Lab 4 Navigation with IMU and Magnetometer

- Niket Purohit

The lab focused upon navigation stack using two different sensors. The sensor fusion of GPS and IMU was used in this lab to find the adequate outputs required and to find various analysis in different fields.

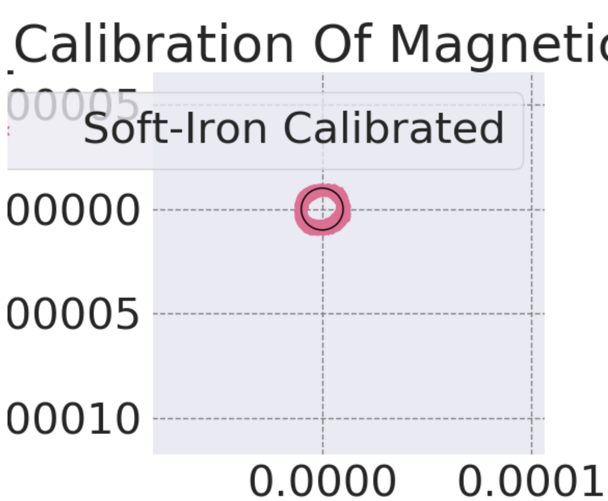
Following are the graphs and answers to the questions mentioned in LAB4.

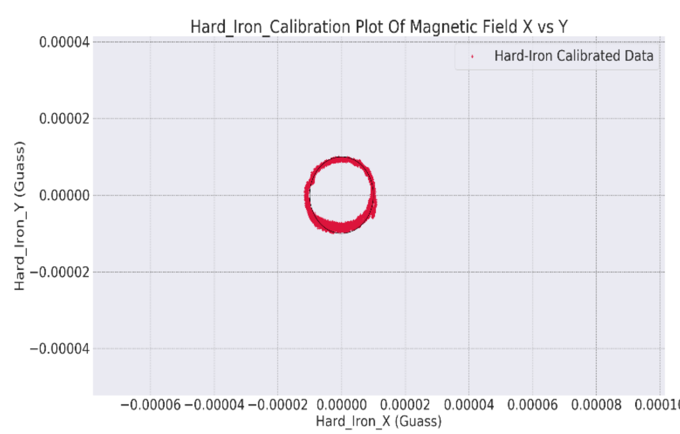
1. A magnetometer is a sensor that analyzes a system's local magnetic field to determine its direction and intensity. The heading of a system regarding magnetic North can then be calculated by comparing this magnetic field measurement to models of the Earth's magnetic field. The magnetic field observed in most practical situations, though, will be a combination of the Earth's magnetic field and magnetic fields produced by nearby objects, also known as magnetic disturbances. The effect of nearby magnetic disturbances must be reduced to get a precise heading approximation. An HSI calibration can be used to account for internal magnetic disruptions that are not time-varying.

   For our lab, the work with magnetometer is bifurcated in two major distortion caused. These two categories are –

   Hard Iron - Distortions in hard iron are caused by things that generate magnetic fields. For instance, a speaker or fragment of magnetized iron will produce a hard iron distortion. This kind of hard iron distortion will result in a persistent bias in the sensor output if the magnetic component is physically connected to the same reference frame as the sensor.

   Soft Iron - They are regarded as deflections or modifications to the current magnetic field and are known as soft iron distortions. Depending on how the magnetic field behaves in relation to the sensor, these distortions will extend or distort the field. Metals like nickel and iron are frequently responsible for this kind of deformation. In most instances, hard iron distortions will contribute significantly more than soft iron to the total uncorrected error.





