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COURSE NAME : ROBOTIC SENSING AND NAVIGATION

CRN : 33639

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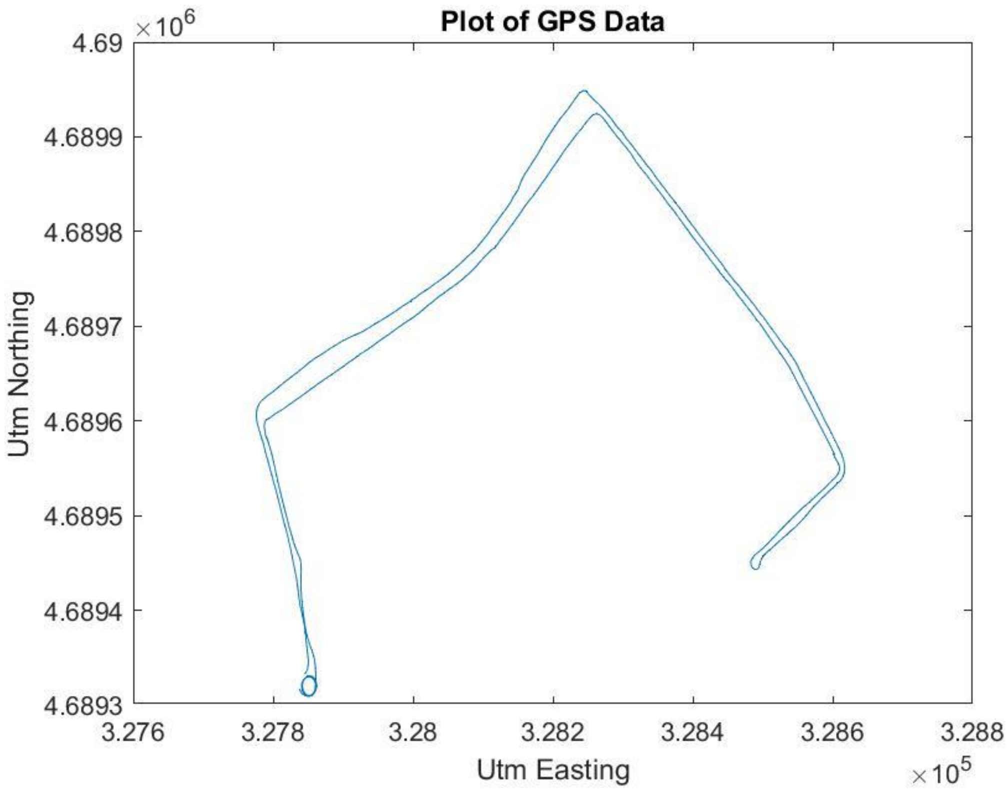
NORTHEASTERN UNIVERSITY, BOSTON

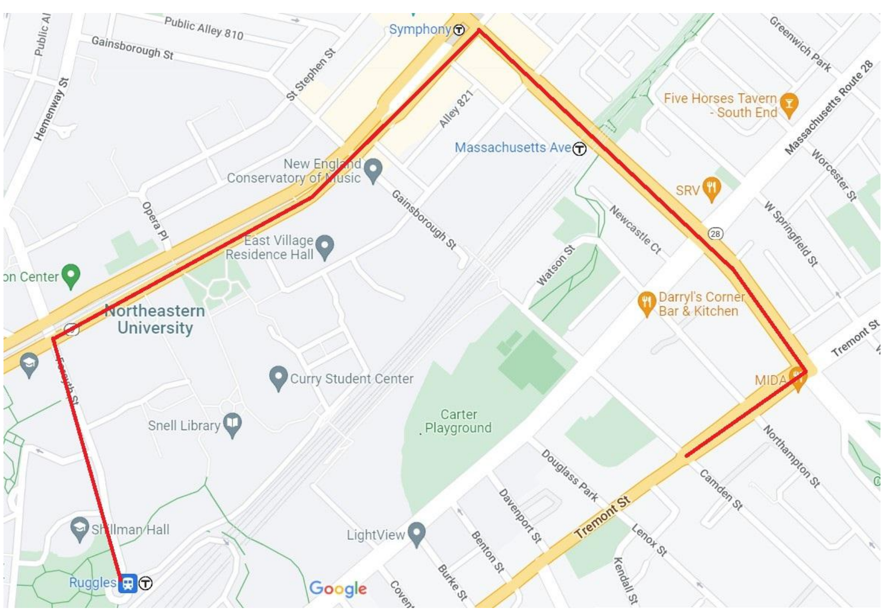
LAB-4 REPORT

(Used 1 extra day out of 4)

Part A: Collect Data in a car for dead reckoning as a team:



The previously written GPS nodes and IMU nodes were launched using roslaunch. Both stationary data and the driving around data was collected using the device driver. The path traversed is as shown below:



Part B: Analysis on the data collected in Part A :

