REPORT

In this lab we are using 2 different sensors- GPS and IMU to build a navigation stack and trying to understand how it works. Here we placed the IMU sensor in front of the autonomous car dashboard and the GPS sensor on the top of the car and started collecting data. We first made 4-5 circles around the roundabout near Ruggles T-station and went on a fixed path and returned to the starting point, to analyze the IMU and GPS data.

The first part is to find the heading (yaw angle) of the data: -

We first plotted the data of the magnetometer readings that was taken when we were going in a circle near Ruggles T-station. As you can see from fig 1(a), the original magnetometer reading has some errors in it.

The first step of removing this error is hard iron correction, it is done by subtracting the x and y offset from the original data. The hard iron corrected data is shown in fig 1(b). As we can see from the graph, the offset has been removed. The next step is soft iron correction. For this we first must rotate the elliptical plot in such a way that the major axis is of the ellipse lies on the x-axis, after this we must scale it into a circular form. For this we are diving the major axis with the ratio of major axis and minor axis, i.e.,

$$gama = \frac{major\ axis}{minor\ axis}$$

The soft iron corrected plot is shown in fig 1(c). From the graph we can see that the plot is properly rotated and scaled into a circle like form.

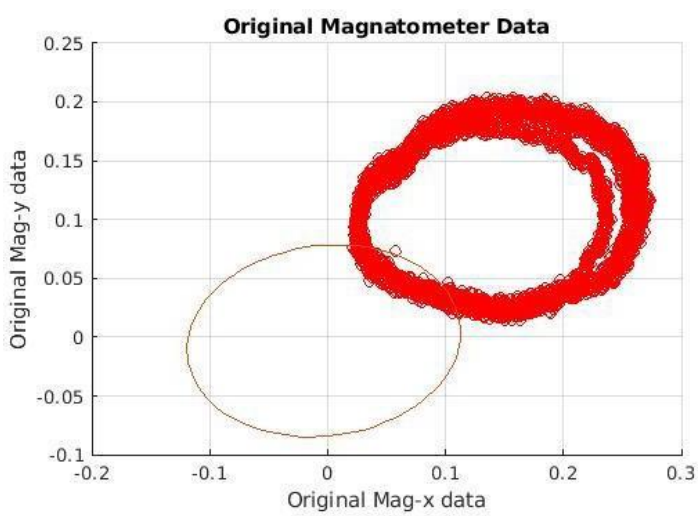

Fig 1(a)

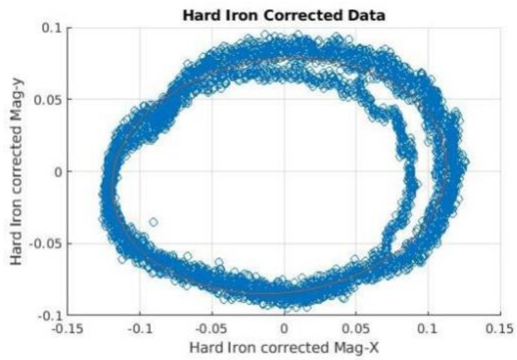

Fig 1(b)

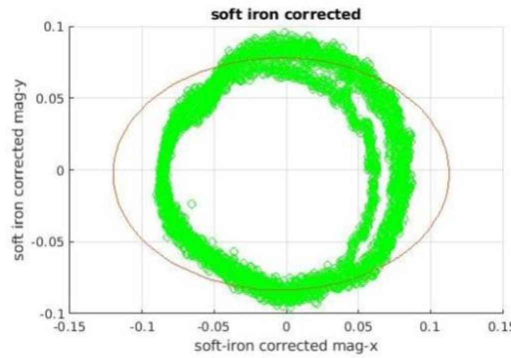

Fig 1(c)

From this corrected magnetometer data, we take the correction values to correct the entire data plot. After doing that, we find the yaw angle of the entire magnetometer data. Fig 2(a) shows the plot of yaw angle of corrected magnetometer. However, from the plot we can observe that there are lot of noise components present in the data. However, from fig 2(b), plot of yaw angle from gyroscope measurement, the plot is very smooth, and it does not have any noise component, but it has some drift in the plot.

