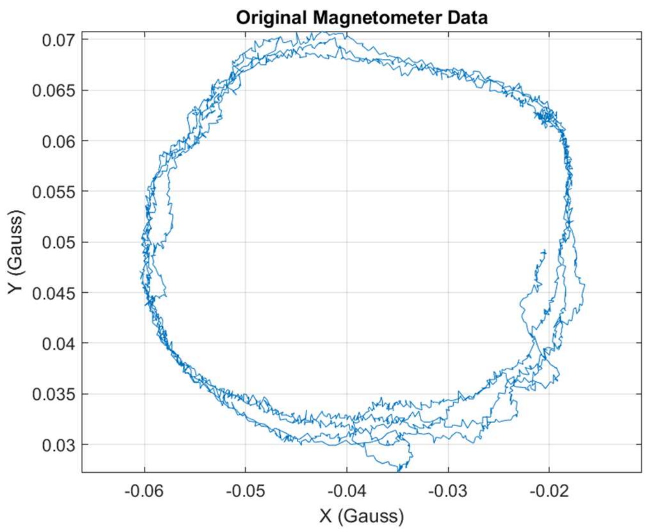
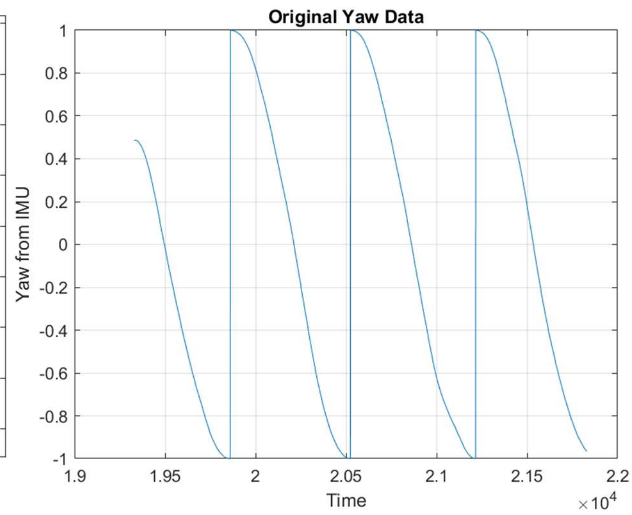
Lab 4 : Navigation with IMU and Magnetometer

1. Magnetometer Calibration

Plotting the raw magnetometer data without any corrections.





As you can see, from the magnetometer plot, there is presence of hard and soft iron effects. This data is to be corrected for those effects. But even before correcting for these effects, we need to understand that there might be presence of elevation and banking angle. So, to correct those we need to estimate those angles as per below.

1.1 Elevation

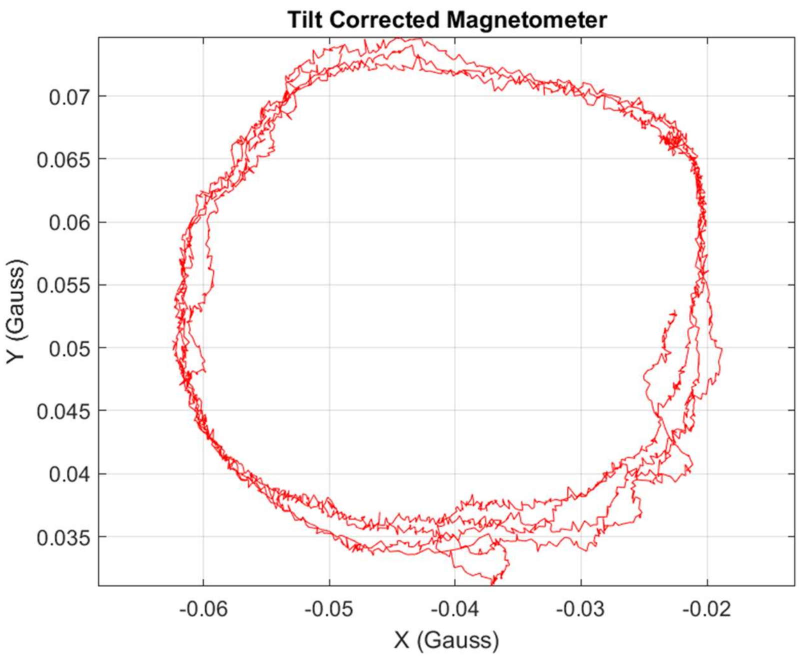
Elevation is defined as the angle formed between the x axis and the horizon/ground.

It is calculated by tan inverse of mean of linear acceleration in X direction and Z direction

1.2 Bank angle

Bank angle is defined as the angle formed between the y axis and the horizon/ground. Gravity exerts a constant acceleration of 1 g, which may be used to calculate elevation and bank angle.

It is calculated by tan inverse of mean of linear acceleration in Y direction and Z direction.

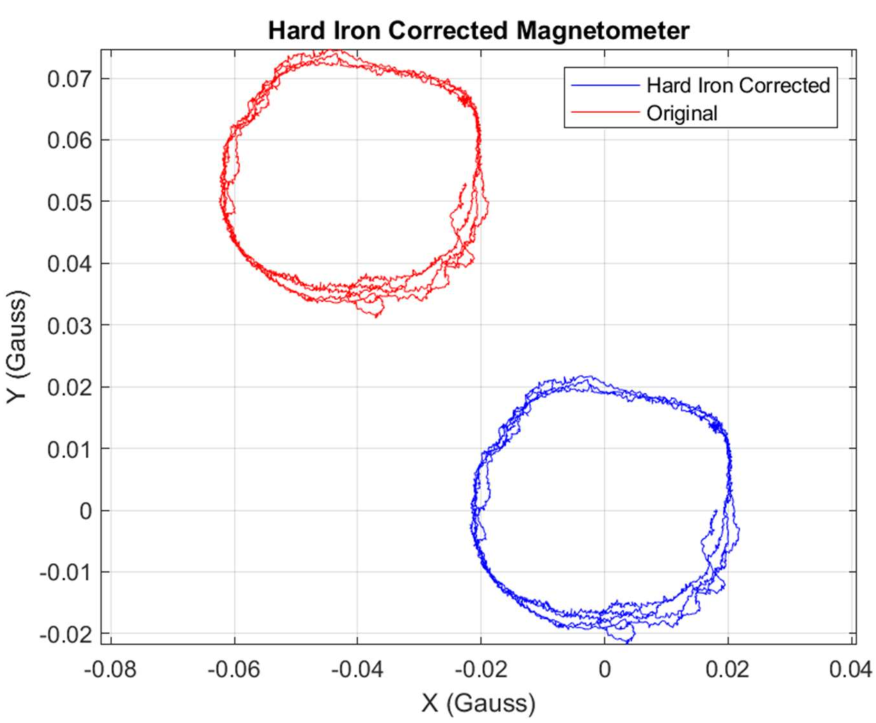


From the above picture, as you can see there is not much change in the magnetometer readings. This proves that there is no much effect of elevation and banking angles. This is because the sensor was placed on a horizontal plane.

