

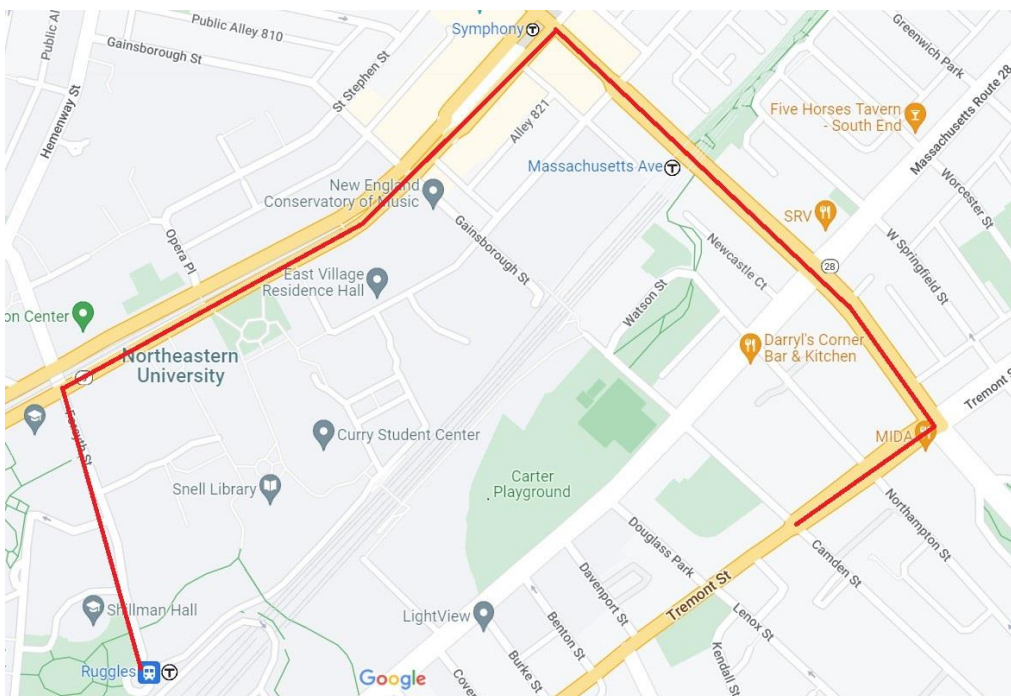
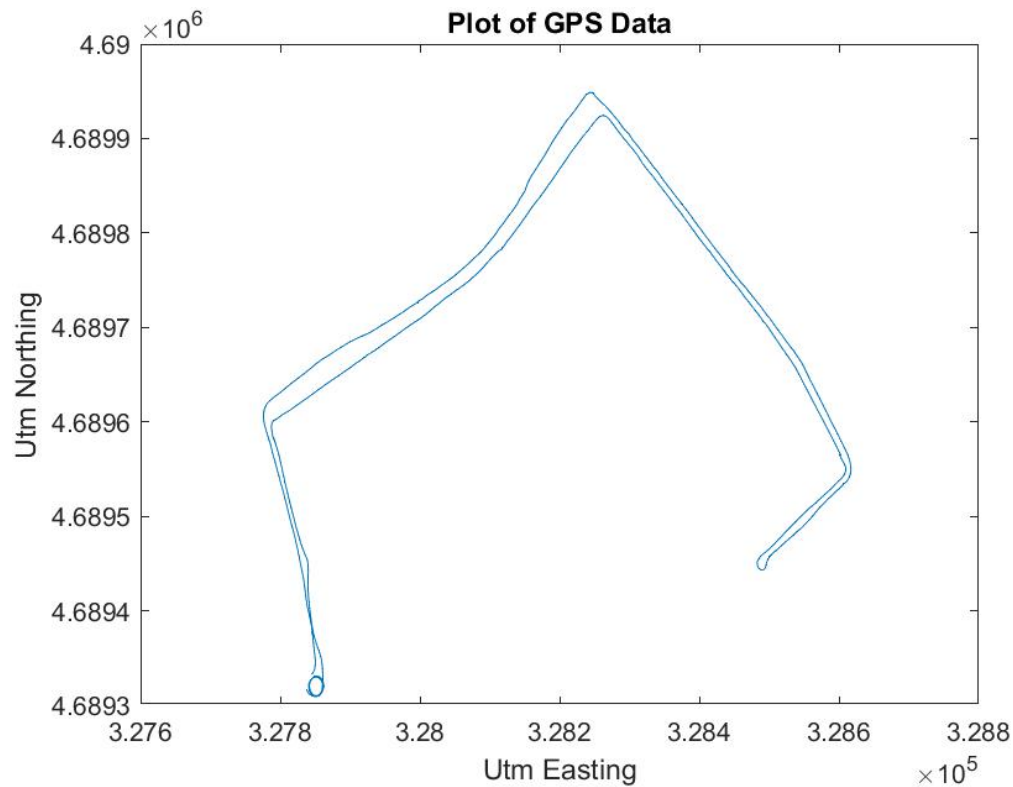
LAB 4

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(Using 1 extra day out of the 4)

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

The two device drivers were launched together using roslaunch tool launching previously written GPS nodes and IMU nodes. The stationary data and the driving around data was collected using the device driver.