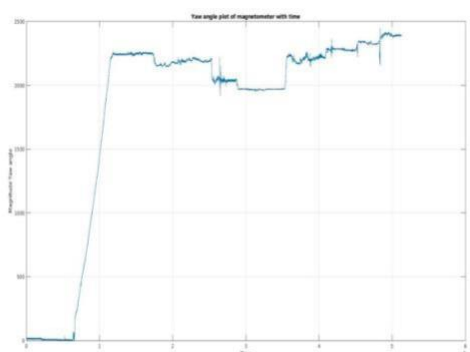

Fig 2(a)

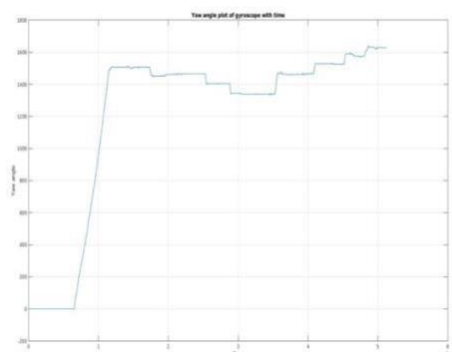

Fig 2(b)

To remove the noise from the magnetometer data plot, we pass the that data through a low-pass filter and gyroscope data through a high-pass filter and adding these two filters to get a complimentary filtered output. Fig 2(c) shows the plot between complimentary filtered data and the yaw angle calculated from orientation. The overall trend of the plot is very similar and especially in some points the plot is very consistent to the IMU data plot. These are the points where the car stopped due to red signal, showing that the magnetometer and gyroscope data are accurate during these moments.

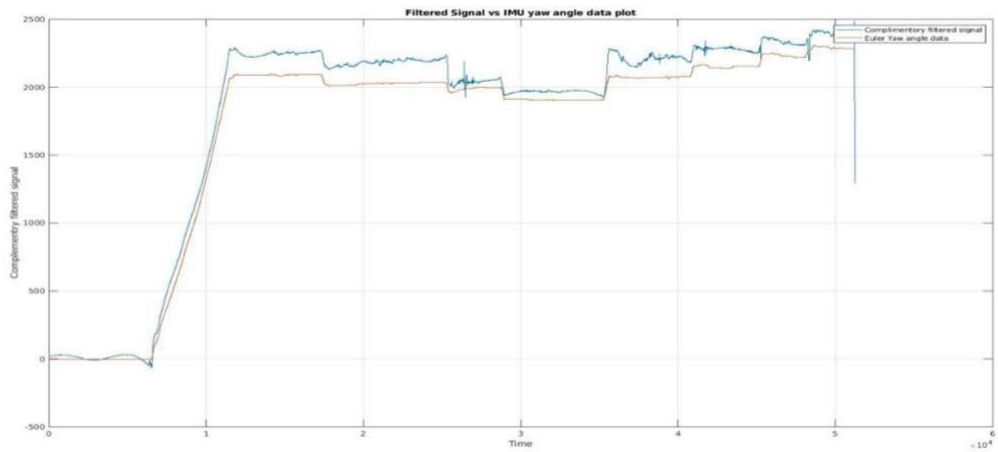

Fig 2(c)

The second part is to estimate forward velocity: -

We first integrate the linear acceleration data in the x coordinate to get the linear velocity. The plot for that is shown in fig 3(a), from this plot we can observe a lot of noises present in the plot when compared with the plot of estimated velocity from the GPS data as shown in fig 3(b).