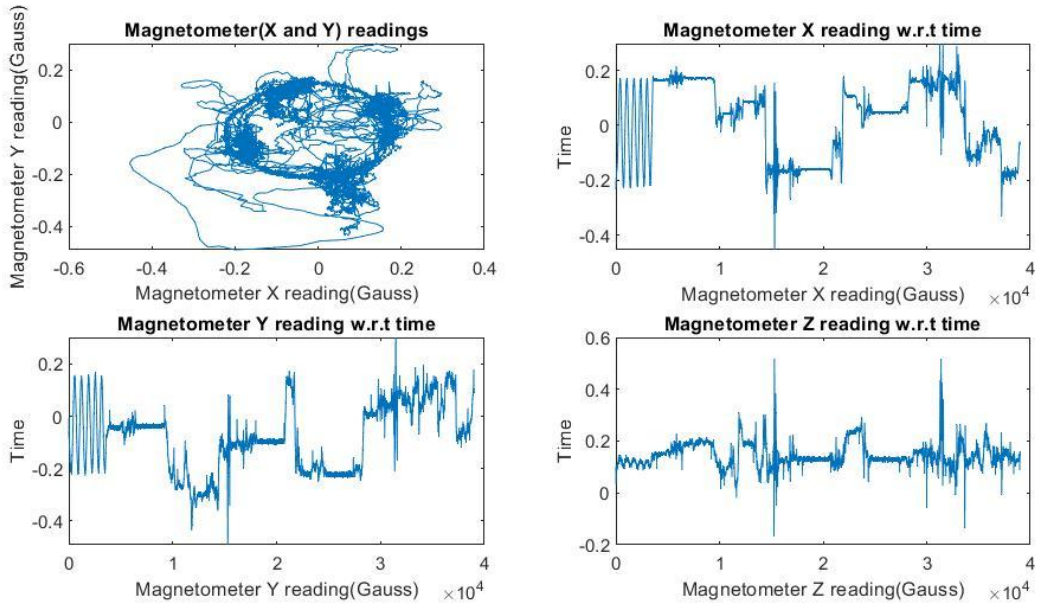
The data was collected driving around the path as follows:

1. Executing 4 circles driving around Ruggles circle
2. Forsyth St.
3. Huntington Ave.
4. Massachusetts Ave.
5. Tremont St.

Before and after starting the drive, stationary data was collected for about 2 minutes.

B.1. Magnetometer Calibration:

First, the data is looked at individually for biases. The biases are then subtracted from the actual data so that it is centered around zero. We are plotting the x and y magnetometer readings along with Magnetometer X,Y, and Z plotted against Time, to observe the changes in the values. The sinusoidal crinkle observed at the beginning of the Magnetometer X,Y and Z vs Time indicates the magnetometer calibration while going in circles around Ruggles. The slow shift in the values indicates the calibration.



B.2. Estimating Heading Yaw:

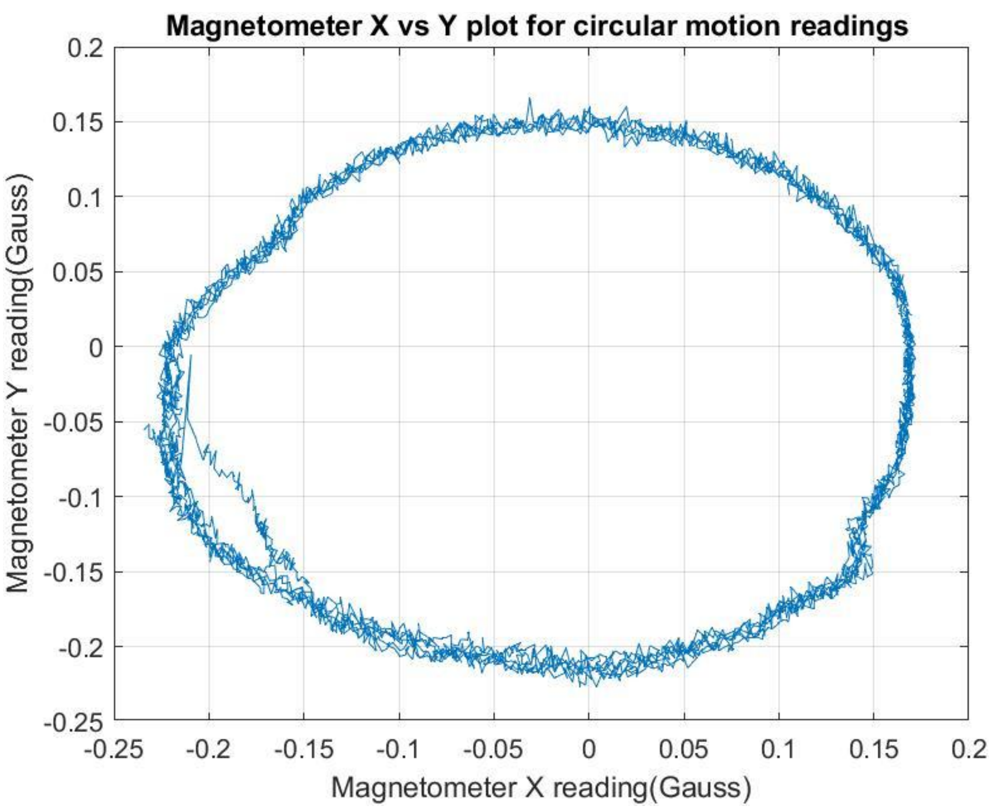
The magnetometer readings are affected by the hard and soft iron effects. To calibrate the magnetometer, we need to eliminate the soft and hard iron effects. Ideally if there is no error it should be a perfect circle at (0,0). To eliminate the effects, we start with finding the center of the reading plotted, removing the hard iron effects. Now we have an ellipse at (0,0). We remove the soft-iron effects by finding the ellipse axis and matching it with the x-axis. Using the scaling factor 0.5 we are making it a circle successfully elimination the hard and soft iron effects.