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

The dead reckoning data was collected driving around the following path:

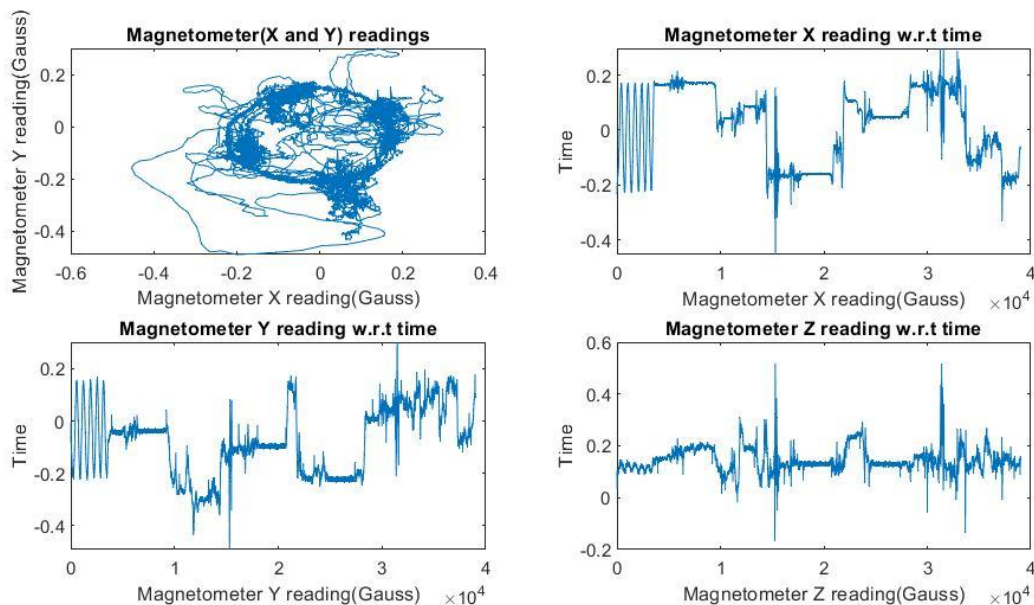
1. Around Ruggles 4 times
2. Forsyth St.
3. Huntington Ave.
4. Massachusetts Ave.
5. Tremont St.

And back to where we started following the same route to Ruggles.

B.1. Magnetometer Data:

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

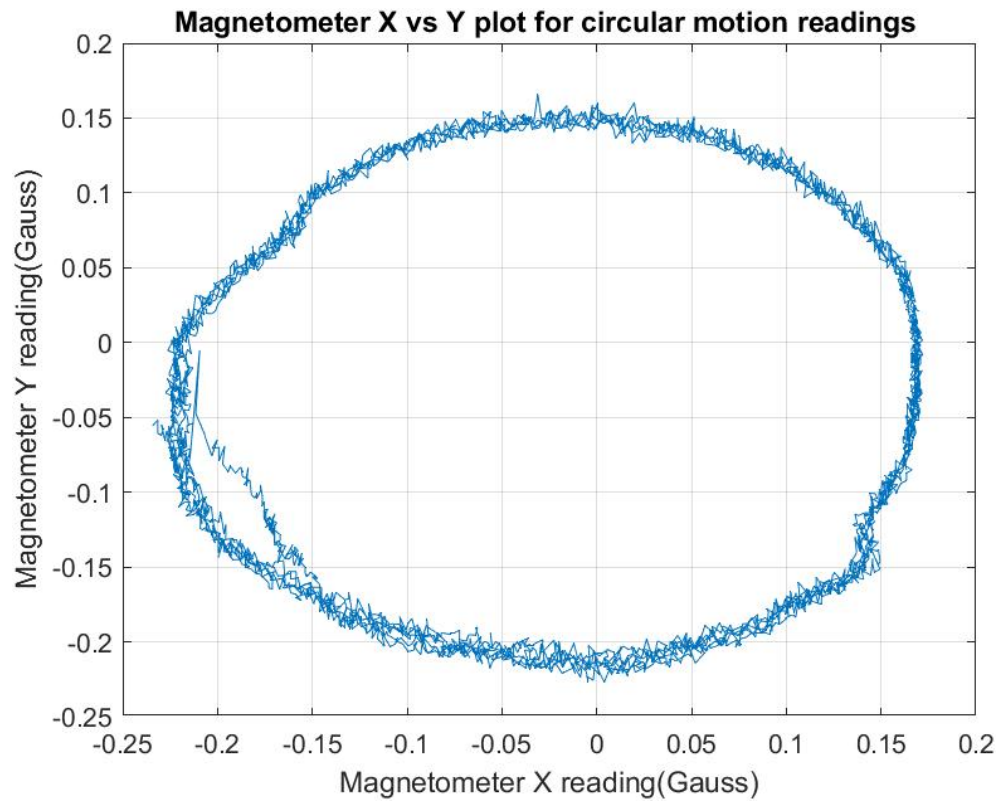
The magnetometer readings are affected by the hard and soft iron effects. To calibrate the magnetometer, we need to eliminate the soft and hard iron effects. Ideally if there is no error it should be a perfect circle at (0,0). To eliminate the effects, we start with finding the center of the reading 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 eliminating the hard and soft iron effects.