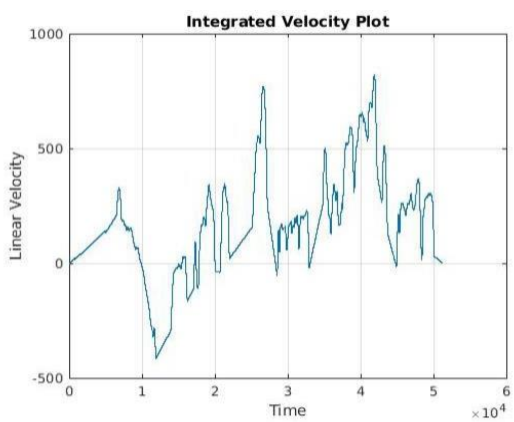

Fig 3(a)

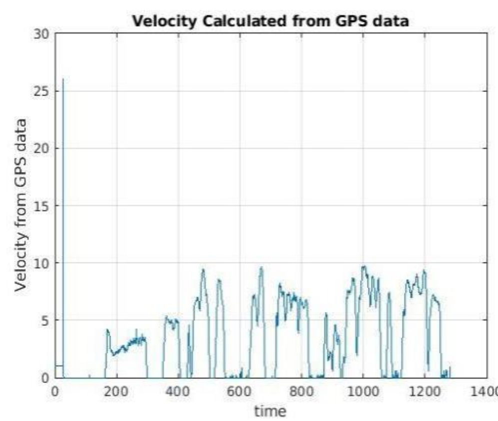

Fig 3(b)

We need to make some adjustments to the accelerometer data to get a proper forward velocity. In the original accelerometer data, there were lot of high frequency noises present, even when we were in a stationary point, there was noise present in the data. At the time stamp 10000 sec – 11190, you can see that the graph has a negative slope when we applied brake. These error values are removed by the following method,

- First, we find the data point range on which we wish to make the correction.

- Second, we find the mean value for that range of values and subtract it from the original data.
- This subtracted result gives us the corrected accelerometer data as shown in the below fig 3(c)

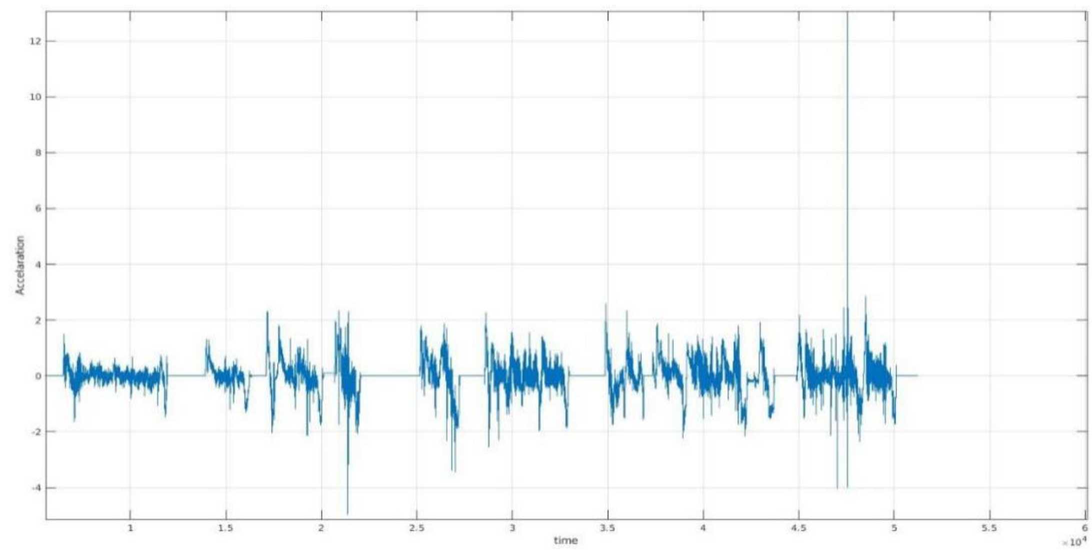

Fig 3(c)

From this corrected, we integrate it to get the forward velocity. When we compare it with the estimated velocity the values are more reasonable and closer to the true value. The overall trend is very similar to the GPS estimate. The corrected linear velocity plot is shown in fig 3(d)

