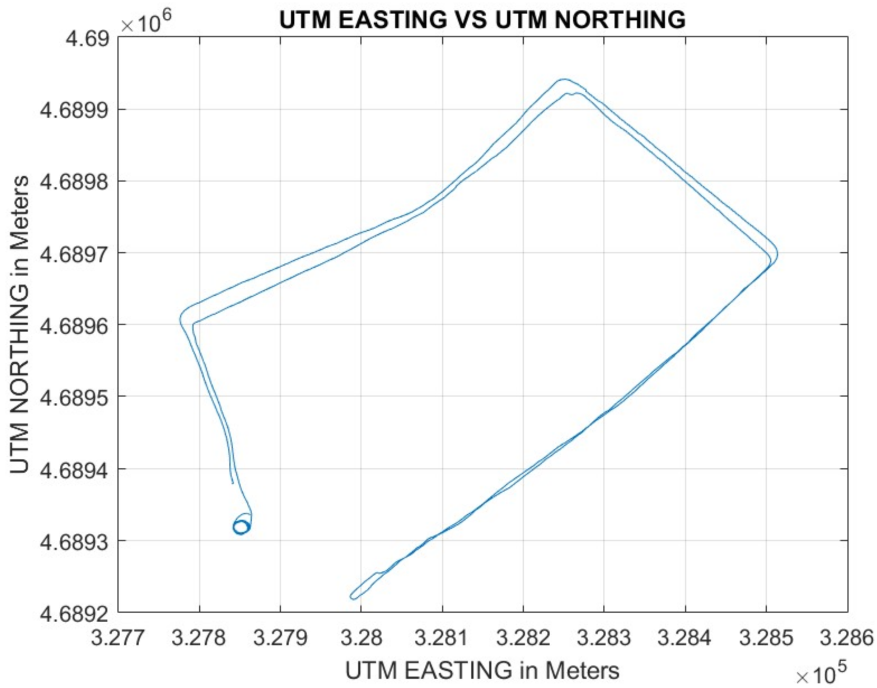
Robotics Sensing and Navigation
EECE 5554
Navigation with IMU and Magnetometer
LAB-4

The data was collected in a single rosbag file, and it includes the following message topics gps_message, imu_message, mag_message and imu_raw. We collected stationary data for fixed time at Ruggles and then collected data by going in rounds for magnetometer calibration followed by a stop, then moving data was collected for dead reckoning and finally a stop back at ruggles. The gps motion can be observed from the below plot.

