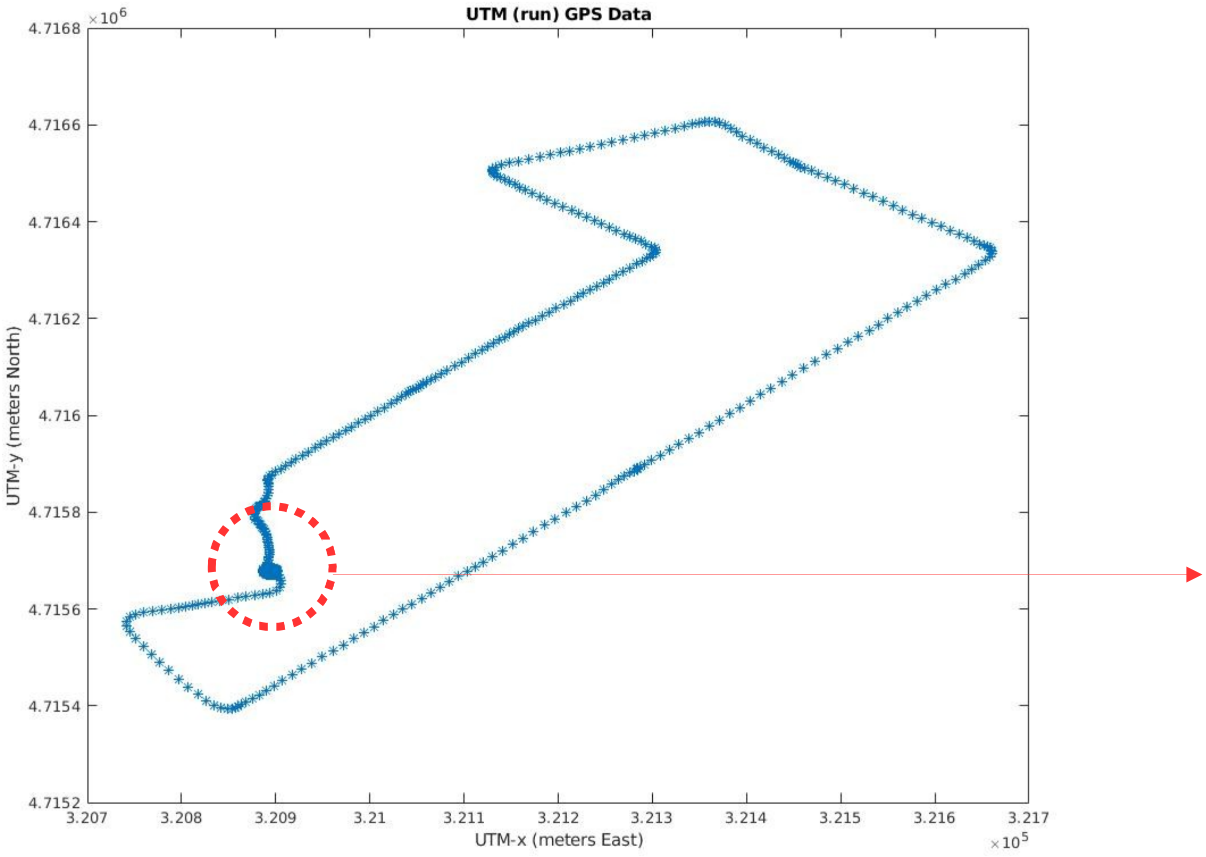
Lab 3 – IMU & GPS on LCM

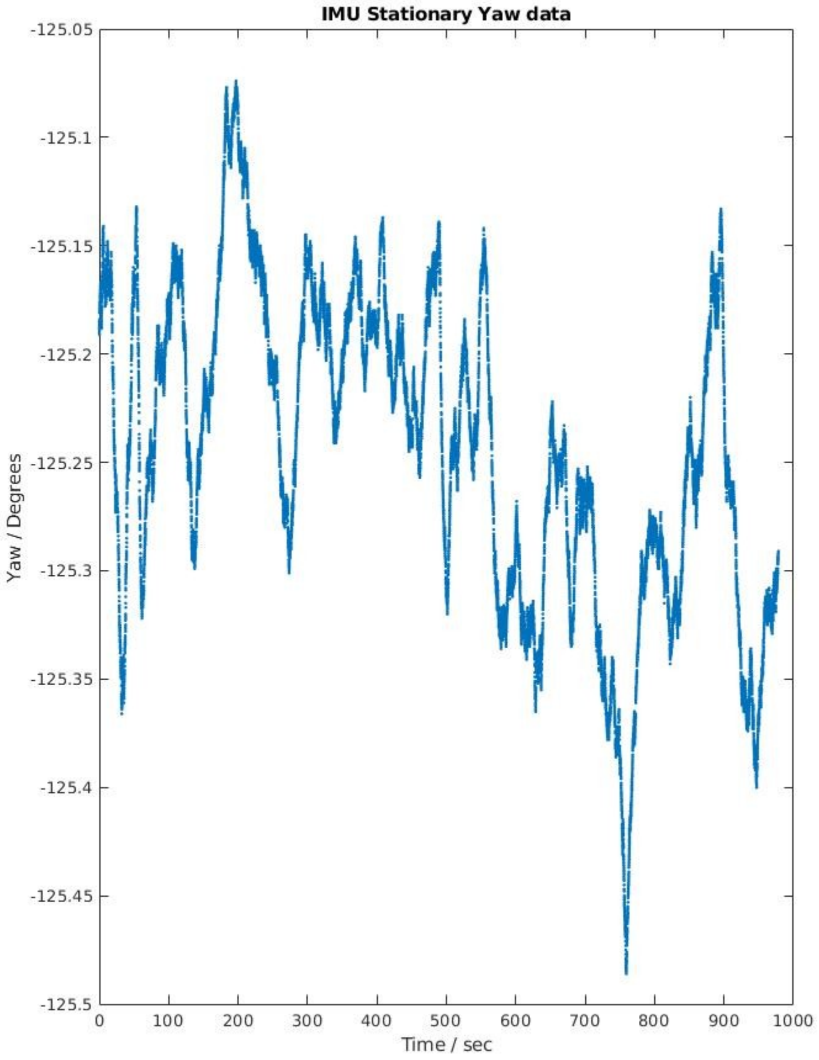
1. GPS and IMU Configuration:
   LCM set up same as lab 1, IMU, GPS sampling rate: 40hZ, 1Hz.
2. Data Collection:
   Stationary – Outside ISEC
   Moving – Neighbourhood near Micro Center on Memorial Drive, Cambridge.
   - Route taken (GPS UTM plot):

