Report 4

Aim:

The aim of this assignment is to draw comparisons between the performance of the IMU and the GPS sensor.

Procedure:

The drivers developed in Lab1 and Lab3 are used to extract data from the GPS module and the IMU sensor respectively. Two sets of data is collected in this experiment. The first set of data is collected when the car is driven in a circle. The second set of data is collected as the car is driven through a predetermined route around the city of Boston. Care was taken to make sure that data from the GPS was uninterrupted throughout the entire session. This means that the route chosen should be clear of any subways, bridges or any infrastructure that could attenuate the GPS signals.

Calibration of the Magnetometer:

The first set of data is used to calibrate the magnetometer. The data collected by driving the car in a circle can be used to determine the correction matrix for soft-iron correction and the hard-iron correction values.

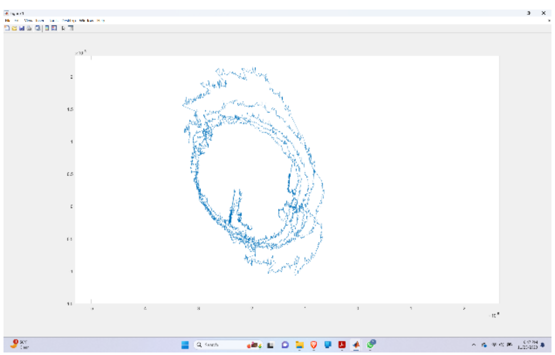

Fig 1.1: X-Y Magnetometer readings(Uncorrected) in milliGauss

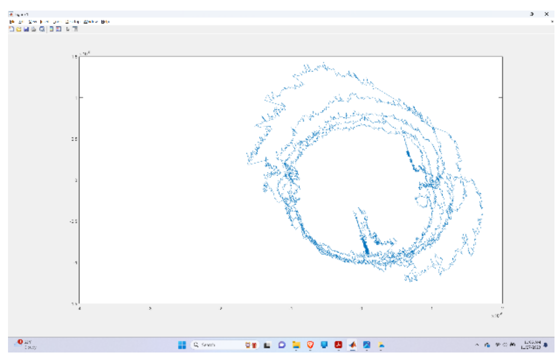

Fig 1.2: Corrected X-Y Magnetometer readings in milliGauss

Soft-Iron Correction:

```
M =

    0.8492   -0.5280         0
    0.5280    0.8492         0
         0         0    1.0000
```

Hard-Iron Correction:

```
K =

   1.0e-04 *

  -0.2014
   0.0545
        0
```

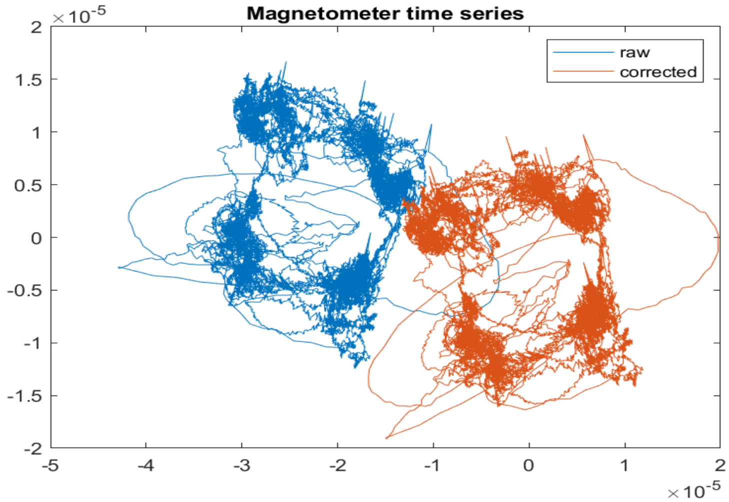

Fig 1.3: Corrected and Uncorrected X-Y Magnetometer readings in milliGauss as time-series data

Extracting the readings from the sensors:

The Gyro, Magnetometer readings and the GPS data from the second data set is used to extract the heading and velocity of the car. To do so, various methods were used and the results of each method is exhibited in the graphs.