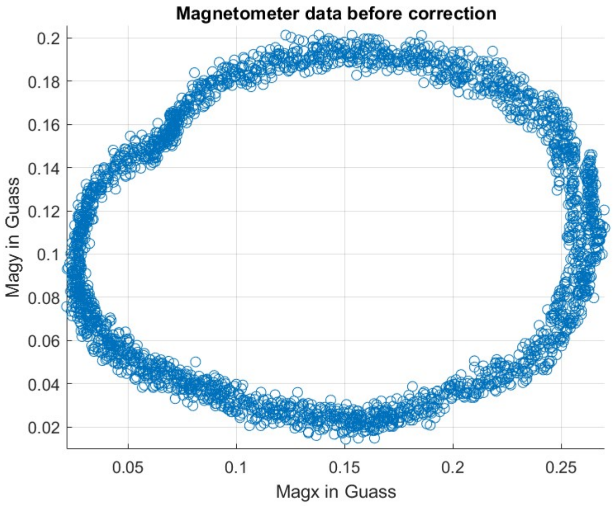


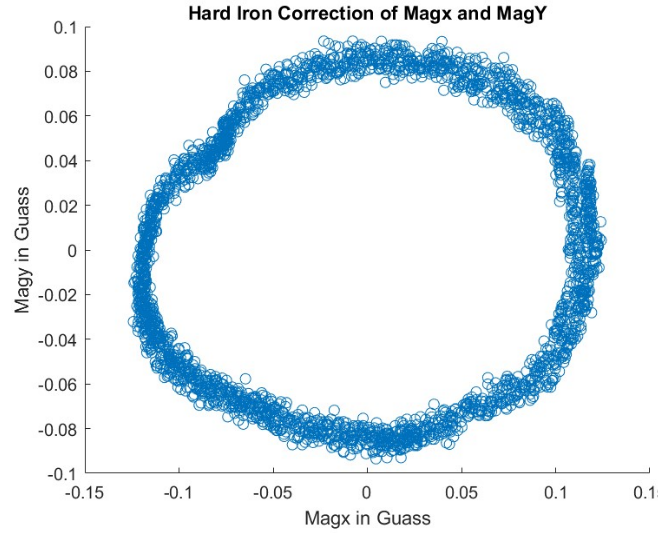
1. Estimating the heading (Yaw):

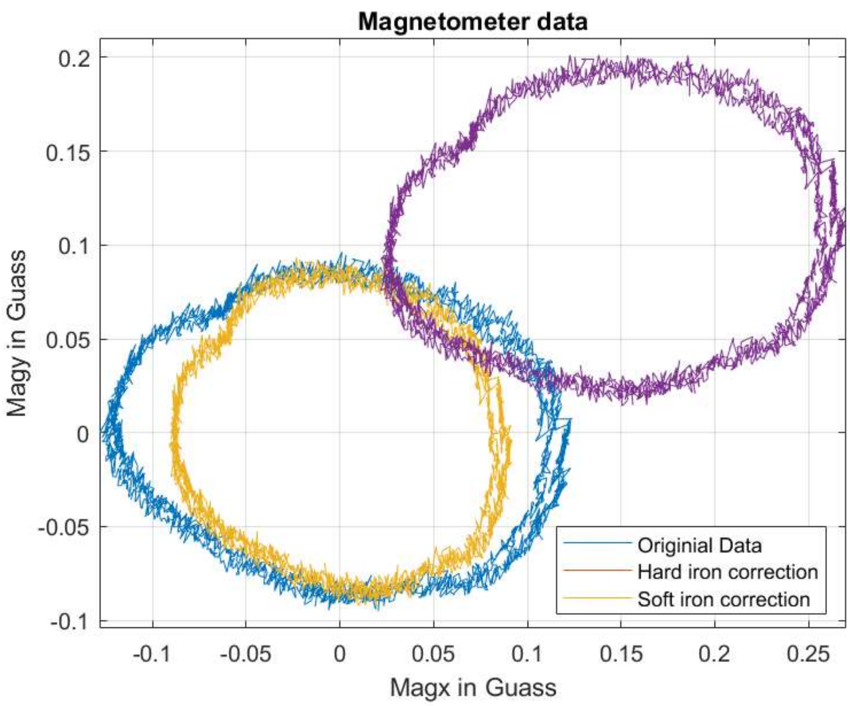
Magnetometer Calibration

- Below are the magnetometer readings plotted for before correction and after soft and hard iron corrections.
- Hard iron distortions are generated by earth's magnetic field and the effect it has can be seen below where the origin is shifted. We rectify the shift by removing the offset value by taking average of the maximum and minimum values for each axis and then subtracting it from raw x and raw y magnetometer data. This eliminates hard iron distortion.
- Soft Iron distortion is the result of material that distorts a magnetic field. We assume that tilt and hard iron correction are computed before rectifying soft iron

