EECE: 5554; Robot Sensing and Navigation
Lab 4

Dhruv Bansal

Magnetometer Calibration:

Before calibration:

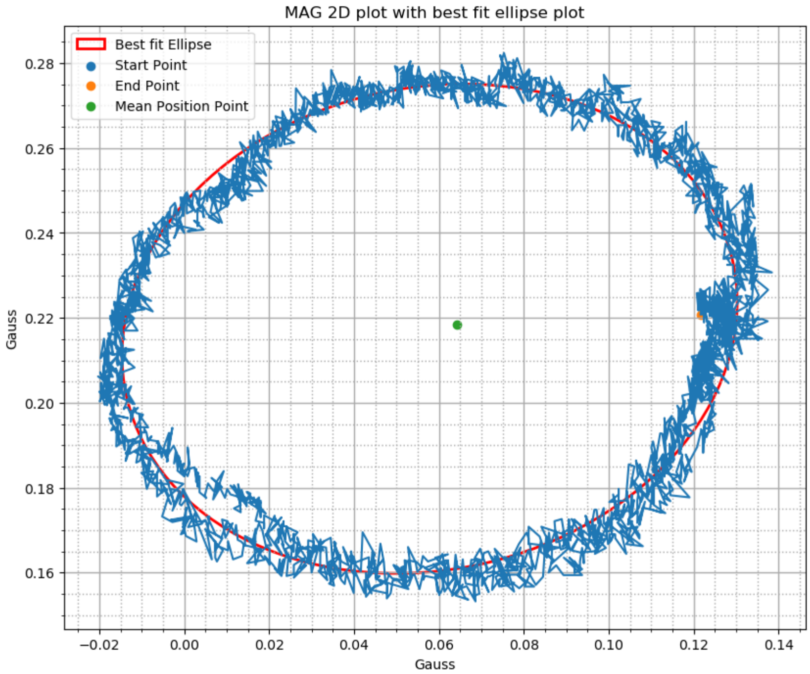

Figure 1

After Calibration:

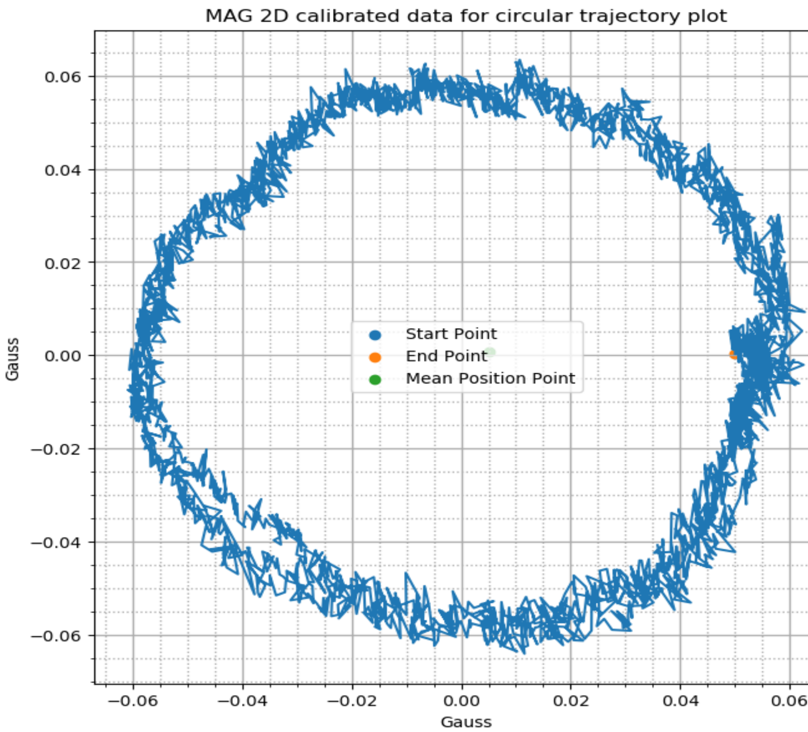

Figure 2

Question: How did you calibrate the magnetometer from the data you collected? What were the sources of distortion present, and how do you know?

