EECE-5554 Robot Sensing and Navigation
LAB-4 Report

Abstract – This document provides the analysis report of the collected data using two different sensors GPS and IMU. We wrote drivers to get the data strings, from which required GPS and IMU data are stored. The 2 types of data sets were collected – driving the car in circles and driving the car around 3 kilometers with a minimum of 10 turns. The GPS and IMU sensors are connected, ran individually to collect the data, stored into a single rosbag, and integrated while analysis

I. Introduction to GPS, IMU, and sensor fusion

GPS is a device used to determine the location and provide navigation information. IMU (Inertial Measurement Unit) sensor is a device that measures acceleration, angular rate, and magnetic field to determine the orientation, position, and motion of an object.

II. Source(s) of error

The major sources of errors are – Time synchronization errors, Calibration errors, Atmospheric errors, Noise errors, and Human errors.

III. Analysis

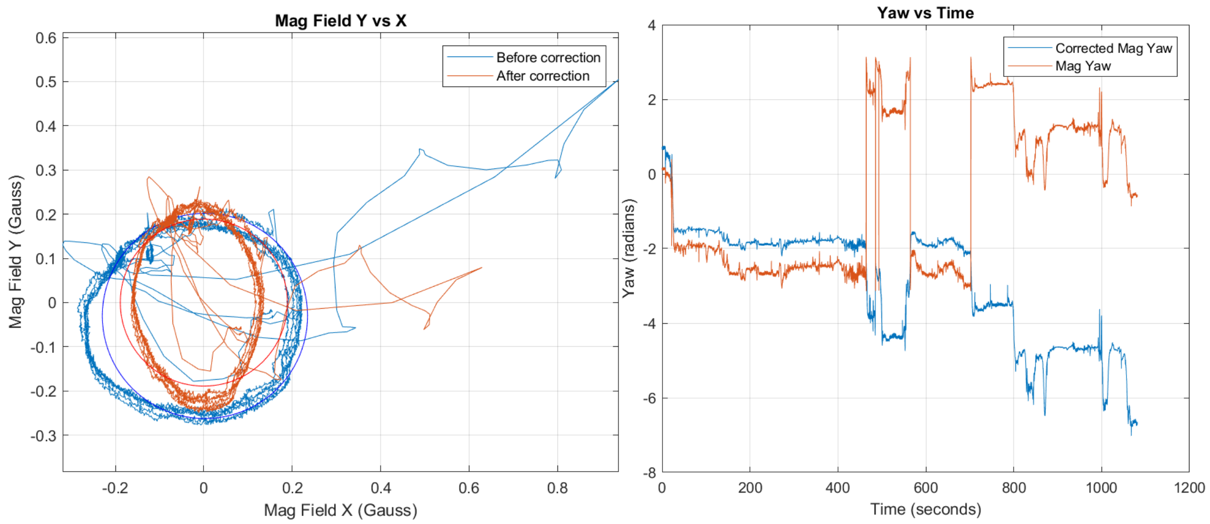


Figure 1: (a) Magnetometer readings in circles *(b) Magnetometer readings while driving*