Now we can proceed to hard iron correction.

1.3 Hard Iron Correction

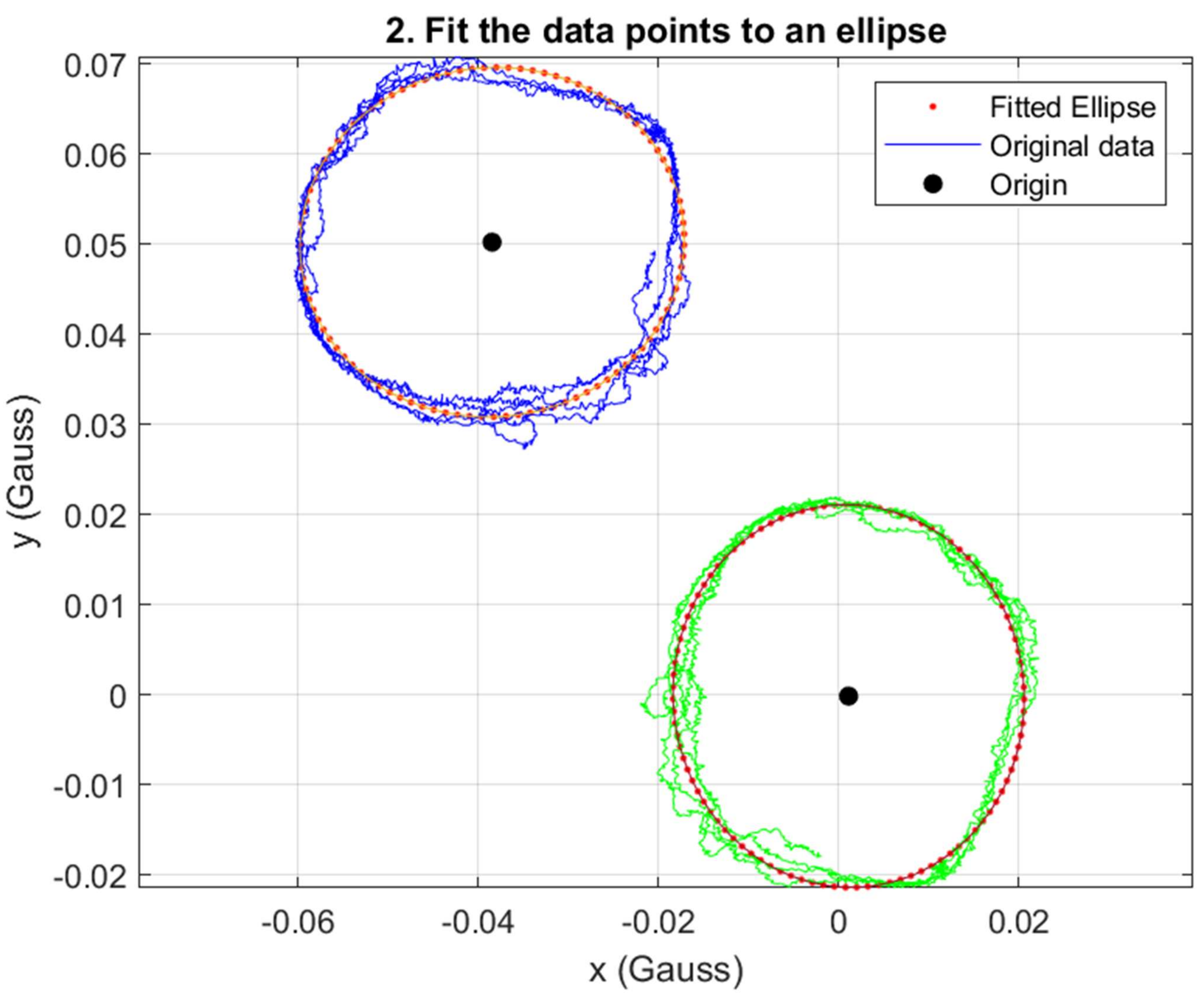
Hard-iron distortion is produced by materials that exhibit a constant, additive field to the earth's magnetic field, thereby generating a constant additive value to the output of each of the magnetometer axes. A speaker magnet, for example, will produce a hard-iron distortion. As long as the orientation and position of the magnet relative to the sensor is constant the field and associated offsets will also be constant. A hard-iron distortion can be visibly identified by an offset of the origin of the ideal circle from (0, 0), as shown in the figure below.



From the above figure the corrected data has a circle centered at almost (0,0). We can now say that we have accounted for hard iron effect.

