Haojie Huang

EECE 5554 Sensor and navigation

Lab 2 Report

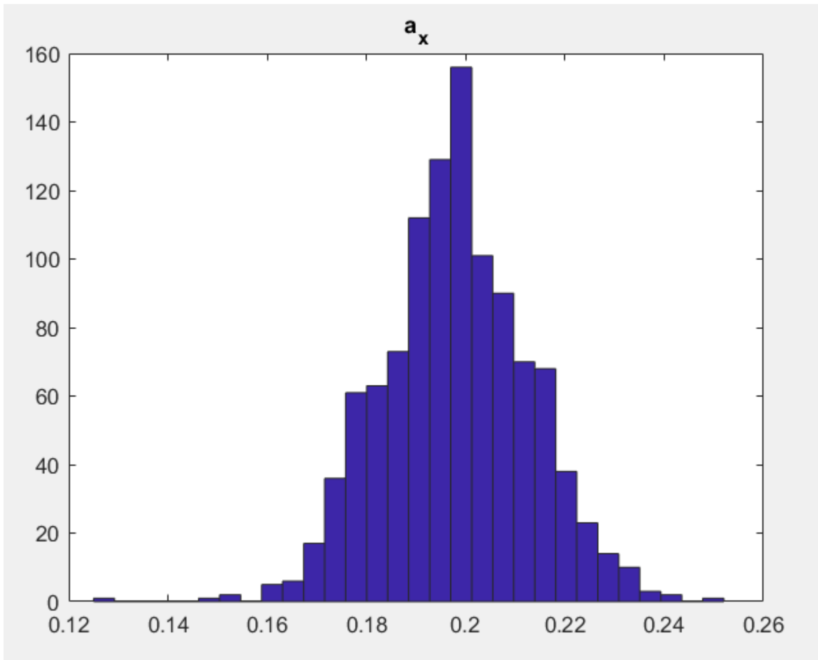
Northeastern University

Part1

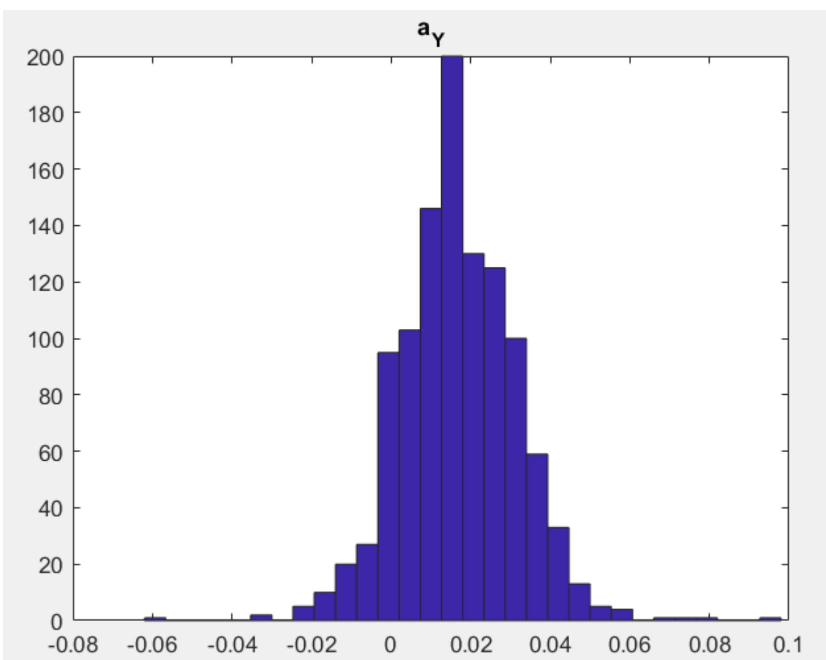
The driver code has been uploaded to the gitlab.

The following figures are the stationary data of the 3 accelerometers, 3 angular rate and 3 magnetometers from the IMU. It is easy to find that they all follow the **Normal distribution** with different mean and variance.

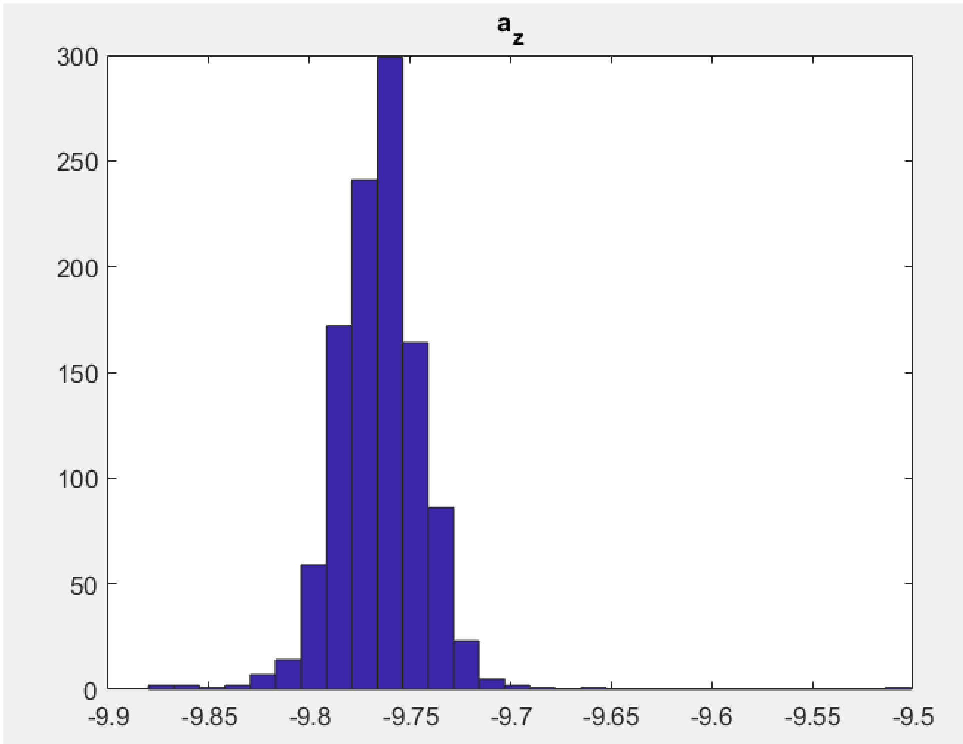
Accelerometer X N ~ (0.1979, 2.1623e-04)