Answer:
The magnetometer data was calibrated by applying transformations using HI and SI values. At first, the ellipse parameters were calculated using SVD methods which are then used to calculate HI and SI parameters which are then used to calibrate the magnetometer data.
The following are the SI parameters obtained:

```
[[-0.75737652 -0.16957336]
 [ 0.21848639 -0.97584   ]]
```

The following are the HI parameters obtained:

```
{'x': 0.05778209908687602, 'y': 0.21744583827422928}
```

While collecting the data using the NUANCE car, there were a lot of electronic devices which emit magnetic fields such as laptops, mobile phones etc. which do cause Soft Iron distortions, where as for Hard Iron distortions can be caused by presence of permanent magnets which are widely present in cars in power windows, power seats, power steerings etc. which can be responsible for Hard iron distortions.

Sensor Fusion

Yaw Estimate:

The following figure 3 is the plot of Yaw estimate using the formula:

$$yaw_{mag} = tan^{-1}\left(\frac{-mag_y}{mag_x}\right)$$

“Yaw Mag Raw” is the calculation using mag_x and mag_y with calibration and “Yaw_mag_corrected” is the calculation using mag_x and mag_y after calibration using the magnetometer calibration method.

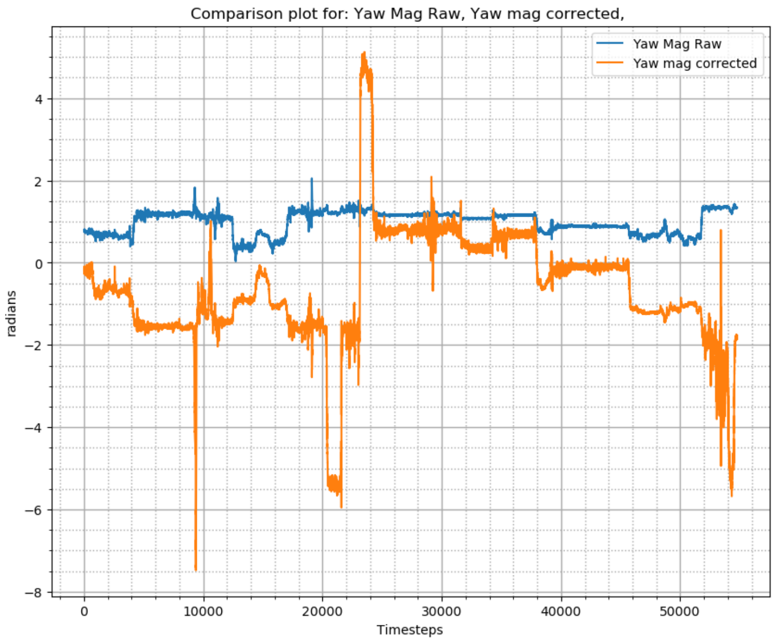

Figure 3

The figure 4 is the comparison plot between the yaw calculated using the integrating yaw rate/gyro from the IMU.

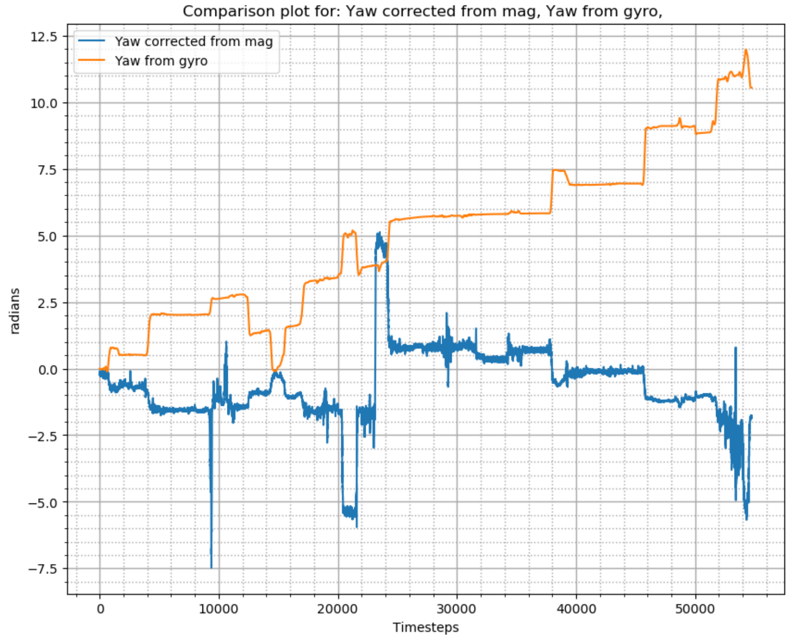

Figure 4

Implementing Complementary Filter:

Question: How did you use a complementary filter to develop a combined estimate of yaw?What components of the filter were present, and what cutoff frequency(ies) did you use?