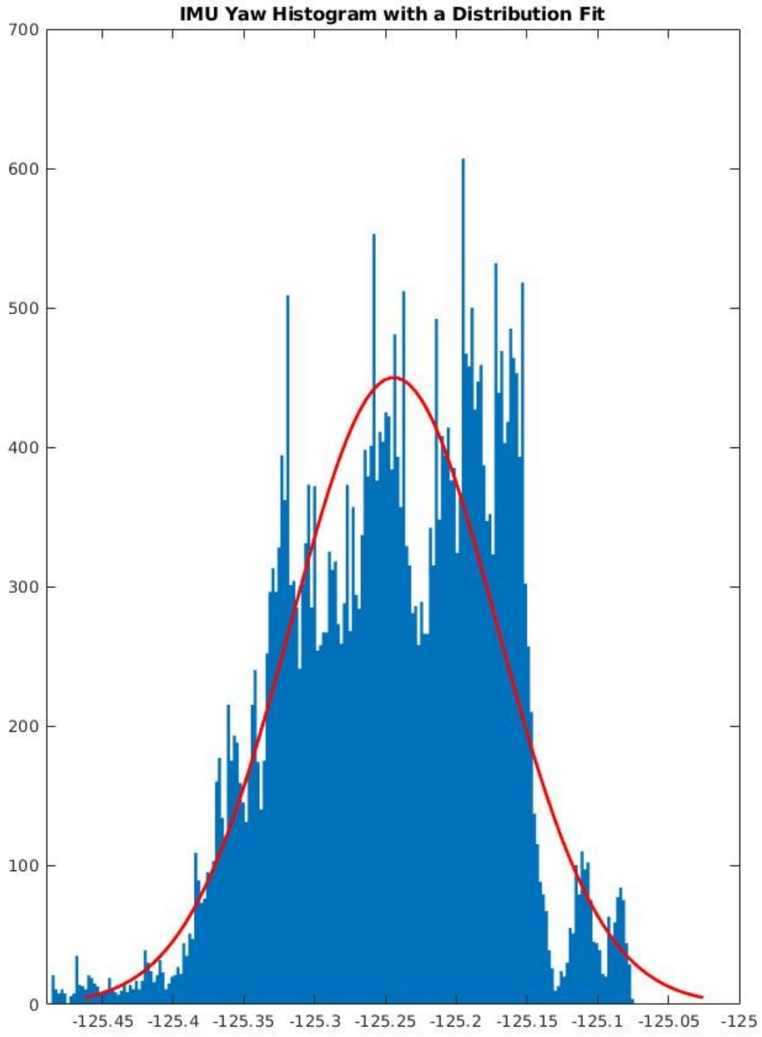


Sensor 360 degrees calibration * 5 (142.7 seconds)

