EECE 5554 - Robot Sensing and Navigation
Lab 2 Report

Introduction:

The primary focus of the third lab is to collect and analyze the IMU data from the Vectornav VN-100 IMU sensor. The driver was written to collect and parse the data from the sensor which were then published on the IMU topic. Once the data is collected using the driver it is then analyzed for the three noise parameter N (angle random walk), k (rate random walk), and B (bias instability). These are estimated using the stationary data acquired from the gyroscope and the accelerometer. Further the sources of noise in the IMU and magnetometer were analyzed.

Data Collection:

The first set of data was collected for 5 – 10 minutes by staying still followed by another set of data which was collected while moving.

The next set of data was collected for a duration of 5 hours at a particular location which is used toanalyze the Allan Variance.

Data Analyses:

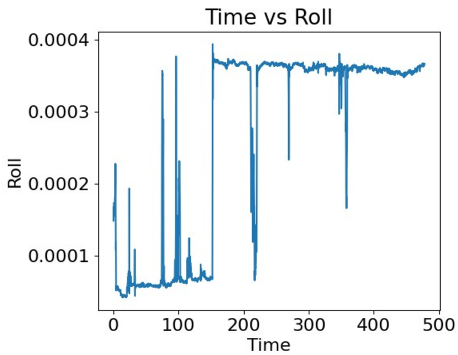
In this section the data collected from the IMU Vectornav VN-100 are analyzed. The data includes:

1. Roll Angle
2. Pitch Angle
3. Yaw Angle
4. Angular velocity in x,y,z directions
5. Linear Acceleration in x,y,z directions
6. Magnetic Fields in x,y,z directions

The Time series and the frequency graphs for each data set were plotted and the noise characteristics of the same were obtained. Further the standard deviation and mean were calculated to understand the noise characteristics.

1.Time and Frequency Plot – Still Data

a. Roll



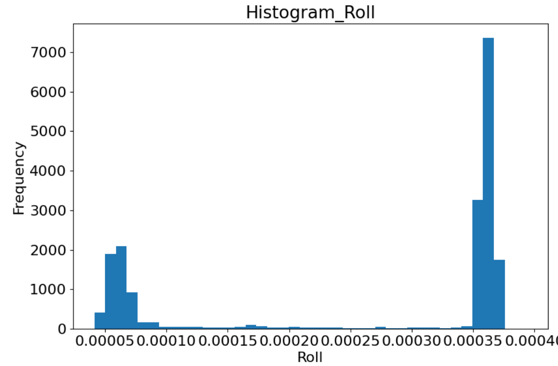
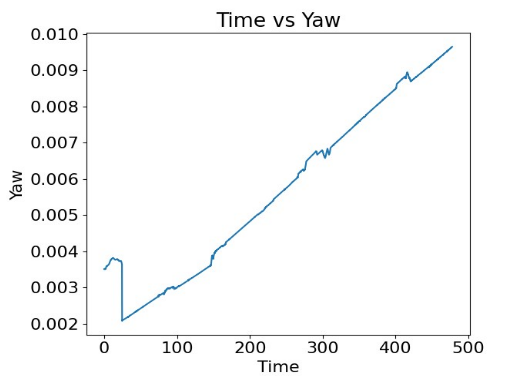


Fig 1 : Time Series Plot

Fig 2: Histogram Plot

The Standard Deviation is 0.00013666773412043738 and the mean is 0.00026413970819086065. The graph follows the Gaussian Distribution

b. yaw



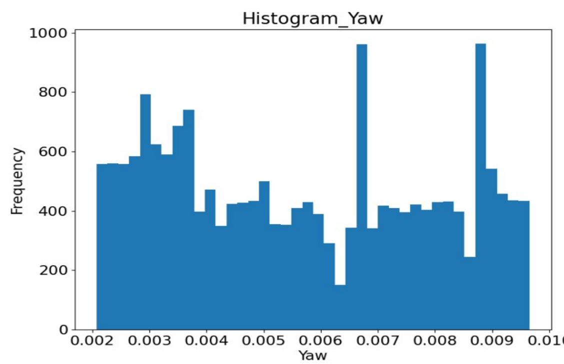
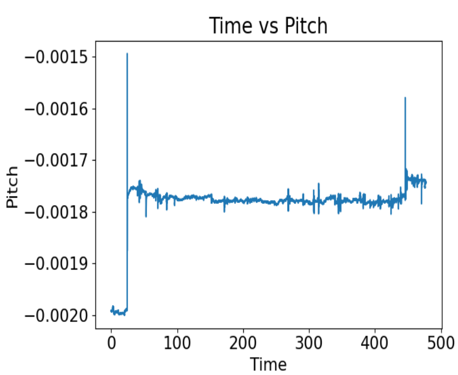


Fig 3 : Time Series Plot

Fig 4: Histogram Plot

The Standard Deviation is 0.0022916305902757703 and the mean is 0.005681540288727236. The graph follows the Gaussian Distribution

c. Pitch



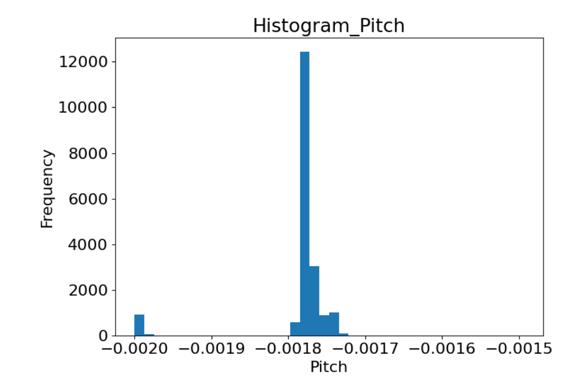
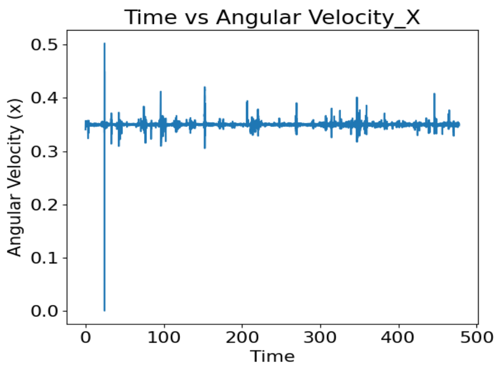