Answer:

Figure 5 is the plot of data after passing through different filters in the order of: Yaw_{mag} (Yaw from magnetometer after correction) is passed through low pass filter, Yaw from IMU (Yaw_{gyro}) through a high pass filter. Both the values are added together to make it a complementary filter. The LPF coincides with the Complimentary due to which only green plot is visible. The cut-off frequency used was set at "0.05" and "5" and was made of second order.

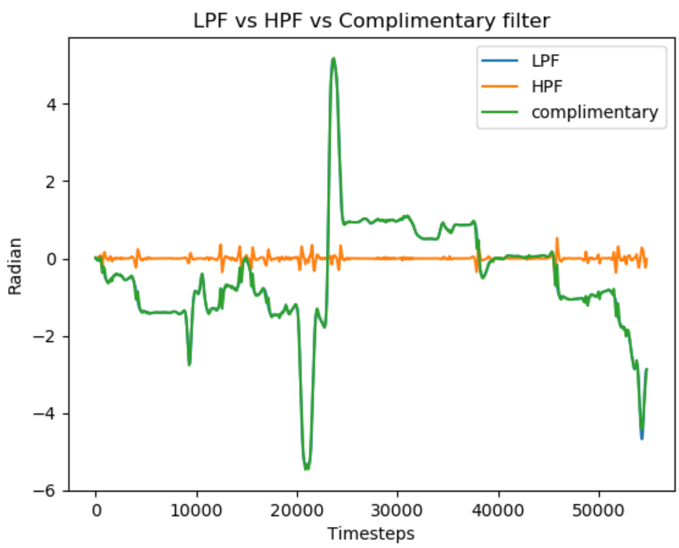

Figure 5

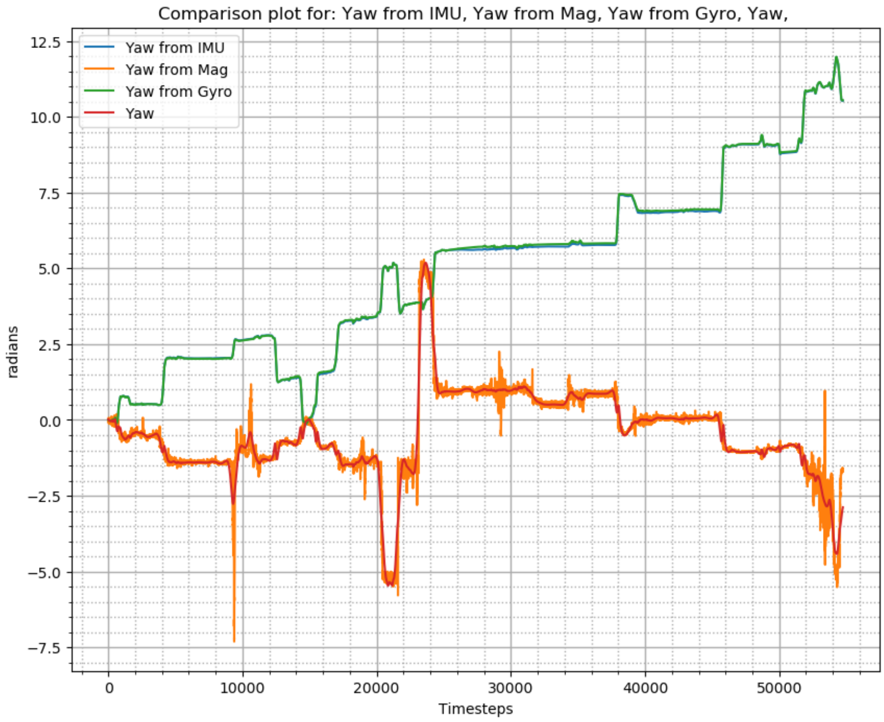

Figure 6

Question: Which estimate or estimates for yaw would you trust for navigation? Why?
Answer:

I would prefer using “Yaw” calculated using orientation x,y,z and w i.e., quaternions to euler or yaw from magnetometer after correction as they are better dealt with frequency outliers rather than the single filter or integration as the bias get added up again and again over time.