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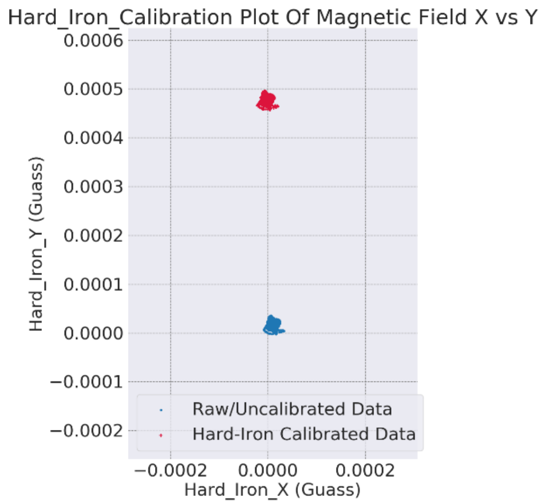

2. After the magnetometer's calibration with hard and soft iron, the yaw angle is discovered. It can also be obtained by combining readings from gyroscopes. Both calculated yaw closely resembles the internal yaw angle that the IMU determined. In comparison to the IMU yaw, the yaw computed from the gyroscope data is somewhat smoother and less sensitive (fewer peaks), whereas the yaw derived from the magnetometer data is somewhat straight and smooth. The thought behind it is because the data from magnetometer is pretty accurate and hence finds that the plot for that data has lesser deviation and is close to 0.

   For complimentary filters, we used the following two methods to help is understand things better.

   a) The magnetic data is subjected to an LPF(low pass filter) in order to maintain its consistent low drift and clip-off any high frequency noise.
   b) Since the gyro data tends to shift over time, an HPF(high pass filter) is applied to the gyro data. Therefore, an HPF is used to maintain high frequency readings and clip-off the bias from low frequency drift while integration.

      For my data, I used the digital method and hence put the alpha value at 0.75. I started the range from 0.75 and found this to be my optimal output.

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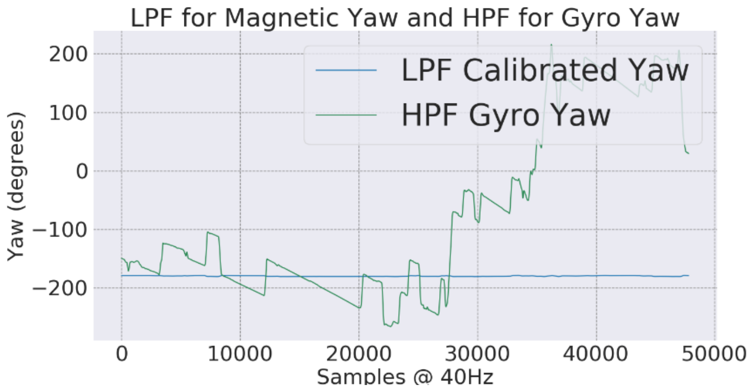
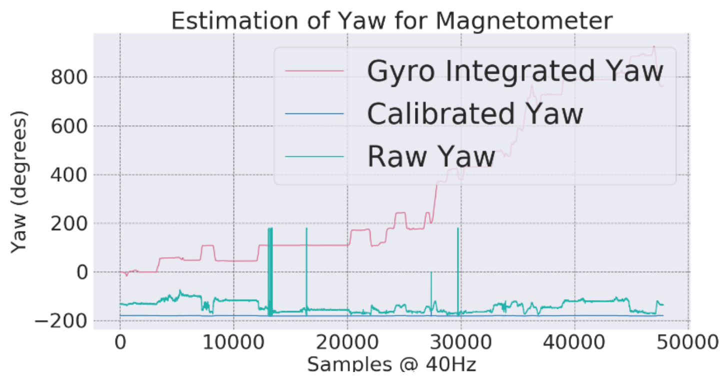
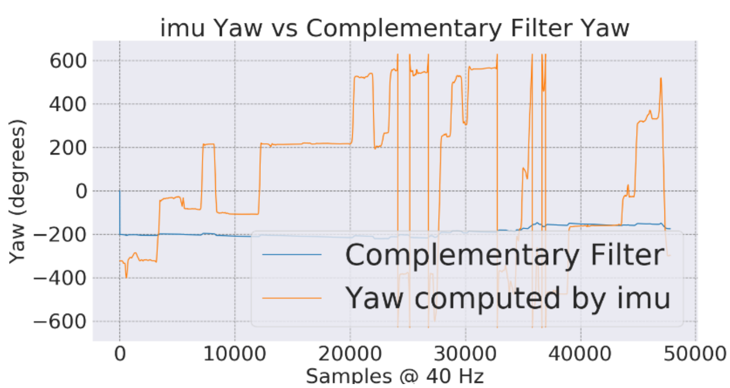