Fig 5 : Time Series Plot

Fig 6: Histogram Plot

The Standard Deviation is 4.990087852723967e-05 and the mean is -0.0017846910895807999. The graph follows the Gaussian Distribution

a. Angular Velocity x direction:



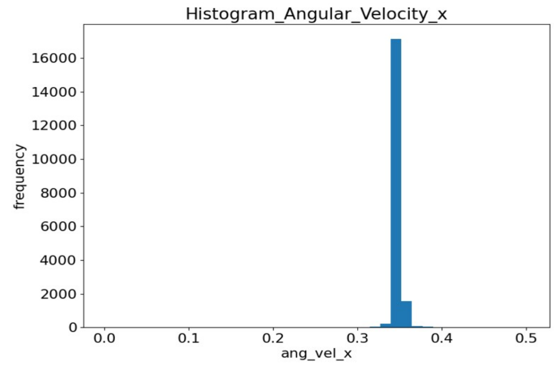
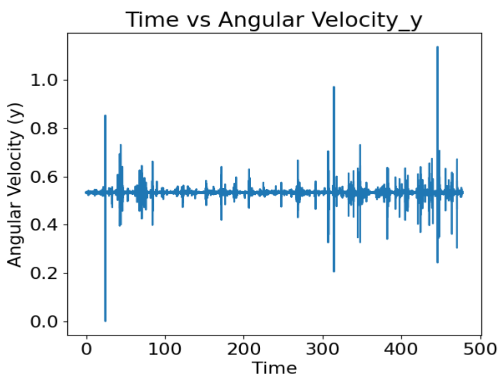


Fig 7 : Time Series Plot

Fig 8: Histogram Plot

The Standard Deviation is 0.004981807086126119 and the mean is 0.3499388569409547. The graph follows the Gaussian Distribution

b. Angular Velocity y direction:



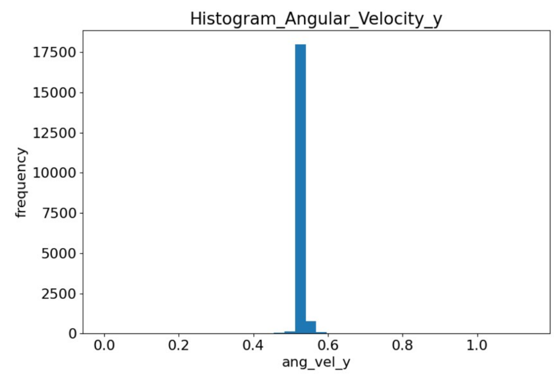
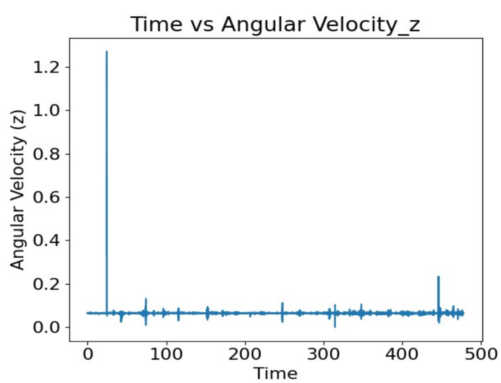


Fig 9 : Time Series Plot

Fig 10: Histogram Plot

The Standard Deviation is 0.013820060607551816 and the mean is 0.5336036195561139. The graph follows the Gaussian Distribution

c. Angular Velocity z direction:



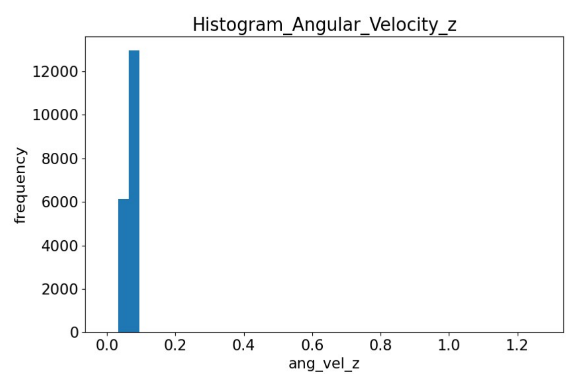
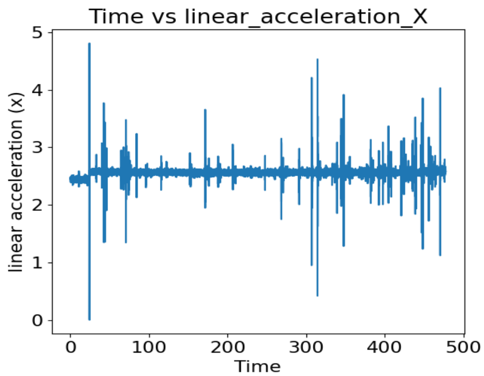


Fig 11 : Time Series Plot

Fig 12: Histogram Plot

The Standard Deviation is 0.011695988169656994 and the mean is 0.06425245948492463. The graph follows the Gaussian Distribution

a. Linear Acceleration x direction:



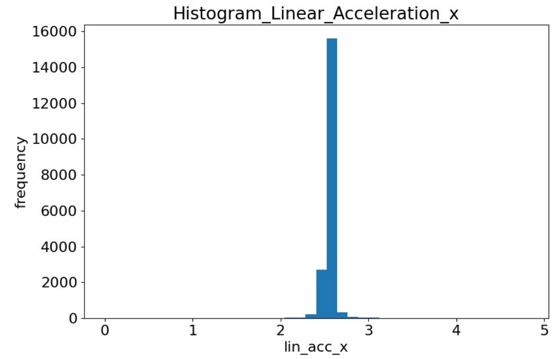
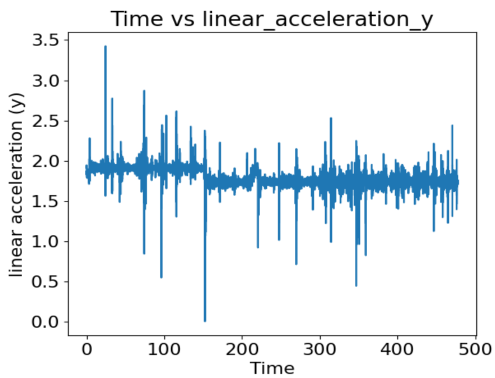