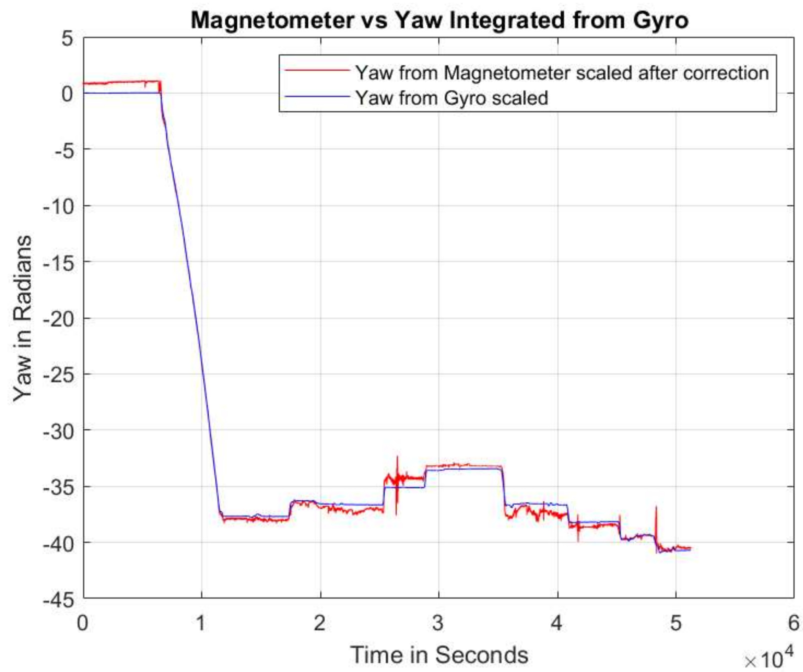
distortion. A scale factor is determined by the ratio of length of the major axis to the minor axis. We rotate the data by the angle found and remove the soft iron distortions.



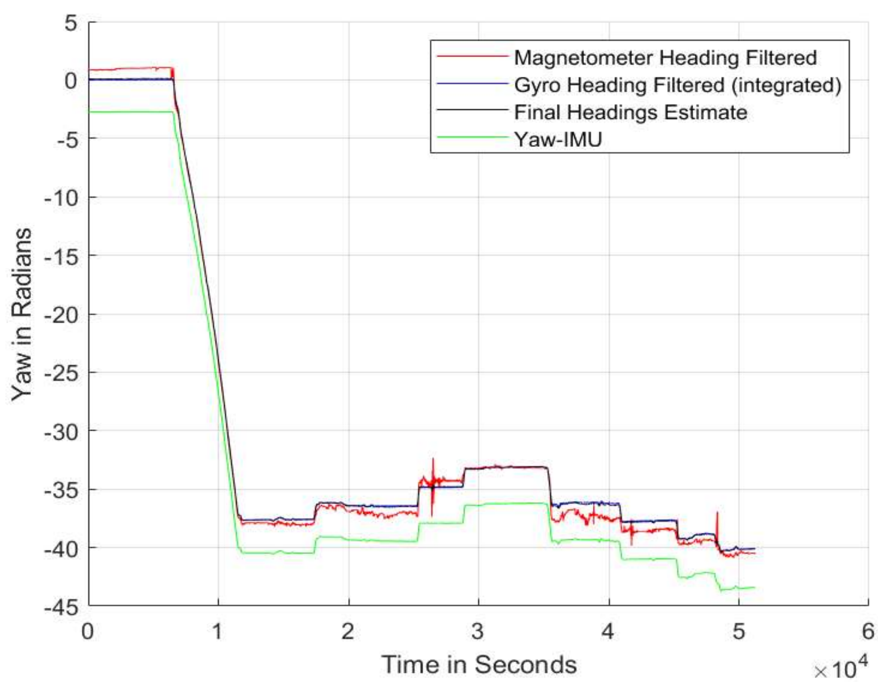




The above plot represents the original data, hard iron correction and soft iron corrections.



Comparing the yaw angles from above two methods, we can say that the yaw gyro values are stable compared to the magnetometer data. Any electronic devices in the vicinity of the sensor could have caused the fluctuations in the magnetic field. One more observation to make is that looking into the graph we can say that they are following a similar trend after scaling it.