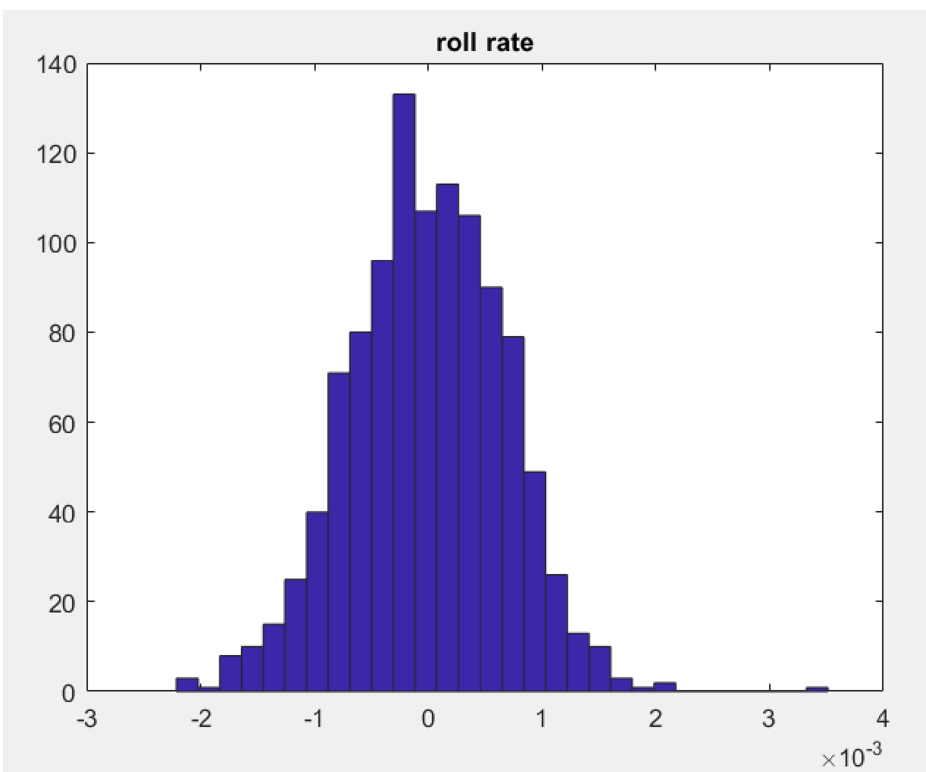
Accelerometer Y N ~ (0.0170, 2.1045e-04)



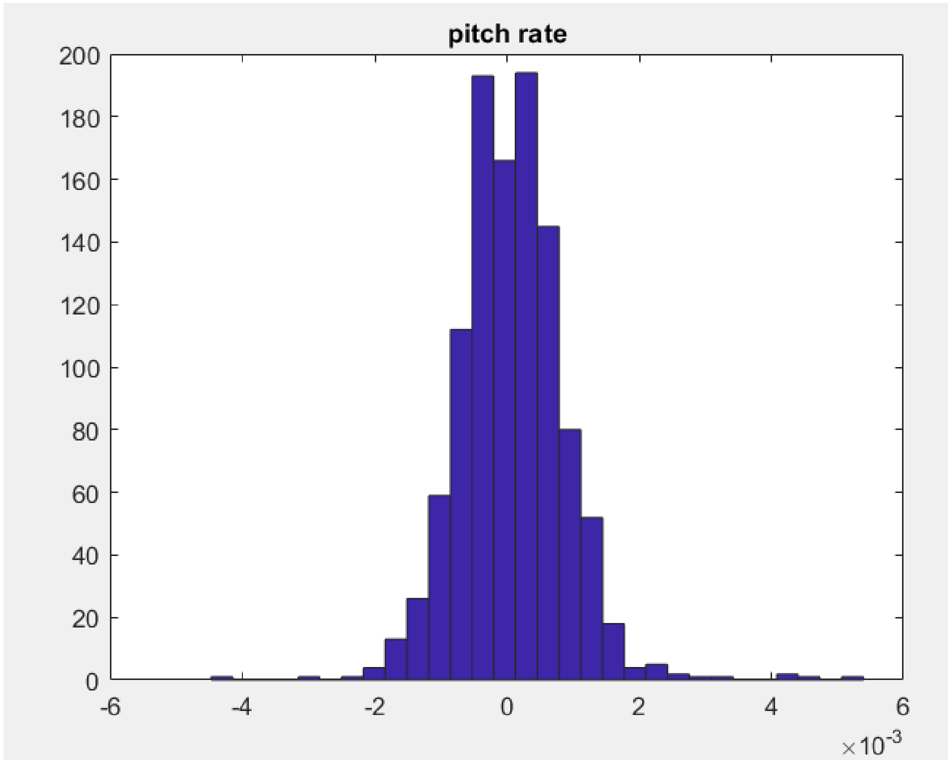
Accelerometer Z   N ~ (-9.7650, 4.9152e-04)



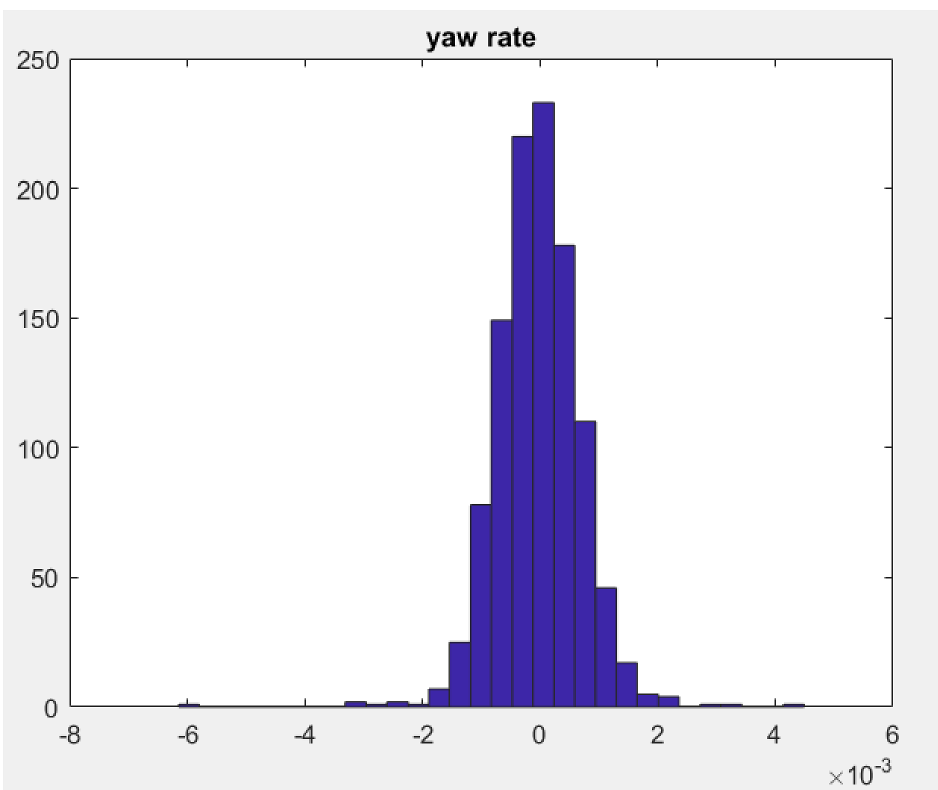
Roll rate   N ~ (-1.0441e-05, 4.5961e-07)



