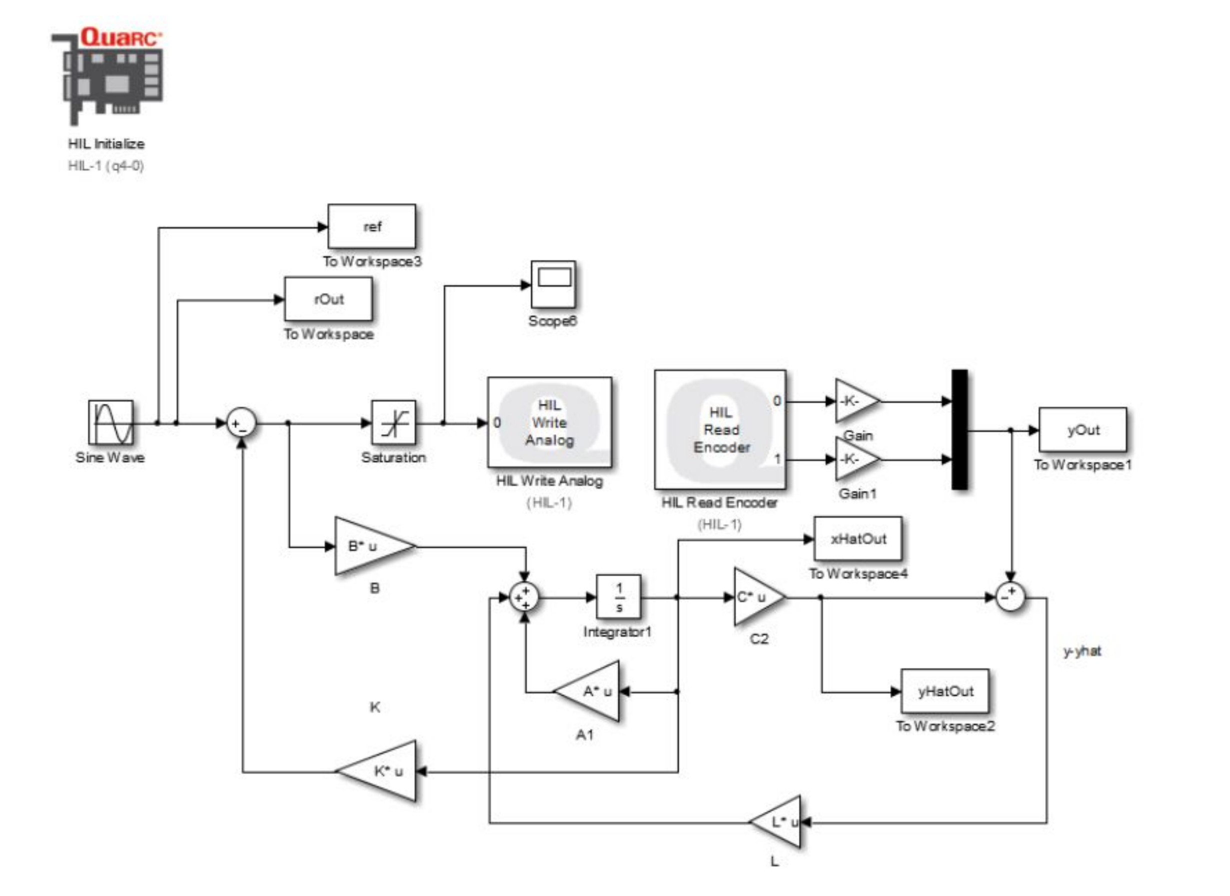
QUARC
HIL Initialize
HIL-1 (q4-0)
ref
To Workspace3
rOut
To Workspace
Scope6
Sine Wave
Saturation
HIL Write Analog
HIL Write Analog
(HIL-1)
HIL Read Encoder
HIL Read Encoder
(HIL-1)
-K-
Gain
-K-
Gain1
yOut
To Workspace1
B* u
B
xHatOut
To Workspace4
1/s
Integrator1
C* u
C2
y-yhat
A* u
A1
K
yHatOut
To Workspace2
K* u
L* u
L

Figure 4.1.3:

Task 2

Cart and Pendulum Reference Position and Angle = 0:

For zero reference position, the observer system had more oscillatory behavior while the discrete system maintained a vertical position with much smaller amplitude oscillations. The discrete system was noisy in both derivative data acquisition and volume.

