Laboratory Assignment 4

Feedback Control

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CSE 360

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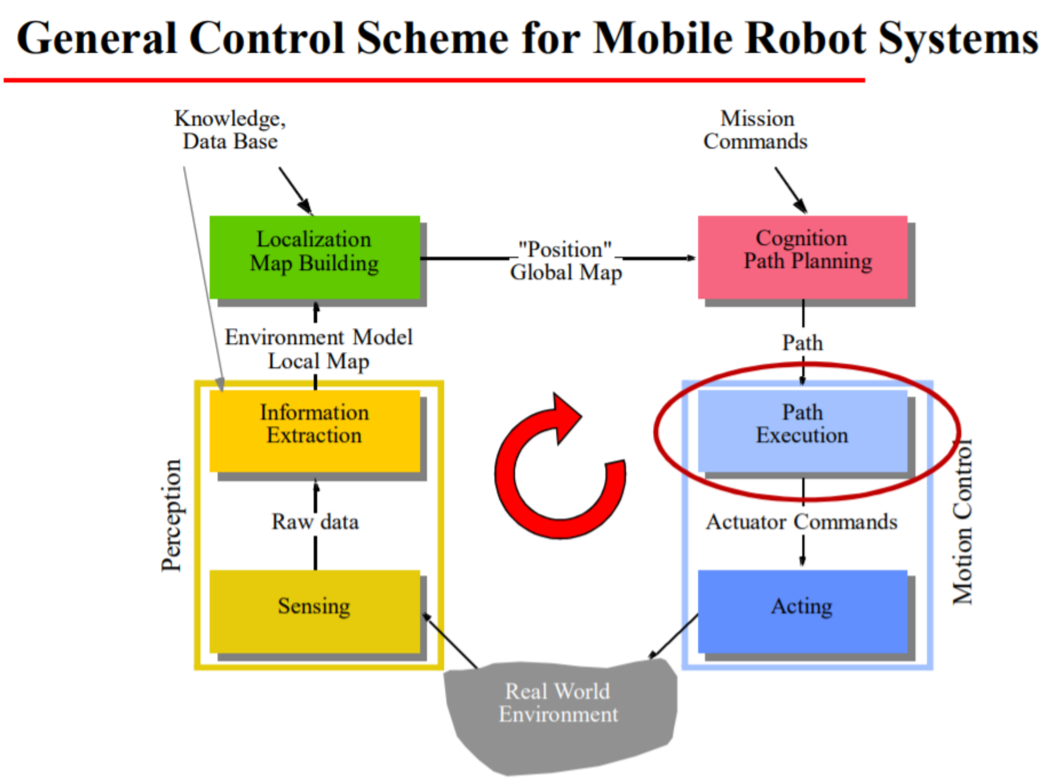


From Slide 2, Lecture 8

Determining the Optimal Gain:

Theory states that the optimal gain for a robot controller is when the k_p and k_d values set this expression $(k_d^2 - 4k_p)$ equal to 0 (critically damped). In actuality this may not always be the case, often times the robot performs better when the equation is set to slightly greater than zero (over dampened). Inorder to find the optimal gain settings, we tested 5 different k_p and k_d values and graphed their behavior. The values we tested are shown below in the table & the graphs from each of the runs is shown below as well. After qualitatively looking at each graph, we found the optimal k_p to be 1.0 & the optimal k_d to be 2.4.

We came to this conclusion based on the fact that the settling time and rise time were the fastest when compared to the other gain sets. Also, the overshoot seemed to be minimal for this gain set. Although, there seems to be a slight deviation in the values in the plot when started from the right, we believe it is an outlier that has caused it to deviate.