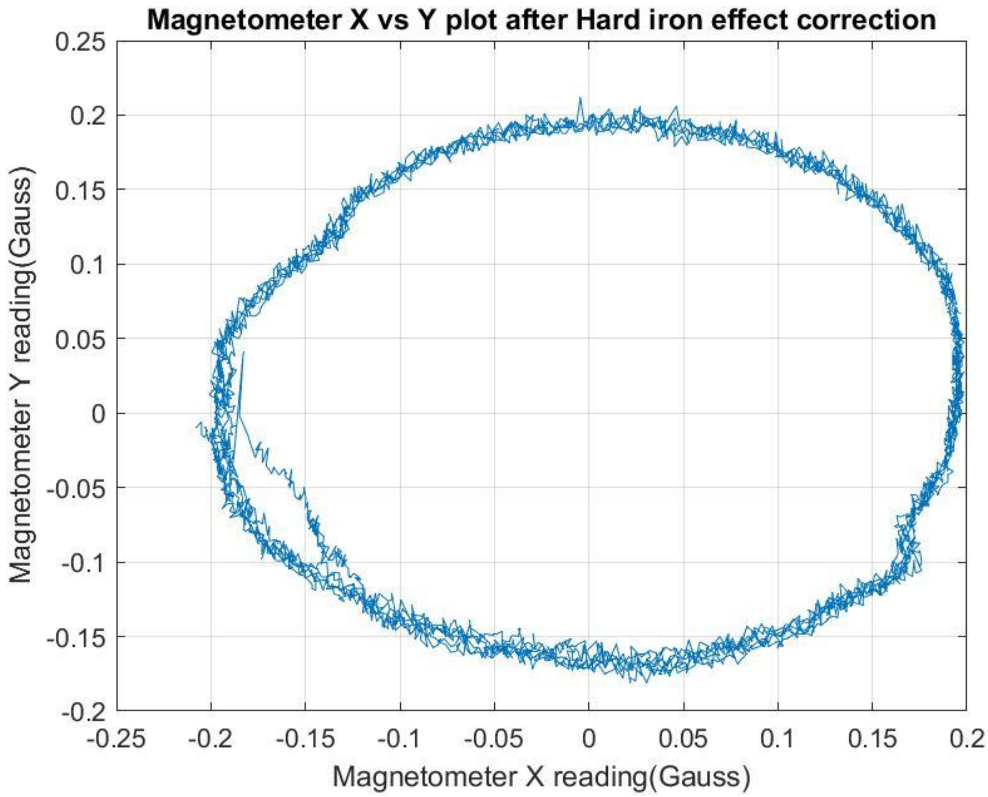
Equations for HI and SI corrections

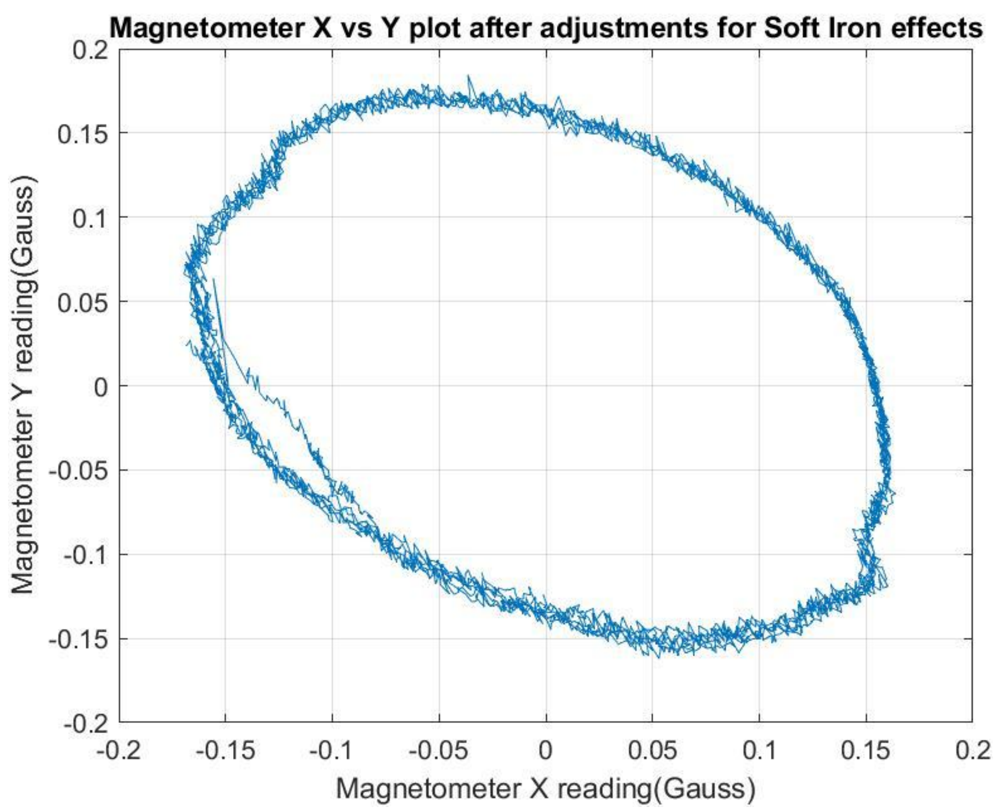
$$\boldsymbol{m_c} = S_I(\tilde{\boldsymbol{m}} - \boldsymbol{b_{HI}})$$