Fig 13 : Time Series Plot

Fig 14: Histogram Plot

The Standard Deviation is 0.0854477342753909 and the mean is 2.556479585427136. The median was found to be 2.5600000000000005. The graph follows the Gaussian Distribution

b. Linear Acceleration y direction:



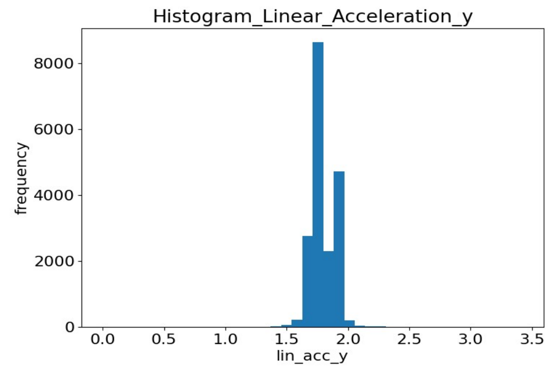
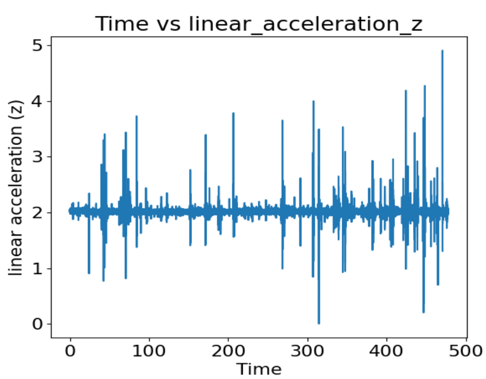


Fig 15 : Time Series Plot

Fig 16: Histogram Plot

The Standard Deviation is 0.10432697693274105 and the mean is 1.792683835845896.The median was found to be 1.762. The graph follows the Gaussian Distribution

c. Linear Acceleration z direction:



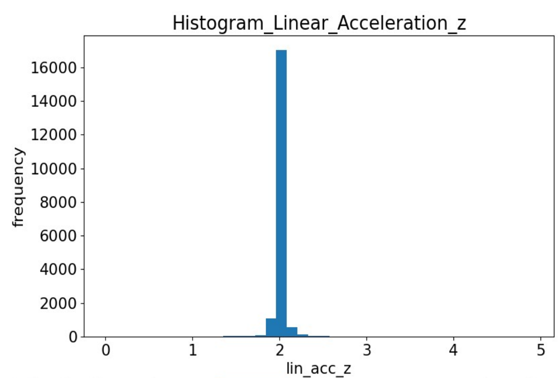
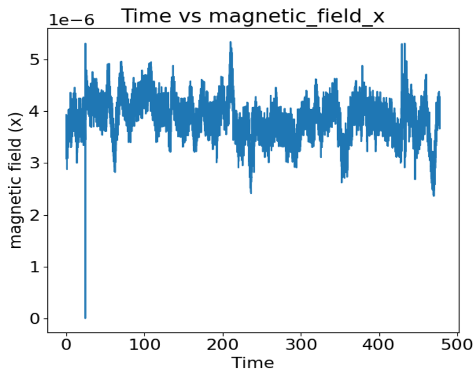


Fig 17 : Time Series Plot

Fig 18: Histogram Plot

The Standard Deviation is 0.09535785563884462 and the mean is 2.0148387772194303. The median was 2.0150000000000006.

a. Magnetic Field x direction:



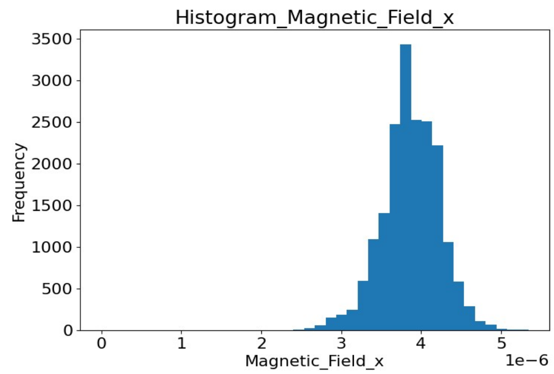
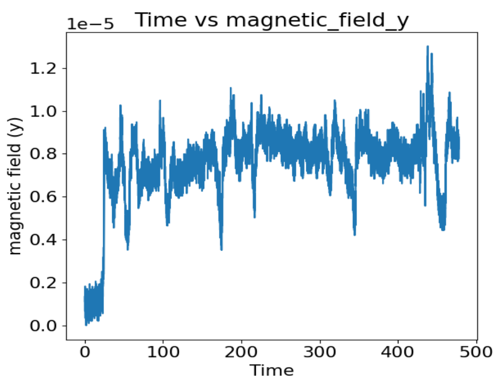


Fig 19 : Time Series Plot Fig 20: Histogram Plot

The Standard Deviation is 3.619777009326471e-07 and the mean is 3.8701182998832495e-06. The graph follows the Gaussian Distribution

b. Magnetic Field y direction:



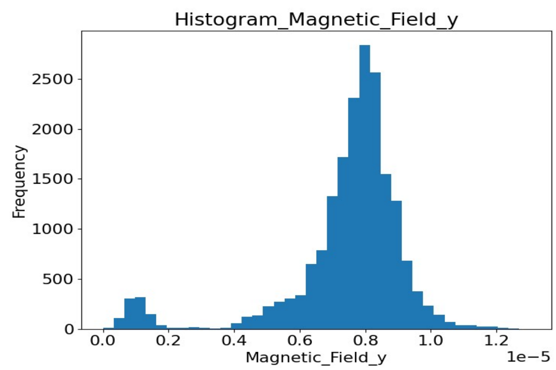
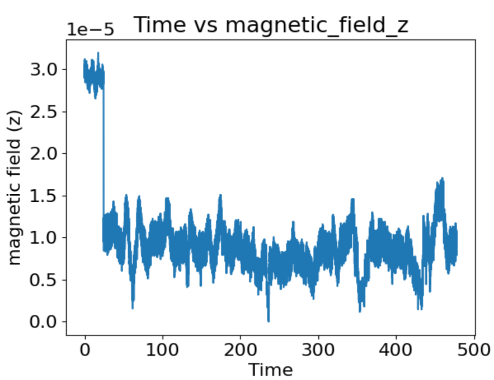


Fig 21 : Time Series Plot Fig 22: Histogram Plot

The Standard Deviation is 7.461181427973198e-06 and the mean is 1.8506218514999647e-06. The graph follows the Gaussian Distribution

c. Magnetic Field z direction:



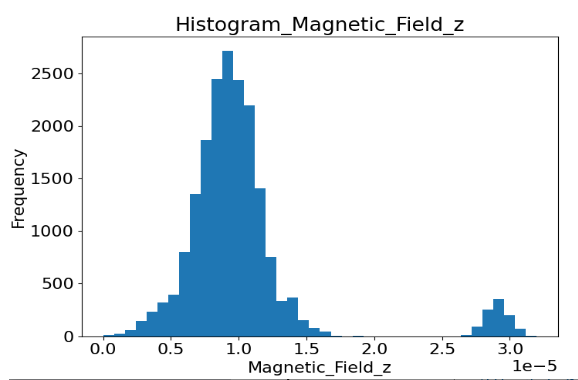
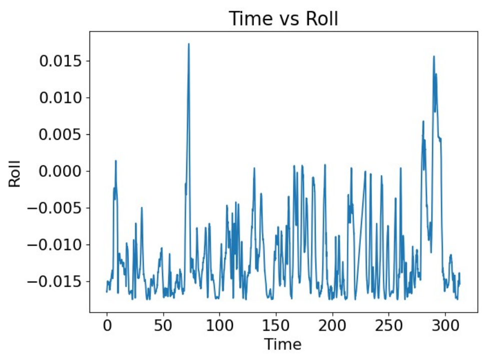


Fig 23 : Time Series Plot Fig 24: Histogram Plot

The Standard Deviation is 4.961524402586694e-06 and the mean is 1.0169055695142375e-05. The graph follows the Gaussian Distribution

2.Time and Frequency Plot – Moving Data

a. Roll



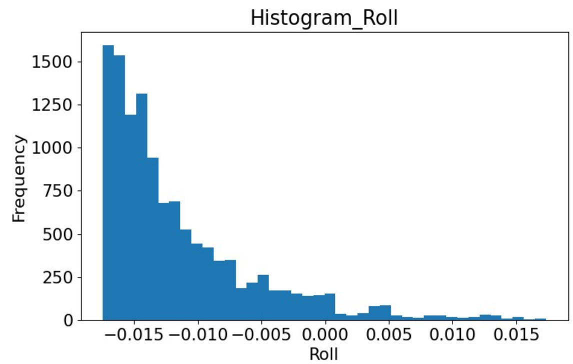
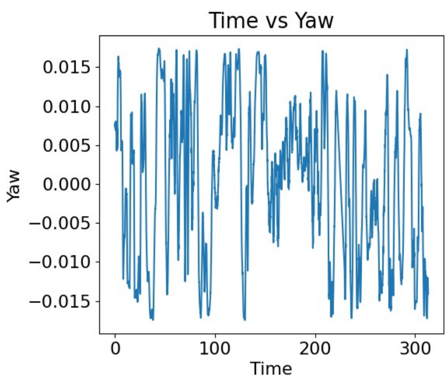


Fig 25 : Time Series Plot

Fig 26: Histogram Plot

The Standard Deviation is 0.006032098825909373 and the mean is -0.011475416680962781. The graph follows the Gaussian Distribution

b. yaw



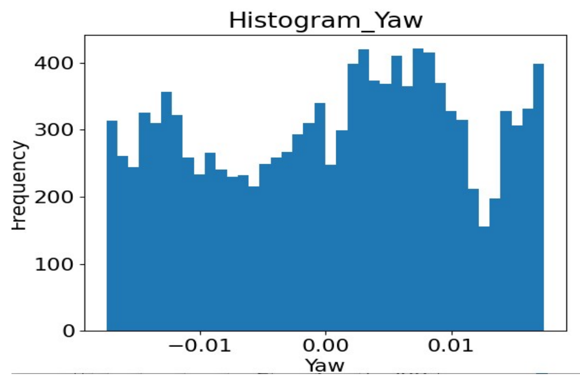
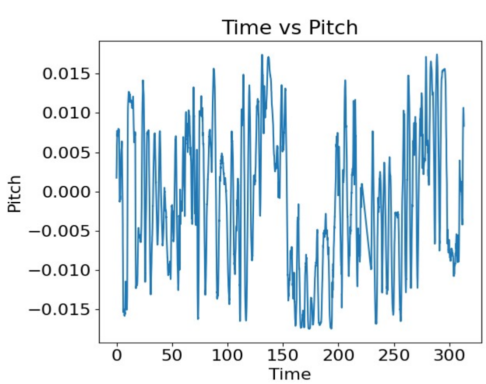