1.4 Soft Iron Correction

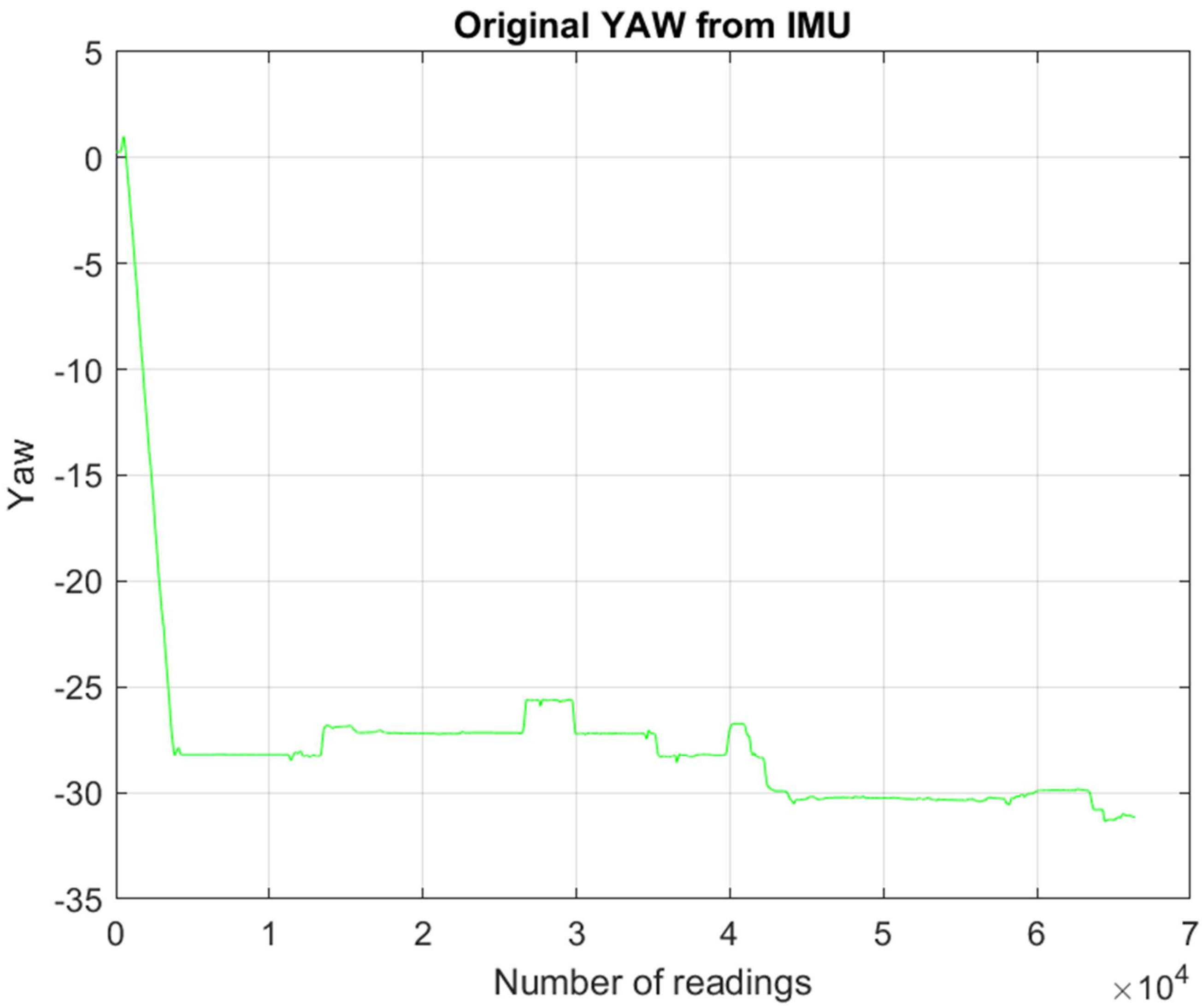
Unlike hard-iron distortion where the magnetic field is additive to the earth's field, soft-iron distortion is the result of material that influences, or distorts, a magnetic field—but does not necessarily generate a magnetic field itself, and is therefore not additive. Iron and nickel, for example, will generate a soft-iron distortion. While hard-iron distortion is constant regardless of orientation, the distortion produced by soft-iron materials is dependent upon the orientation of the material relative to the sensor and the magnetic field. Thus, soft-iron distortion cannot be compensated with a simple constant; instead, a more complicated procedure is required.



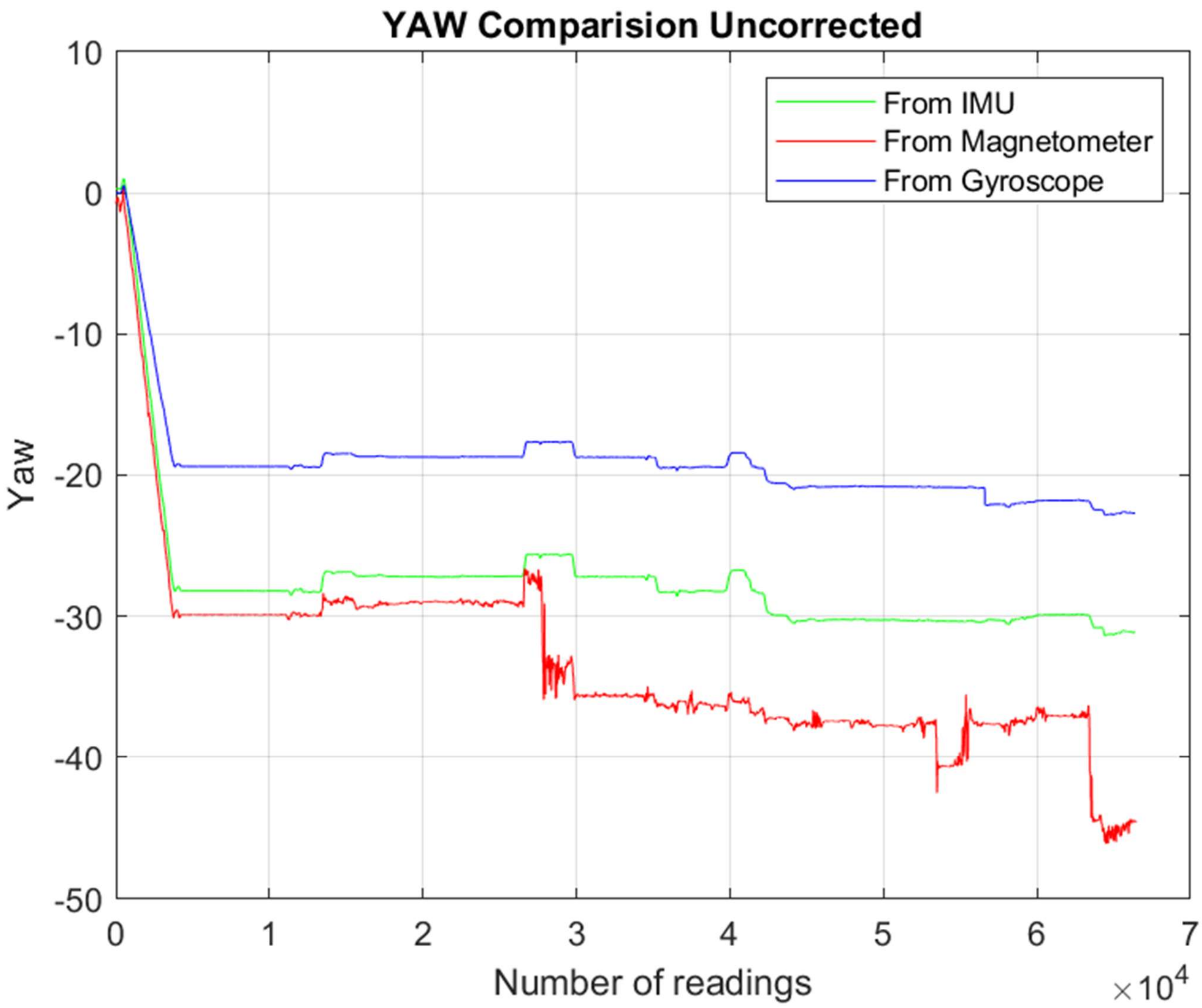
Fitting an ellipse into the data will give us a better insight on the soft iron corrections. As you can see the green plot is the soft and hard iron corrected data which is centered at almost (0,0) and the fitted ellipse is almost circular. This proves that out data is free from hard and soft iron effects.