$$\begin{bmatrix} m_{c_x} \\ m_{c_y} \\ m_{c_z} \end{bmatrix} = \begin{bmatrix} C_{00} & C_{01} & C_{02} \\ C_{10} & C_{11} & C_{12} \\ C_{20} & C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} \tilde{m_x} - b_{H_0} \\ \tilde{m_y} - b_{H_1} \\ \tilde{m_z} - b_{H_2} \end{bmatrix}$$

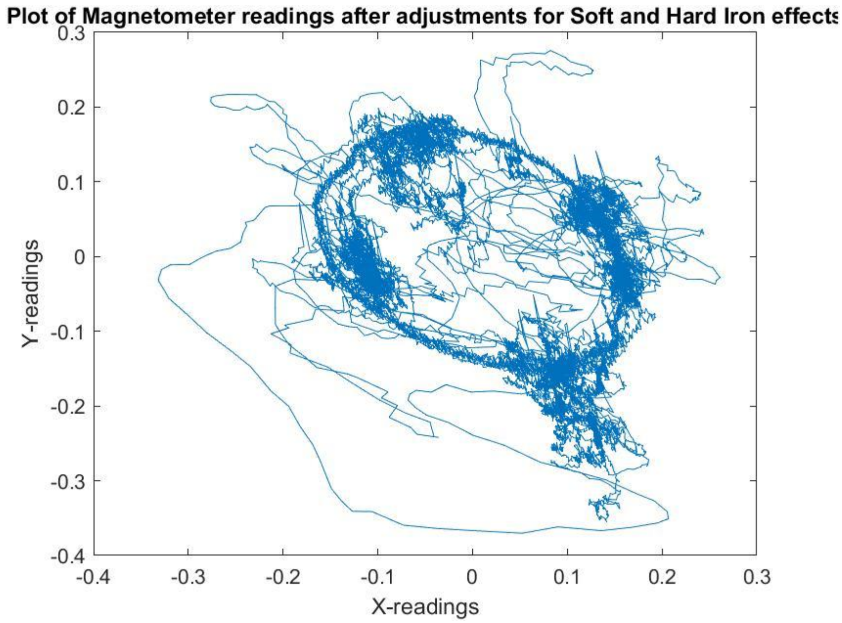
The below graphs x-y are a plot of the magnetometer data collected circling around Ruggles.




Magnetometer X vs Y plot after Hard iron effect correction
Magnetometer Y reading(Gauss)
Magnetometer X reading(Gauss)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2

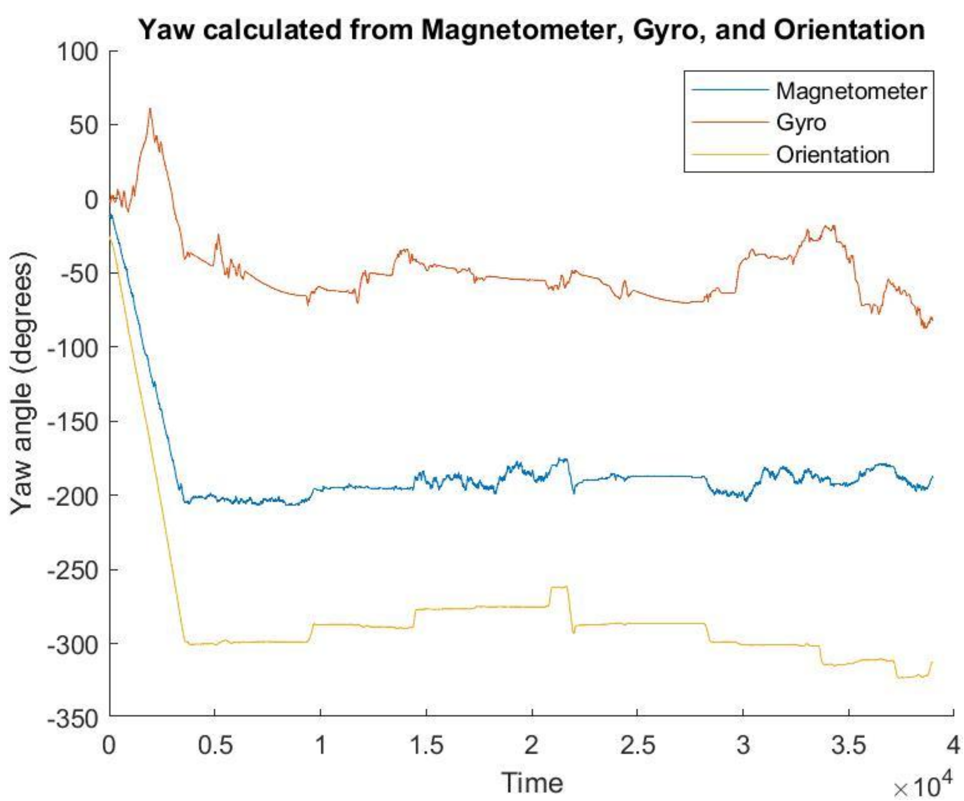

Magnetometer X vs Y plot after adjustments for Soft Iron effects
Magnetometer Y reading(Gauss)
Magnetometer X reading(Gauss)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2

After eliminating the soft and hard iron effects, the adjusted magnetometer data appears to be as plotted below.