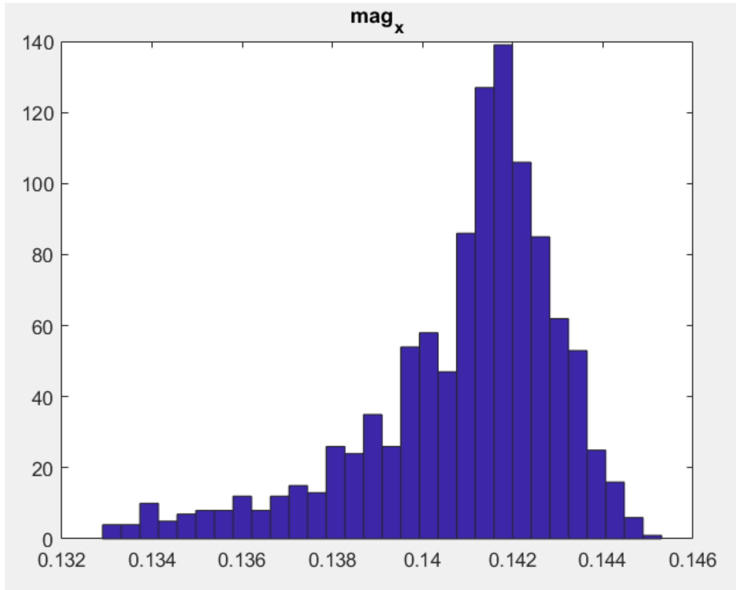
Pitch rate   N ~ (7.3970e-05,6.4105e-07)



Yaw rate   N ~ (-3.2470e-05, 5.2289e-07)

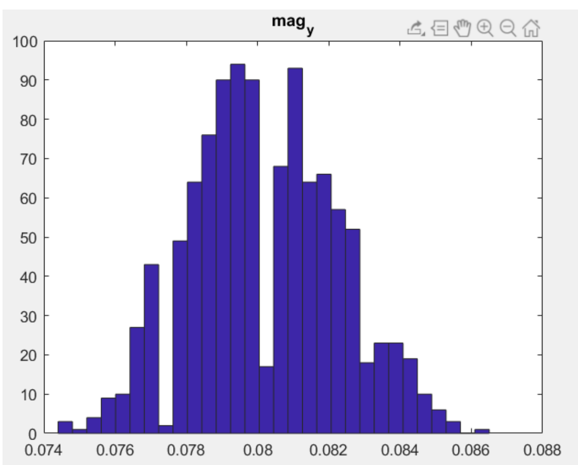


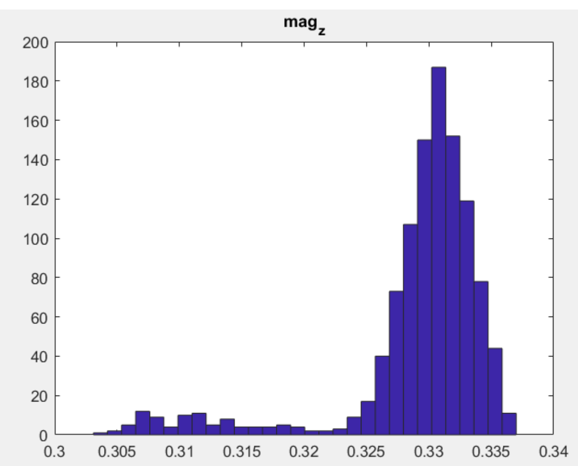
Magnetometers X N ~ (0.1409, 4.7614e-06)



Magnetometers Y N ~ (0.0802, 4.2293e-06)

Magnetometers Z N ~ (0.3291, 3.5179e-05)





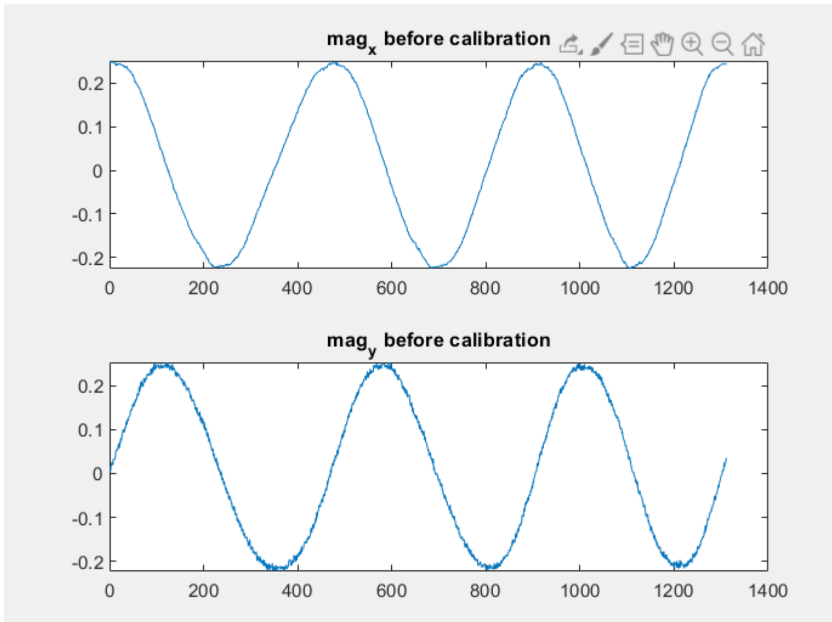
Part2

Part 2 was completed as the instruction and the data could be find in the lab2/bag_files in gitlab.