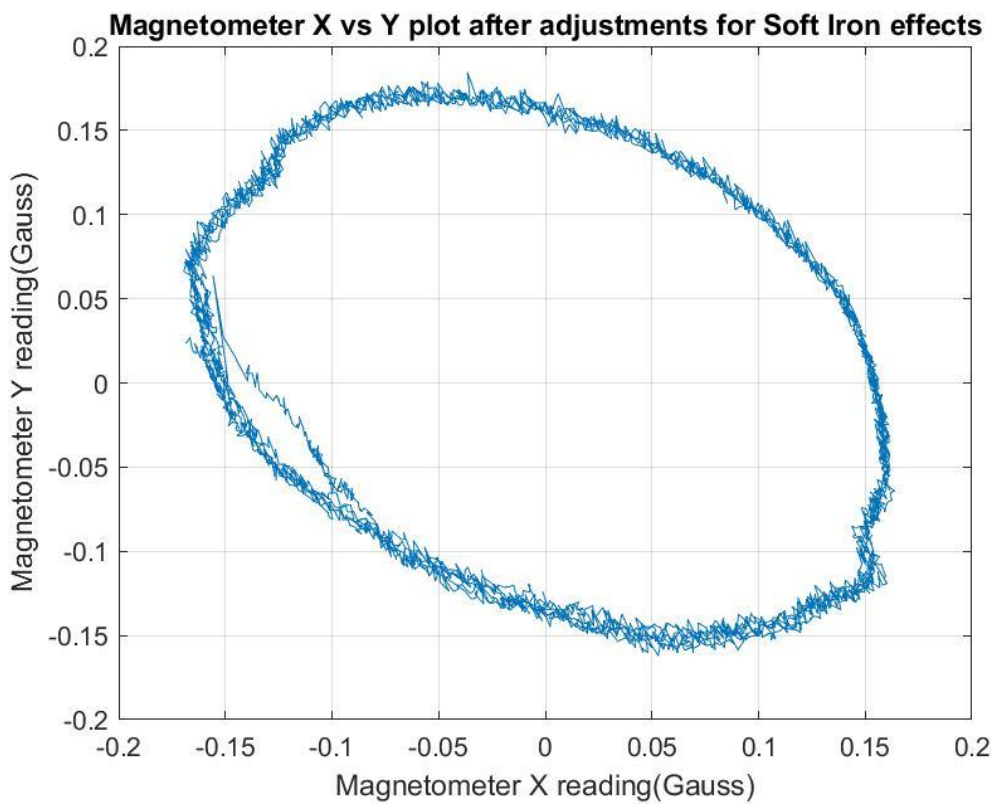
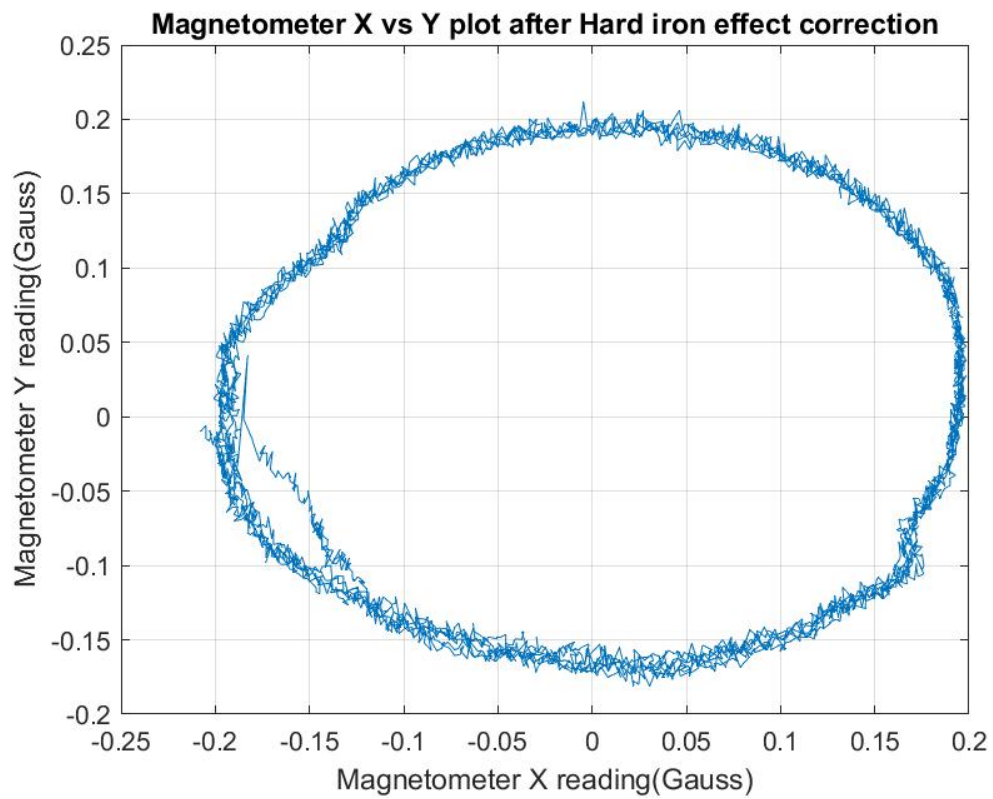
Equations for HI and SI corrections