Stationary IMU Data - Yaw

- Stationary yaw mean = -125.2441 degrees

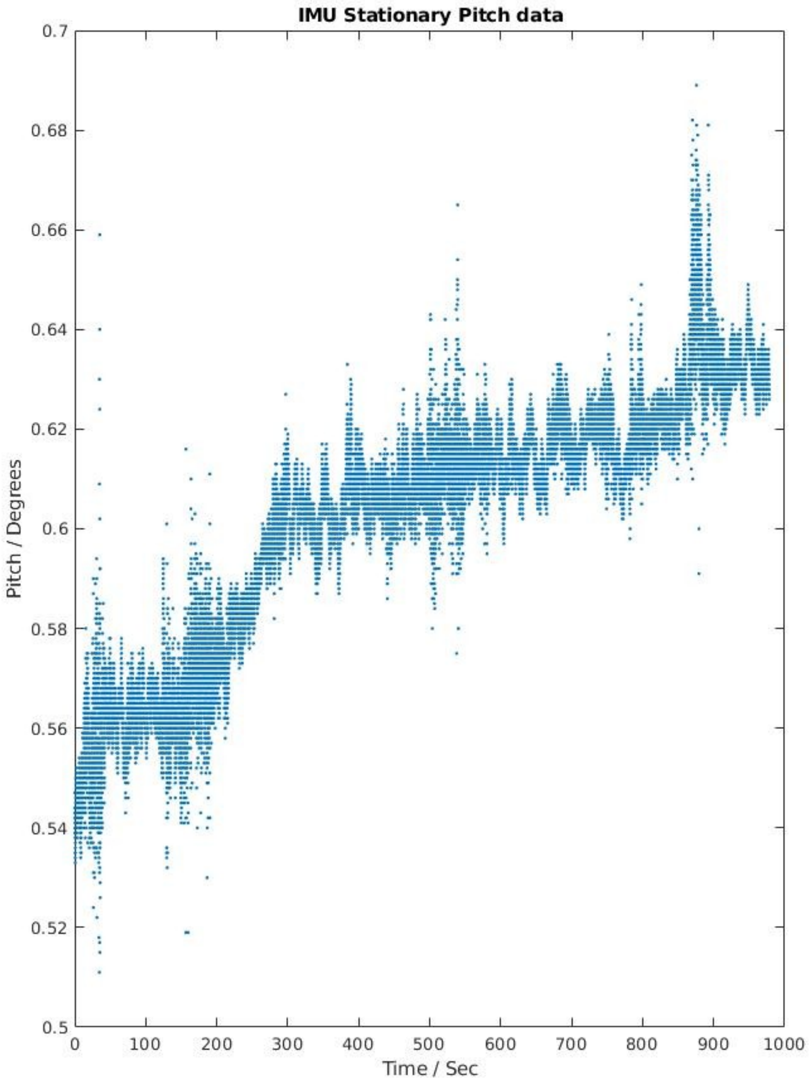


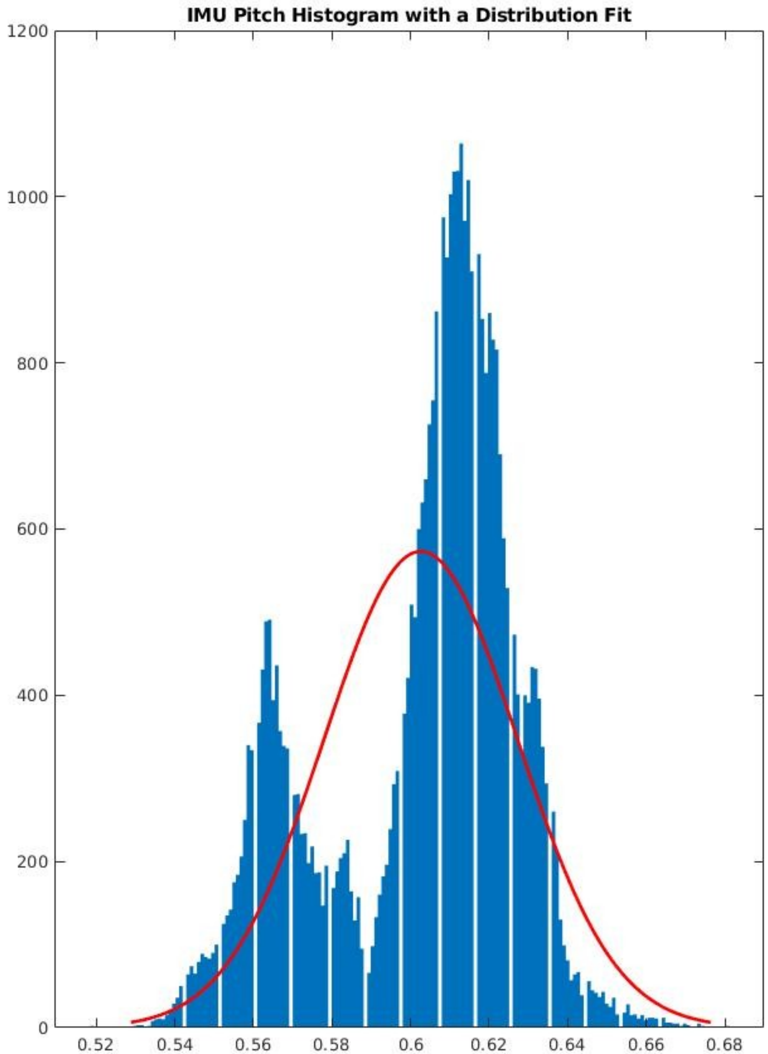


Deviation in acceptable range, fluctuation due to windy condition.