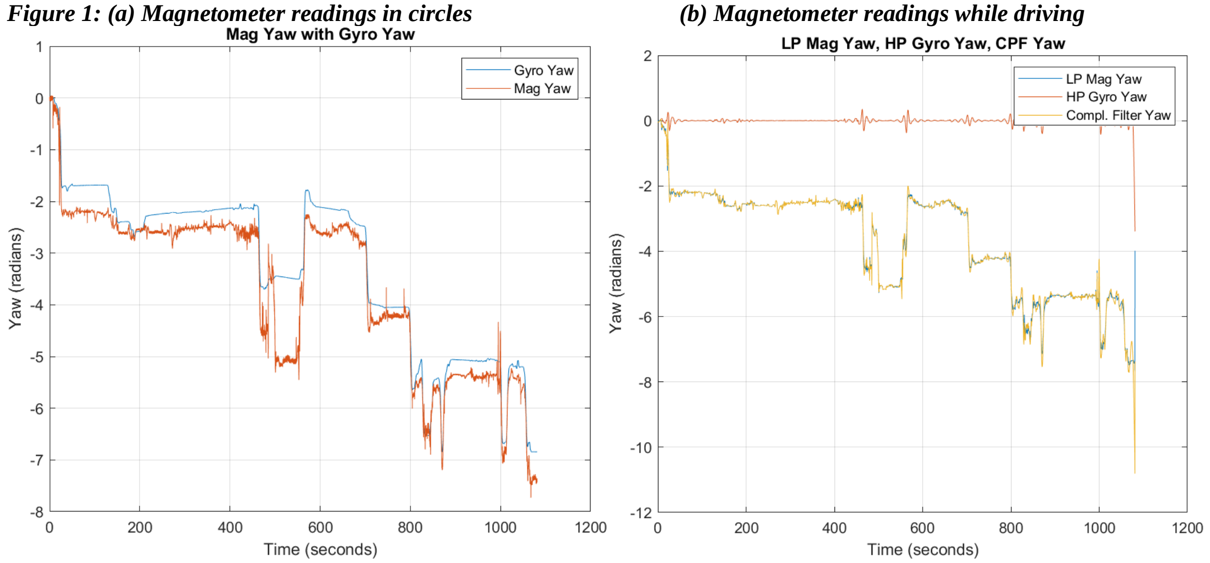
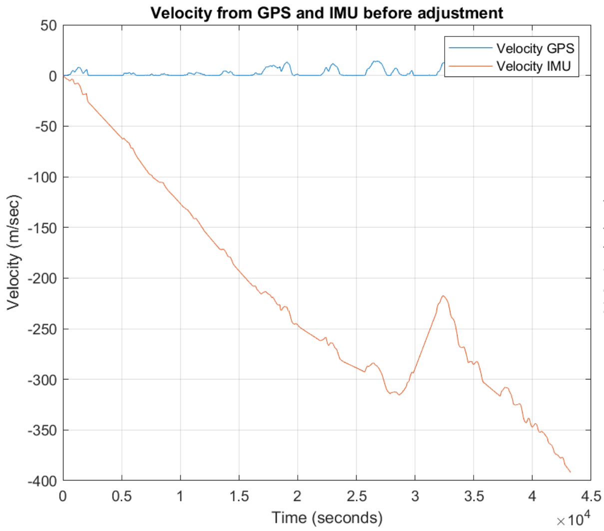


Figure 2: (a) Comparison of Gyro Yaw and Mag Yaw *(b) Estimation of Yaw angles using filters*



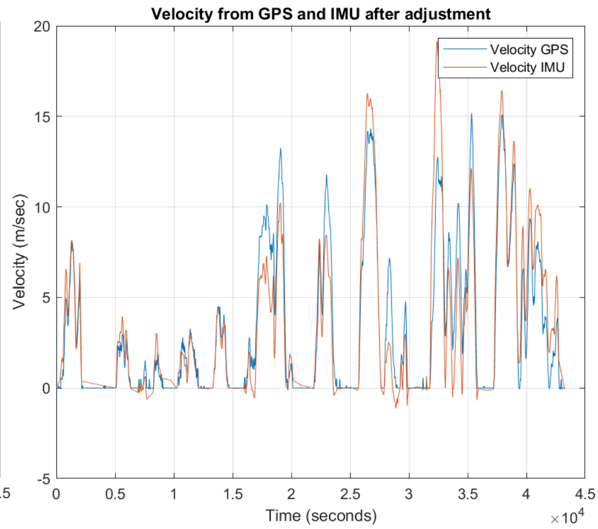
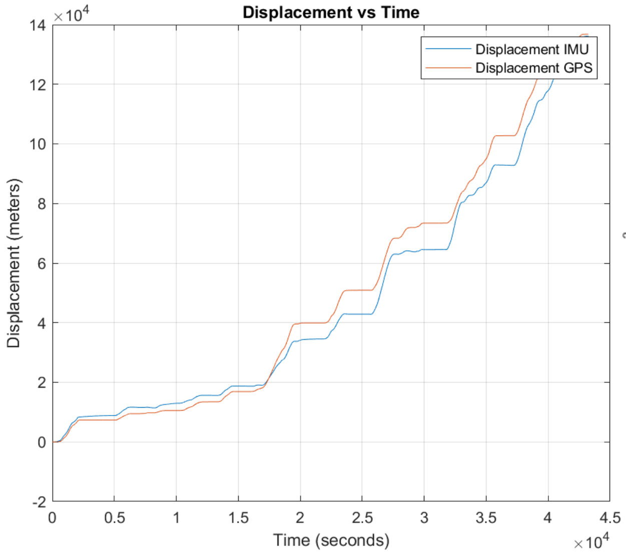


Figure 3: (a) Velocity estimation before adjustment ***(b) Velocity estimation after adjustment***