2. Yaw Calculations

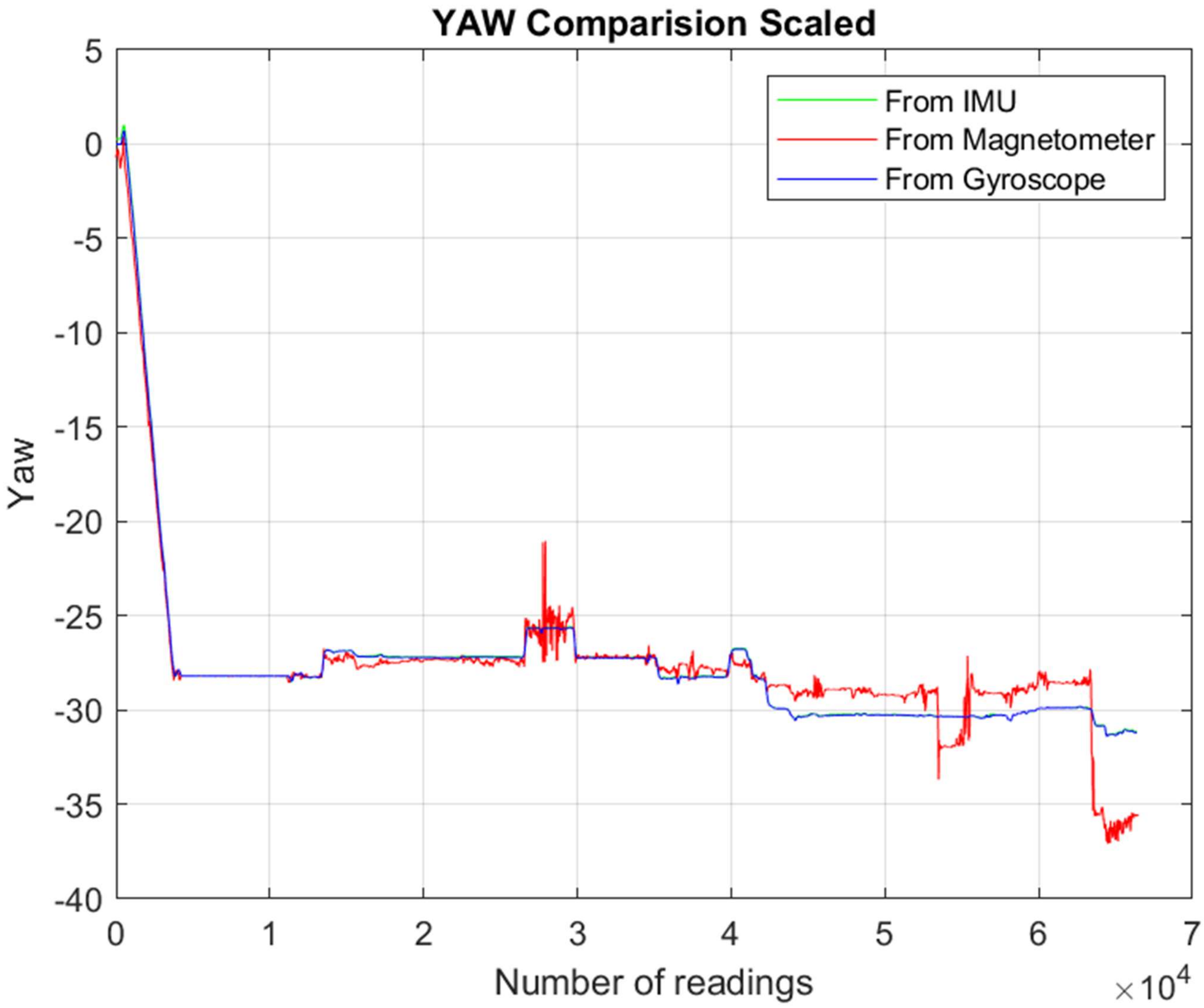
IMU sensor gives YAW data by corrected hard iron and soft iron effects and compensating other noises. Our aim is to model match this data as accurately as possible to validate our analysis.