Stationary IMU Data - Pitch

- Stationary pitch mean = 0.6026 degrees

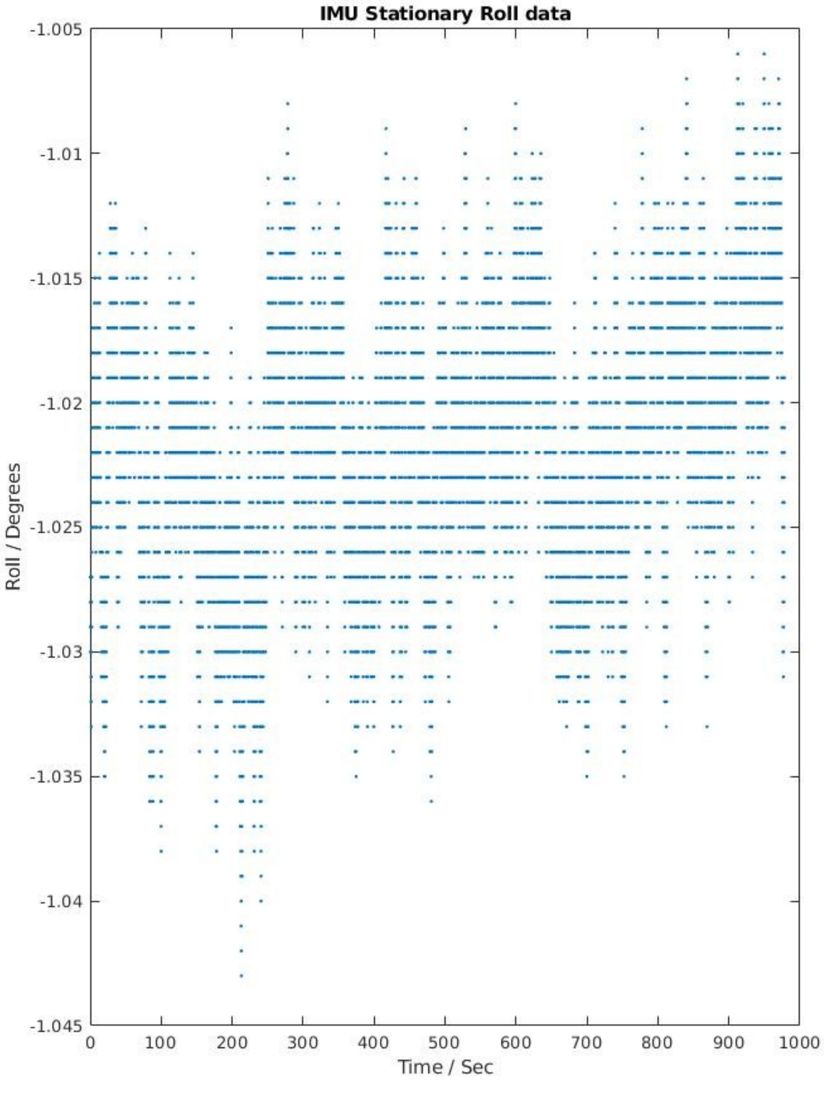


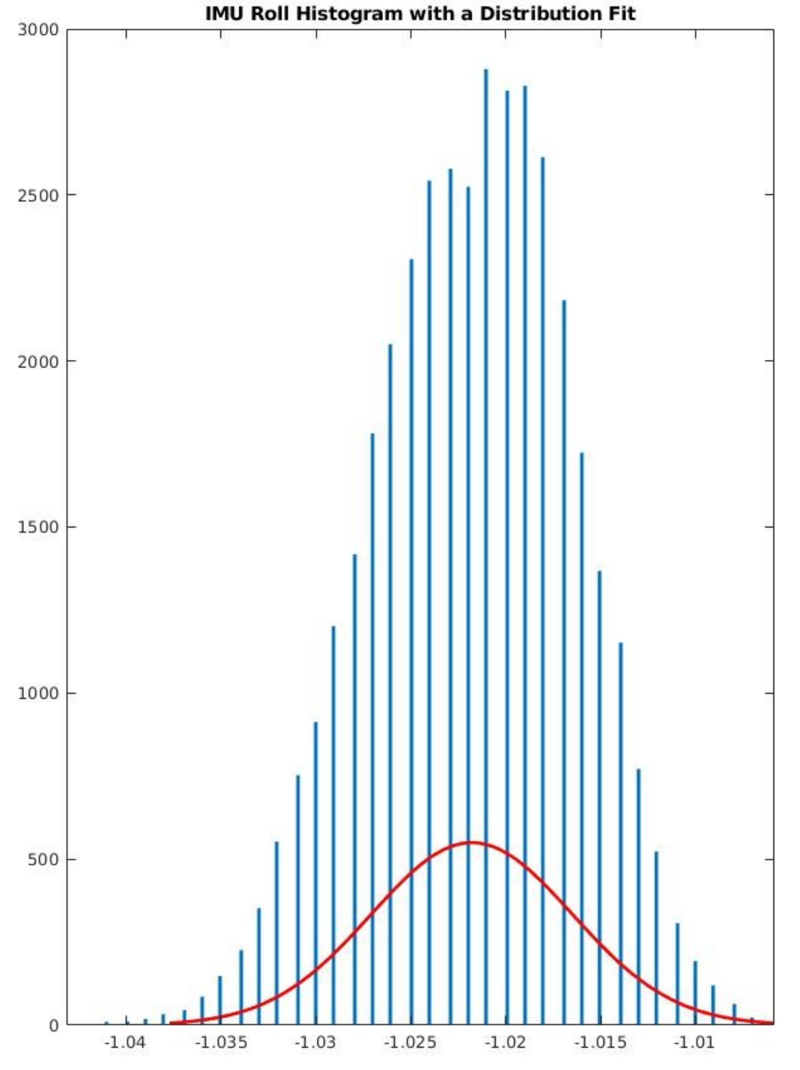


Deviation in acceptable range, fluctuation might due to windy condition.

Stationary IMU Data - Roll

- Stationary roll mean = -1.0218 degrees





Standard normal deviation, more stable compared to collected yaw and pitch data, IMU was placed under a brick .

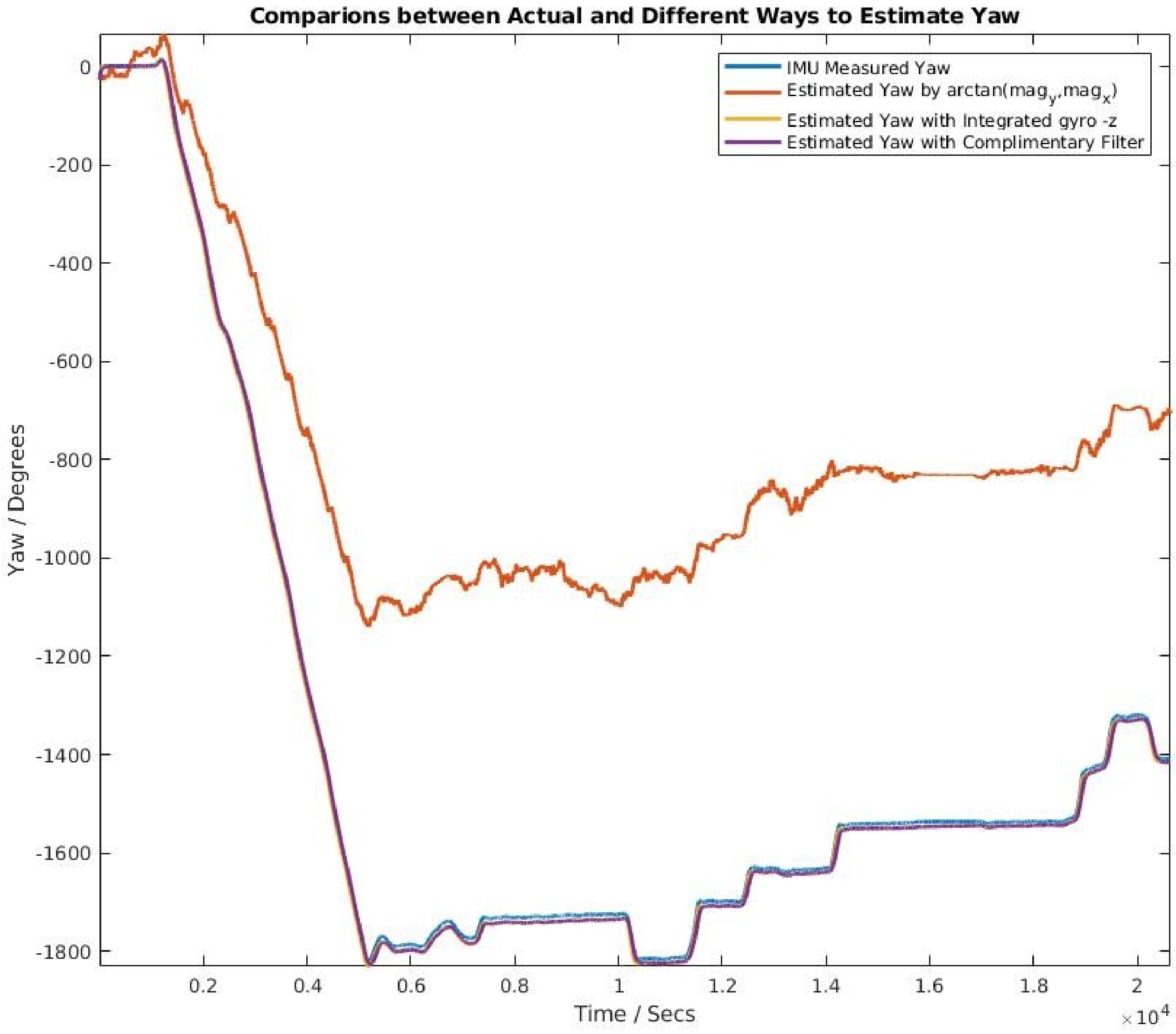
LCM Over the Network

```
Ifconfig                 // get ip and local adapter name
sudo ifconfig wlp2s0 multicast
sudo route add -net 224.0.0.0 netmask 240.0.0.0 dev wlp2s0
export LCM_DEFAULT_URL=udpm://239.255.76.67:7667?ttl=1

lcm-logplayer  // lcm-spy on another machine
```

