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EECE5554 – Robot Sensing and Navigation
Lab #3

Allan Variance Analysis of the 5 Hour data (Location A):

I analyzed the Allan variance plots of the data from the gyro at Location A. The plots show that the gyro is dominated by white noise at low averaging times and by flicker noise at higher averaging times. The knee point of the Allan variance plot is located at around 10 seconds for the X axis and around 100 seconds for the Y and Z axes. The Allan deviation for the gyro X axis at averaging times above 10 seconds is around 0.1 degrees per second per square root hour. The Allan deviation for the gyro Y and Z axes at averaging times above 100 seconds is around 9 (approx.) and 10 (approx.) degrees per second per square root hour, respectively.

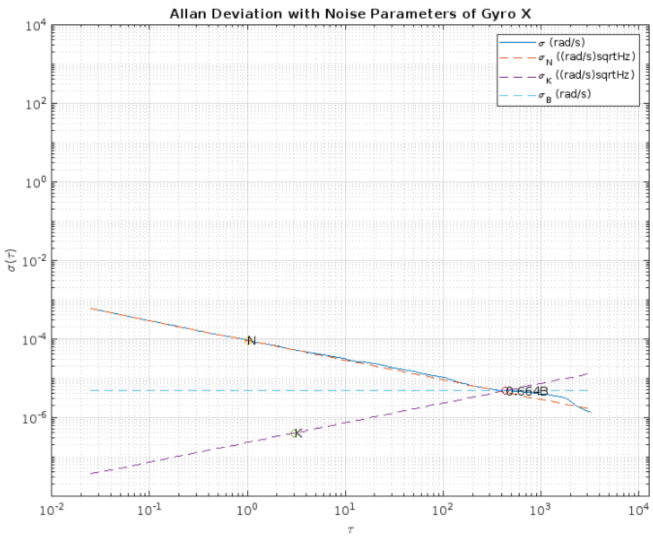


Figure 1: Allan Deviation with Noise Parameters of Gyro in x axis plot

N_angularVelocity_X = 7.4125e-11
K_angularVelocity_X = 4.5948e-14
B_angularVelocity_X = 2.1539e-12

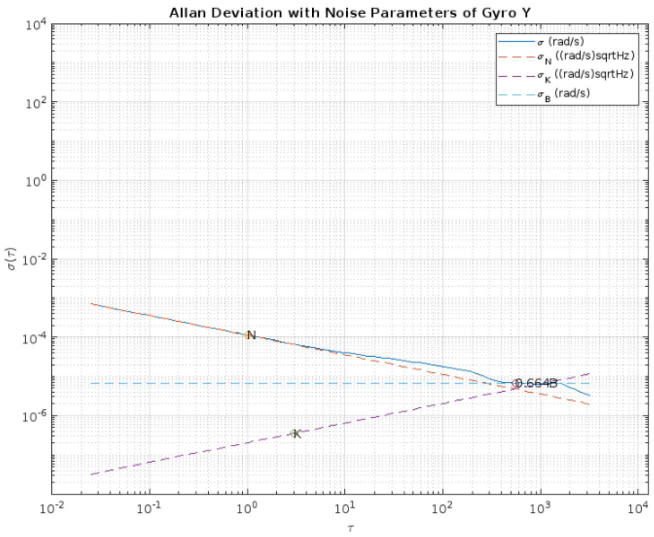


Figure 2: : Allan Deviation with Noise Parameters of Gyro in y axis plot

N_angularVelocity_Y = 1.9502e-10
K_angularVelocity_Y = 1.2089e-13
B_angularVelocity_Y = 5.6669e-12