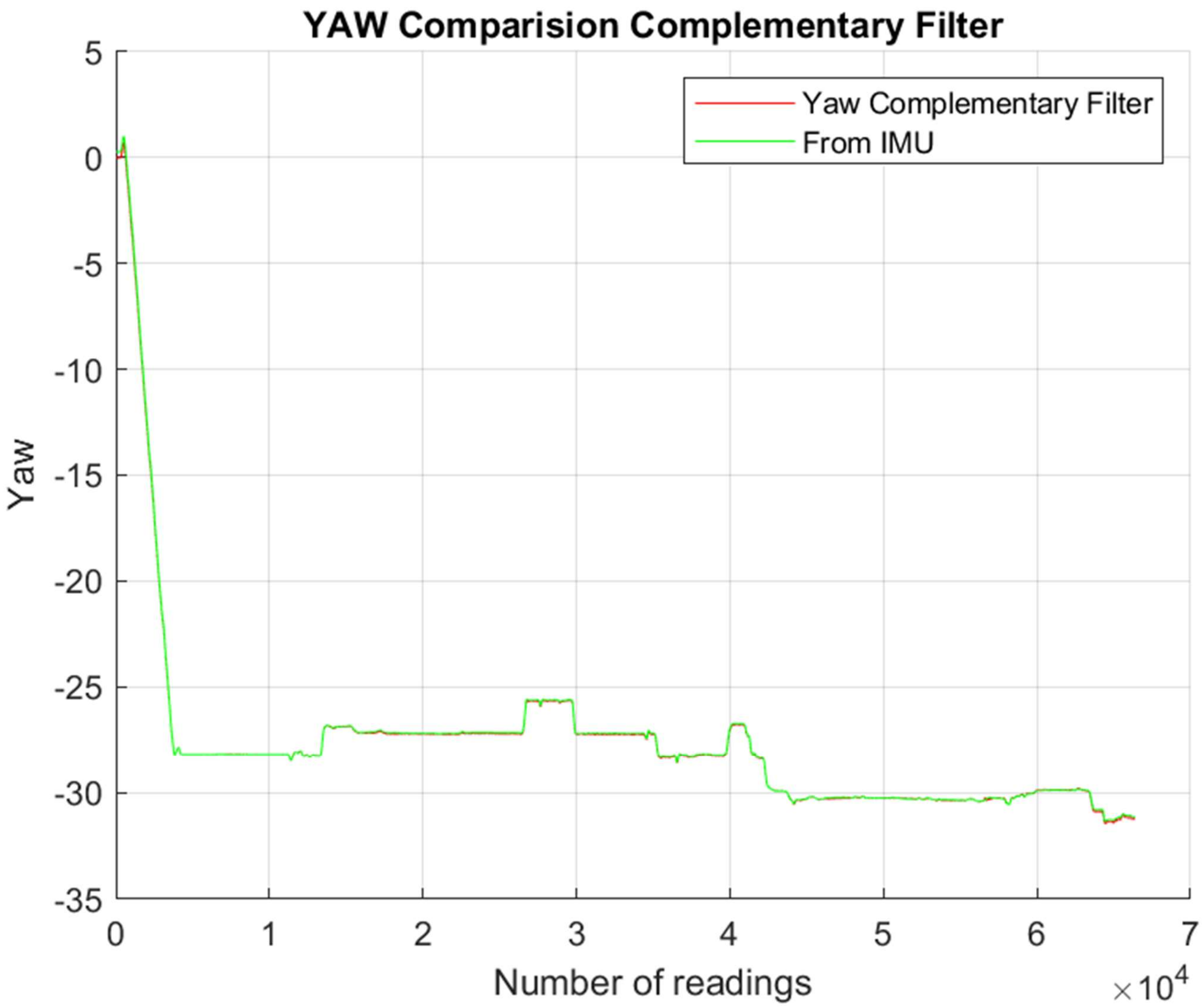


Using the above yaw as reference, we calculate yaw from magnetometer and gyroscope.



From the above picture we can see that the magnetometer and gyroscope are following the pattern close to the actual yaw data but the data needs to be scaled. After applying a scaling factor in the data, they tend to follow the actual data as shown below.