B.2.1. Estimating the Yaw Angles:

The yaw angles of magnetometer and gyro meter are being plotted in the graphs below. The yaw angles are an integration of sensor readings.

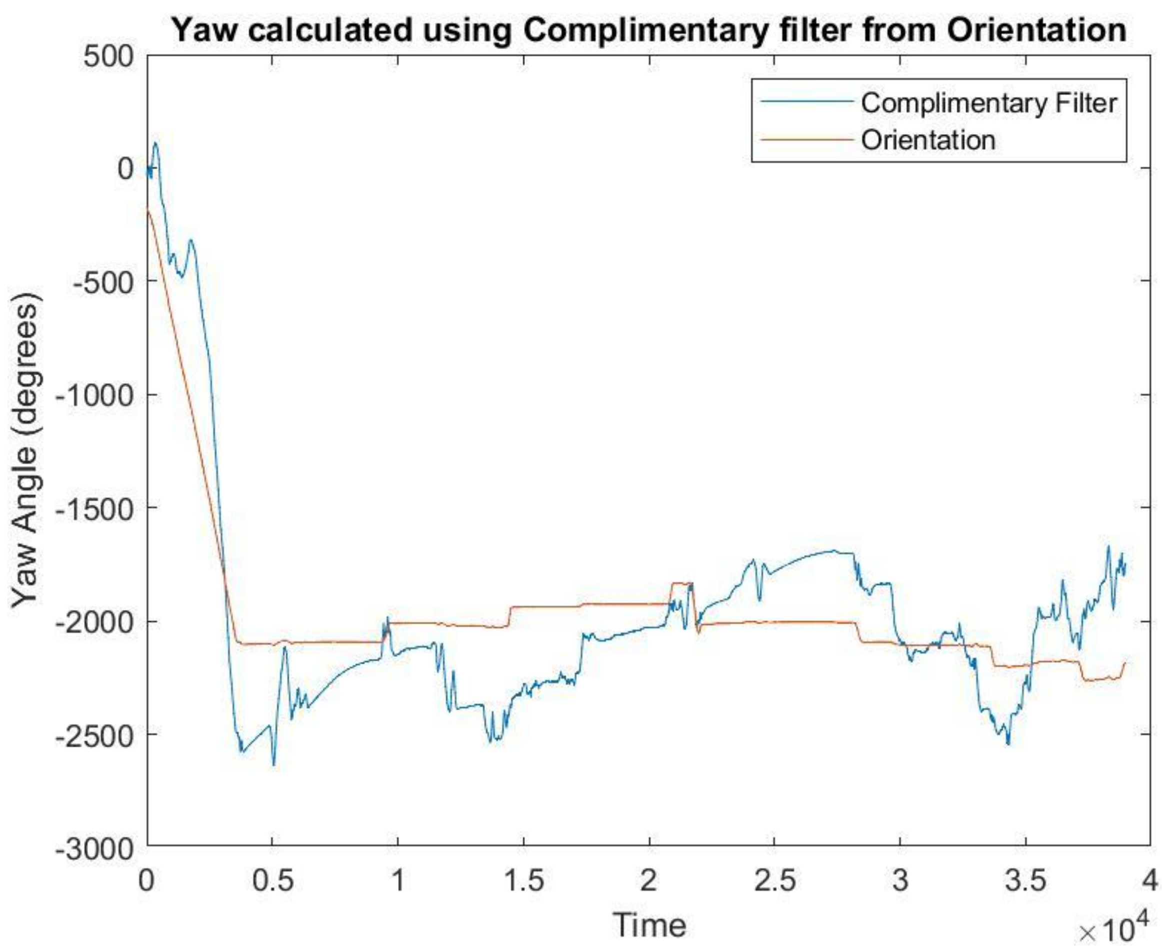


The yaw angles found by the integration and yaw angles obtained from the IMU are being compared. From the graphs, it can be seen that the graph of magnetometer yaw angle displays a lot of fluctuations, mostly because of its sensitivity to low frequencies. Hence, it seems to pick up slight changes and fluctuations.

On the other hand, the graph of IMU Orientation and Gyro are comparatively steady. IMU orientation displays the expected steady results. These are calibrated towards high frequency, making it less susceptible to fluctuations.