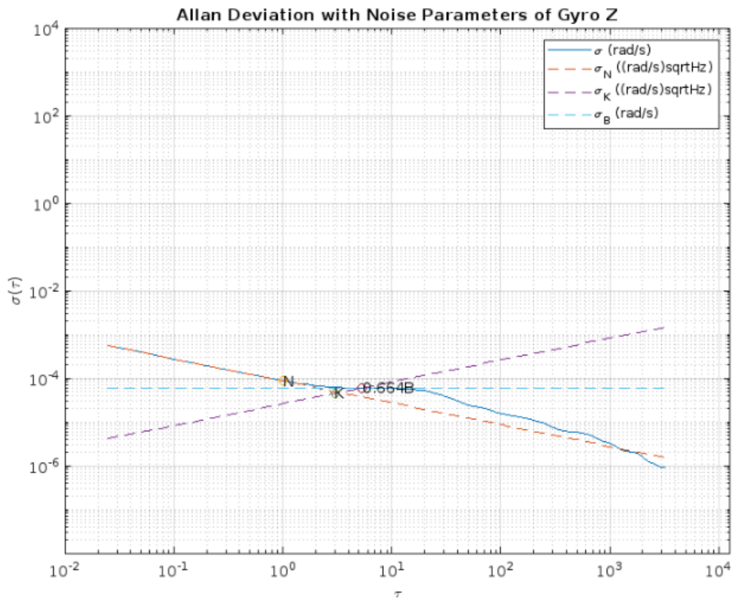


Figure 3: : Allan Deviation with Noise Parameters of Gyro in z axis plot

N_angularVelocity_Z = 8.6236e-05
K_angularVelocity_Z = 4.4661e-05
B_angularVelocity_Z = 8.9362e-05

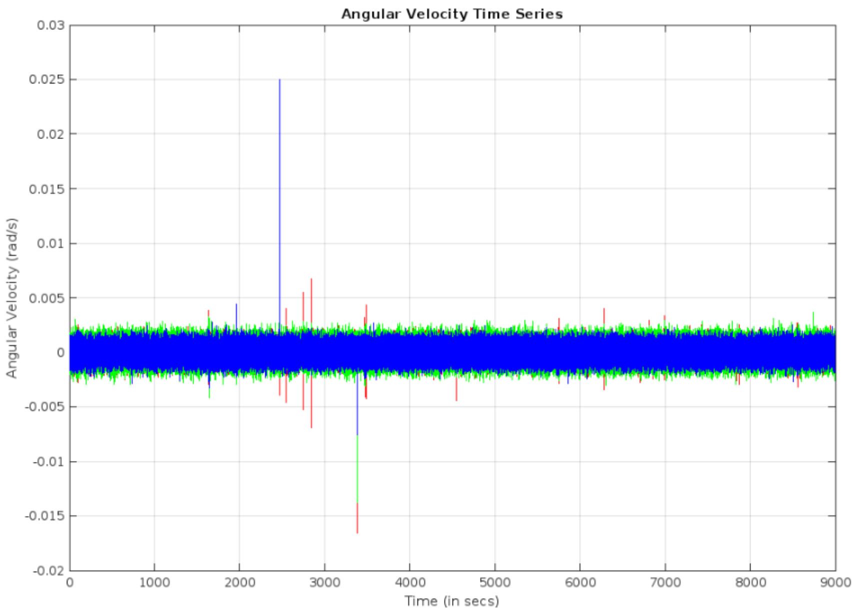


Figure 4: Angular velocity time series plot

The above plot is the angular time series plot from the imu data.

The gyro X axis is the most stable of the three axes, followed by the gyro Z axis and then the gyro Y axis. The Allan variance plots also show that the gyro is more stable at higher averaging times. This is because the noise in the gyro data averages out over time.

Based on the Allan variance plots, the most likely place where the data was collected is the basement. This is because the Allan variance plots show that the gyro is more stable at higher averaging times. The basement is typically a quieter environment than the other locations you have provided, which means that the gyro is less likely to be disturbed by noise and vibration.

Thus, I believe this data has been collected in the ISEC basement.

Similarly, analysing the other data, I infer that –

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

Location D – Snell Library Basement

(As we are only a group of 3, we were able to analyse data from 3 Locations – location A, C, D)

Short Stationary Data:

The stationary data was taken in one of the classrooms of the snell library. The room was quite with minimal moving objects around also no electrical devices where near the sensor.