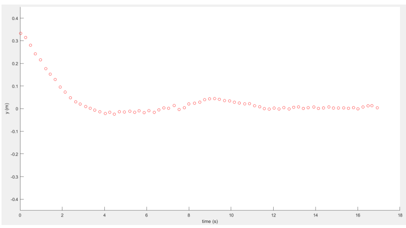
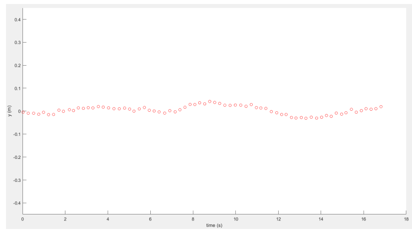
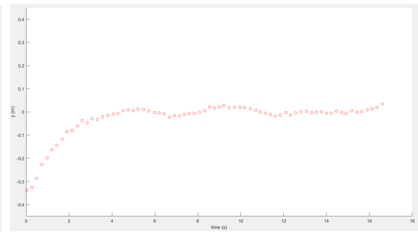
Table

k_p	k_d
1.0	2
1.0	2.2
1.0	2.4
1.0	2.6
1.0	3.0

Graphs

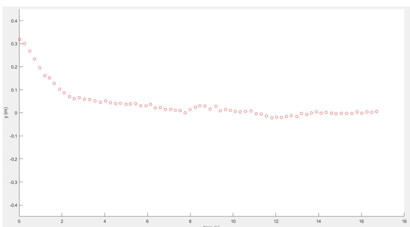
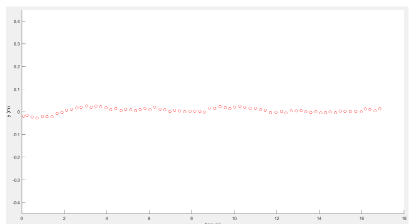
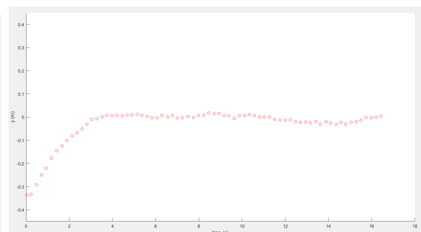
[1, 2.0]

Left | Center | Right

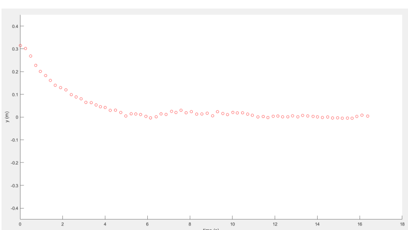
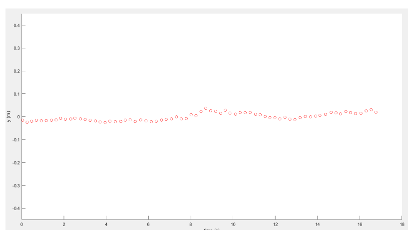
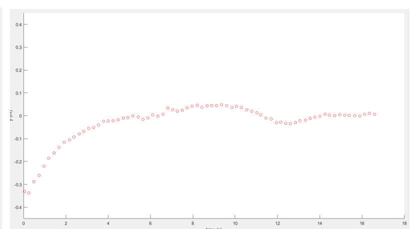
[1, 2.2]

Left | Center | Right

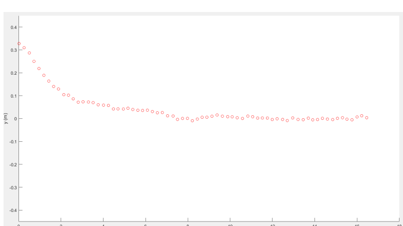
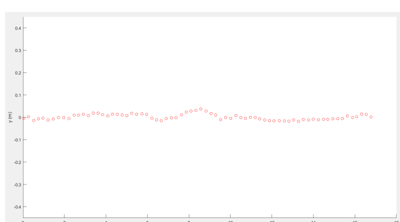
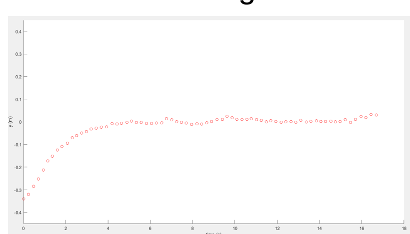
[1, 2.4]

Left | Center | Right

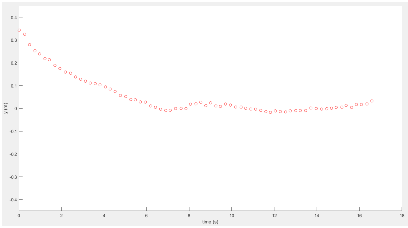




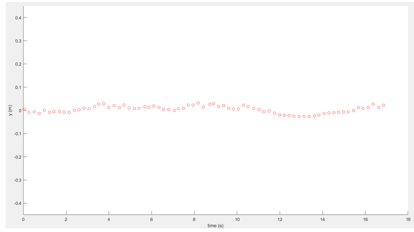
[1, 2.6]