Yaw Data:

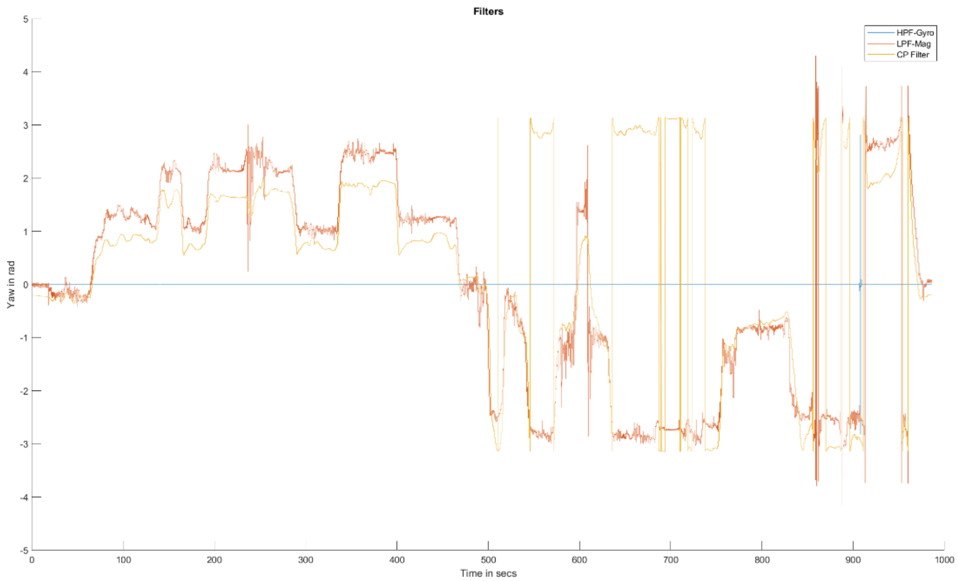

Fig 1.4: Outputs of different filters

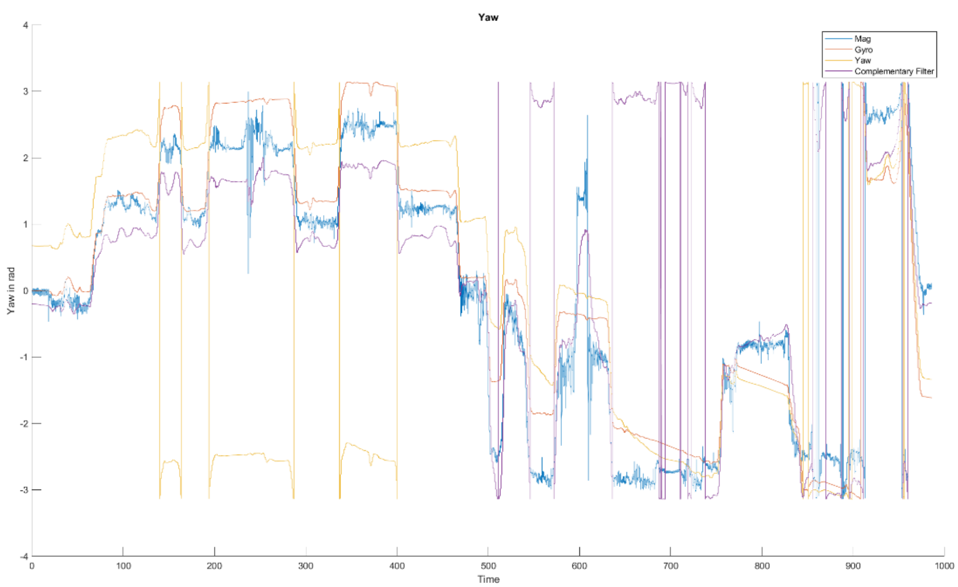

Fig 1.5: Yaw readings

Velocity Data:

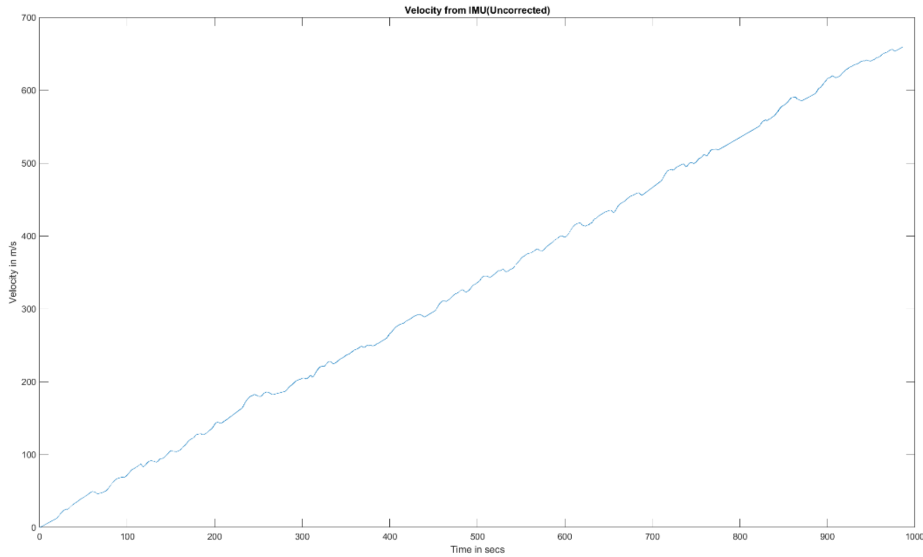

Fig 1.6: Unadjusted IMU readings

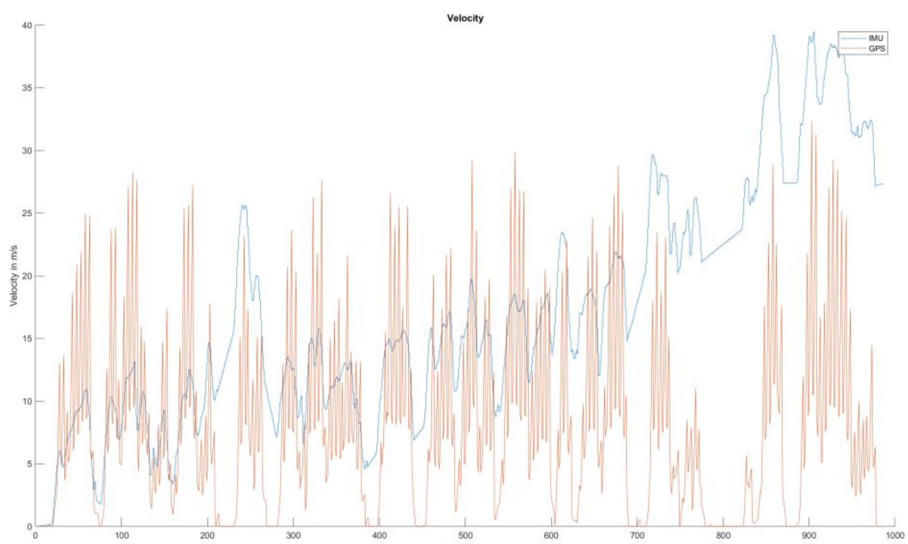

Fig 1.7: Velocity from IMU and GPS

Dead-Reckoning:

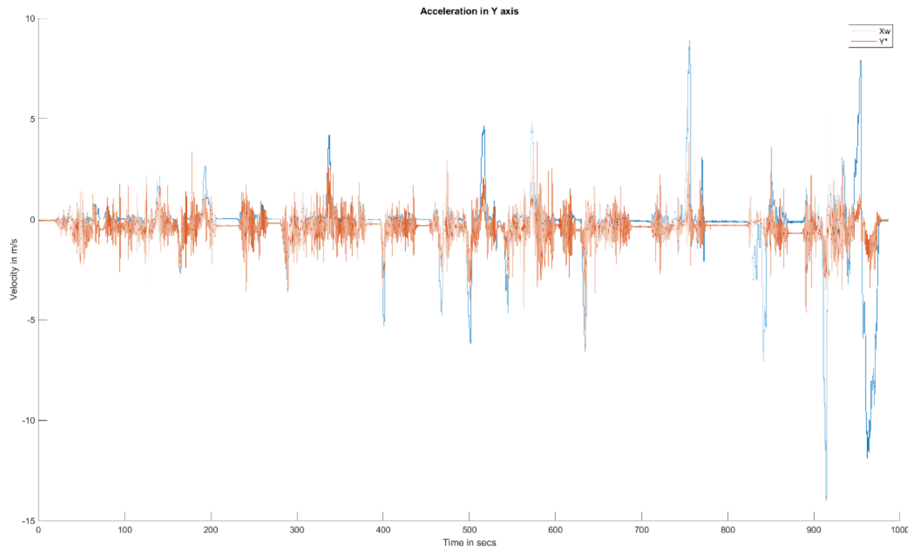

Fig 1.8: Acceleration along Y-axis

Results:

1. The distortions present in the magnetometer readings were hard-iron distortions and soft-iron distortions. Hard iron distortions can be identified by checking if there the center of the circular data is offset. Soft iron distortions can be identified if the circle is distorted. The offset vector is the hard-iron correction while the rotation matrix to align the ellipse's major axis is the soft-iron correction.
2. The cut-off frequency used in this experiment was 2Hz for the High pass filter and 15Hz for the Low pass filter. The complementary filter takes the Gyro data, the accelerometer data and the Magnetometer data as input and gives an estimate of the heading/yaw.
3. From the above graphs, it can be concluded that rather than relying on a sole sensor, fusing multiple sensors provides a better estimate of the current state. Therefore, the estimate from the complementary filter is to be better trusted.
4. The acceleration along X axis is not initially zero, this is probably due to the incorrect calibration for the gravity vector. Hence, before estimating the velocity, the acceleration values had to be normalized using the first acceleration value.
5. It can be noticed that the velocity estimate of using IMU has a drift in the values that builds on and becomes more noticeable as the time progresses. This is caused due to all the minor errors accumulating since velocity is obtained by performing integration.
6. A slight difference can be observed from the graph. This is likely caused by high frequency noise and accumulation of small errors.

7.

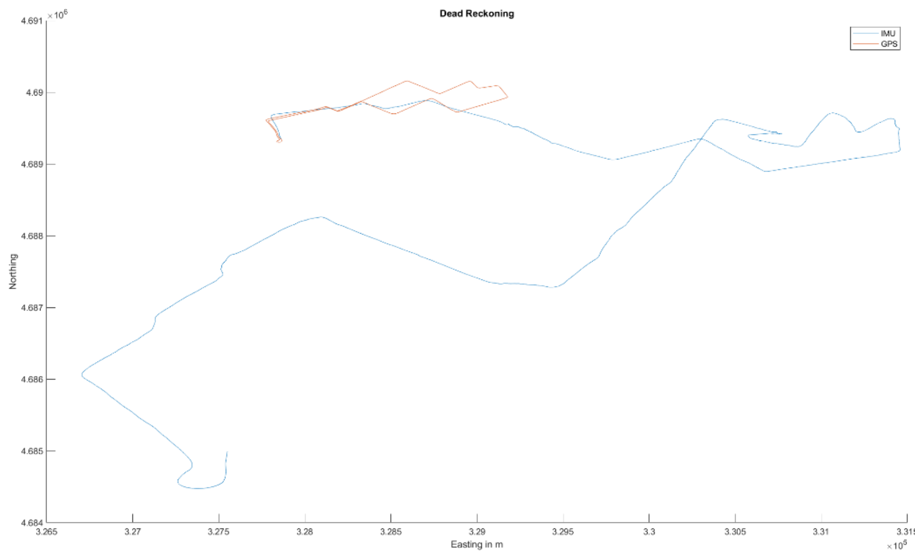

Fig 1.9: Estimation of Trajectory using IMU and GPS

8. From the experiment, the IMU can be expected to give estimates with reasonable degree of error for about a minute without a position fix. Beyond that, the error accumulation builds up and causes drift.
9.

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

Where, $\ddot{x}_{obs}$ is $\ddot{x}_{imu}$, $\ddot{x}$ is $\ddot{x}_{gps}$ and $Y = 0$

So, $a_{imu} + \ddot{x}_{gps} = \omega^2 x_c$,

$X_c = (a_{imu} + \ddot{x}_{gps})/ \omega^2$

$X_c = 0.83$ m