$$\mathbf{m}_c = S_I(\tilde{\mathbf{m}} - \mathbf{b}_{HI})$$
$$\begin{bmatrix} m_{c_x} \\ m_{c_y} \\ m_{c_z} \end{bmatrix} = \begin{bmatrix} C_{00} & C_{01} & C_{02} \\ C_{10} & C_{11} & C_{12} \\ C_{20} & C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} \tilde{m}_x - b_{H_0} \\ \tilde{m}_y - b_{H_1} \\ \tilde{m}_z - b_{H_2} \end{bmatrix}$$

Solving for Figures

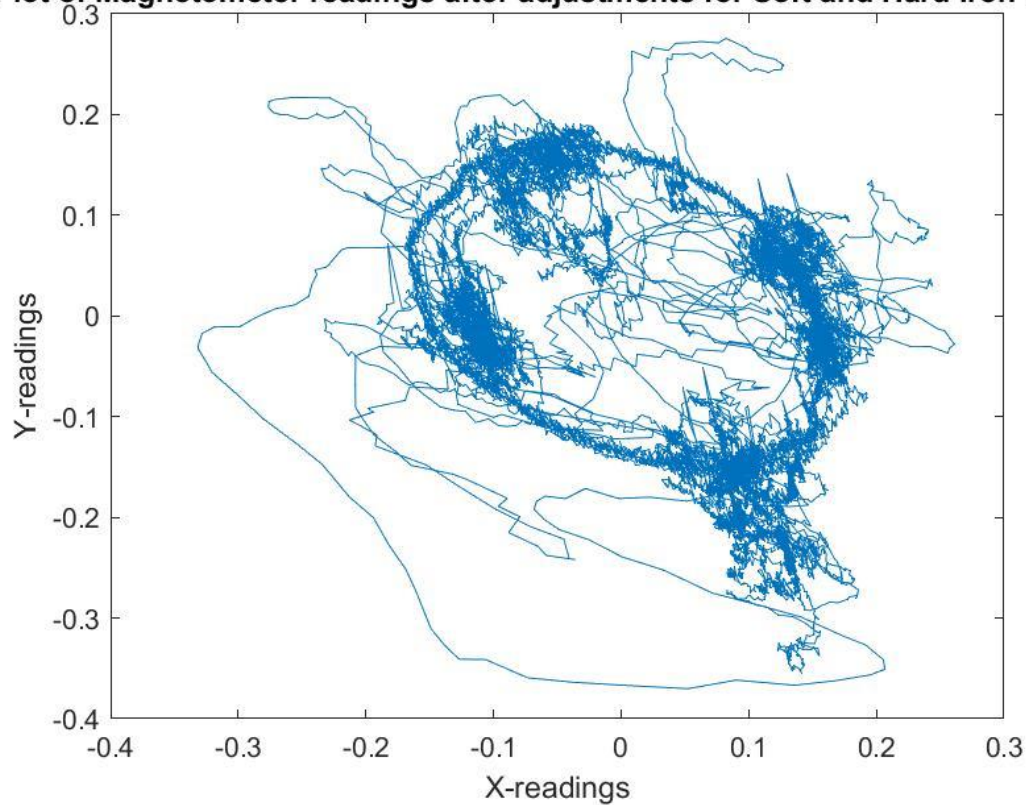
$$\mathbf{m}_c = \begin{bmatrix} .75 & -.1443 & 0 \\ -.1443 & 0.9167 & 0 \\ 0 & 0 & 1.0 \end{bmatrix} \begin{bmatrix} \tilde{m}_x - 200 \\ \tilde{m}_y - 100 \\ \tilde{m}_z - 0 \end{bmatrix}$$