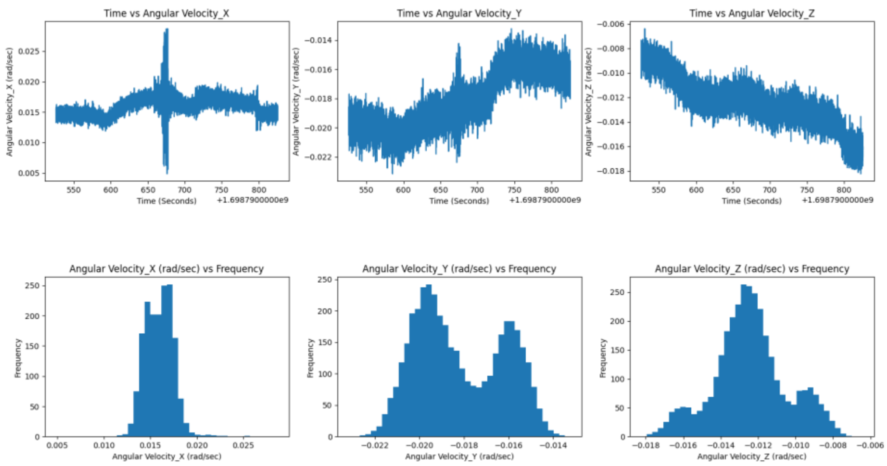


Figure 5: Angular Velocity plots

Mean & Standard Deviation of Angular Velocity:

Mean in X = 0.015954298340698742

Standard deviation in X = 0.0015794387629835236

Mean in Y = -0.018164688234803637

Standard deviation in Y = 0.001970976717007815

Mean in Z = -0.012415558242308012

Standard deviation in Z = 0.0019900990919285402

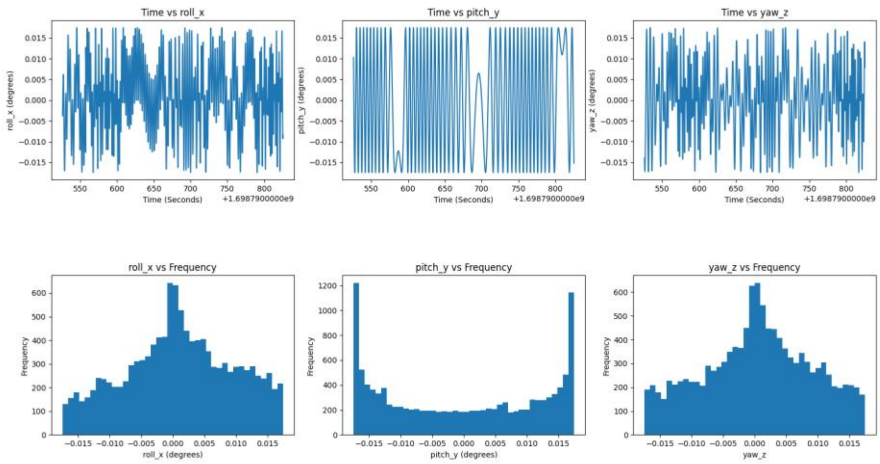


Figure 6: Roll, Pitch, Yaw plots

Mean & Standard Deviation of Roll, Pitch, Yaw:

Mean in Roll = 0.0009905957492235508

Mean in Pitch = -0.0002711653873784166

Mean in Yaw = 0.0004181693934014655

Standard Deviation in Roll = 0.008609579360191856

Standard Deviation in Pitch = 0.01232007040523245

Standard Deviation in Yaw = 0.008637298738161844

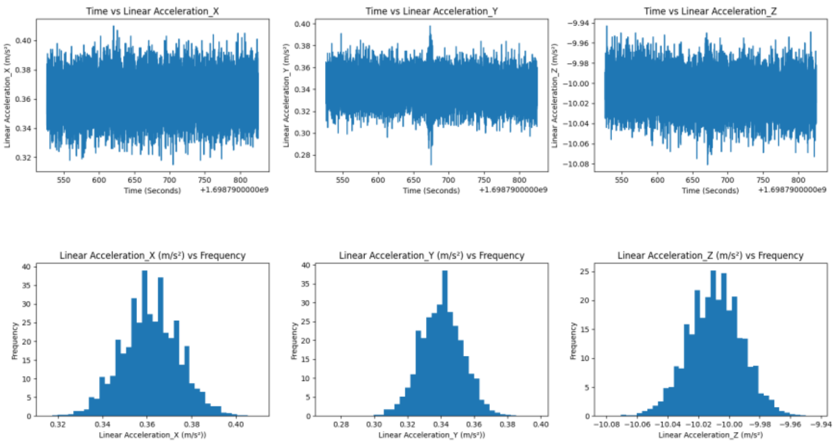


Figure 7: Linear Acceleration Plots

Mean & Standard Deviation of Linear Acceleration:

Mean in X = 0.3615350621195697

Standard Deviation in X = 0.012864803498182064

Median = 0.361

Mean in Y = 0.3615350621195697

Standard Deviation in Y = 0.012864803498182064

Median in Y = 0.361

Mean in Z = 0.3615350621195697

Standard Deviation in Z = 0.012864803498182064

Median in Z = 0.361

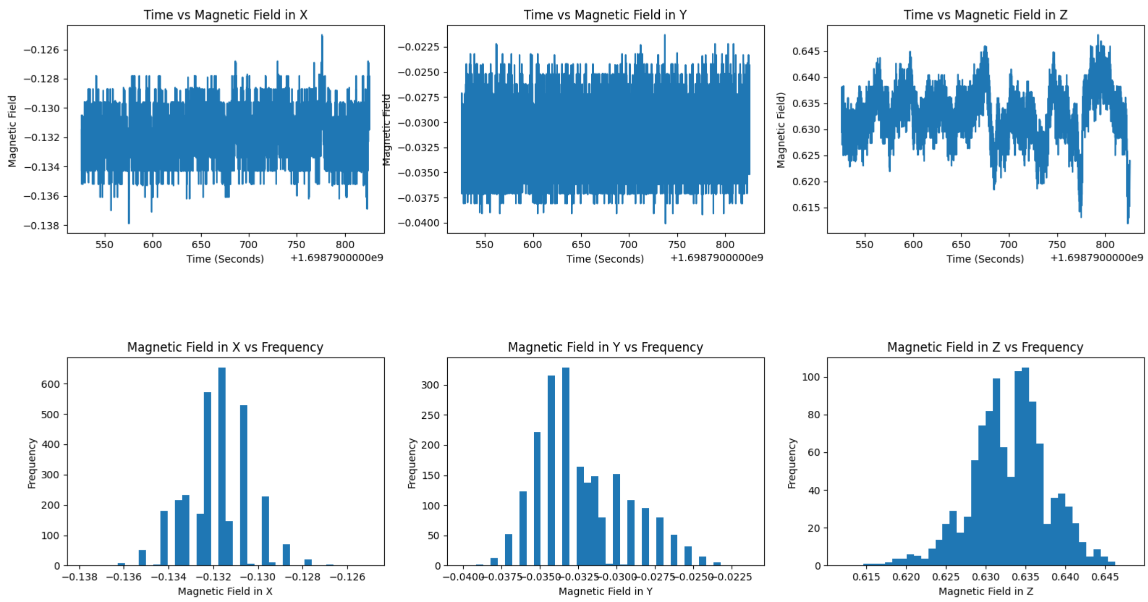


Figure 8: Magnetic Field Plots

Mean & Standard Deviation of Magnetic Field:

Mean in X = -0.13181851913616277

Standard Deviation in X = 0.0014348387899089747

Mean in Y = -0.03220512799132828

Standard Deviation in Y = 0.002852969077067144

Mean in Z = 0.6330289502209622

Standard Deviation in Z = 0.004860415396754386

The 5-minute IMU data from a stationary sensor shows that the angular velocity in all three axes (X, Y, and Z) is very close to zero, with some small fluctuations due to noise. The frequency spectrum of the angular velocity data shows that the noise is concentrated at low frequencies.

The sources of noise could be thermal noise, mechanical noise, electrical noise. These noises are hard to tackle in an environment like a building or basement.

Moving Data (Collected in Group):

5 min data was collected, where my team-mate Junnan Wang was moving the IMU in multiple direction. This was conducted to check various noise and accuracy of the IMU sensor. A video of Junnan moving the imu was taken and will be used to analyse the data along with various plots.

URL of the complete Video:
https://drive.google.com/file/d/1RY2hPG0CuIx2ahkFXO_7hXpiixQtkLfV/view?usp=sharing

Below are all the plots for the data collected.