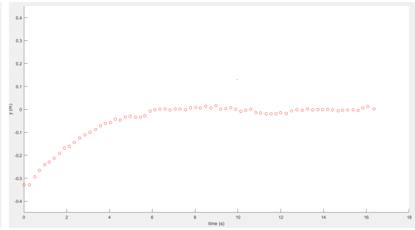
Left | Center | Right

[1, 3.0]

Left 

Center 

Right 

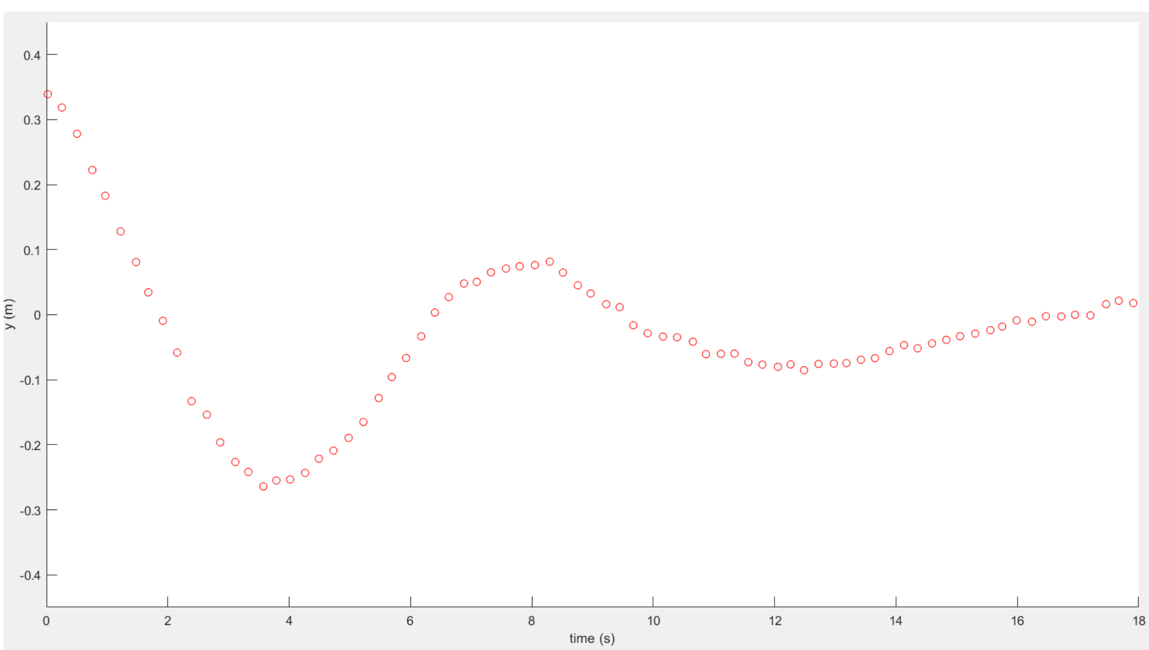
Rise Time, Settling Time & Overshoot:

Below is a table of what we calculated as the rise time, settling time & overshoot of the optimal gain setting (we analyzed the left graph for [1, 2.4]).

Rise Time	4.0s
Settling Time	6.144s
Overshoot	3.5mm

Underdamped Behavior:

Below is a graph of an underdamped control behavior. The k_p & k_d values used for this gain setting were 1.0, 1.0 respectively.



Below is a table of the settling time, rise time and overshoot for the underdamped graph.