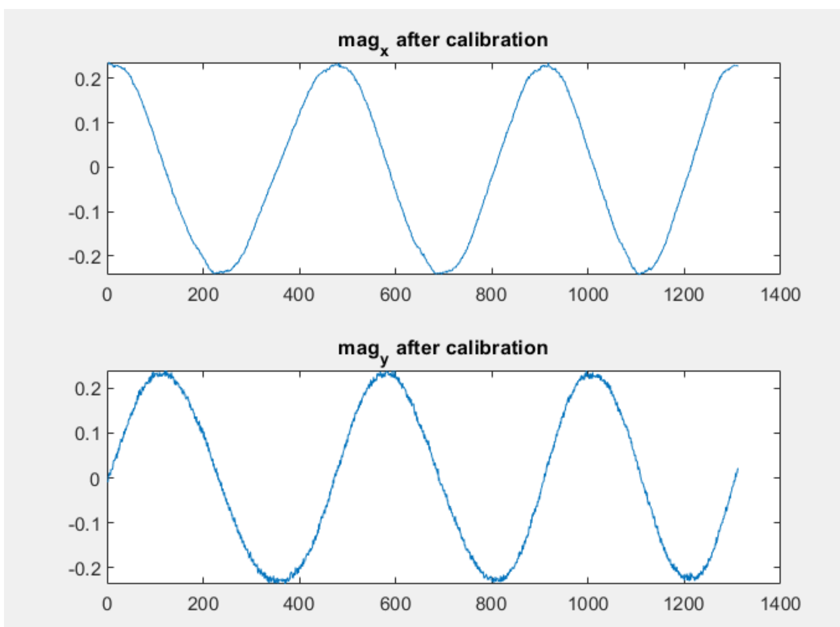
Part3

1. Use matlab function ‘magcal’ to calibrate the magnetometer X and Y

Before calibration

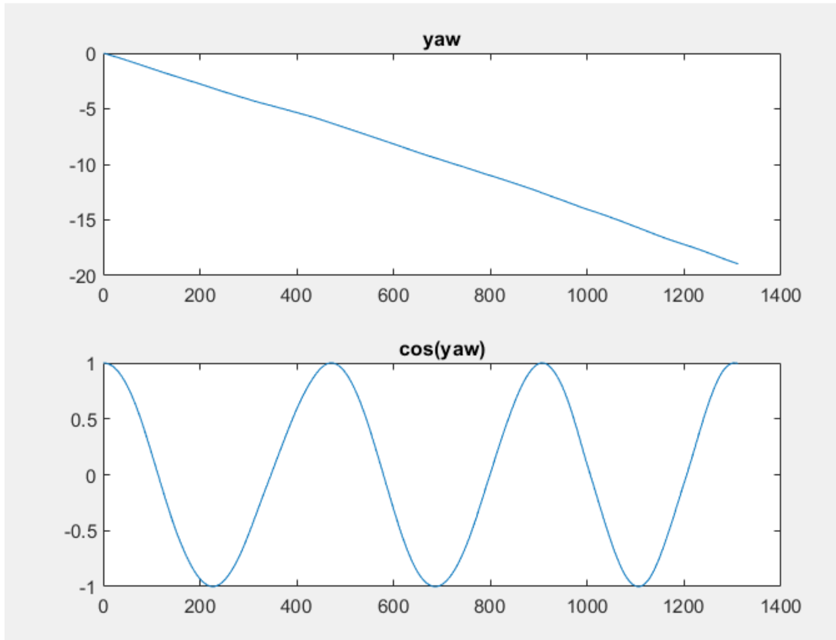


After calibration



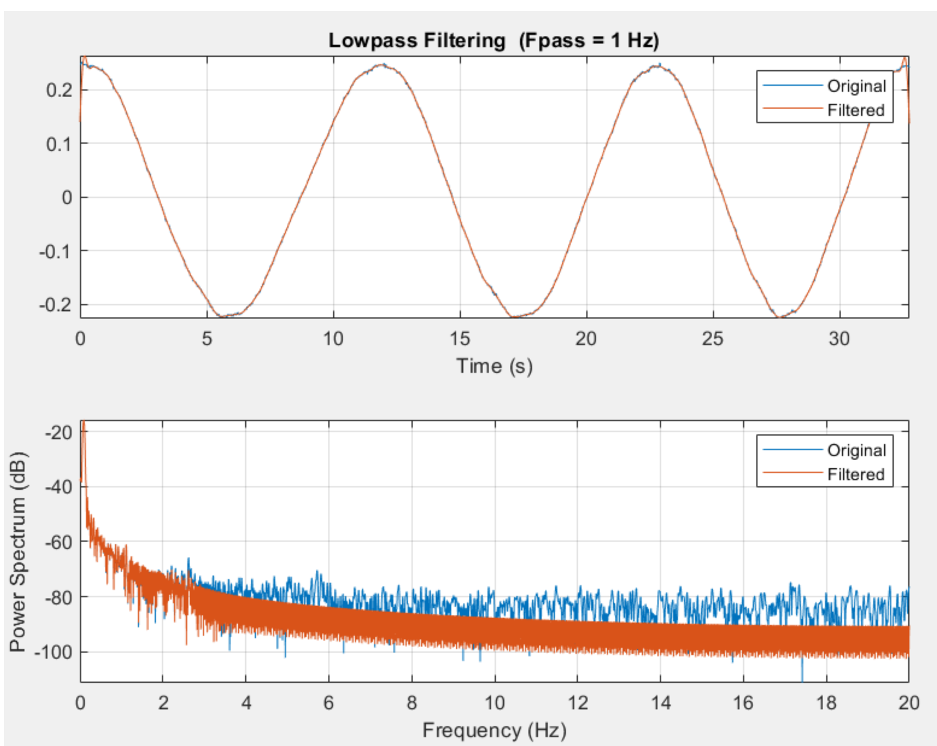
After the calibration the small hard iron error and the soft iron error were decreased.