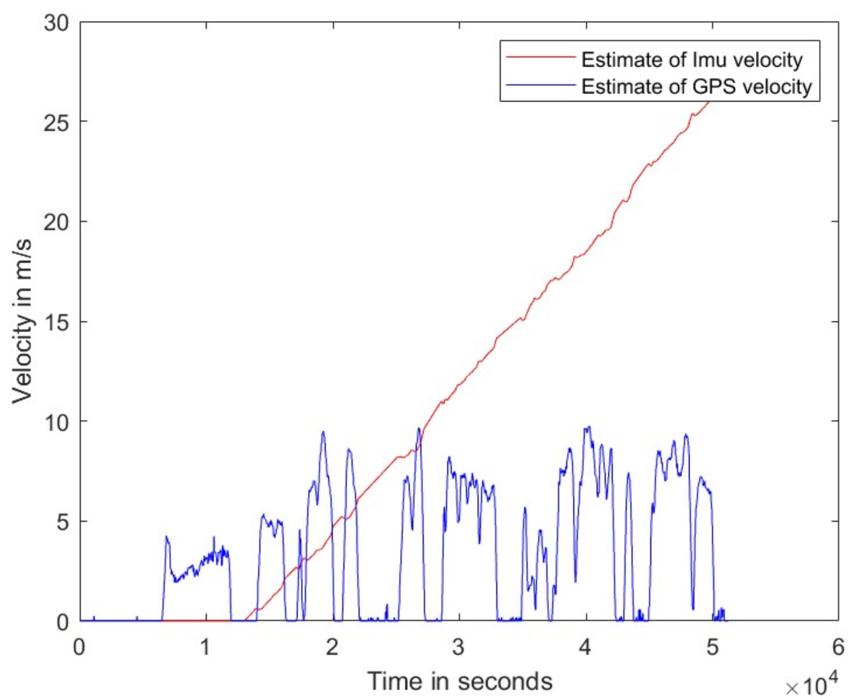


We can see the yaw data from the IMU is resembling the filtered data from the magnetometer and gyro. Spikes can be seen in the plot, and it might have been caused by the disturbances in the magnetic field.

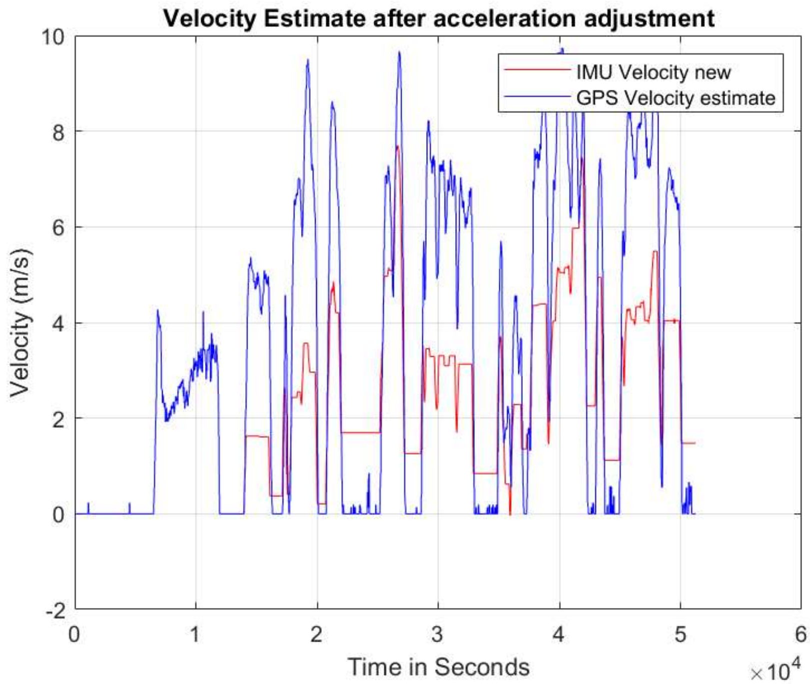
Alpha Value of the complementary filter was set to 0.1 and it gave the closest value and maintained the trend of plot.

2. Estimate the forward velocity

Linear acceleration in x was integrated to find the velocity and the velocity from gps measurements were also calculated. Main observation made were that when we integrate the linear acceleration in x the velocity shoots up. This is because the initial errors were integrated over time and second observation is to not integrate the negative velocity of the car because we did not drive backwards, and we have to take care of data when the car was in stationary positions near signals.