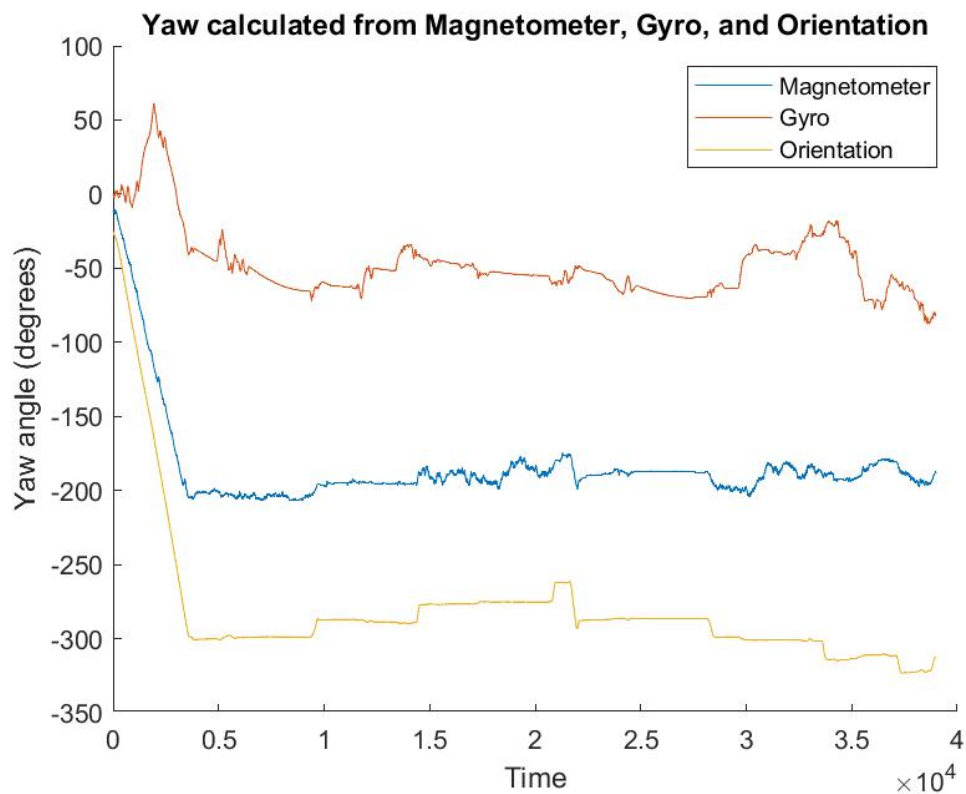
After eliminating the soft and hard iron effects, the adjusted magnetometer data appears to be as plotted below.

Plot of Magnetometer readings after adjustments for Soft and Hard Iron effects



B.2.1. 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.