Integrate the yaw angular rate to get the yaw angle

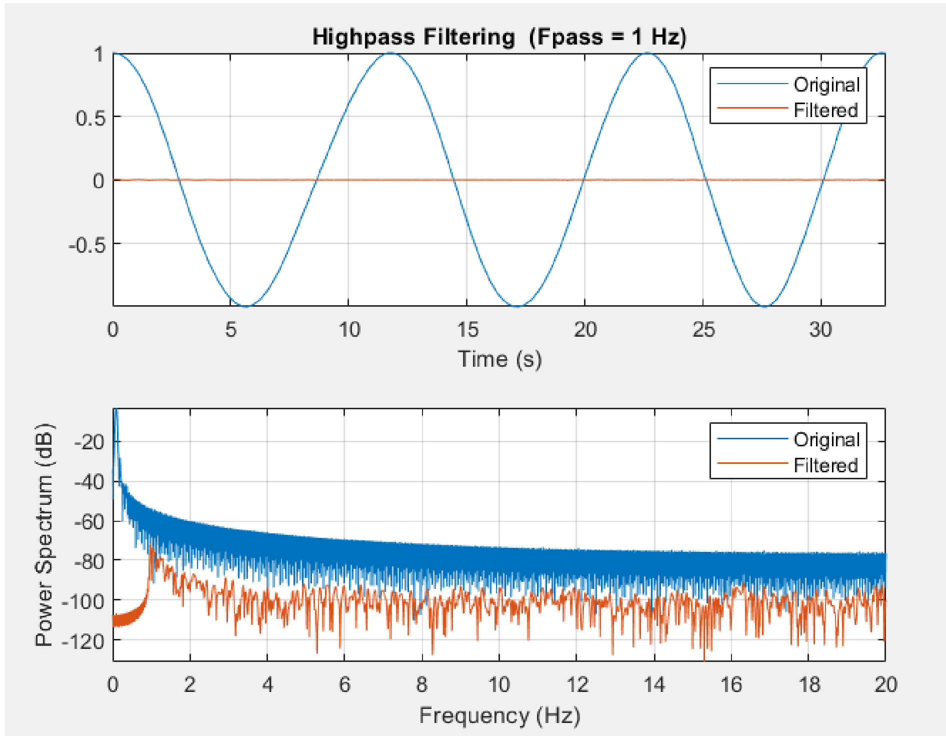


Comparation: the two method gives us the yaw angle. Both of them indicate a 3-round circle. (3 * 2Pi = 18.84)

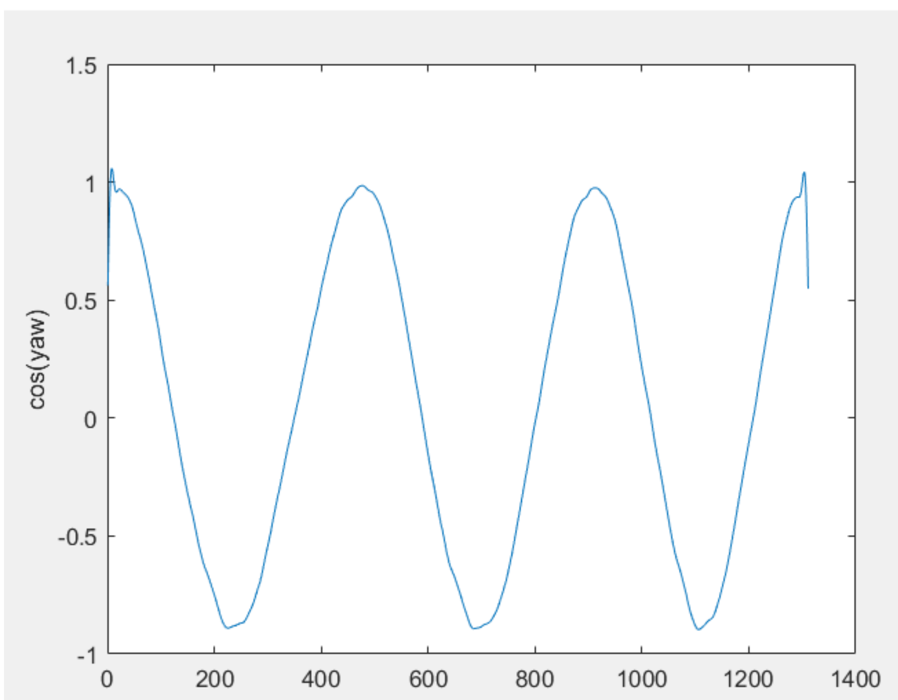
The magnetometer method has much noise even after calibration and thus we can use a low pass filter with the threshold of 1 HZ.