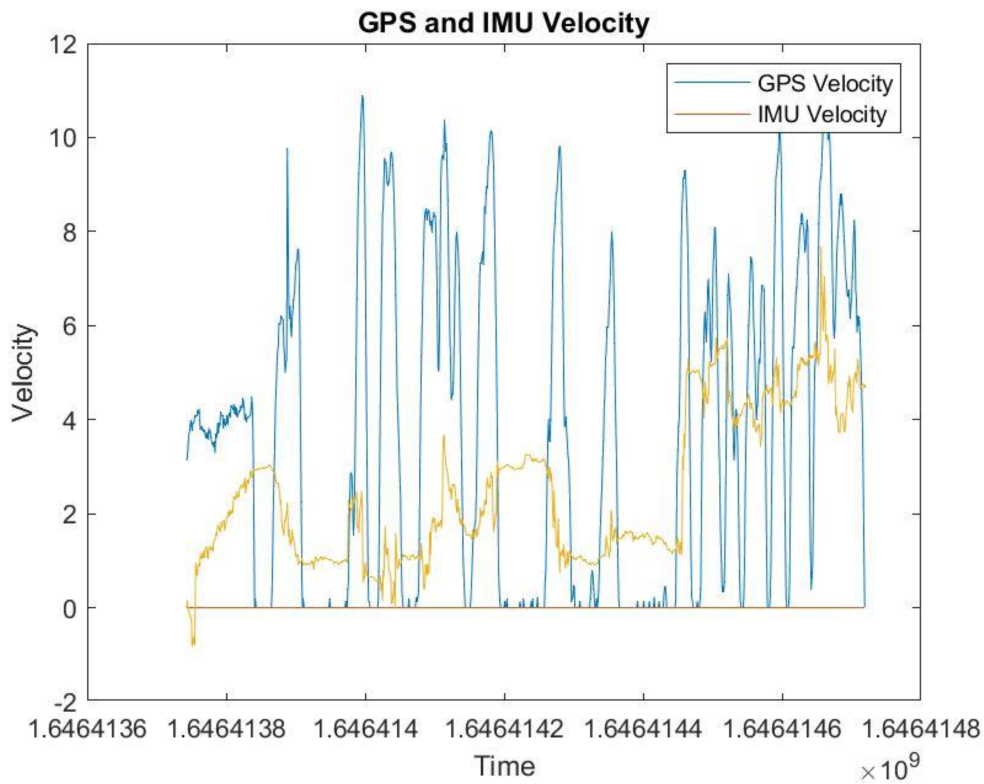
The below graph, we can observe that the complementary filter effects. Complementary filter is a combination of high-pass and low-filter. Use of a high-pass and low-pass filters gave undesired effect and hence a complementary filter is being used.

Hence, we try to eliminate the high frequency noise and low frequency bias from magnetometer and gyro meter respectively, we use complementary filter which estimates the best of both the errors with a scaling factor of 0.4. Below is the graph that we obtain:



B.3. Estimating Forward Velocity:

Acceleration is affected by its posture and bias. We are plotting a graph of the GPS and IMU velocity:



Looking at the plotted velocity graph, we can observe that integrated velocity keeps incrementing. The GPS velocity and the IMU velocity are varying and are not close to similar. We can deduce that some noise was introduced causing the IMU velocity to keep adding up and hence we observe a rise in the graph. To get rid of all the errors the initially introduced is subtracted from all the values and the forwards velocity is integrated to get better results.

We can observe some fluctuation in the values in the graph which was plotted after adjusting the error. A potential cause of these errors can be the environmental conditions, traffic leading to acceleration and deceleration while on the drive. Every little error introduced gets added up resulting in a high value of error in the graph. If this error is not adjusted for, it will keep building up over time, we can fit it by identifying the noise introduced and subtracting it from the velocity readings.

We can still see fluctuations in the velocity, this high frequency noise is possibly generated by the vehicle's vibration. Moreover, the values should not be negative since the car is moving forwards constantly. We can call this deceleration error. It can be fixed by using scaling factor.

B.3. Dead Reckoning with IMU:

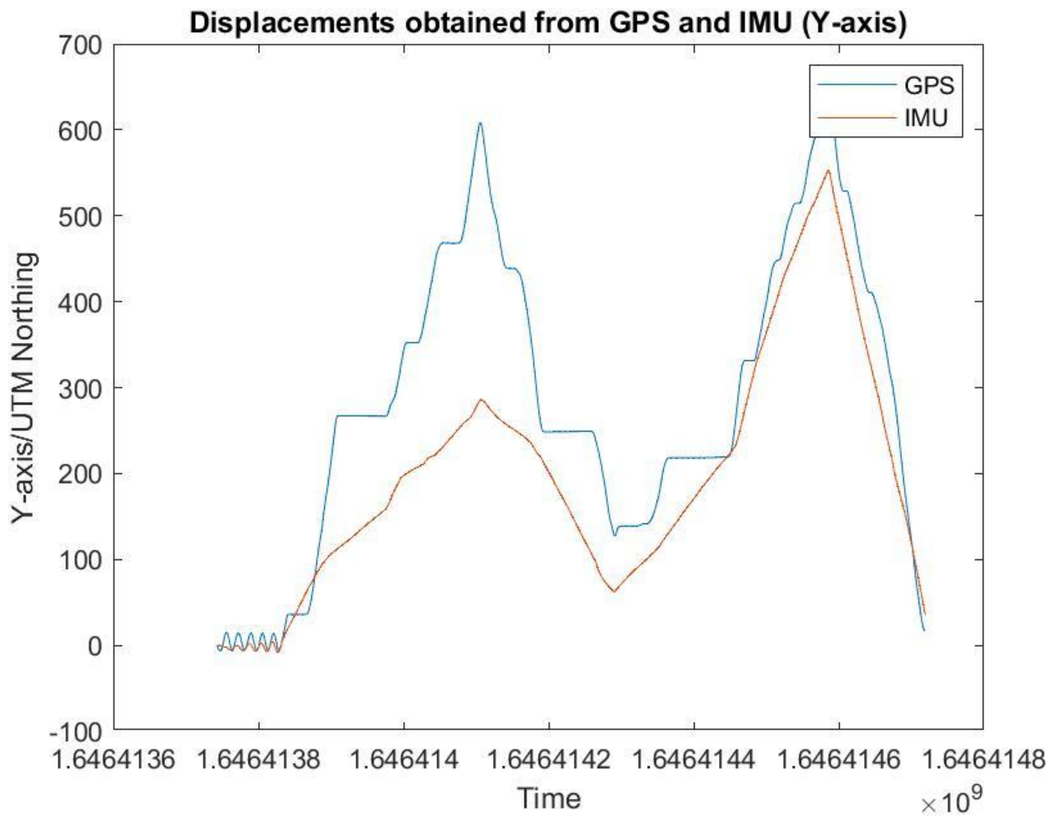
$$\ddot{y}_{obs} = \ddot{Y} + \omega\dot{X} + \dot{\omega}x_c$$

We are assuming $\ddot{Y}$ *and* x_c to be zero.

Therefore,

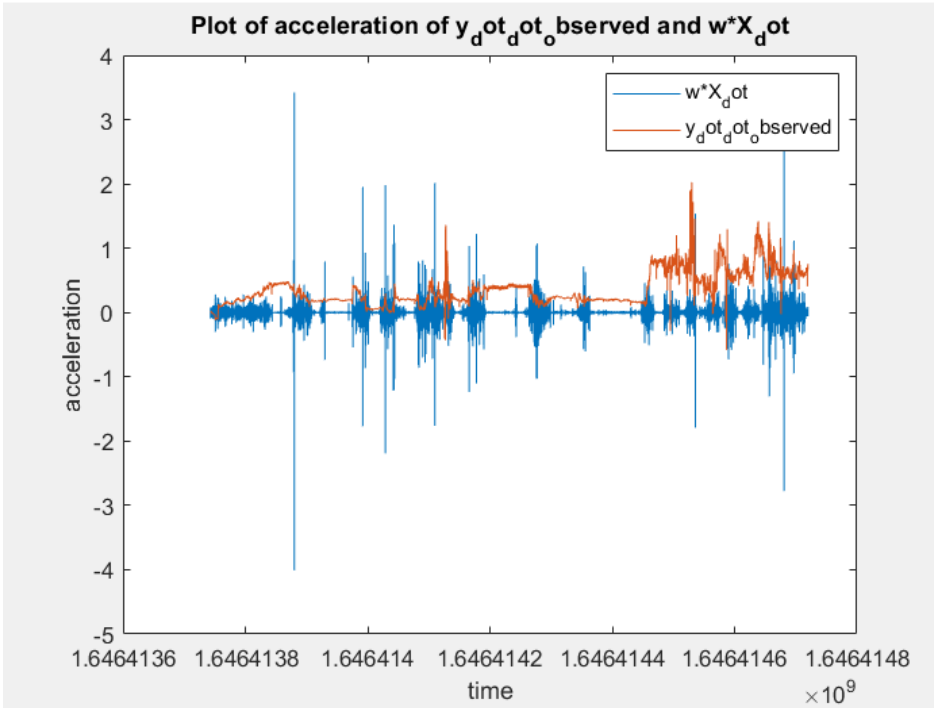
$$\ddot{y}_{obs} = \omega\dot{X}$$

Integrating the IMU data, the below graphs were observed. Displacement of GPS and IMU