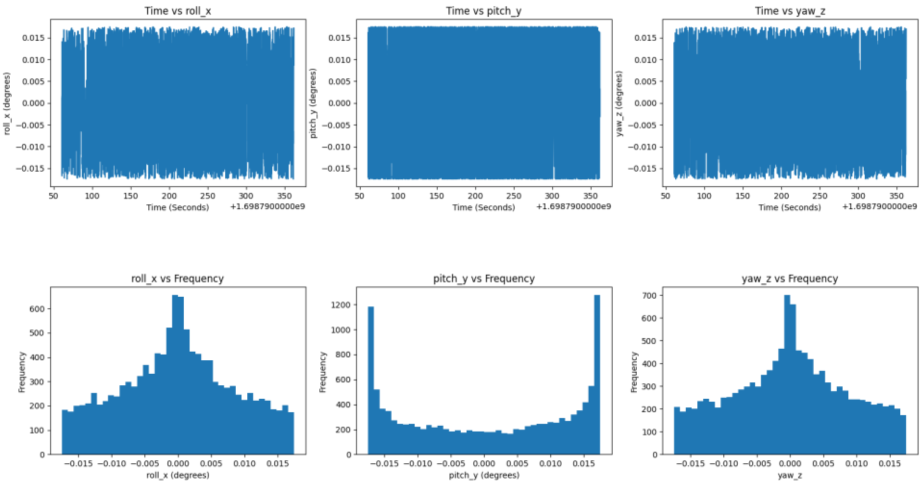


Figure 9: Roll, Pitch, Yaw of Moving Data

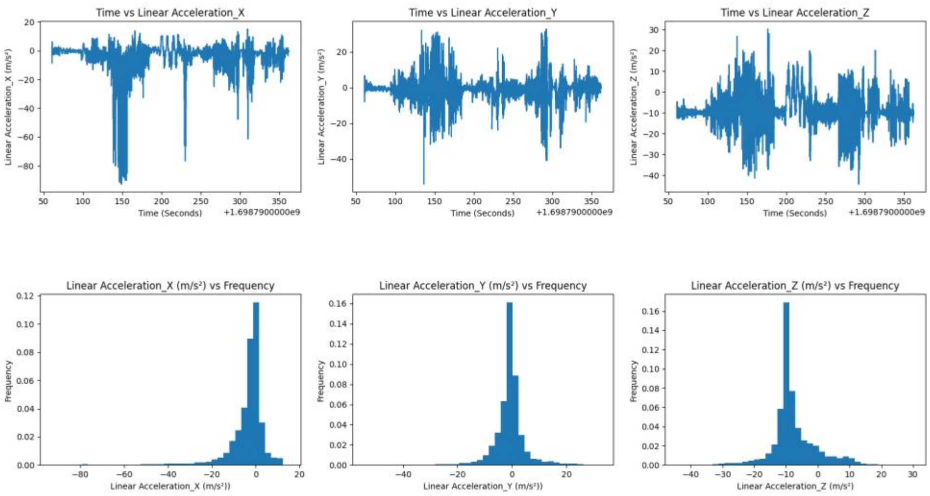


Figure 10: Linear Acceleration of Moving Data

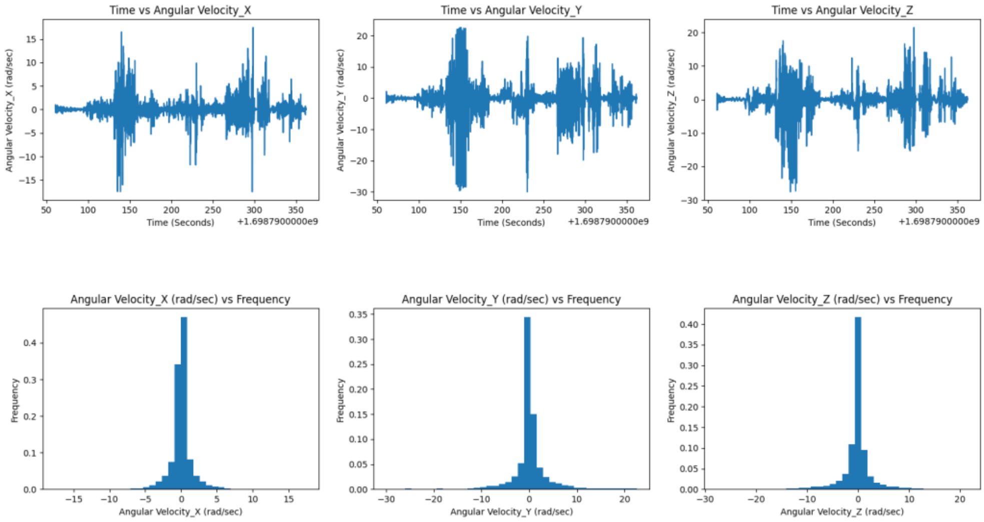


Figure 11: Angular Velocity of Moving Data

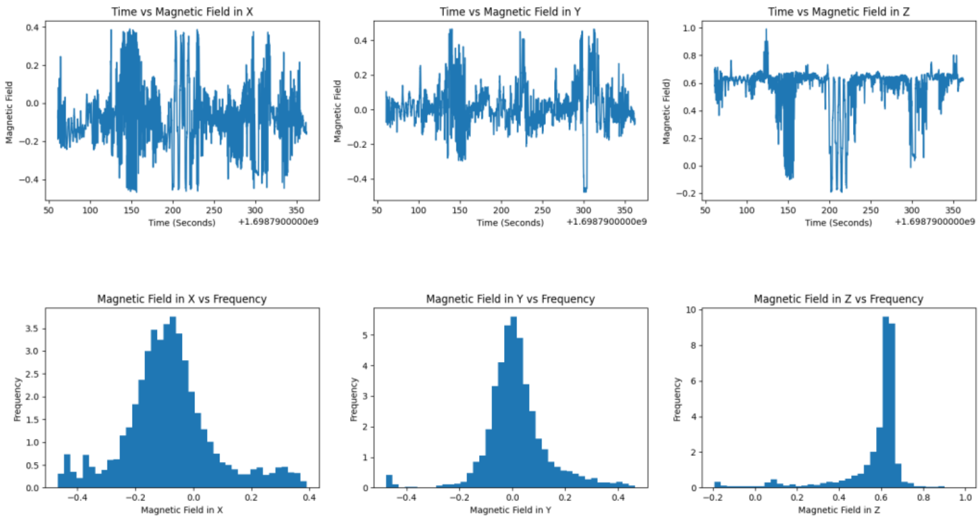
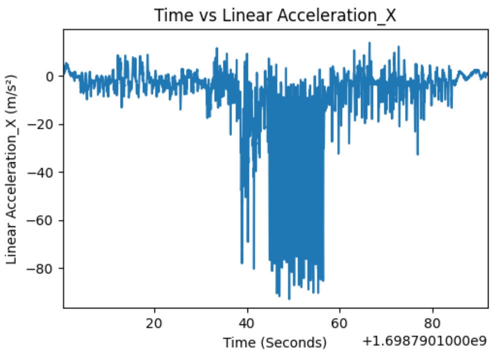