The velocity obtained from the gps and new IMU velocity can be seen in the plot below. They are following the same trend and it resonates the adjustment done to the velocity. There is slight offset between the two, but it can be removed by further filtering it out or scaling it. The offset was made by a value of 0.291 to make the estimate adjustment.



3. Dead Reckoning with IMU

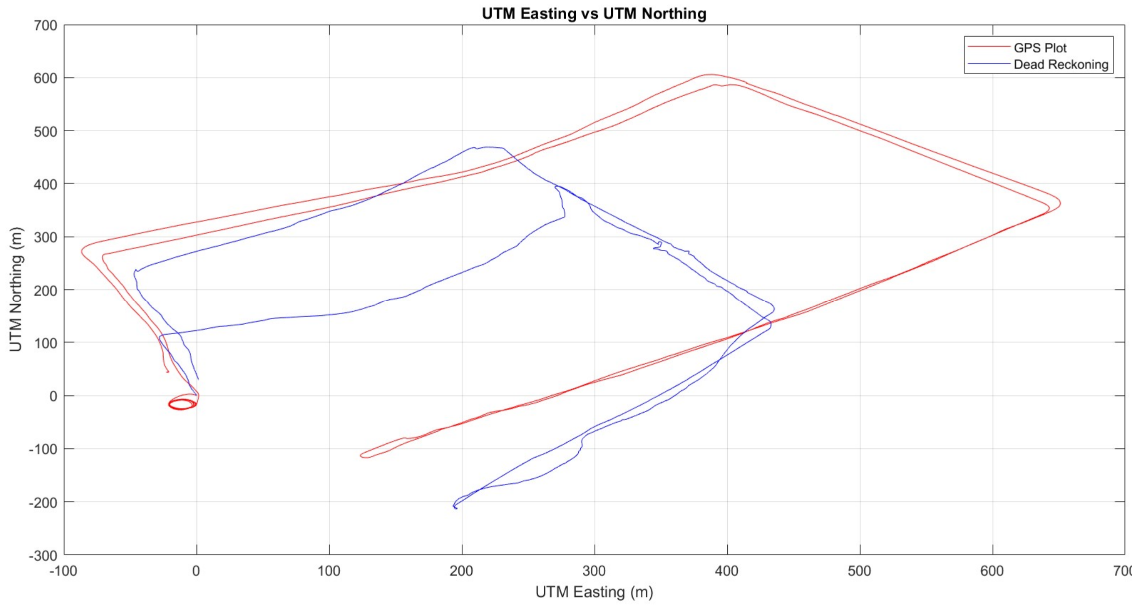
We will be using the equations given for reference to derive the necessary values required for dead reckoning. Here omega is obtained by integrating the accelerometer data in x direction. We assume Y^ is equal to zero, we ignore the the offset x_c and consider it as zero. Now we integrate $\ddot{X}$ to get $\dot{X}$

omega$\dot{X}$ is obtained by the values of velocity and gyro. We compare this with the values form the accelerometer values in y axis.

The equations are as follows

$$\ddot{x}_{obs} = \ddot{X} - \omega\dot{Y} - \omega^2 x_c$$
$$\ddot{y}_{obs} = \ddot{Y} + \omega\dot{X} + \dot{\omega}x_c$$

Below is the graph obatined after performing dead reckoning with IMU. Adjustments were made to get the same starting point and headigs. Since we have taken u-turn in one place, we need to remove the offset by using a correction angle of -4.36 radians and update the trajectory. The trajectory had different scaling after integration. So it was scaled by a factor of 0.9.



To calculate x_c we will use the following equation decuced from above equations

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

It was found that the value of x_c is -0.436m. It can be said that the sensor was 43.6 cm away from the center of gravity of the car. The sensor was placed near the dashboard of the car. This value might be slightly more because of the assumptions made to derive the value of x_c