Rise Time	1.75s
Settling Time	16.45s
Overshoot	0.265m

Effects of Robot Starting on Right or Left Side:

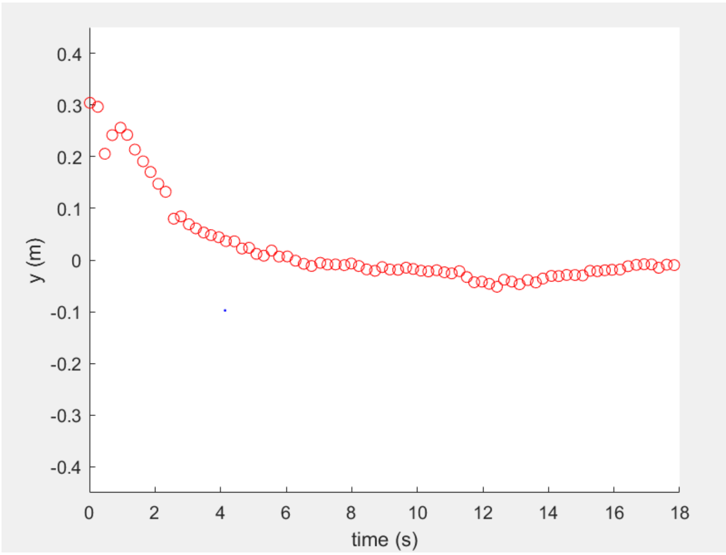
There was no significant difference between the robot starting on the left or right side of the line. Aside from the robot moving towards the line from a different direction & overshooting in that direction; once the robot had settled, the oscillation about the line was the same for both cases (symmetric). This behavior can be seen in the graphs above.

Effect of Velocity Variation:

Below are the graphs obtained when investigating the effect of velocity. The k_p & k_d values used for this gain setting were 1.0, 2.4 respectively with an update rate of 5hz.

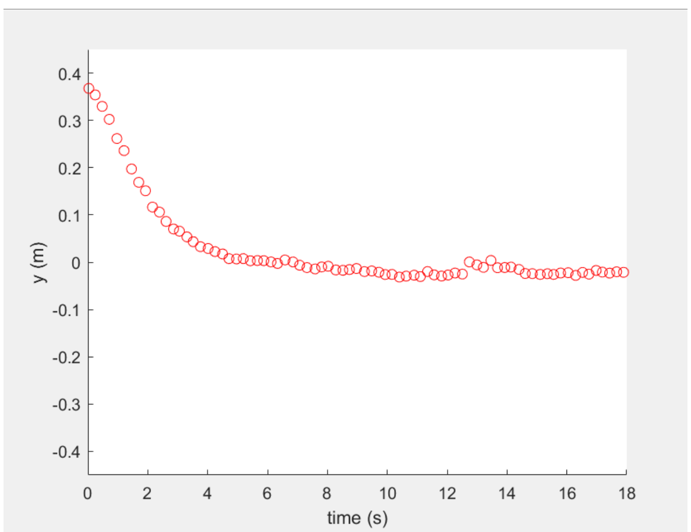
We observed that as velocity increases, the robot deviates further from the blue tape and therefore increased the settling time. This makes sense because as the velocity increases with the sampling rate held constant, there is more distance that the robot can travel before it is signaled to be redirected. If the robot was traveling at the speed of sound, the lidar wouldn't have enough time to pick up its location and redirect it in a reasonable amount of time.

0.1m/s



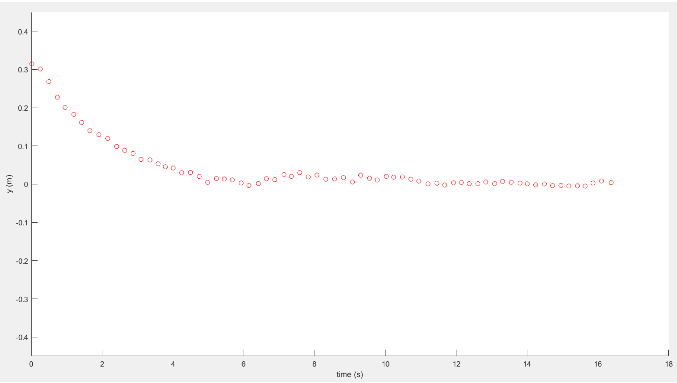
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