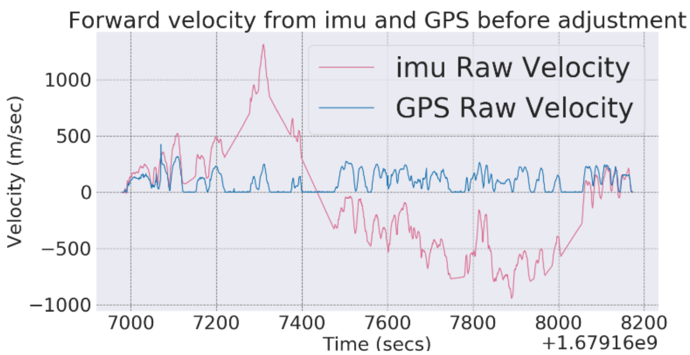


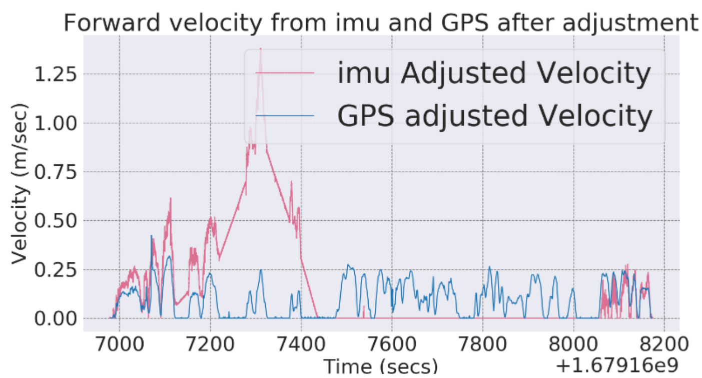
3. I would prefer the complimentary filter and for the given data the gyro yaw output since it gives the data through acceleration and not magnetic fields. By integrating the angular rate measurements from the gyroscopes, an estimate of the yaw angle can be obtained.



4. By getting the integral of acceleration and calculating the instantaneous velocity of each GPS data point, velocity can be calculated. We integrate the sensor data to determine the vehicle's velocity or speed. Here, we are only using the accelerometer's X component of linear acceleration, which is mounted with its direction facing directly out the front of the car. Because the car is not skidding in a sideways orientation in this experiment, we do not take into account

the linear acceleration of the Y component. Another way to determine forward velocity is to take the gradient regarding time and the hypotenuse of the X and Y components (easting and northing) of our GPS position data. Also, I took the data in the direction that does not go in negative and changed the data that showed in negative to represent as 0 on the graph because the forward velocity cannot be negative but while deceleration our sensors do not measure that.