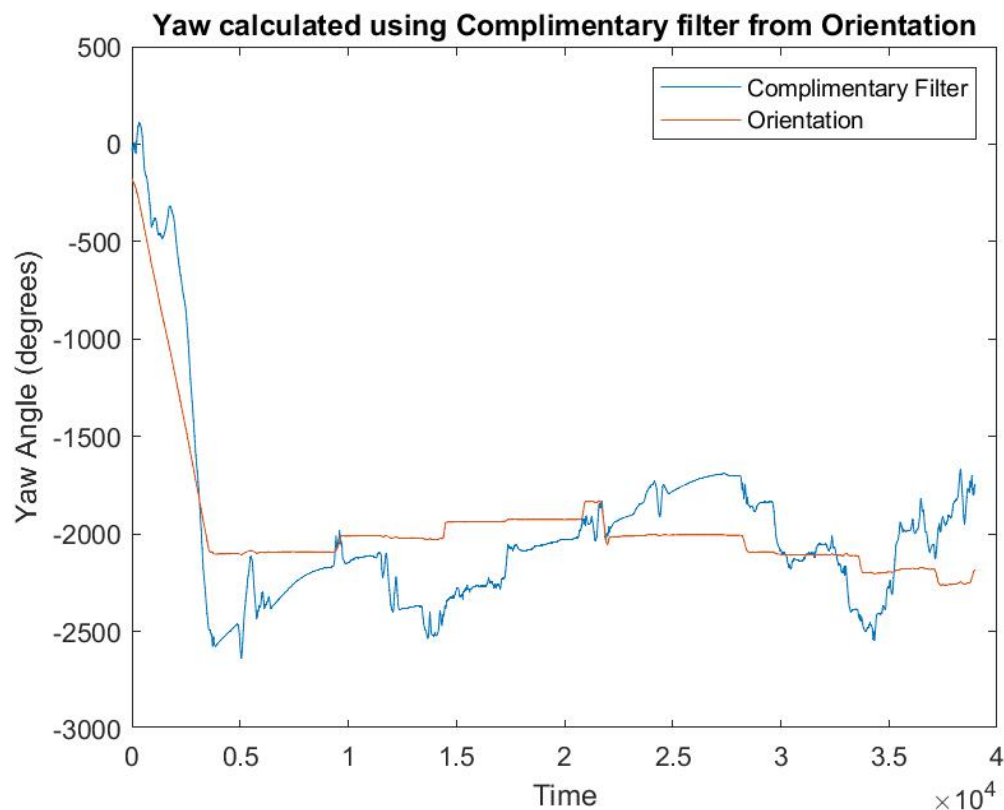


We are comparing the yaw angles found by the integration and yaw angles obtained from the IMU. Looking at the graphs we can deduce that the graph of magnetometer yaw angle displays a lot of fluctuations, this is mostly because it is very sensitive to low frequencies and picks up the slightest changes and fluctuations.

On the other hand, the graph of IMU Orientation and Gyro are comparatively steady. IMU orientation displaying 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. Using high-pass and low-pass filters gave undesired effect and hence we are using complementary filter.

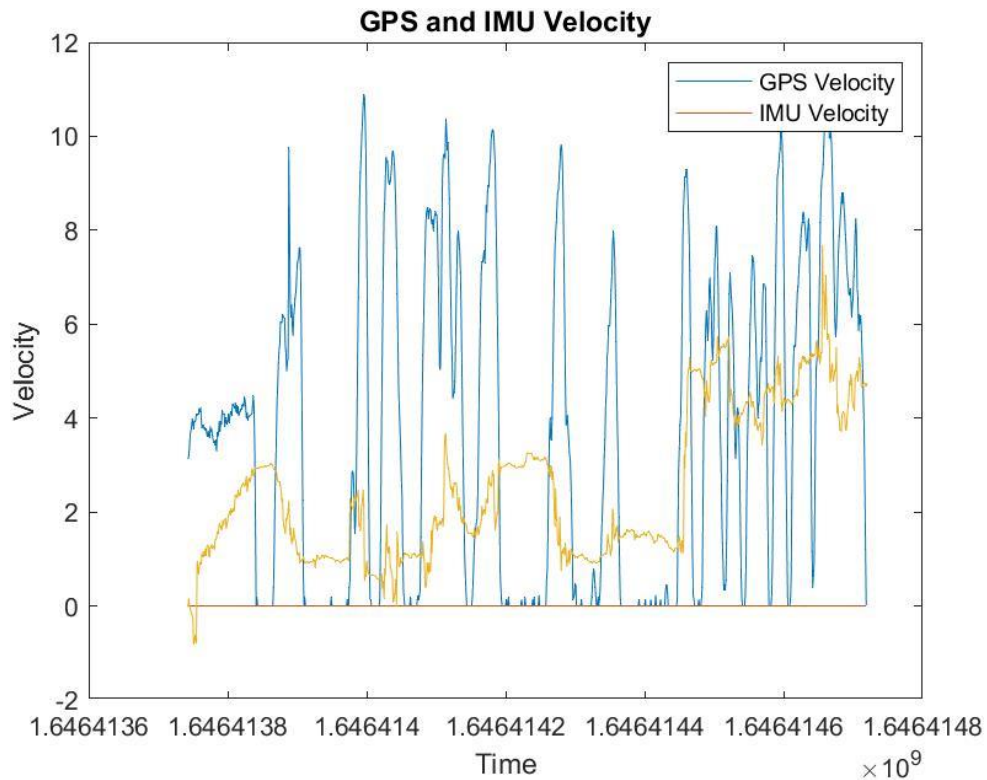
We are trying to eliminate the high frequency noise and low frequency bias from magnetometer and gyro meter respectively, we use complementary filter which estimates the best of both the errors with a scaling factor of 0.4. Below is the graph:



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 adjected 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.