lcm-spy receiving undecodable data (no corresponding lcm_struct)

Motion IMU: Yaw Estimation Methods Comparison



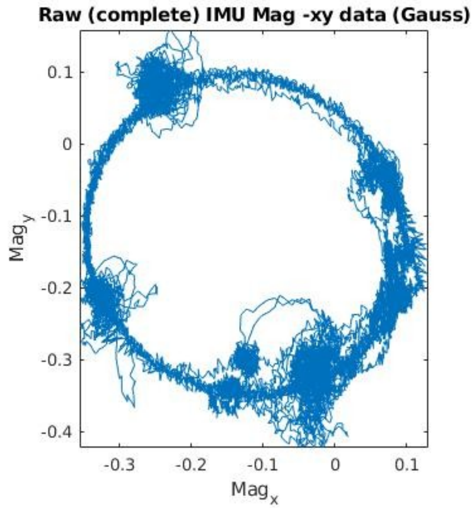
1. Arctan(mag_y, mag_x):
Displayed as the orange line, the errors are caused by the distortion in mag_x and mag_y that is not completely removed after soft/hard iron compensation.

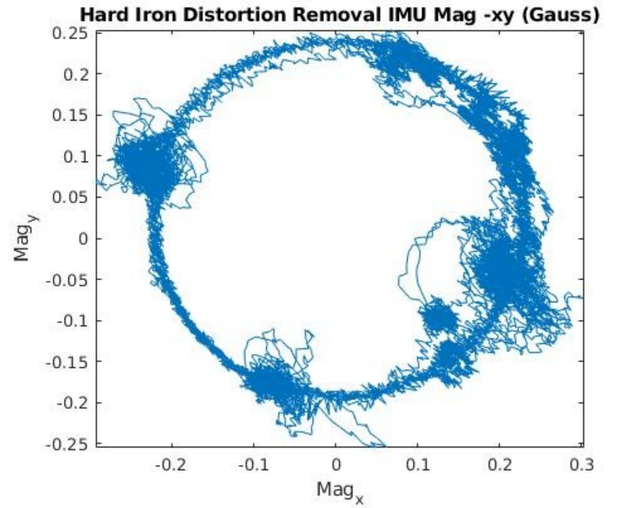
2. Integrating gyro -z with cumulative trapezoidal integration (yellow line):
Closer to the actual measured yaw.

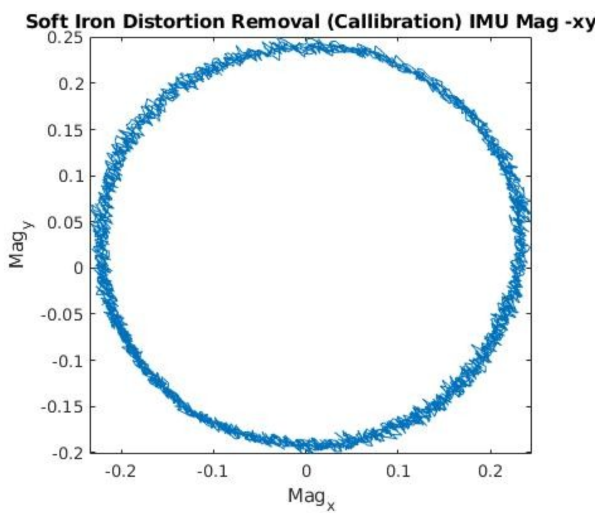
3. Complimentary filters:
- Added a low pass butterworth filter to yaw calculated by arctan(mag_y, mag_x)
- Added a high pass butterworth filter to gyro -z
- Used the following formula with alpha = 0.033:

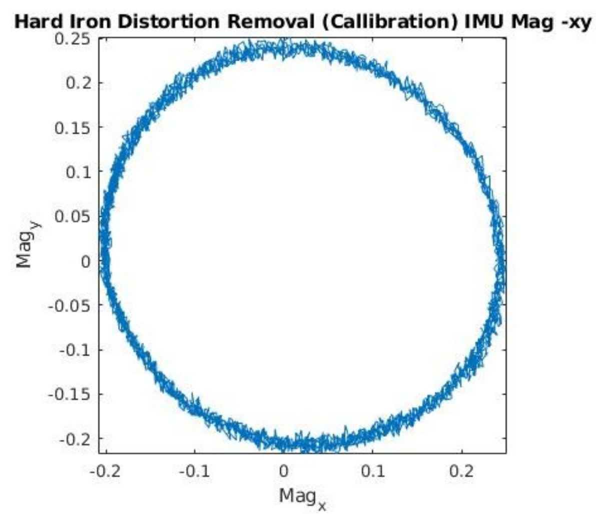
yaw = (1-alpha) * (yaw' + high-pass filtered (gyro -z)* dt) + alpha*low-pass filtered(arctan(mag_y, mag_x)

Motion IMU: Soft and Hard Iron Compensation







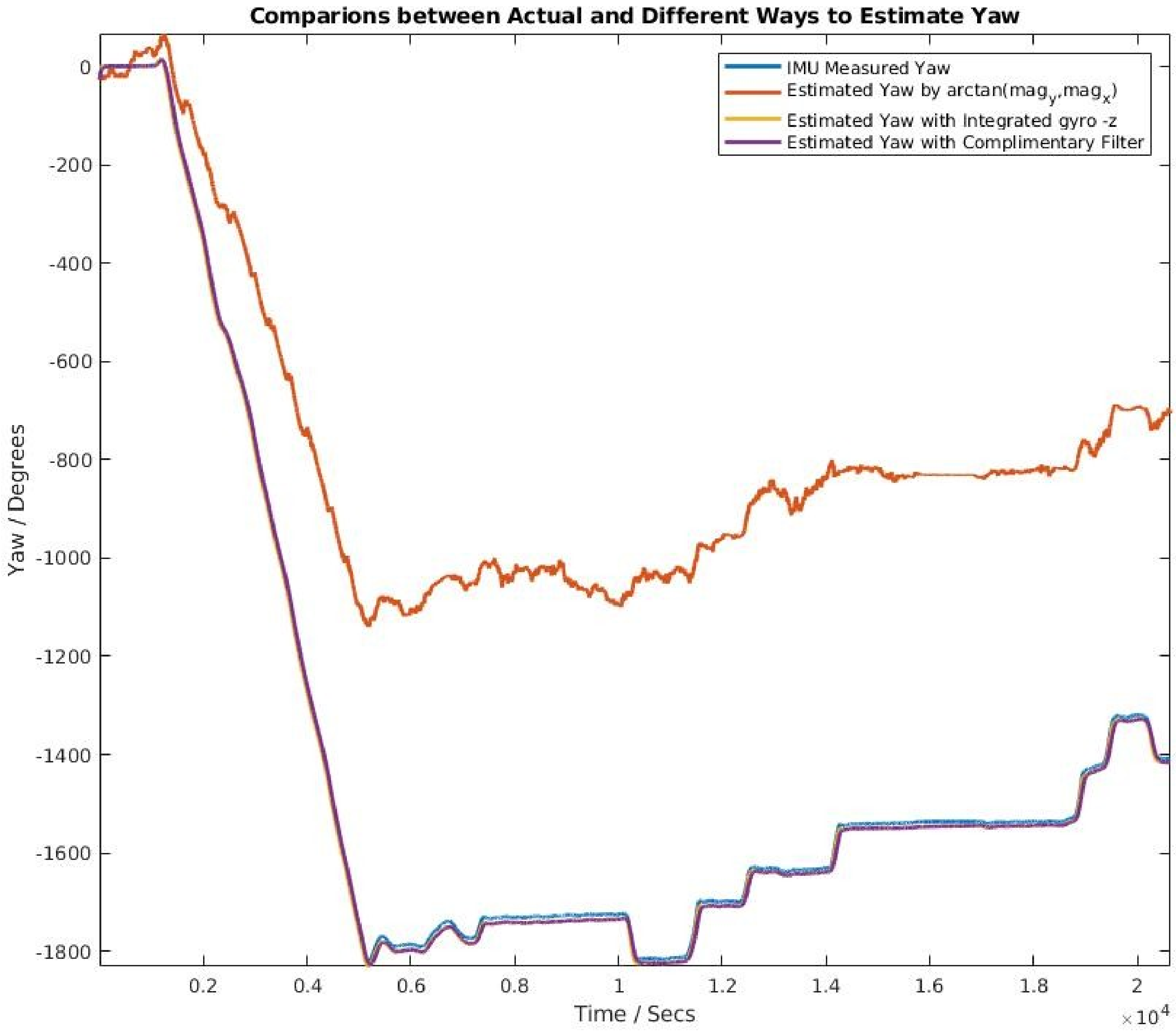


Hard iron effects : produced by produced by materials that exhibit a constant, additive field to the earth's magnetic field. Removing offsets: (max – min)/2 from both x and y axis, to move the ellipse to origin (0,0).

Soft iron effects: result of material that influences, or distorts, a magnetic field. Compensated by first calculating the rotation angle when the major axis overlap x and y axis, then multiply the rotation matrix to the raw mag data. (credits: fit_ellipse.m)

All soft and hard iron correction parameters are taken during 360 degrees calibration (29 sec to 125 seconds)

Motion IMU: Yaw Estimation Methods Comparison



1. Arctan(mag_y, mag_x):
Displayed as the orange line, the errors are caused by the distortion in mag_x and mag_y that is not completely removed after soft/hard iron compensation.