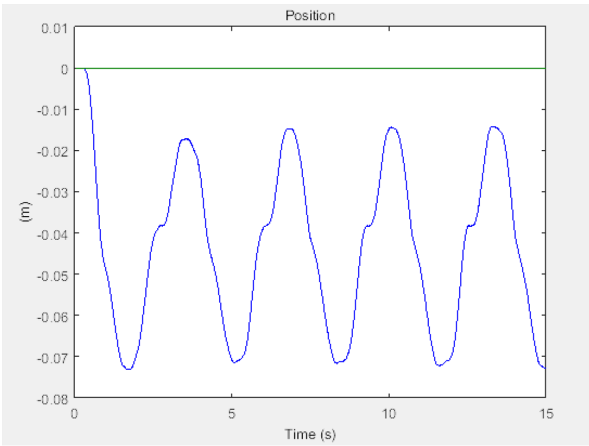

Figure 4.2.1 a: Discrete System Response

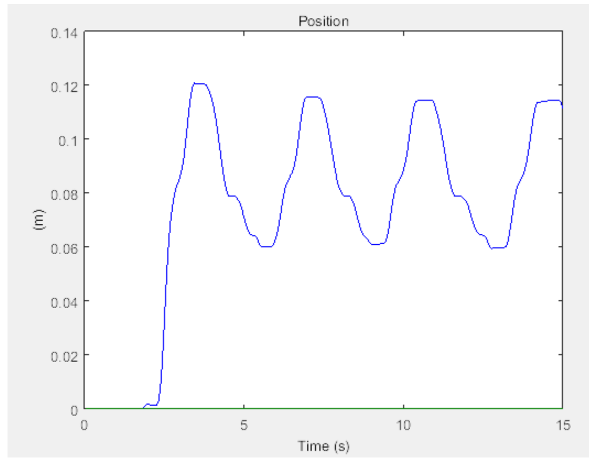

Figure 4.2.1 b: Observer System Response

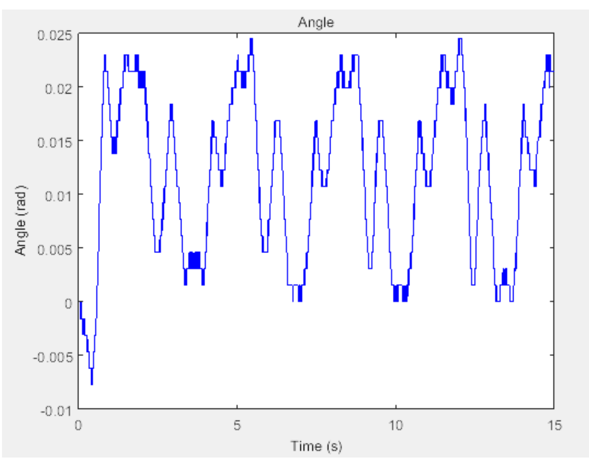

Figure 4.2.1 c: Discrete System Response

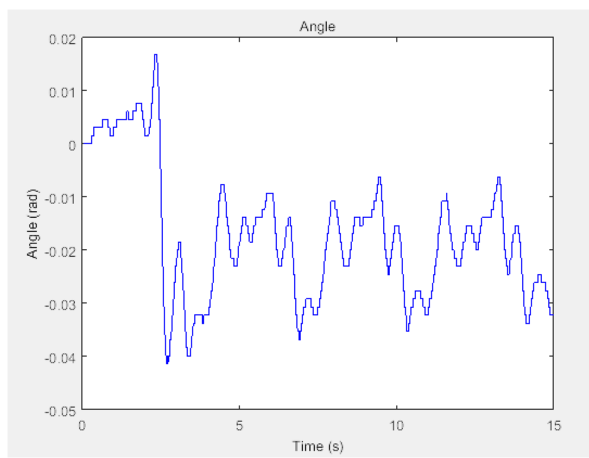

Figure 4.2.1 d: Observer System Response

Small Perturbations:

The discrete system was faster in response while recovering from small perturbations and stayed closer to the reference point while the observer system was a bit delayed in responding to the perturbations and was not able to maintain the reference position.