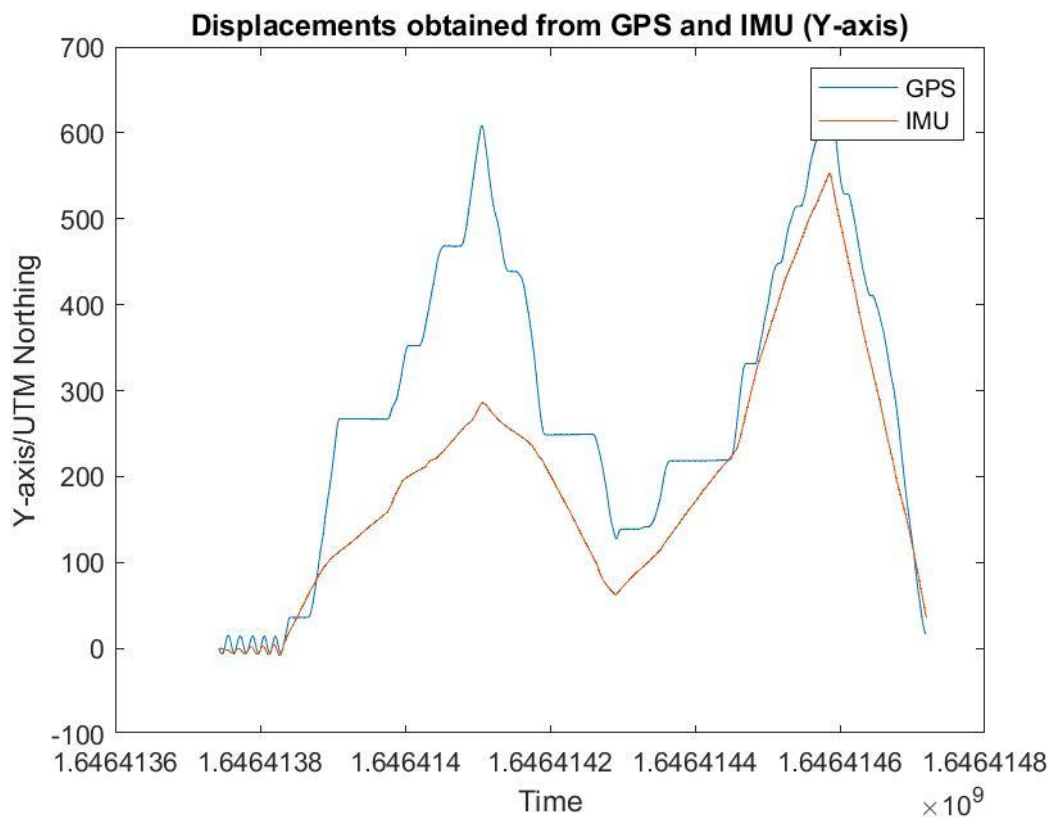
Therefore,

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

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.