2. Integrating gyro -z with cumulative trapezoidal integration (yellow line):
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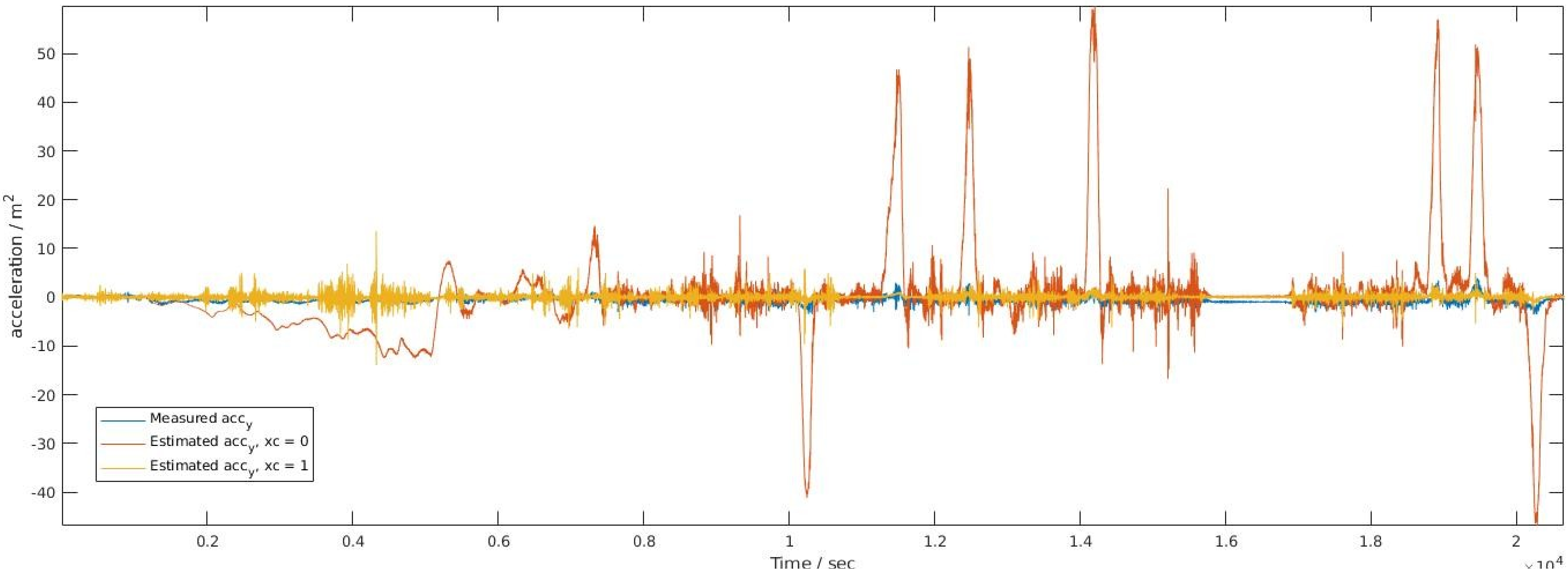
Motion IMU: acc_y Estimation and comparison



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

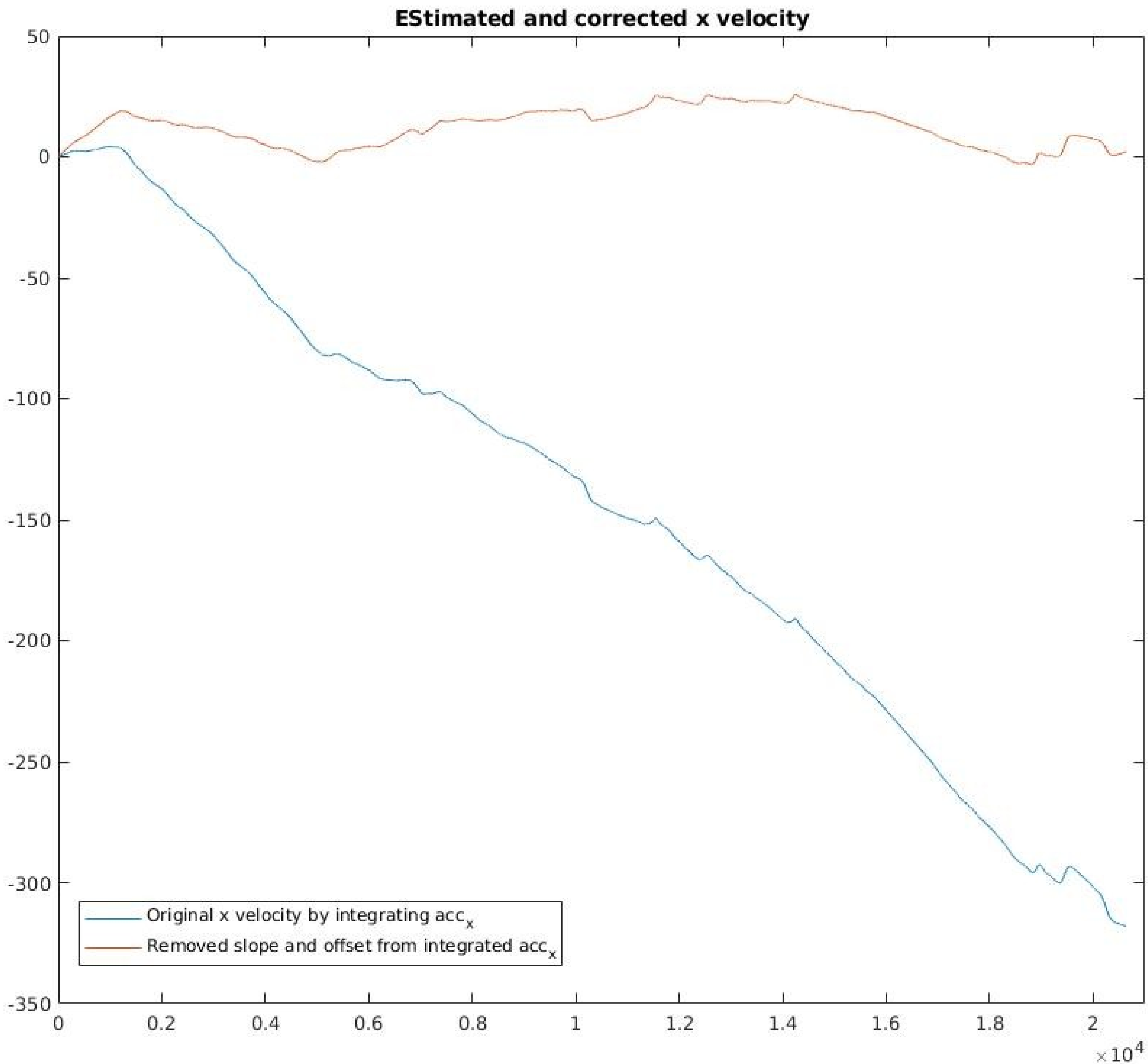
Assuming that $\ddot{Y}$ = 0, according to the given formulas:

$$\ddot{y}_{obs} = \ddot{Y} + \omega\dot{X} + \dot{\omega} x_c$$

When xc = 0, acceleration – y is computed with acceleration -x integrated once and multiplied with gyro – z (shown in red). Compared with the measured acceleration – y, the main cause for the difference is because of setting xc = 0, neglecting the position of the IMU in the vehicle, implying that the IMU turns the same amount of degrees as when located in the center-of-mass in the vehicle.

The best fit for xc to make the estimated acc_y close to the measured acc_y is 1 (yellow line in above graph).

Motion IMU: Estimating and Correcting velocity - x

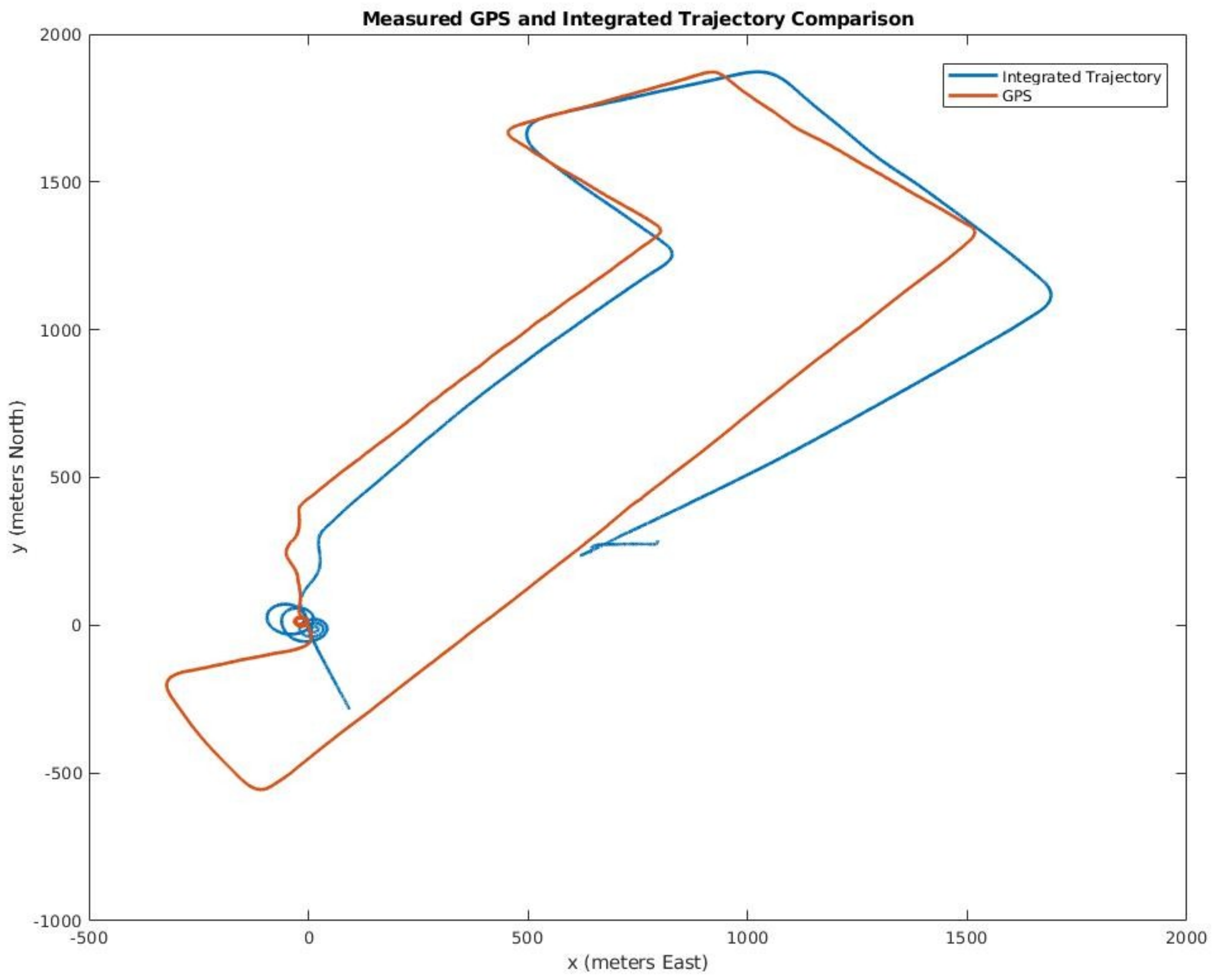


Estimation of the velocity is done by integrating the measured acceleration – x once (blue in left plot).

We do see a stable slope of the velocity due to the IMU is not placed completely flat at the time of data collection

A rotation angle was derived from “polyfit” and atan function, then used as a rotation matrix applied to the original estimated x velocity. Offset/bias also removed (setting min as 0).

Motion IMU: Integrated vehicle position and GPS



(two plots adjusted to same at the same origin (0,0), Integrated position rotated 20 degrees clockwise shifted to overlap starting point; GPS plot enlarged twice in size.)

Position of vehicle obtained by integrating (corrected) x – acceleration once again, then multiplying the estimated yaw angle to each segment of the integrated twice acceleration x data (multiply sin for x, cos for y).

Inaccuracy of estimated position plot due to accumulative error from yaw angle estimation, velocity estimation and existing pitch angle.