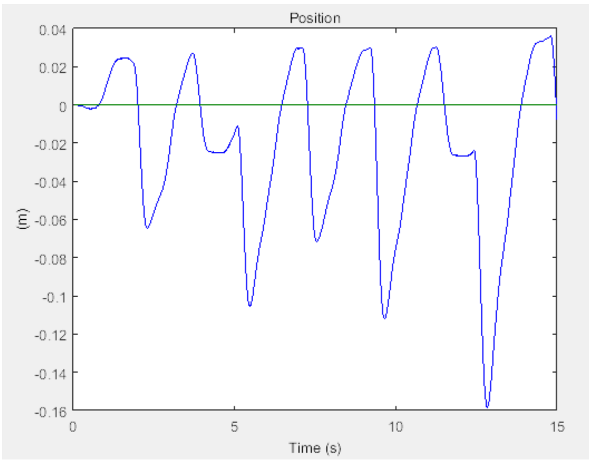

Figure 4.2.2 a: Discrete System Response

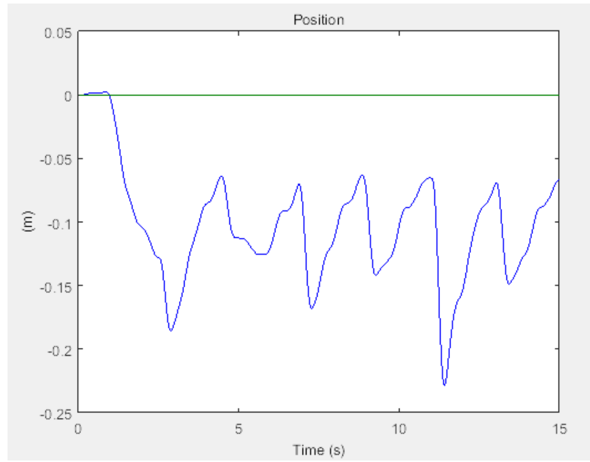

Figure 4.2.2 b: Observer System Response

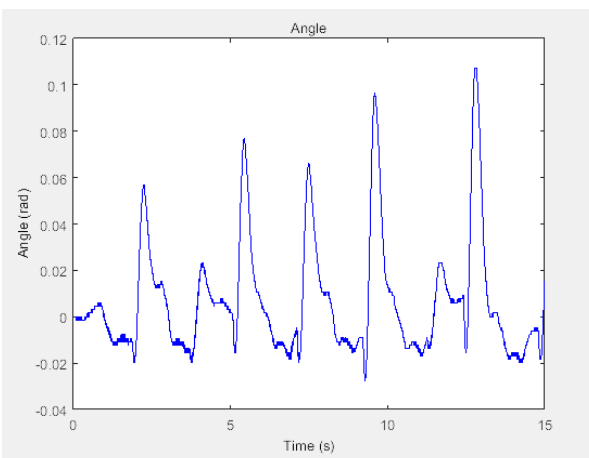

Figure 4.2.2 c: Discrete System Response

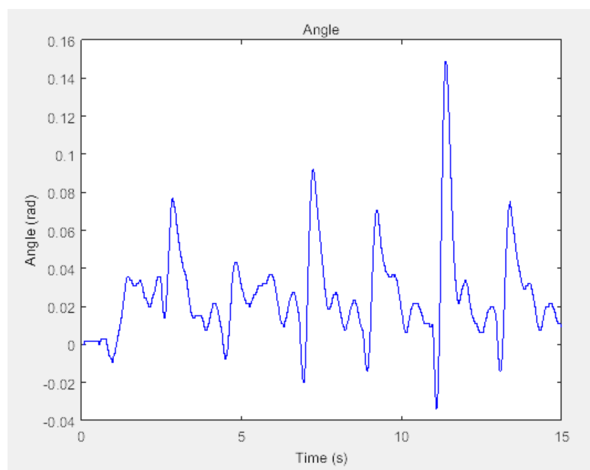

Figure 4.2.2 d: Observer System Response

Sin Wave:

The discrete system was able to track the sine input with moderate delay while the observer system was unable to properly track the sine reference.