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

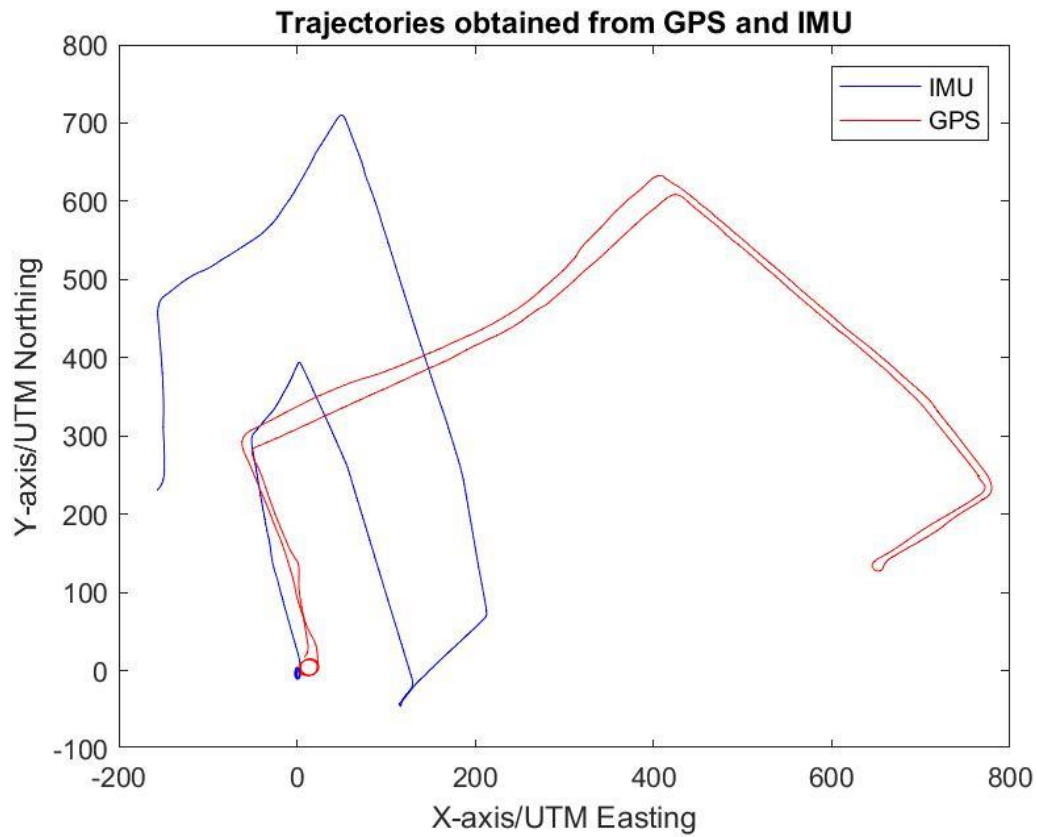
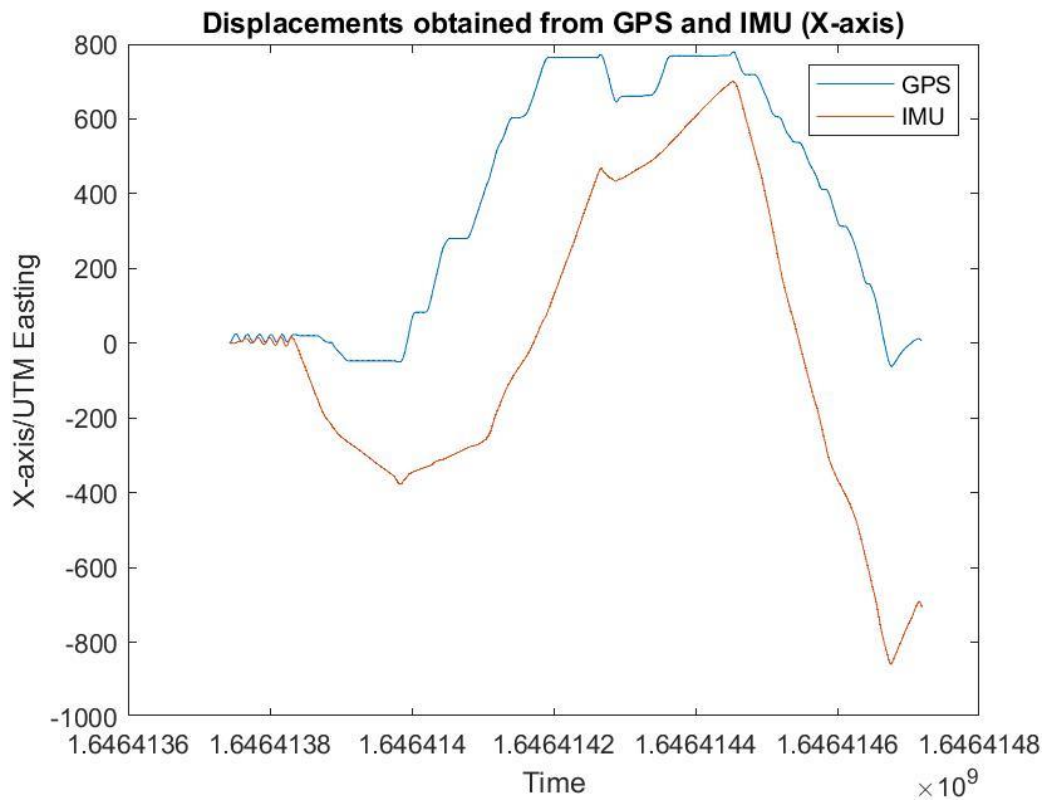


IMU displacement is calculated using velocity and yaw angles calculated previously.

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.

Derivation of \ddot{y}_{obs} and $\omega \dot{X}$.

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 be because of the offset x_c , distance between center of mass and IMU device in the vehicle.



Here scaling factor used is 0.9. Anything less than or more than 0.9 was throwing undesirable observations.

Conclusion:

Having previously analysis GPS and IMU individually, I have concluded that IMU is better and precise than GPS and can have wide range of applications.

On the other hand, it has come to my observation that IMU has some drawbacks. It is too sensitive, sensitive enough to pick up noise. The signal needs to undergo through a number of cleanings in order to eliminate undesired elements to get clean results.