Use a high pass filter with the threshold of 1 HZ to filter the gyro yaw angle



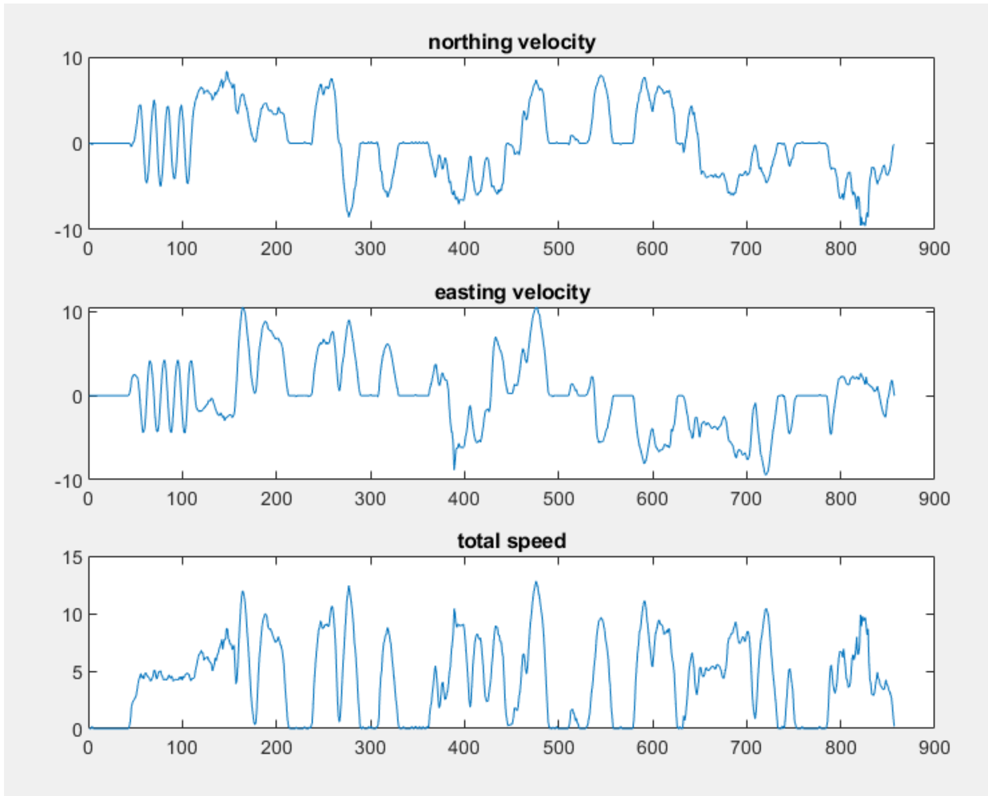
Add them together



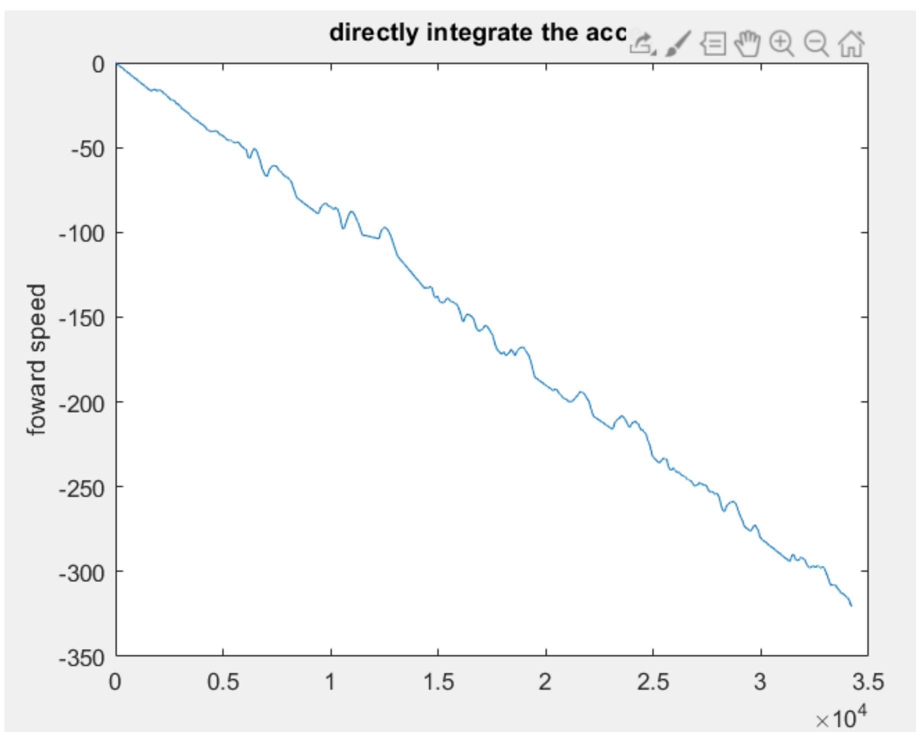
Observation: yaw angle from the magnetometer has much high-frequency noise. After passing through a low pass filter, it looks smooth but has a little distortion. The yaw angle integrated from Gyro is smooth but may has some low frequency error. The combination is more accurate and real.

2. **Forward velocity**

the velocity from the **GPS** measurement



The velocity from the **accelerometer(integrate the ax)**

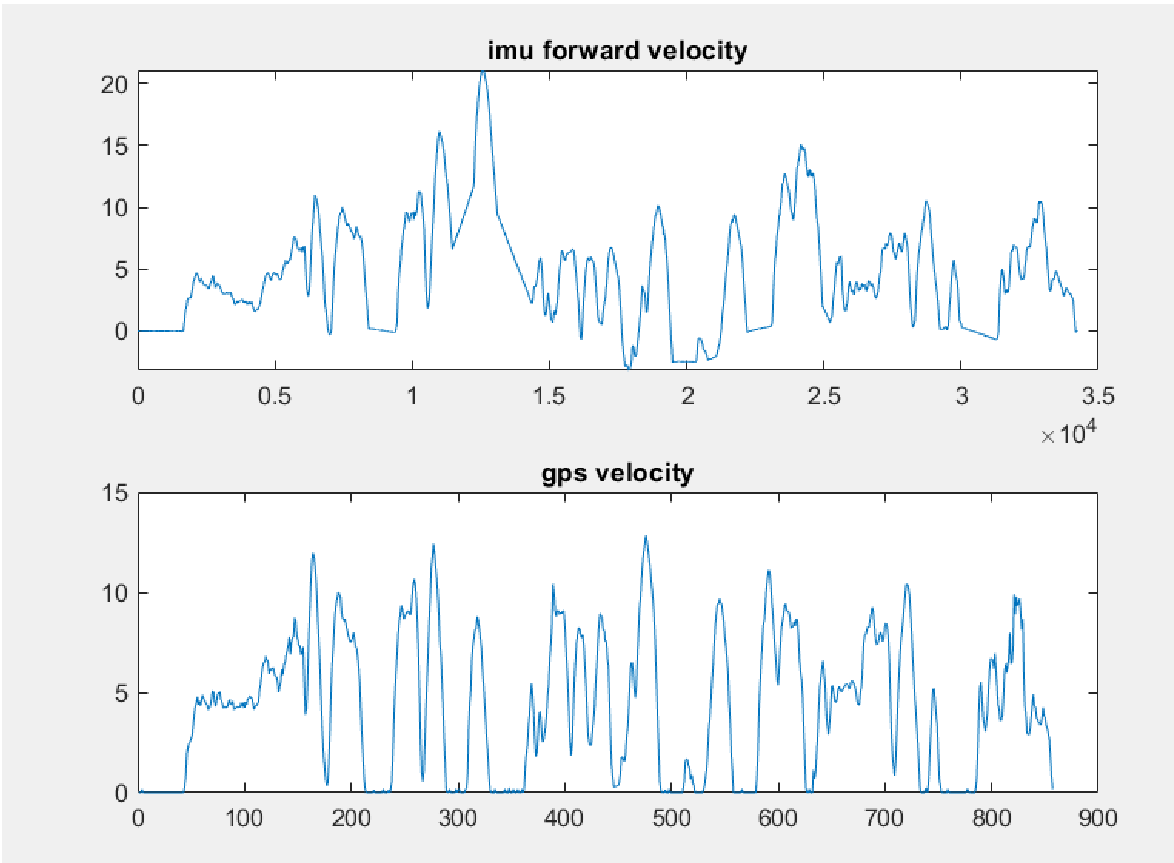


The velocity from the forward velocity is irrational:

- During the first 40 seconds, our car was stopping. So its speed should be zero.
- At the end of the test, the car was also pulling over and its speed should be zero.

This abnormal phenomenon is due to the placement of the IMU which caused some acceleration along the X axis. I use the first 40 seconds to calibrate the static accelerometer X and use the other part of the data to calibrate the moving accelerometer.