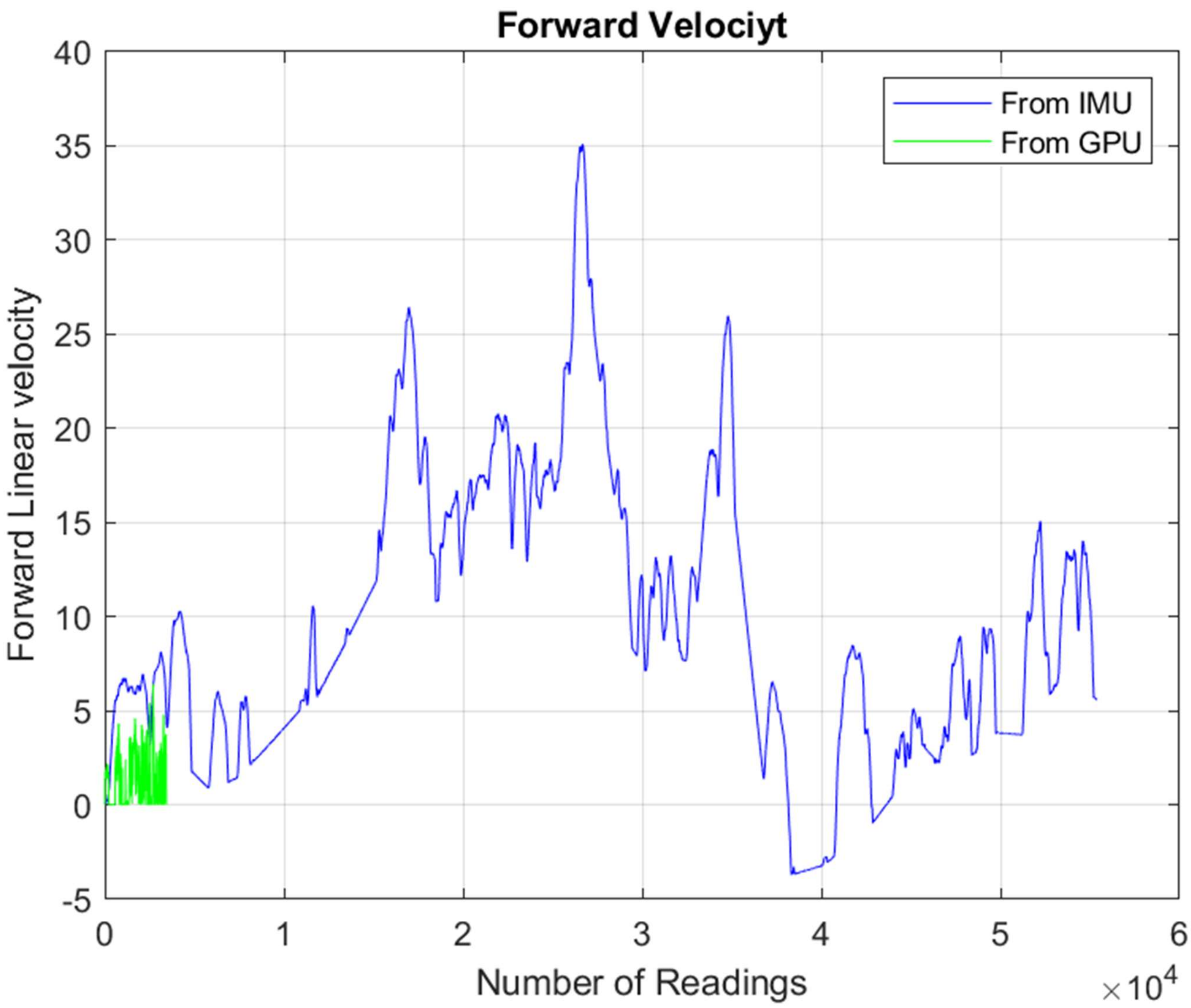




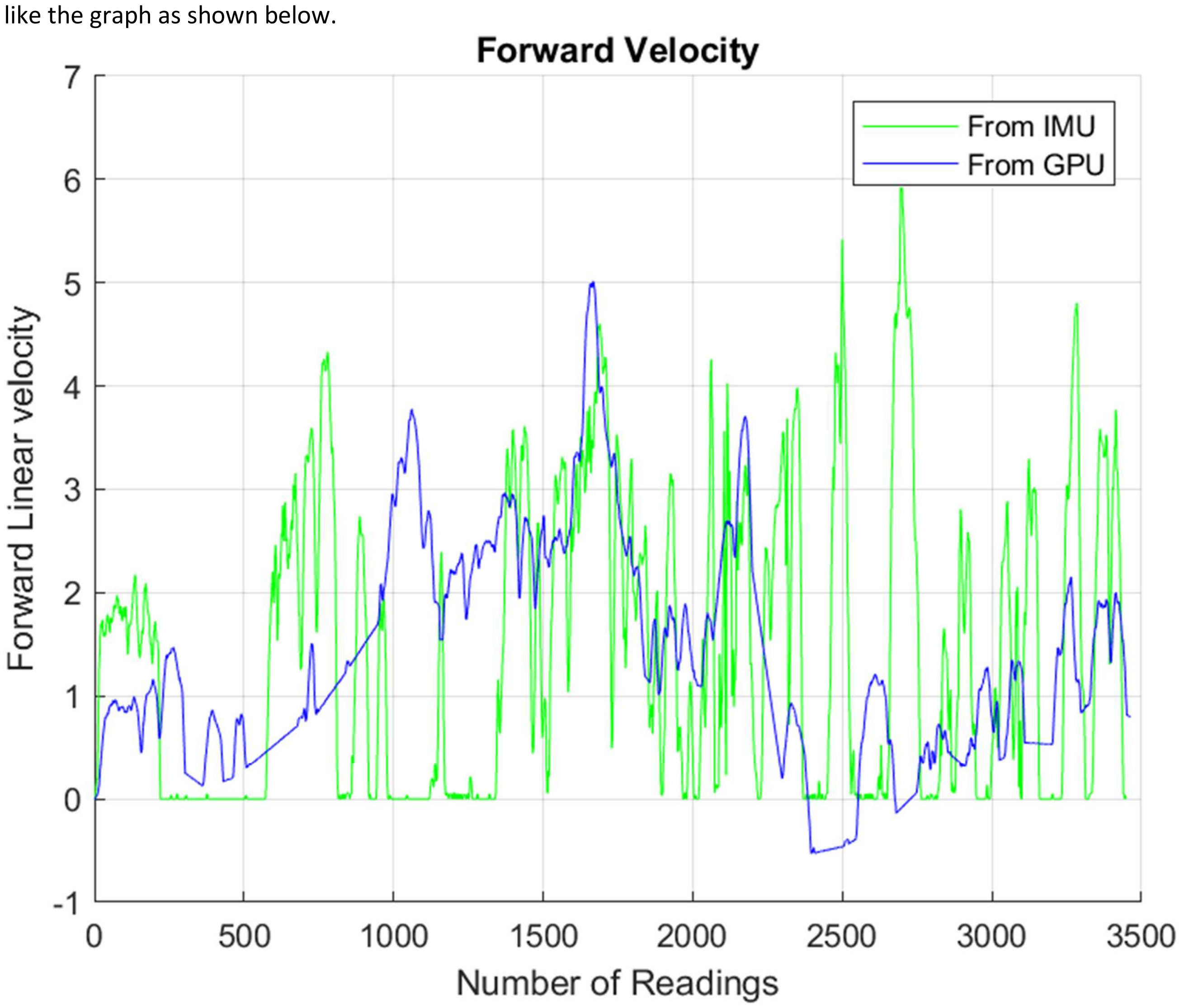
After applying a complementary filter with a combination of both corrected magnetometer data and gyroscope data, It completely matches with the data

3. Forward Velocity Estimation

The forward velocity is estimated by integrating the linear acceleration in the direction of heading with respect to the time.