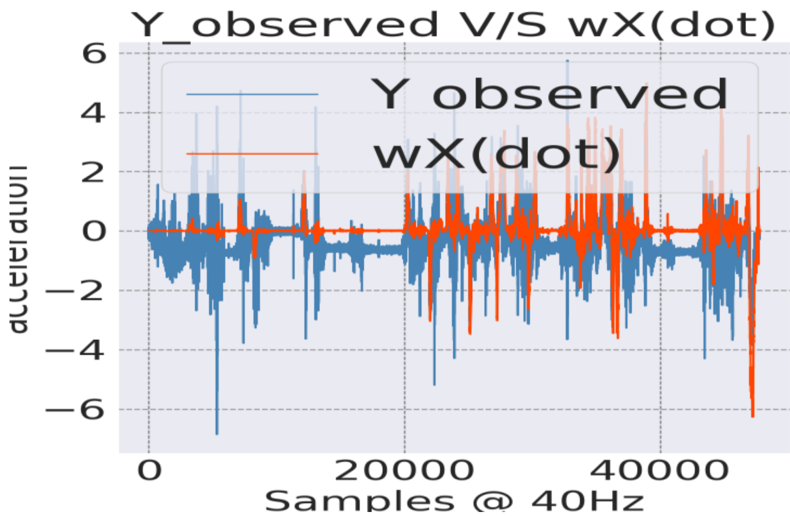




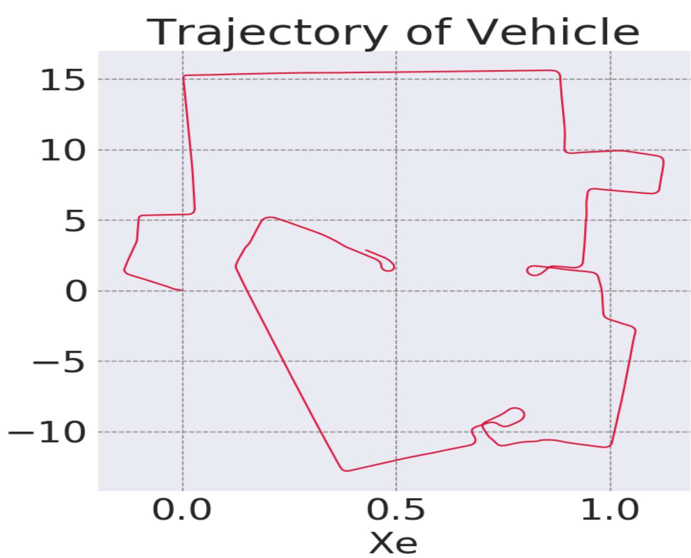
5. We can clearly see that the GPS velocity gives us much more accurate data than IMU and the data formatting is clearer too as the IMU data shoots up and drops down with much more inaccuracy and at times even going to the negative spectrum which is not possible even with deceleration.

6. By simplifying the equations, we get:
   $\ddot{x}$ obs = $\ddot{X} - \omega\dot{Y} - \omega^2 x_c$
   $\ddot{x}$ obs = $\ddot{X}$
   In the same form we obtain:
   $\ddot{y}$ obs = $\ddot{Y} + \omega\dot{X} + \dot{\omega}x_c$

   Here, the vehicle frame is used to assess each variable in these equations. To determine the velocity, we can incorporate. Like that, the velocity can be determined using the formula obs =. The z-axis angular motion from the gyroscope is represented by the. By setting x c = 0, we disregard the offset and presume that the = 0 (i.e., the car isn't sliding sideways meaning that the IMU is on the center of mass of the vehicle, i.e. the point about which the car rotates).



7. Dead reckoning is the process of determining a moving object's current position from information of its previously ascertained position. The only navigation option is dead reckoning, particularly when there are no known-position markers. By multiplying our expected forward velocity by the yaw angle, we can perform dead reckoning using the IMU.



8. R and V, respectively, display the location and velocity of the vehicle's center of mass (CM). Note that this vector is constant in the frame of the vehicle and implies that the displacement of the

IMU sensor is only along the x-axis. This distance between the inertial sensor and the CM is given by:

v = V + ω × r   ω is the is the z-axis angular velocity from the gyroscope

r = (x_c, 0, 0)

V is actual linear velocity

v stands for measured linear velocity).

We show the corresponding acceleration with:

$\ddot{x} = \dot{v} + \omega \times v = \ddot{X} + \dot{\omega} \times r + \omega \times \dot{X} + \omega \times (\omega \times r)$

The range for possible x_c values will be determined by –

“x_c = (V − v)/ω”

According to the aforementioned equation, x_c and are inversely proportional, meaning that small values of will result in big values of x_c and vice versa. The radius of rotation of the vehicle making the turn may be determined using this technique. Additionally, V was set as the minimum velocity when the vehicle was traveling straight ahead at a constant speed, which would produce a variety of more accurate estimates.

9. We know the expected navigation time without a position fix and the period during which the GPS and IMU estimates of position match closely can vary depending on the specific VectorNav product, the operating environment, and the mission requirements. But as we see in the graphs that the GPS data is more accurate and does give us more appropriate idea about the positioning of the vehicle than the IMU. My data did match for the initial few seconds before it varied and matched again before a large distortion in velocity and position. The stated performance for dead reckoning did not exactly match the actual measurements as we found that the yaw angles to have much dip in IMU implying but not specific to the problem of mounting or data collection. However, we do find that the positioning is not accurate yet quite near to the actual position as we coincide the multiplied values of estimated forward velocity to yaw angle.