Fig 27 : Time Series Plot

Fig 28: Histogram Plot

The Standard Deviation is 0.009938829748635128 and the mean is 0.0005579021952951547. The graph follows the Gaussian Distribution

c. Pitch



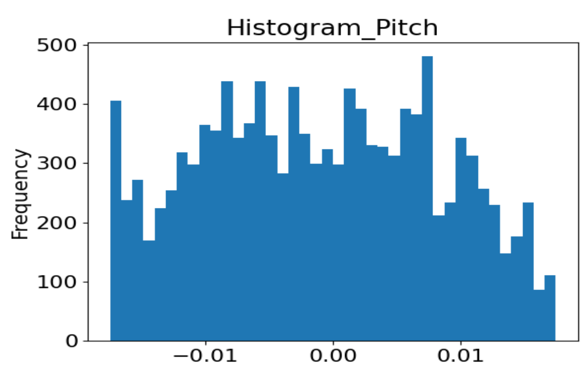
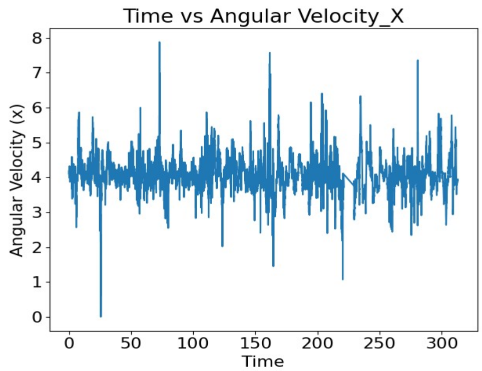


Fig 29 : Time Series Plot

Fig 30: Histogram Plot

The Standard Deviation is 0.009126923219535706 and the mean is -0.0010080121549463745. The graph follows the Gaussian Distribution

a. Angular Velocity x direction:



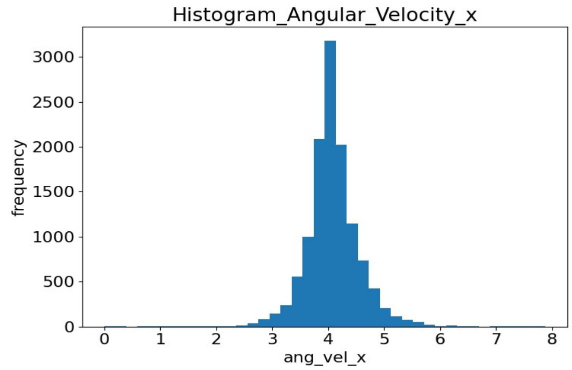
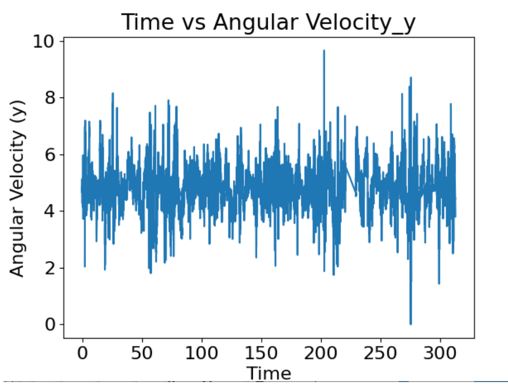


Fig 31 : Time Series Plot

Fig 32: Histogram Plot

The Standard Deviation inis 0.47261944255723526 and the mean is 4.087058052255947. The graph follows the Gaussian Distribution

b. Angular Velocity y direction:



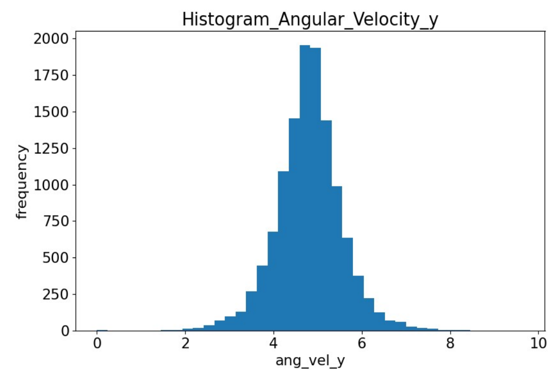
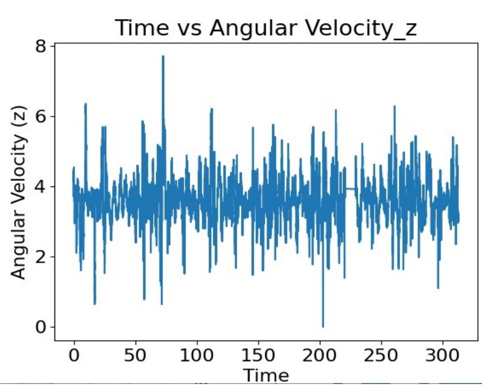


Fig 33 : Time Series Plot

Fig 34: Histogram Plot

The Standard Deviation is 0.7417428942190043 and the mean is 4.805462270631666. The graph follows the Gaussian Distribution

c. Angular Velocity z direction:



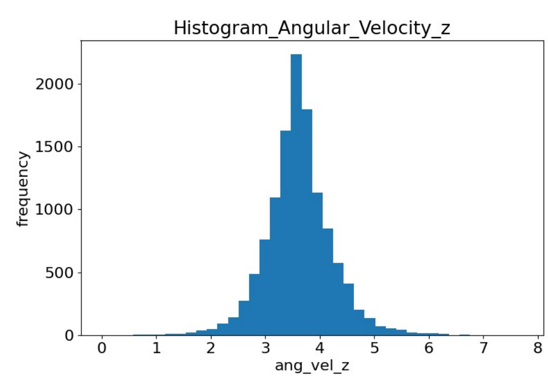
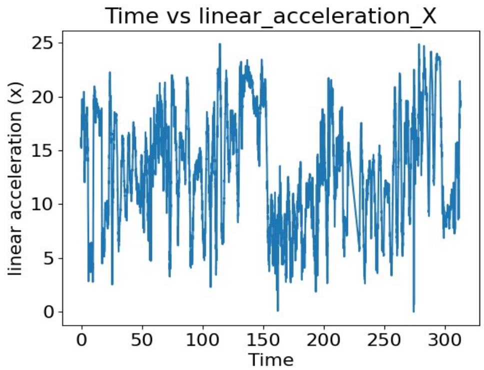


Fig 35 : Time Series Plot

Fig 36: Histogram Plot

The Standard Deviation is 0.6076075882318412 and the mean is 3.6173046156685804. The graph follows the Gaussian Distribution

a. Linear Acceleration x direction:



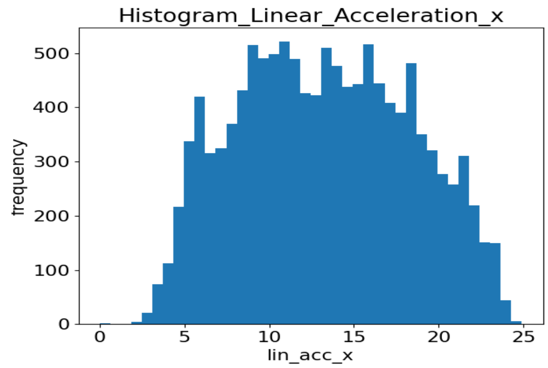
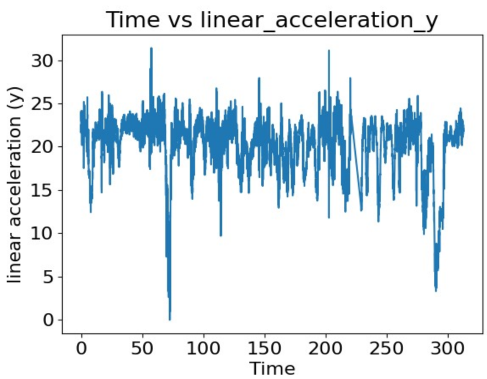


Fig 37 : Time Series Plot Fig 38: Histogram Plot

The Standard Deviation is 5.0904613906341405 and the mean is 13.280016981132077. The median was found to be 13.177999999999999. The graph follows the Gaussian Distribution

b. Linear Acceleration y direction:



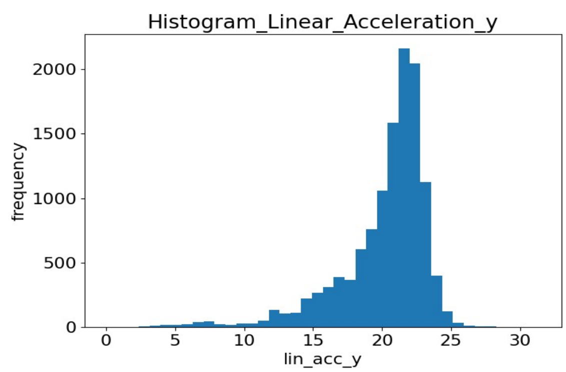
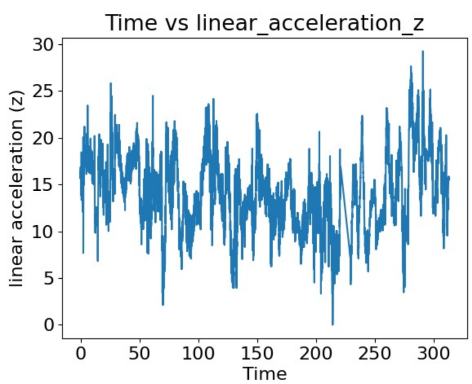


Fig 39 : Time Series Plot Fig 40: Histogram Plot

The Standard Deviation is 3.3152469551853736 and the mean is 20.16311632485644.The median was found to be 21.130499999999998. The graph follows the Gaussian Distribution

c. Linear Acceleration z direction:



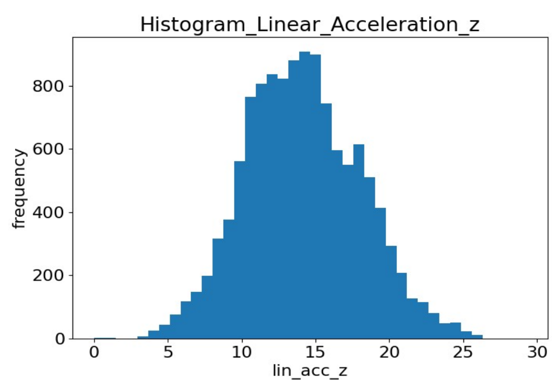
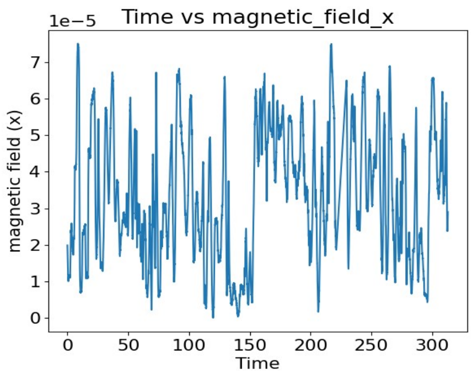


Fig 41 : Time Series Plot Fig 42: Histogram Plot

The Standard Deviation is 3.90246431120465 and the mean is 14.134755127153404. The median was 13.982500000000002.

a. Magnetic Field x direction:



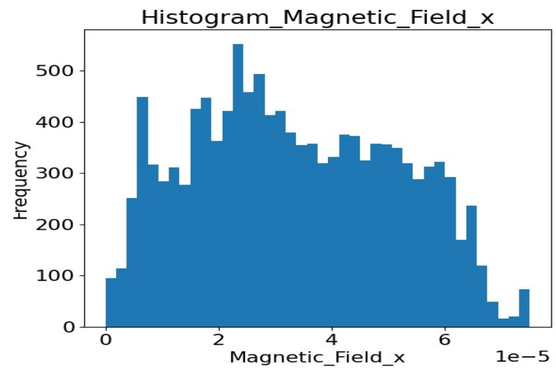
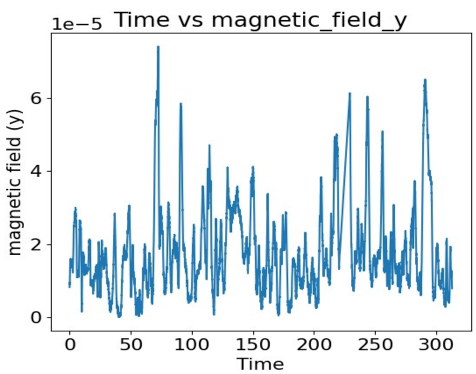