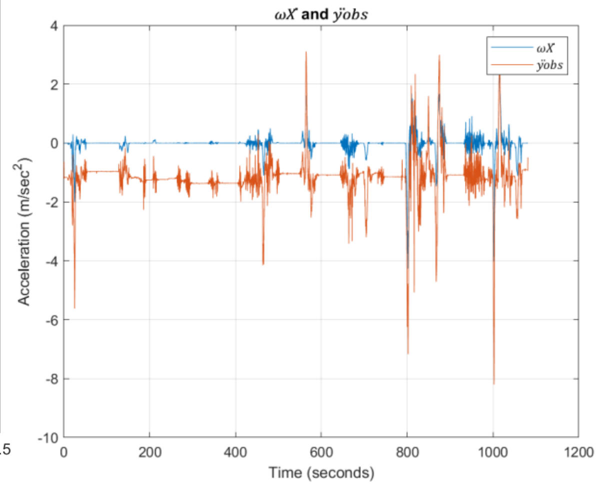


Figure 4: (a) Integration of forward velocity for displacement ***(b) Comparison of wX and Yobs***

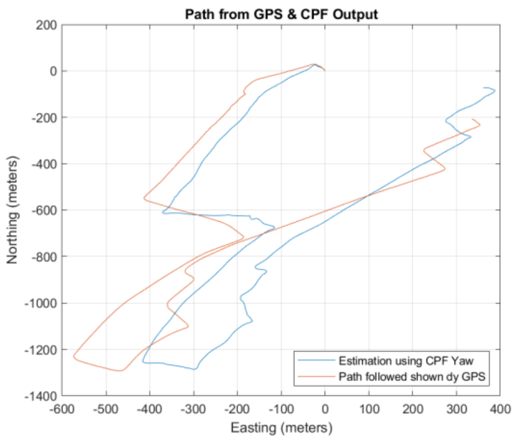


Figure 5: Trajectory estimation of the vehicle

The collected data is plotted which helps us to study and analyze the performed activity using sensor fusion and get the required information.

IV. Conclusion

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

The magnetometer is calibrated by the magnetic field and time synchronization and then computed with the measured and expected field vector. Here, soft iron and hard iron are the distortions, these are reduced/ removed by applying the correction. These are the distortions as ferric/ iron materials cause fluctuations in the magnetic field.

B. *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?*

The gyro and mag field are integrated together for yaw and unwrapped to LP filters and combined with HP filters with correction into CP filter to obtain the estimation as shown in Fig2: (b). The cutoff frequency is 40Hz.

C. *Which estimate or estimates for yaw would you trust for navigation? Why?*

The calibration of the CP filter is best for the estimation of yaw as it contains the sensor noise, sensor fusion, sampling rate, and environmental errors.

D. *What adjustments did you make to the forward velocity estimate, and why?*

The output/ Accel is corrected for the bias to reduce drift which helps to improve accuracy.

E. *What discrepancies are present in the velocity estimate between accel and GPS. Why?*

The negative velocity is the discrepancy observed here where the vehicle is not moving or stopped. The environmental conditions, noise, and sampling rate are general discrepancies as there would be sensor noise, bias and drift for the accelerometer, whereas there might be a signal blockage and multipath error in GPS. Also, they both have different sampling rates.

F. *Compute ωX and compare it to y_{obs}. How well do they agree? If there is a difference, what is it due to?*

Most of the part agrees together but there is a slight difference, so it must be due to bias (noise or environmental factors) and also happens sometimes due to calibration error.

G. *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.*

As we can see from above the trajectory of the vehicle compared to the GPS is almost the same but has a minute difference.

H. *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?*

Probably we could navigate for 10 minutes. For the first 5 minutes, the estimates match closely. The dead reckoning was close but there is a slight difference in the plot, so it must be noise errors/ signal blockage. Sometimes fusion and calibration errors take place too.

V. References

Some interesting research papers related to GPS and IMU are listed below

[1] S. Sukkarieh, E. M. Nebot and H. F. Durrant-Whyte, "A high integrity IMU/GPS navigation loop for autonomous land vehicle applications," in IEEE Transactions on Robotics and Automation, vol. 15, no. 3, pp. 572-578, June 1999, doi: 10.1109/70.768189.

[2] C. S. Raveena, R. S. Sravya, R. V. Kumar and A. Chavan, "Sensor Fusion Module Using IMU and GPS Sensors For Autonomous Car," 2020 IEEE International Conference for Innovation in Technology (INOCON), Bangluru, India, 2020, pp. 1-6.