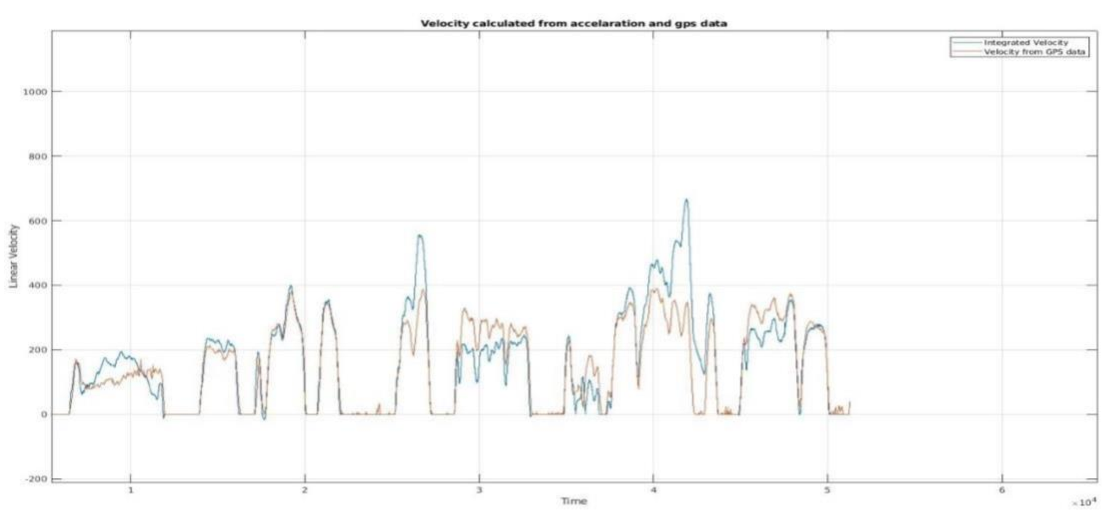

Fig 3(d)

The final part is dead reckoning – To integrate IMU data for obtaining displacement: -

In the first stage we must compute $y''_{org} = \omega * X'$. Where it assumed that there is no skidding of the vehicle and to ignore the offset value. The below fig 4(a) shows the plot between $\omega * X'$ and linear acceleration in y coordinate. As we can observe the overall trend of the multiplied value is like that of the linear acceleration value. However, the acceleration value measured by the IMU is very noisy, as we can observe many fluctuations throughout the time.

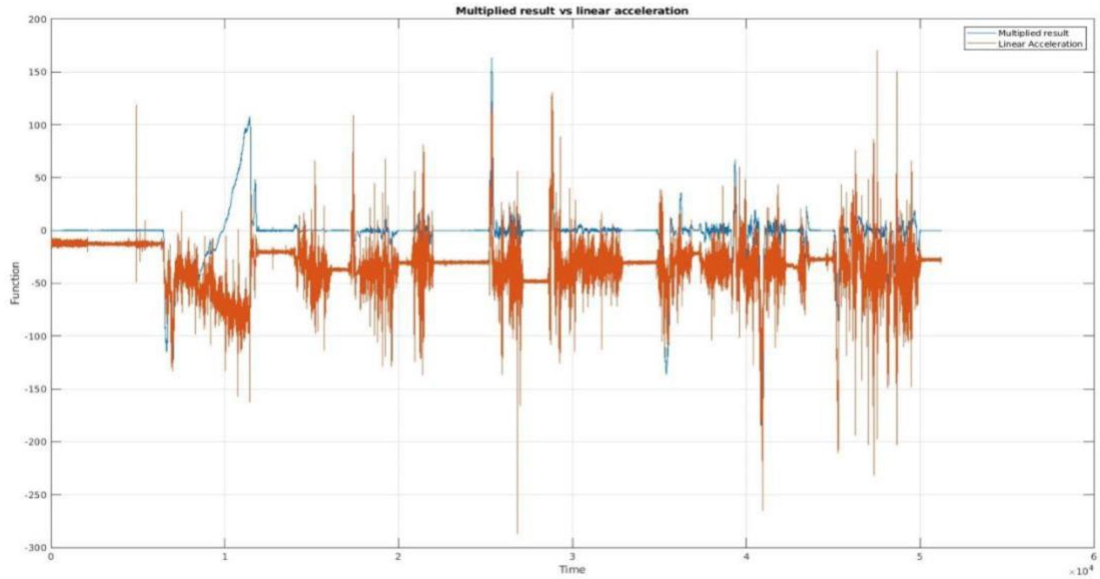

Fig 4(a)