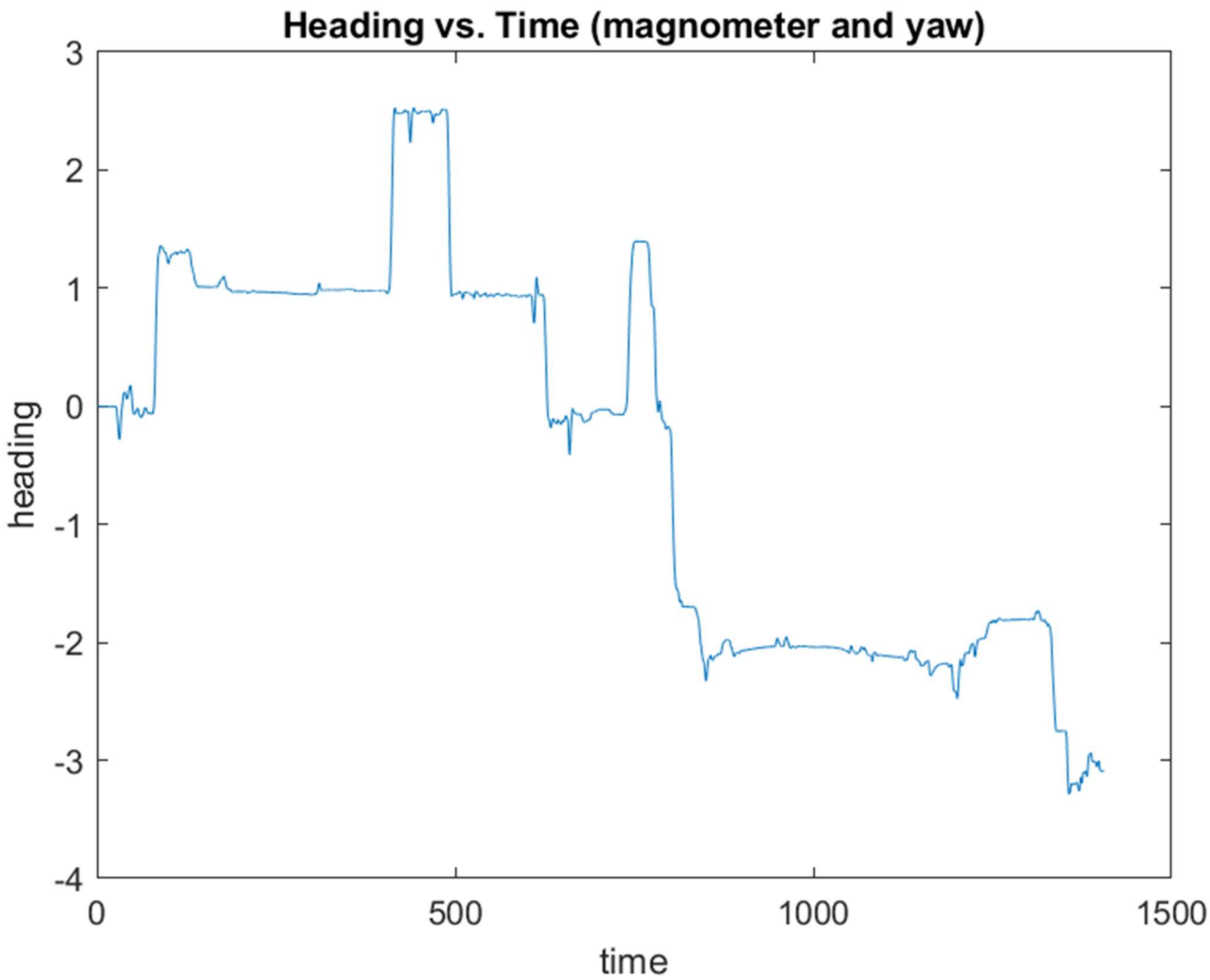


AS you can see that the scale of both readings is highly offset. This is because the difference in sampling rate in both sensors. IMU has a sampling rate of 40 where as GPS has only 1.This is why there is difference scale of both readings. Bringing them both to a single scale with compensation of velocity scale too, will looking like the graph as shown below.