After calculating, the offset of the static acceleration is -0.405 and the offset for the moving is -0.3728



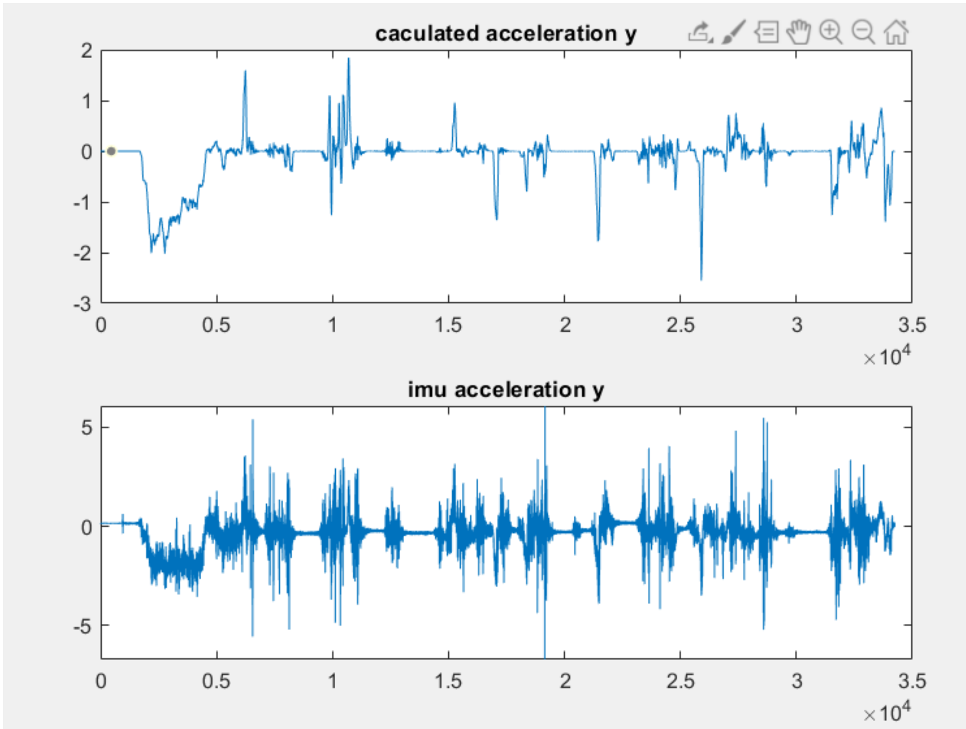
For now, it seems similar to the GPS velocity.

There exists some difference due to following reasons:

- The GPS velocity give us the truth
- The imu acceleration has some error due to its placement, the bumpy road and the inertia delay.

3. Dead reckoning with IMU

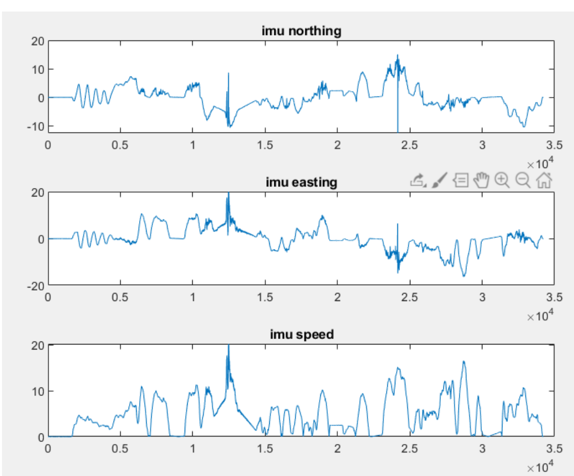
After getting the forward velocity, it easy to get the acceleration Y. (ay = W×V)



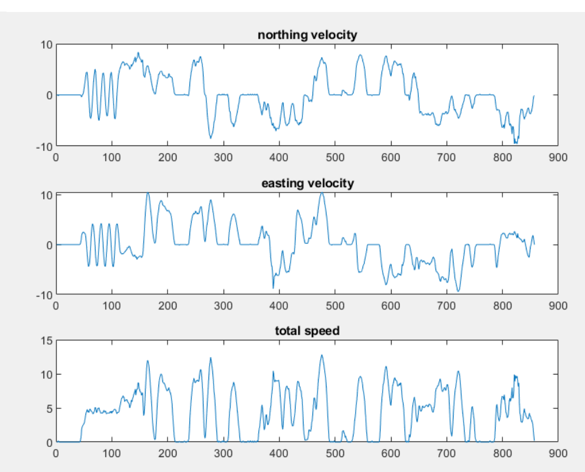
The calculated ay has the same trend as the IMU ay but there are some difference due to:

- Actually, the vehicle would be skidding sideways.
- The offset between the center of the car and the position of the IMU is not zero.
- The placement of IMU cannot make sure the center of the car and the IMU is along the X axis.
- The road is not totally flat

Use the magnetometer to get Velocity_Northing and Velocity_easting from the forward velocity