Fig 43 : Time Series Plot

Fig 44: Histogram Plot

The Standard Deviation is 1.7849656841479087e-05 and the mean is 3.3549114027891716e-05. The graph follows the Gaussian Distribution

b. Magnetic Field y direction:



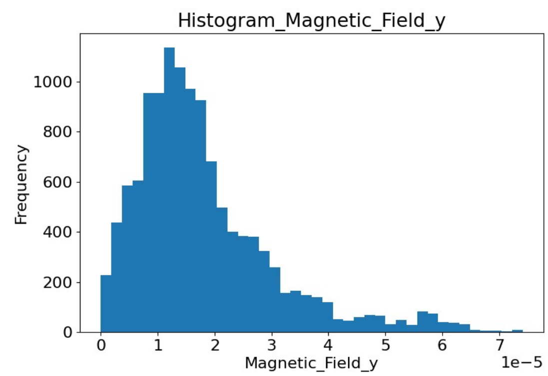
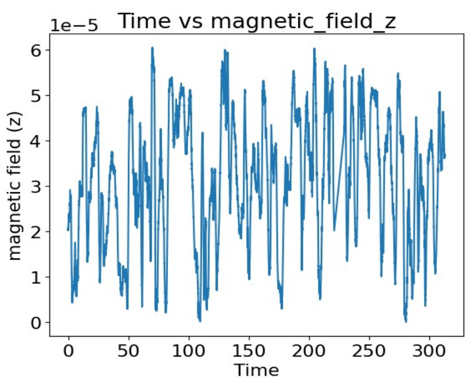


Fig 45 : Time Series Plot

Fig 462: Histogram Plot

The Standard Deviation is 1.2234170248279917e-05 and the mean is 1.7919148482362597e-05. The graph follows the Gaussian Distribution

c. Magnetic Field z direction:



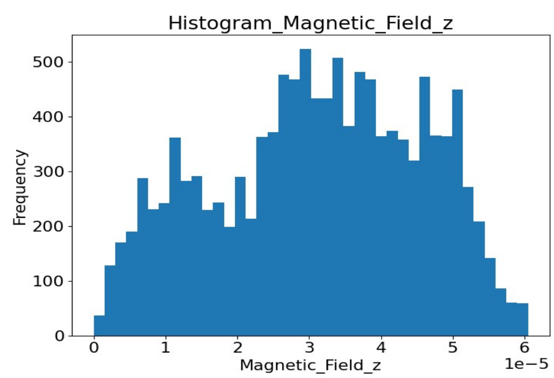


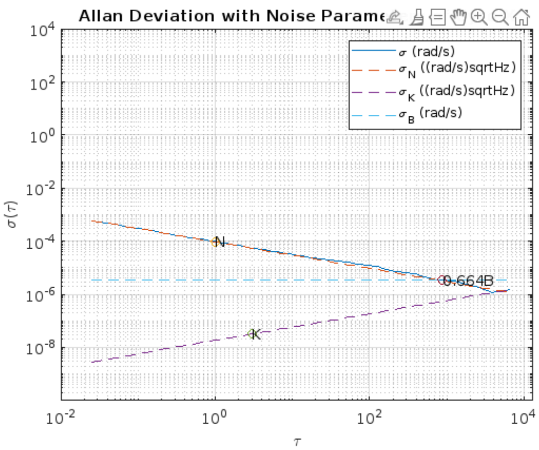
Fig 1 : Time Series Plot

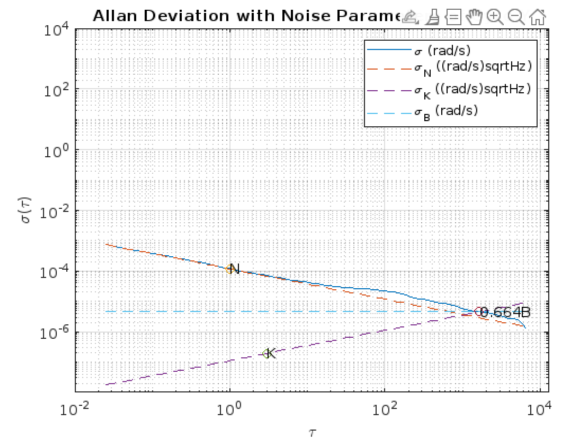
Fig 2: Histogram Plot

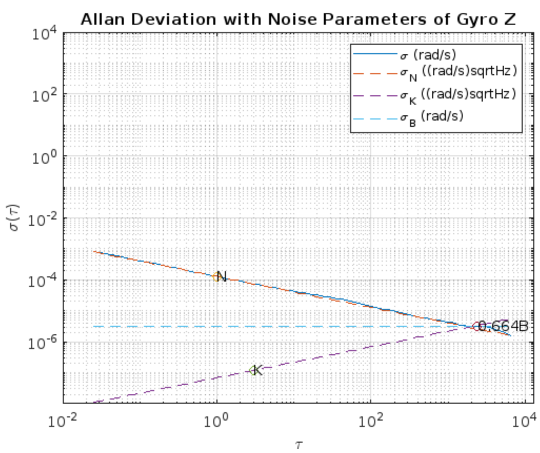
The Standard Deviation is 1.4401590814311745e-05 and the mean is 3.1179352748154 22e-05. The graph follows the Gaussian Distribution

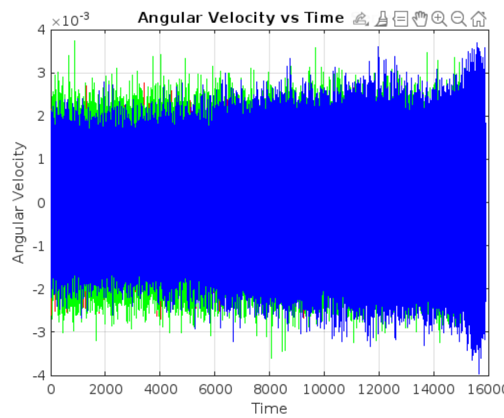
3. Allan Variance Plot – Location D data

a) Allan Deviation of Gyroscope in x,y,z direction – Noise Parameters









The above graph presents the allan variance of gyroscope in x,y,z direction and the angular velocity vs time graph.