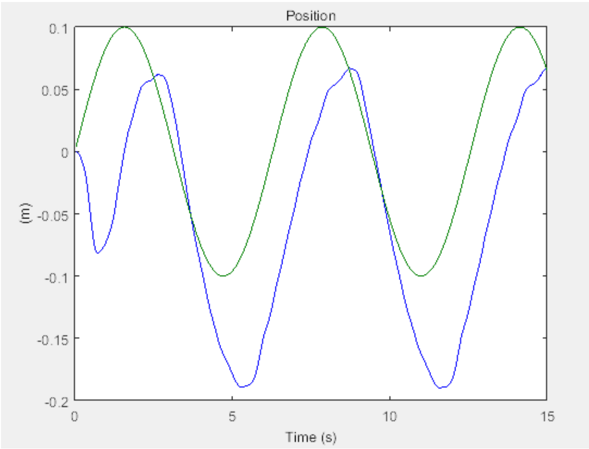	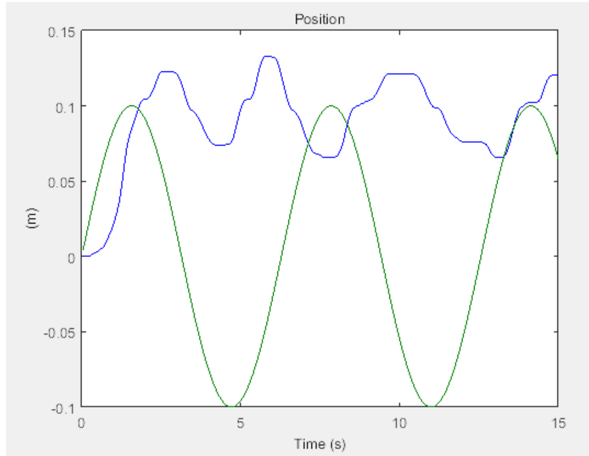
Figure 4.2.3 a: Discrete System Response	Figure 4.2.3 b: Observer System Response

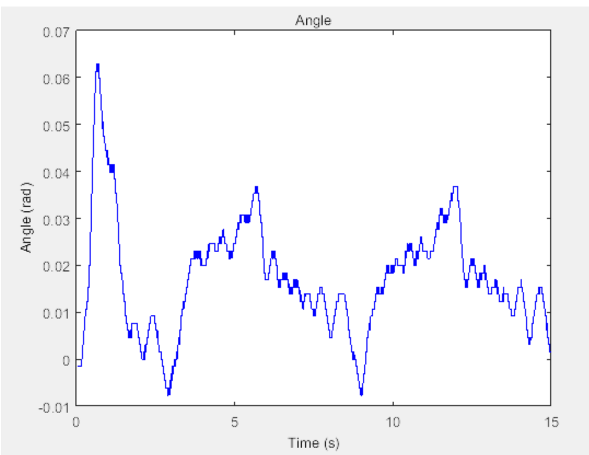	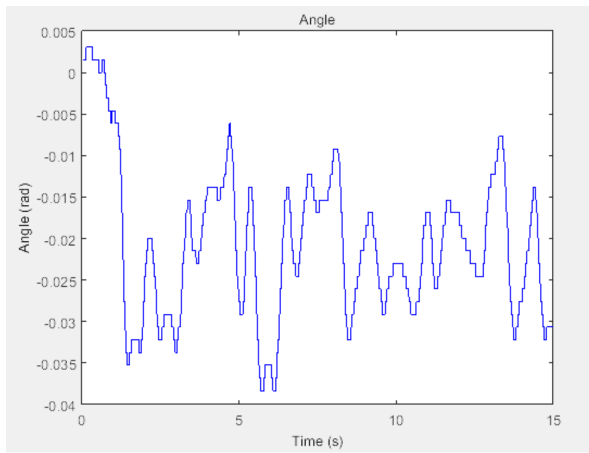
Figure 4.2.3 c: Discrete System Response	Figure 4.2.3 d:Observer System Response