0.2m/s

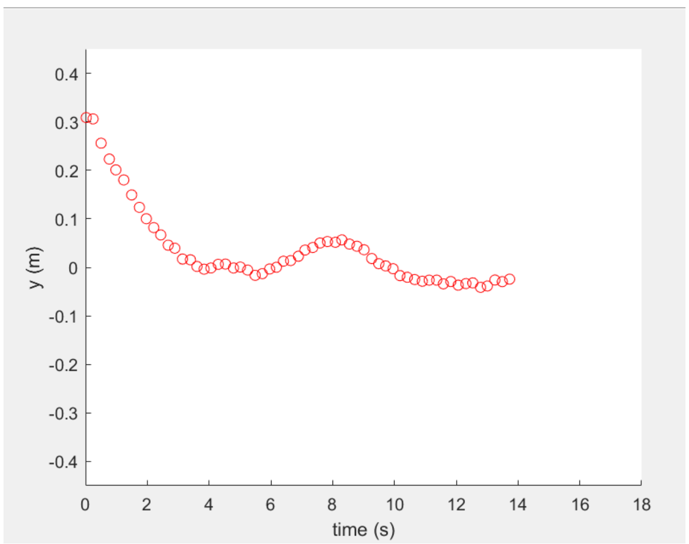


0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

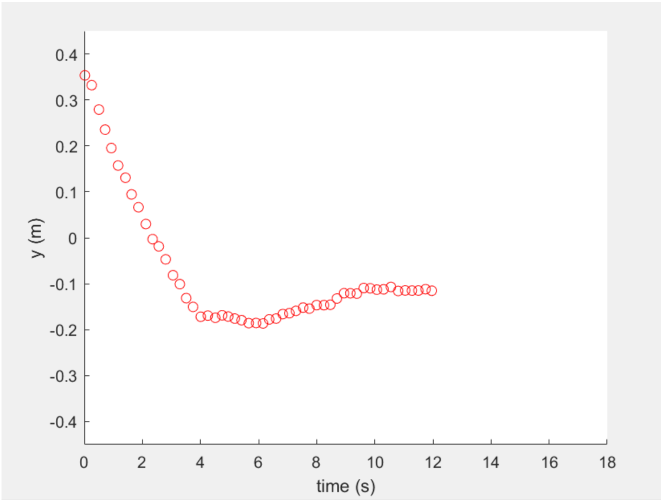
0.25m/s



0.3m/s



0.4m/s



Effect of Update Rate:

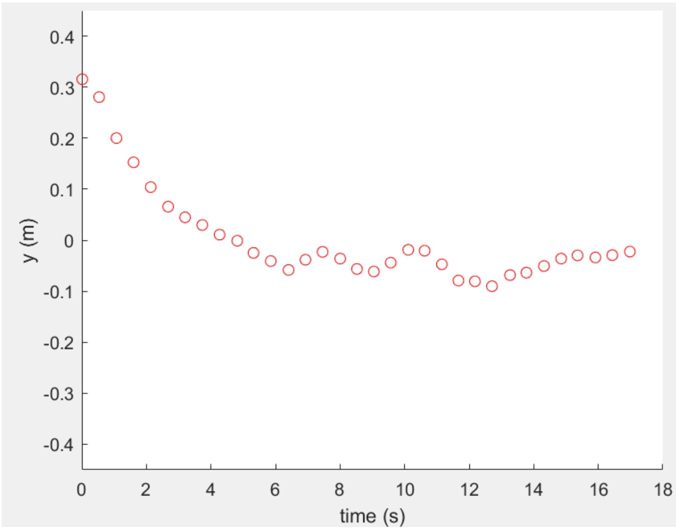
Below are the graphs obtained when investigating the effect of update rate. The k_p & k_d values used for this gain setting were 1.0, 2.4 respectively with an velocity of 0.25m/s.

We observed that with the increase in Update Rate, the robot was able to do a better job at staying along the blue tape and therefore decreased the settling time.