The values of Fs and T0 considered for the graph are 40 hz and 0.025 sec.

Nx = 9.5110 e^-5   Ny = 1.1811 e^-4 Nz = 1.2796 e^-4

Kx = 3.1830 e^-8   Ky = 1.9097 e^-7 Kz = 1.1792 e^-7

Bx = 5.1225 e^-6   By = 6.7183 e^-6 Bz = 4.7634 e^-6

We can infer that the datas for all the locations were collected from

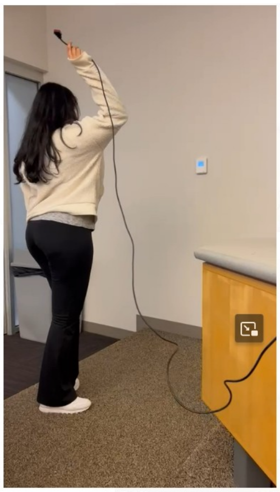
Location A - ISEC basement

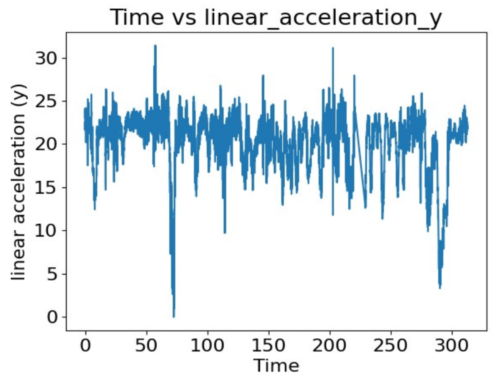
Location B -

Location C – 3rd Floor Wooden House or 5th floor of ISEC

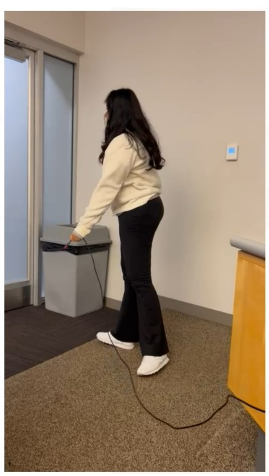
Location D – Snell Library Basement

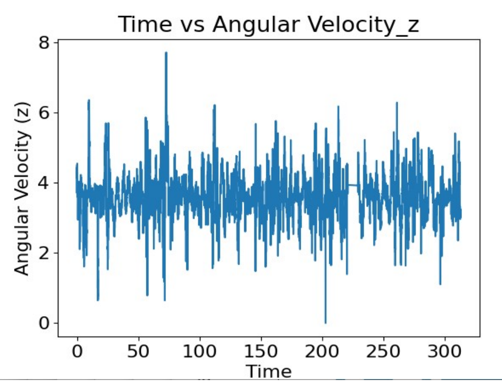
Video Drive link:
(https://drive.google.com/drive/folders/1FhQptb6TJiFHC5AfT2wNGD3R88pDuw-G?usp=sharing)





We can find from the graph that at around 70 secs there is a huge spike the linear acceleration in y direction during the motion shown in the image.





We can find from the graph that at around 200 secs there is a huge spike the angular velocity in z direction during the motion shown in the image.

Questions:
1. What can you say about the noise in your short stationary data? What was the median, mean, and distribution?

The noise in the short stationary data was found to be very limited as shown in the graphs above. Further the noise found in the data could be thermal noise, mechanical noise, or the electrical noise. (Mean, Median and Distribution has beenmentioned above below each plot).

2. How did you align the video and Vectornav data? What inferences did you draw from the IMU data to successfully link it with the video?

While analysing the video and the various plots that were plotted during the analysis we can infer that the imu data obtained from the sensor is very accurate and so is the noise level in the data.

3. How do your measurements compare to the performance listed in the VN100 datasheet?

Compared to the datasheet provided for the VN100 IMU sensor, the data was very accurate with decent level of error,which is also mentioned in the data.

4. If the performance in your dataset was worse than the datasheet, what sources of noise do you think were present? Why?

Sources of noise in the imu sensor could be from multiple sources like mechanical noise, electronic noise, environmental noise and thermal noise. These errors can be broadly divided into systematic and unsystematic errors. The Systematic errors usually have a similar or proportional values for each and every measurements that are made, while unsystematic errors are usually very random and cannot be predicted.

5. If you had to suggest which AVAR (Allan Variance) plots went with which locations/conditions, how would you match them? What sources of noise would be present in this environment?

In order to match the AVAR plots to locations at which they were taken, we could consider the following,

The slope of the AVAR plot at low frequencies, ie. A a slope of -o.5 usually indicates angle random walk noise which is caused by the changes in the orientation of the sensor over time. The slope of 0.5 indicates the rate random walk that could be caused by the change in the angular velocity of the sensor. A slope of 0 indicates the bias instablity noise which is due ot the constant offset.

The magnitude of the AVAR plot at low frequency shows that the overall level of noise in the sensor output. A lower AVAR indicates a lesser noise.

Finally the shape of the AVAR plot at high frequencies can be used to figure out the specific source of noise.

6. What do your results tell you about the conditions you should measure Allan variance under to understand the best sensor performance possible?

- Position the sensor in a calm environment devoid of vibrations.
- Securely fasten the sensor to eliminate any vibration interference.
- Employ a top-notch data acquisition system.
- Ensure a high sampling frequency, preferably above 100 Hz.
- Gather data over an extended duration, lasting at least 1 hour.

7. If you were trying to characterize a new sensor with unknown performance, briefly (2 sentences max) explain what, where, and how you would measure to understand sources of noise in the sensor and environment, and the performance you could expect under its operating conditions.

I would conduct extensive measurements in a controlled environment to identify sources of noise in both the sensor and its surroundings. This would involve measuring the sensor's output under various conditions, meticulously analyzing data points, and assessing the impact of environmental factors such as temperature and vibration. By systematically evaluating these parameters, I can gain insights into the sensor's noise sources and predict its performance accurately in real-world operating conditions.