Task 3:
The position measurements inherently had noise, and this noise was amplified by the discrete controller numerical derivative blocks. On the other hand, the observer seemed to be less affected by the position signal noise rather than amplifying it, as can be seen by the continuous lines on the observer velocity estimates.

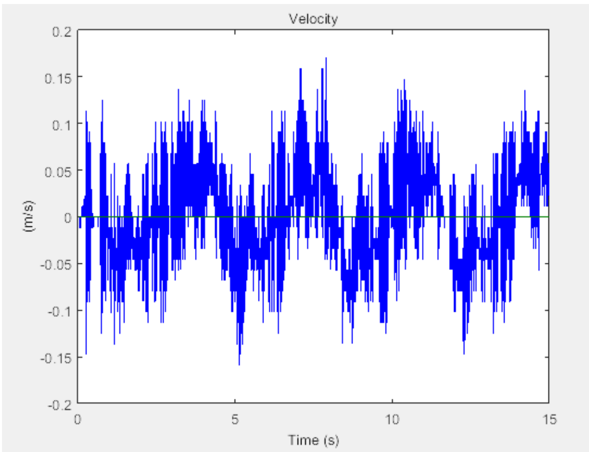

Figure 4.3 a: Discrete System Response

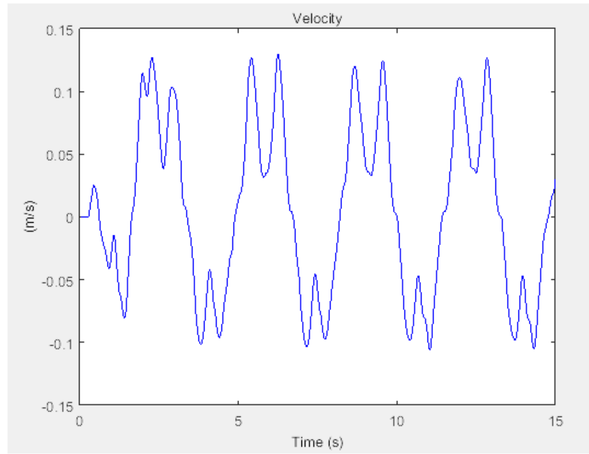

Figure 4.3 b: Observer System Response

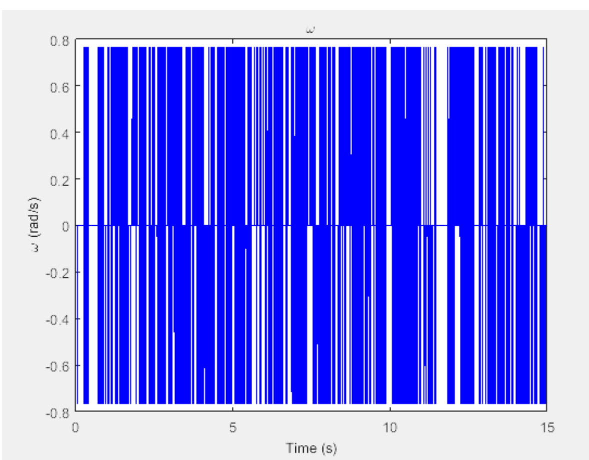

Figure 4.3 c: Discrete System Response

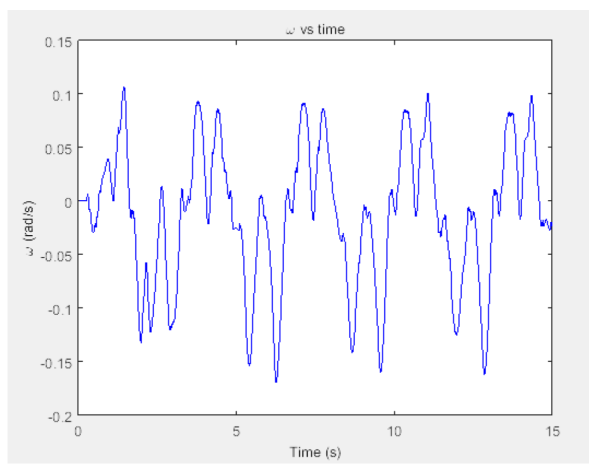

Figure 4.3 d: Observer System Response

Task 4:
The observer system was slower in response and failed to track sinusoidal inputs properly. However, the observer system provided much smoother velocity data and did not have the issue of grinding the motor that was present in the discrete controller. The discrete system was also able to hold a stationary reference position and angle without the large oscillations that the observer system tended to have. Because of this, the observer system seemed better for smoother but slower cart movement while the discrete derivative system seemed optimized for speed and performance-oriented cart movement.

5 Appendix:

```
%% MEC134 Lab6bPrelab Jeremy Chow, David Lovell, Robert Vivanco
%% 3.1
clc
clear all
close all
Mc=.94;
% kg Mass of cart
r=6.36e-3;
% m
Rm= 2.6;
% Ohm
Kt= 7.67e-3;