The next step is to use heading from the magnetometer to rotate it to a fixed reference frame. Here to calculate the linear displacement we multiple the corrected linear velocity with the yaw angle of the IMU data and integrating it. The resultant output will not be proper as shown in fig 4(b). We need to rotate the plot to compare it with the GPS data. We use the rotation matrix from the first part to rotate the integrated output.

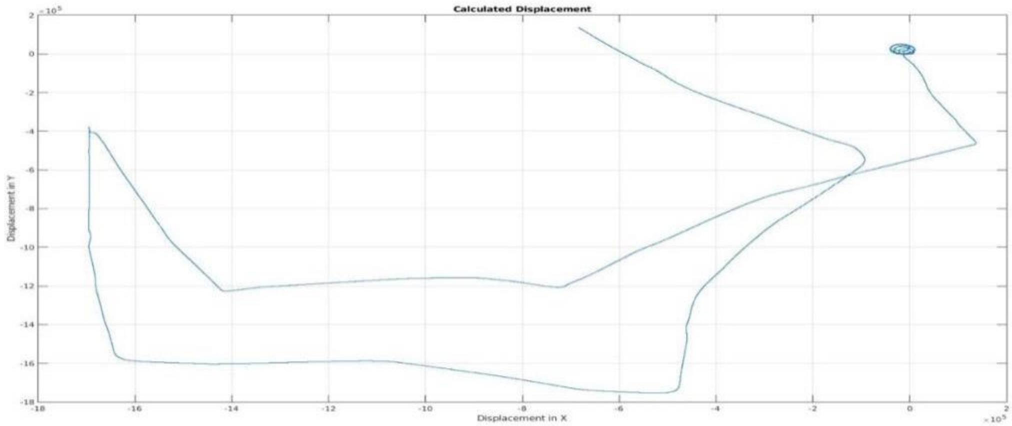

Fig 4(b)

From the fig 4(c) and fig 4(d) we can see that the rotated output is almost like the GPS output data.

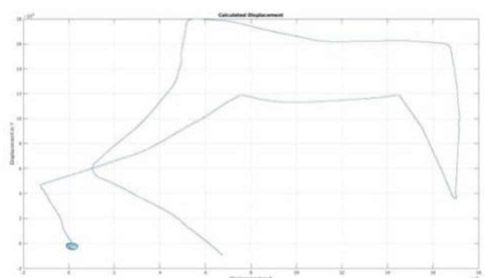

Fig 4(c)

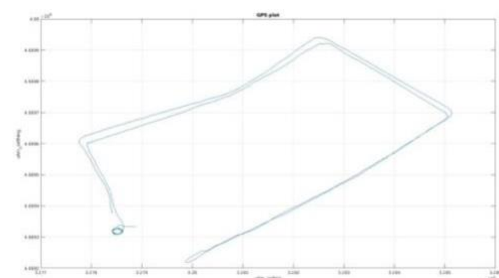

Fig 4(d)

When we compare the two plots the circle data then the like moving straight from it then turning right, and then turning right twice again is similar with the calculated plot. The other directions are also similar but shifted, this may be because of the yaw angle from the magnetometer.

The final task is to estimate the distance between the inertial sensor and center of mass of the vehicle. To estimate the xc value, I first calculate the mean of linear acceleration along y axis to reduce error.

$$xc = (mean(Linear\ acceleration(y - axis)) - (\omega * X'))/X'$$

The estimated distance was found to be +6.25cm