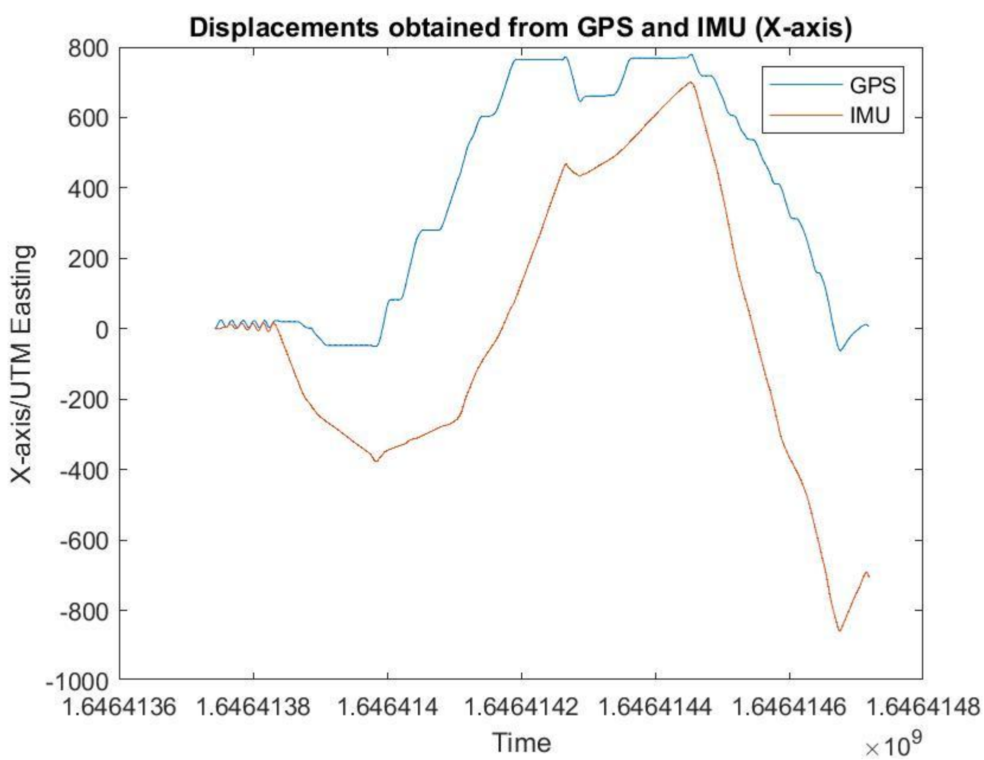


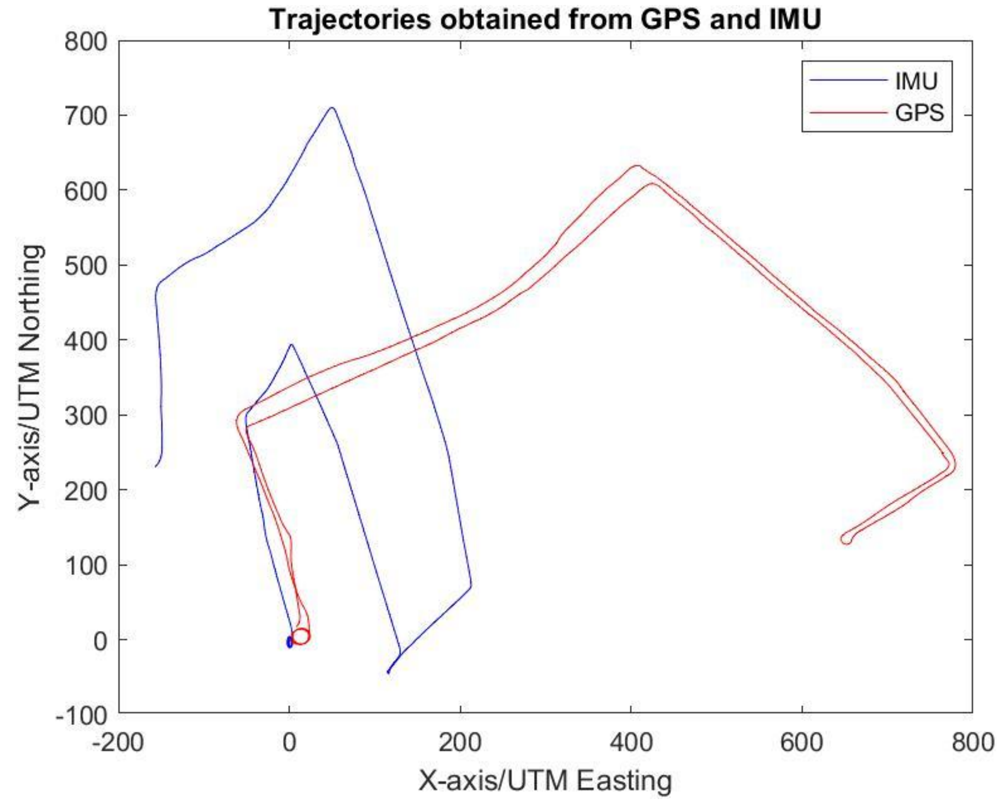
IMU displacement is calculated using velocity and yaw angles calculated previously.

We can observe that the GPS and IMU displacement are similar looking. They both started off identical, but GPS value scaled up as compared to IMU data. The x-axis values match well. These observations will be used to analyze GPS trajectory.



We are observing an offset in the plot. The offset is also observed to be slowly increasing from one stationary point to another with passing time. The magnitude is varying, this could possibly because of the offset Xc, distance between center of mass and IMU device in the vehicle. Here , a scaling factor of 0.9 is used.





Assuming Xc to be non-zero, we get:

$$x_c = (\ddot{y}_{obs} - \omega\dot{X})/\dot{\omega}$$

Using the assumptions and calculating, we get the value of x_c to be 0.0015m.The value is small, since the IMU was placed in the middle of the car on the armrest near the handbrake.

Conclusion:

Having previously analysis GPS and IMU individually, IMU can be concluded to be more accurate and precise than GPS. But it can be observed that the IMU is more sensitive to slighter fluctuations and noise. The signal needs to undergo through a number of filtering processes in order to obtain an accurate heading and velocity estimate. But it still remains more accurate than the GPS.