Estimate forward Velocity:

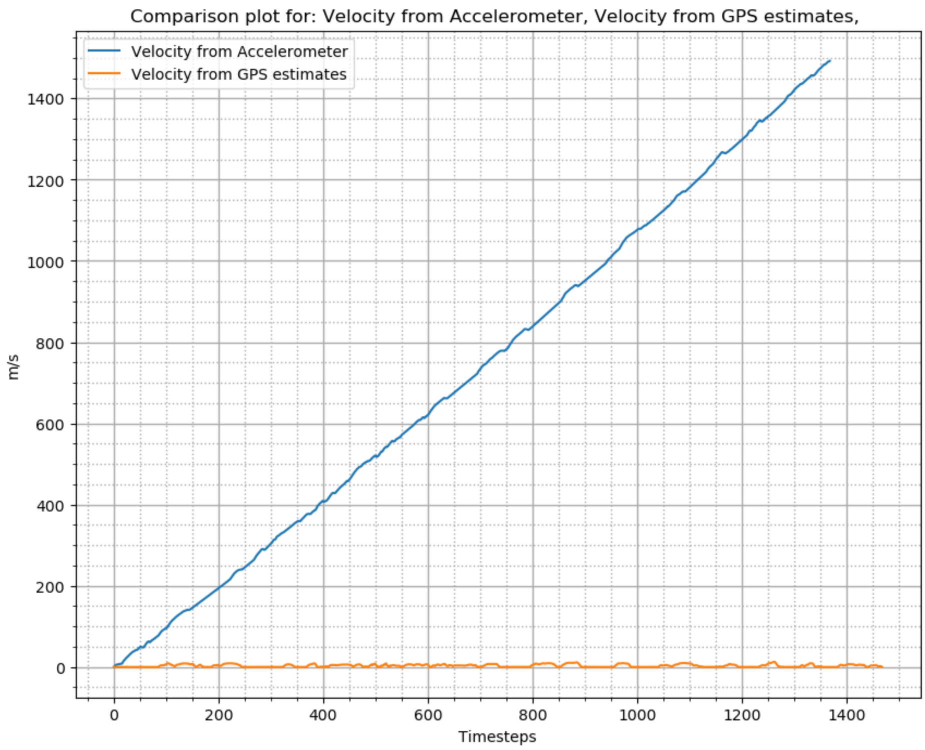

Figure 7

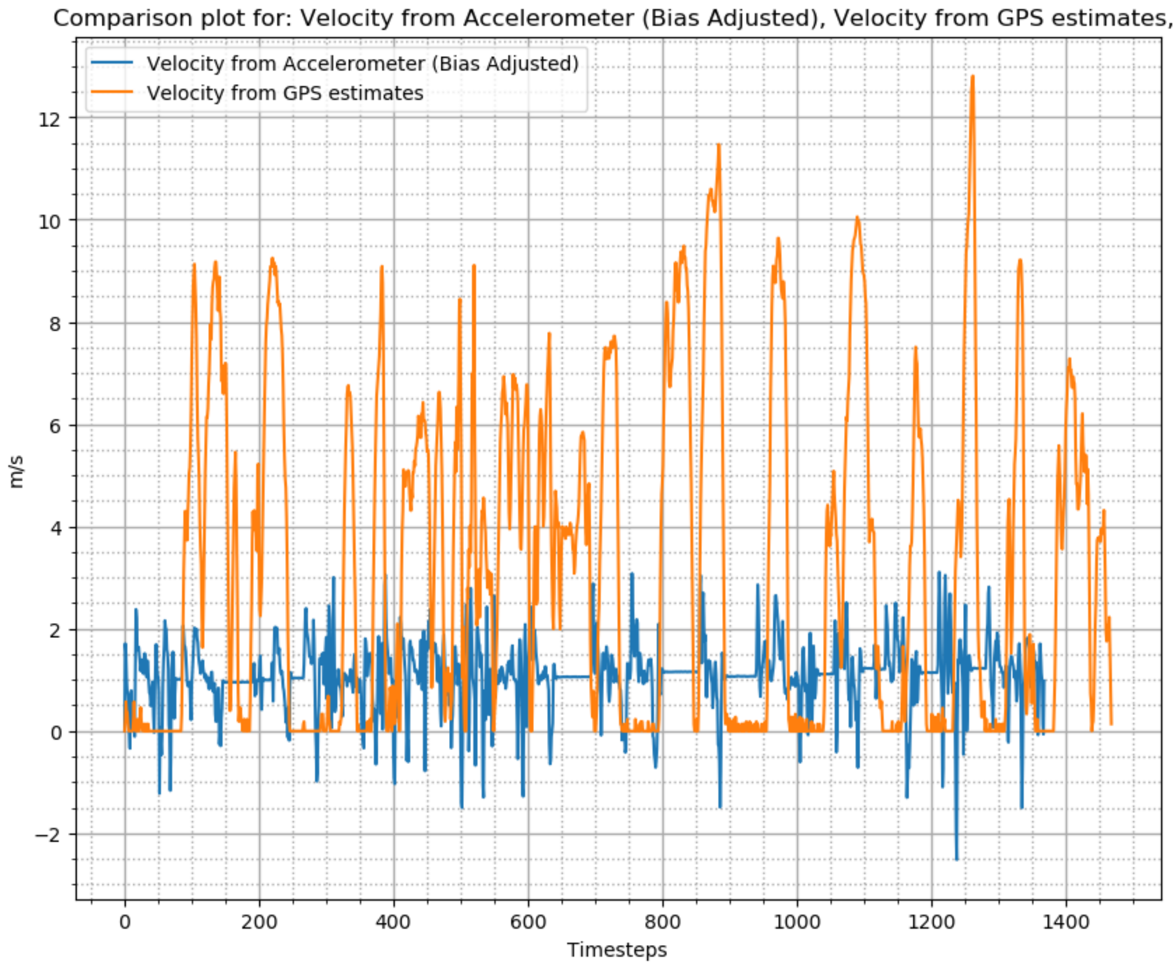

Figure 8

The above plots figure 7 is the comparison between the forward velocity estimate obtained from gps and by integrating the acceleration without any adjustment. Figure 8 is after adding adjustments to the forward velocity estimate from the accelerometer.

Question:What adjustments did you make to the forward velocity estimate, and why?
Answer:
For the adjustments, I calculated the rolling mean over a specific window and subtract that over the values over the time based on a thresholding. The high velocity in figure 7 is due to constant adding up of the bias as we integrate which causes shoot in the velocity.

Dead Reckoning

Question: Compute $\omega\dot{X}$ and compare it to $\ddot{Y}_{abs}$. How well do they agree? If there is a difference, what is it due to?
Answer:
The figure 9 is the plot for the comparison of $\omega\dot{X}$ and $\ddot{Y}_{abs}$. The spikes are the major differences between two which are mostly during making turns as at that point there is not much change in acceleration but ω changes by a lot.