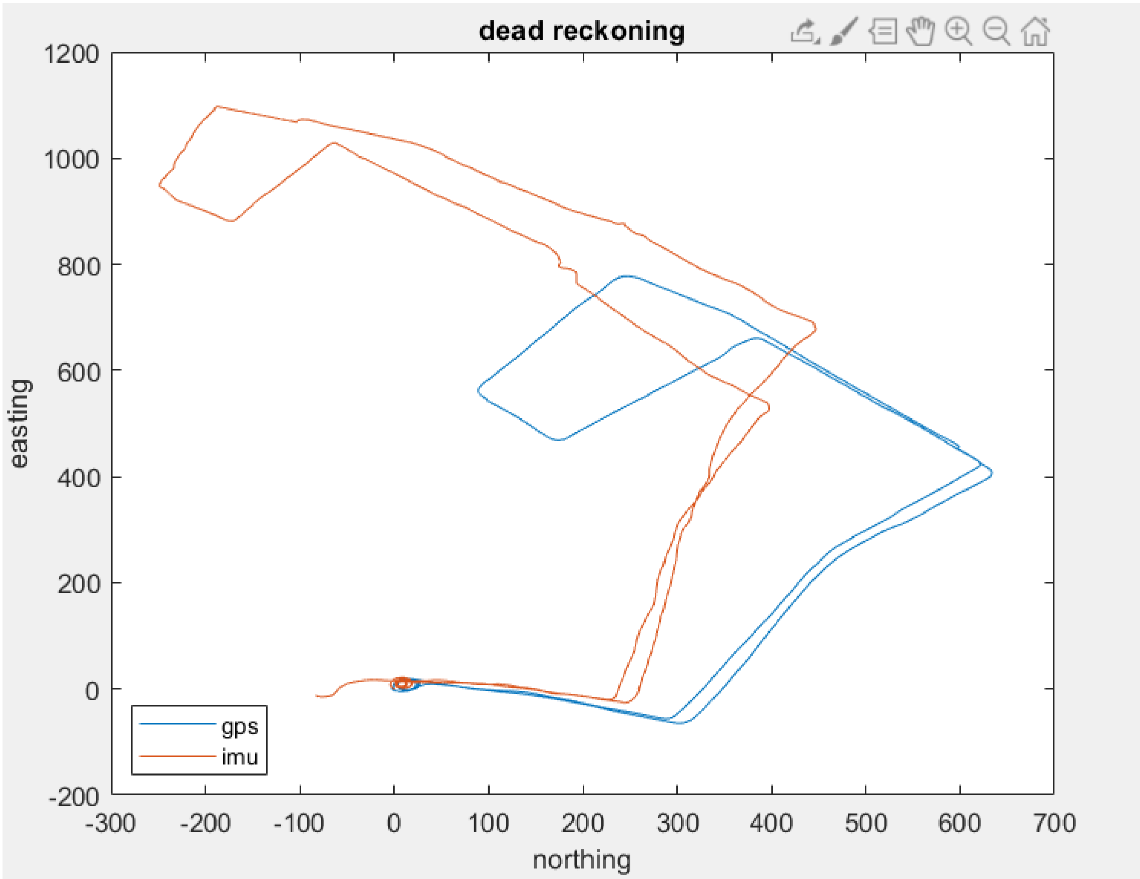


IMU northing, easting and total velocity



GPS northing, easting and total velocity

Integrate the nothing and easting velocity to get the dead reckoning



Scaling factor:

- subtract the GPS northing and easting data with the initial easting and northing.
- The northing distance of imu dead reckoning between #10479 and #15185 was shrunk twice.
- The easting distance of imu dead reckoning between #25842 and #33839 was shrunk 1.6 times.

The outline of the two paths looks similar but the details are different at the corner.

Estimate the Xc:

Decompose the acceleration equation with X-component and the Y-component:

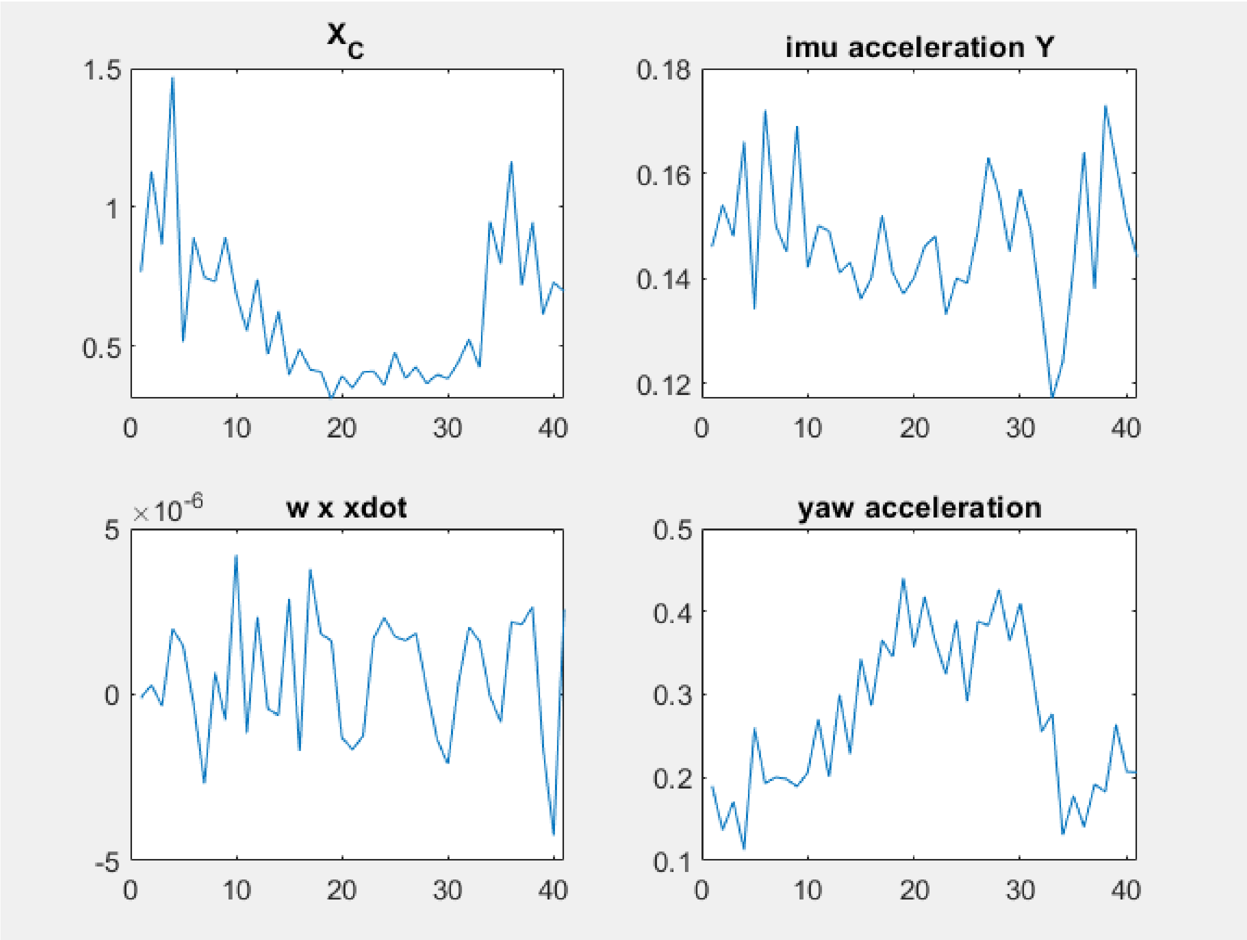
$$a_x = \ddot{X} + \omega \times (\omega \times r)$$

$$a_y = \dot{\omega} \times r + \omega \times \dot{X}$$

We could calculate the Xc from the second equation, where a_y is the accelerometer y read from the IMU, the $\omega \times \dot{X}$ was calculated in the 3.3.1 and the $\dot{\omega}$ could be calculated from the IMU yaw rate.

$$\boldsymbol{r = abs(\frac{a_y - \omega \times \dot{X}}{\dot{\omega}})}$$

I used a small piece of the imu data to calculate the Xc



Duo to the bumpy road and the small shaking of the IMU, the estimate of the Xc has bias and noise. The minimum of the Xc is approaching ZERO and the maximum is about 1.5 meters. We could use the mean value that is 0.62 meter as the estimation.

Reference:

https://www.mathworks.com/help/nav/ref/magcal.html

https://en.wikipedia.org/wiki/Conversion_between_quaternions_and_Euler_angles