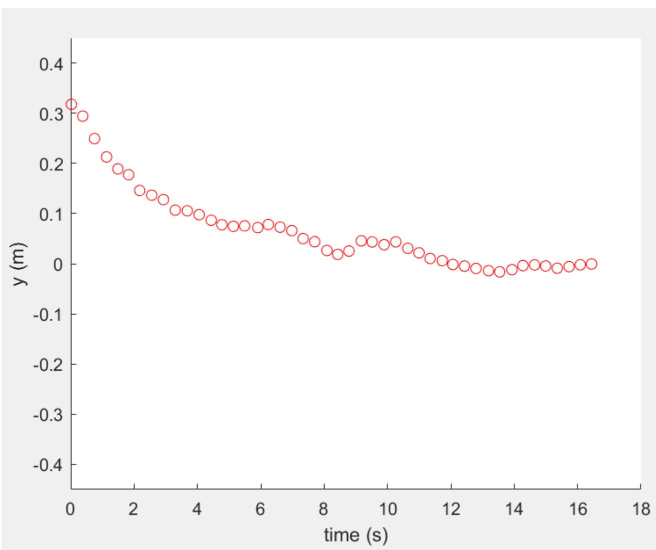
1Hz

1Hz was too low of an update rate that the robot had a very hard time staying on the line. It even ended up turning around and going backwards before we killed the trial run.

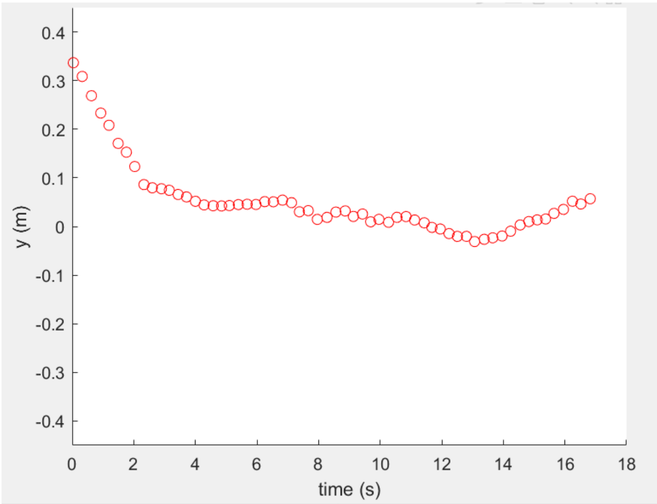
2Hz


0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

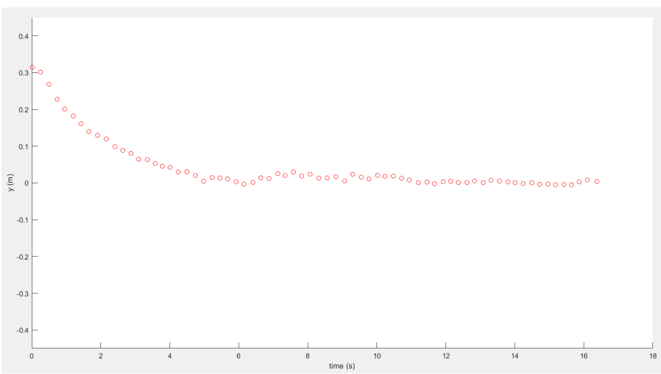
3Hz


0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

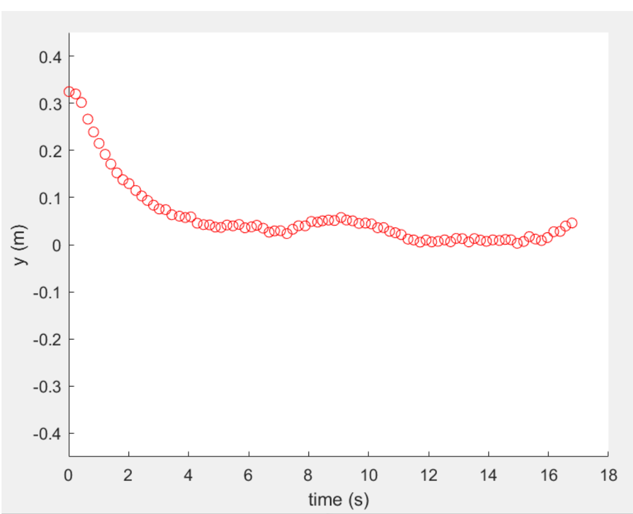
4Hz


0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

5Hz



6Hz


0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
y (m)
0
2
4
6
8
10
12
14
16
18
time (s)

Code:

Attached separately in another pdf.

Contributions:

Both Mitch & Nimesh contributed equally to this lab report.