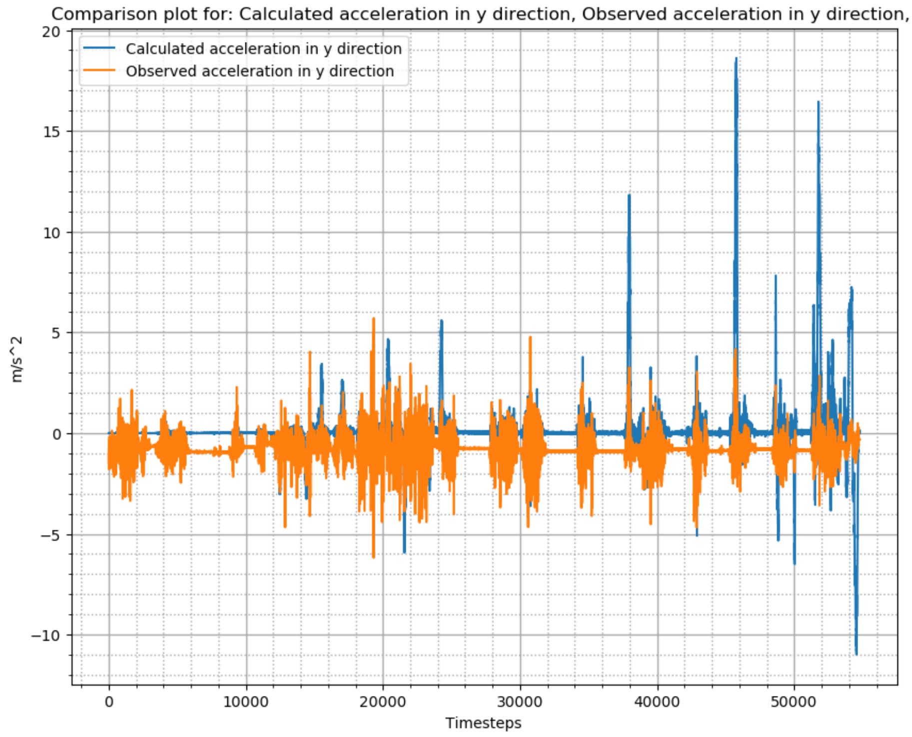

Figure 9

Question:Estimate the trajectory of the vehicle (xe,xn) from inertial data and compare with GPS. (adjust heading so that the first straight line from both are oriented in the same direction). Report any scaling factor used for comparing the tracks.
Answer: Used 0.4 as the scaling factor

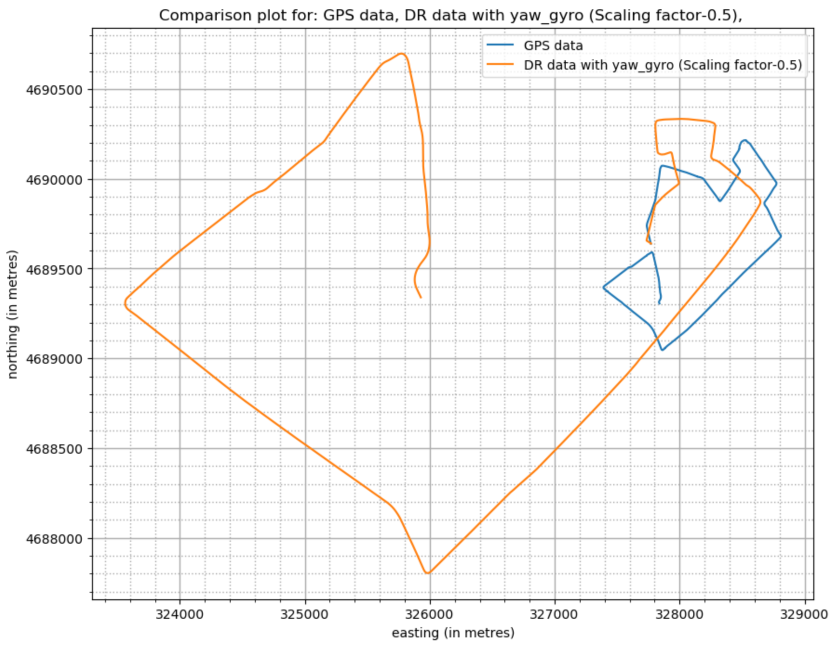

Figure 10

Question: Given the specifications of the VectorNav, how long would you expect that it is able to navigate without a position fix? For what period of time did your GPS and IMU estimates of position match closely? (within 2 m) Did the stated performance for dead reckoning match actual measurements? Why or why not?
Answer: The data is quite correlated with the GPS data as shown in the figure 10. For about 2 minutes the GPS and IMU estimates match closely with each other.

Question: Estimate x_c and explain your calculations (bonus up to 100%)

Answer:

I used the following equation to calculate x_c **:**

$\ddot{Y}$ **=** $\ddot{Y}$ **+** $\omega\dot{X} + \dot{\omega}x_c$

The above equation everything is known except x_c, for $\ddot{Y}$ I have taken that part of data where the car is moving in a straight line i.e., constant velocity which allows us to put $\ddot{Y}$ **= 0.**

Hence, we get x_c, after solving the above equation. We get the following answer.

```
x_c =>  1.1510329230457481
```