   % Nm/A
Km= 7.67e-3;
% Vs/rad
Kg= 3.71;
% Gear ratio
Jm= 3.9e-7;
% kg m^2
g=9.81;
%m/s^2 gravity
Lp=.3302;
% (m) Half length of pendulum
mp=.23;
% kg Mass of pendulum
AngleEncoder=-1/652;
PositionEncoder=1/ 4.4067e+04;
a12=1;
a22=-4*Kt*Km*Kg^2/(4*Mc*Rm*r^2+Rm*mp*r^2+4*Jm*Kg^2*Rm);
a23=-3*mp*r^2*g/(4*Mc*r^2+mp*r^2+4*Jm*Kg^2);
a34=1;
a42=-3*a22/(4*Lp);
a43=3/(4*Lp)*(g-a23);
b2=4*Kt*Kg*r/(4*Mc*Rm*r^2+mp*Rm*r^2+4*Rm*Jm*Kg^2);
b4=-3*b2/(4*Lp);
A=[ 0   a12     0      0;
   0   a22     a23     0;
   0   0       0       a34;
   0   a42     a43     0];
B=[0 b2 0 b4]';
C=[1 0 0 0;0 0 1 0];
D=[0;0];
```

```
Sys=ss(A,B,C,D);
K=acker(A,B, [-2+10*j,-2-10*j,-1.6+1.3*j, -1.6-1.3*j])

%%
Co=ctrb(A,B);
uncontrollable_states_num=length(A)-rank(Co)
Ob=obsv(A,C);
unobservable_states_num = length(A)-rank(Ob)
%%
% Zero unobservable and zero uncontrollable states. System is both
% observable and controllable.
%% 3.2
% *1)*
%%
% The matrix L must be 4x1 to multiply by the 1x4 C matrix to get a 4x4
% equivalent to the size of A.

%%
% *2)*
L=(place(A',C', [-10+15*1i -10-15*1i -12+17*1i -12-17*1i]))'
%% 3.3
clc
close all
rx=0;
rxdot=0;
rtheta=0;
rthetadot=0;
x0=[.1;0;pi/180*5;0];
open_system('MEC134Lab6bPrelabModel2.slx')
sim('MEC134Lab6bPrelabModel2')
figure
plot(xHatOut.time,xHatOut.Data(:,[1 3])-xOut.Data(:,[1 3]))
legend('Position Error','Angle Error')
xlabel('Time (s)')
ylabel('Error (rad and m)')
title('Error vs. Time')
```

Code Block 1