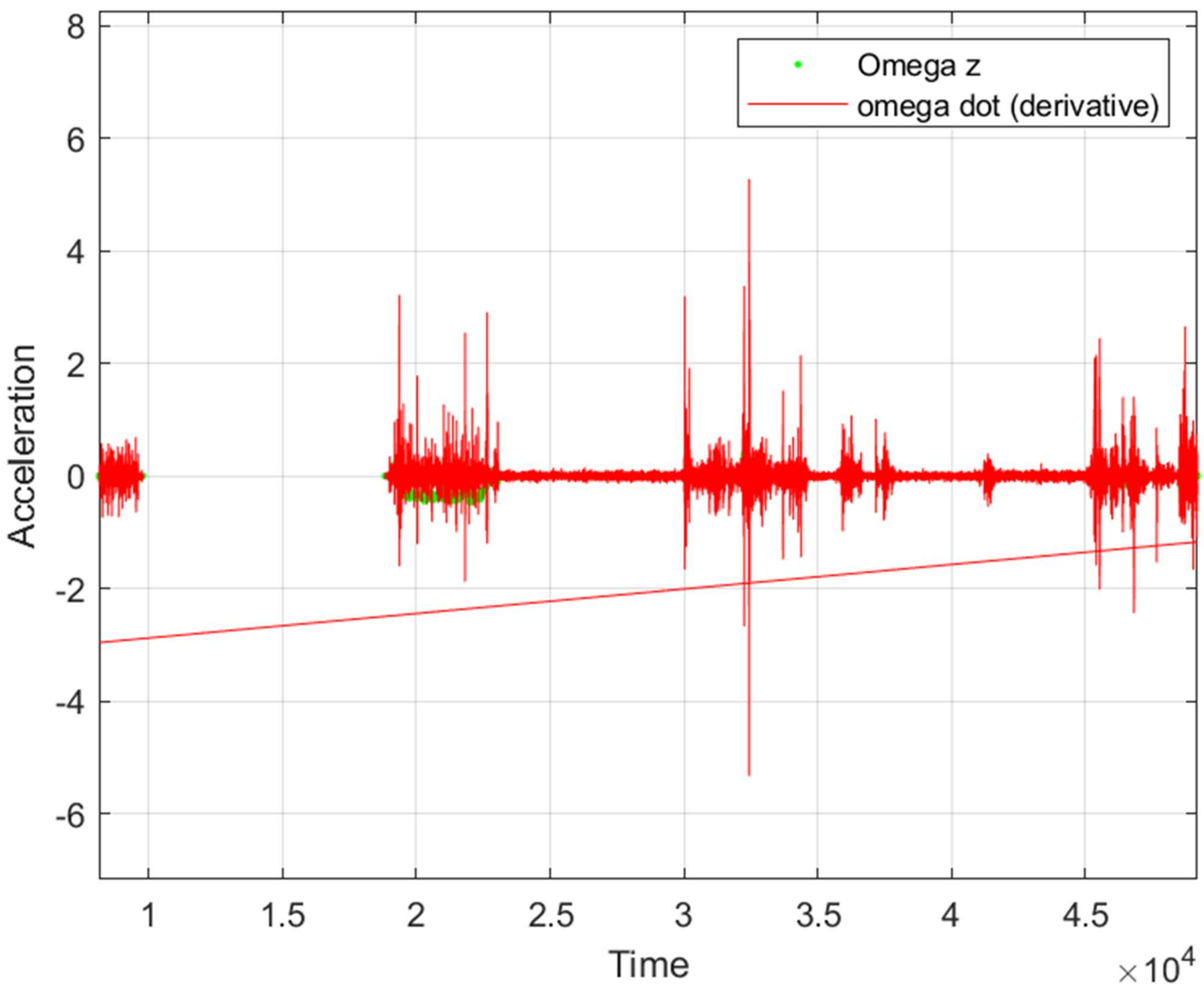
4. Dead Reckoning

Plotting the heading in with respect to time will give us an estimate of the travel.



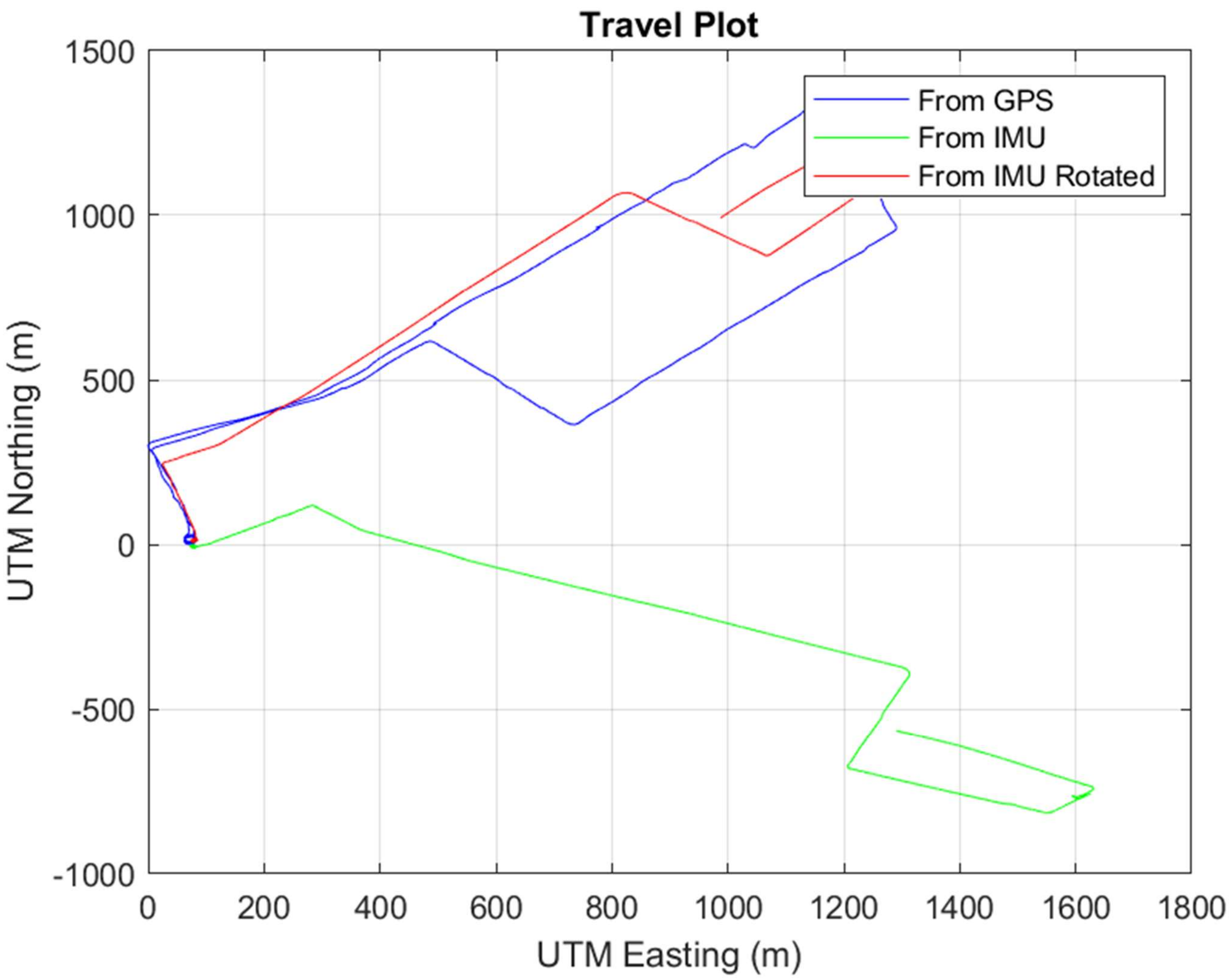
a. Omega x Dot and Y Double Dot

We see that both the Omega X Dot and the Y Double Dot have a similar trend but the y double dot data is very noisy as we have considered the xc to be zero but the factual xc is at a different physical location an hence a bias can be seen. The noise can be attributed to the vibrations the sensor feels as well as some movements in the wire connected to the sensor and being disturbed by the car moving as well as by human error. Even though that’s the case the avg accl comes to be about 0 which is correct and the y double dot follows the trend similar to omega x dot.



b. Compare IMU and GPS Trajectory.

From the above graph it can be seen that the displacement calculated from IMU data and GPS data is very similar in the beginning but as the integration increases the graph starts to create a bias after the first 90_0 turn leading to an offset. The data is rotated to apploximately 90 degrees anticlockwise to match with the gps data. The Magnetometer filtered data and imu filtered data gave us a final yaw which was used to estimate this position.



5 Estimate $\boldsymbol{xc}$

The estimated distance between inertial sensor and the CM point is xc. To better estimated the x_c value, we can calculate the mean value of x_c at time period 115 second to 120 that the car is moving at a nearly constant velocity during this period. $mean$ (xc115: xc120)= +0.776 m=+77.6 cm
The estimated distance I got is 77.6 cm, which is reasonable.