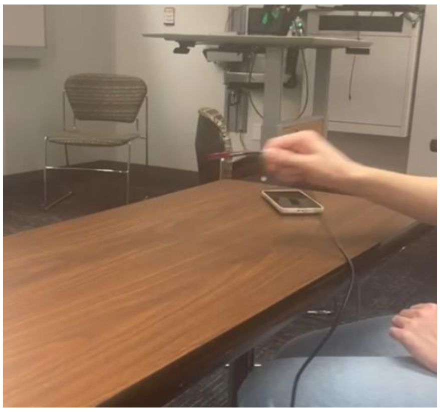


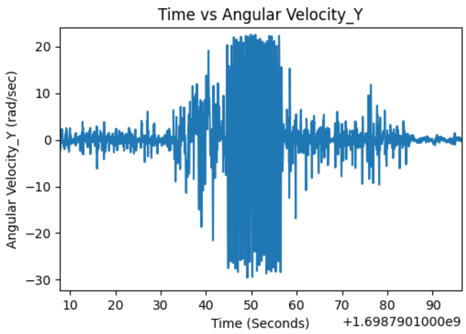
Figure 12: Magnetic field of Moving Data

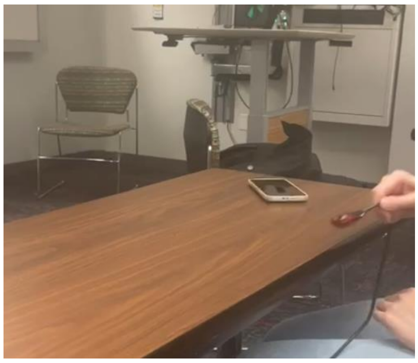
At around 54^{th} sec we can Junnan moving the IMU very rapidly towards himself. Thus, we can see a huge spike in -x direction in Time vs Linear Acceleration in X graph.



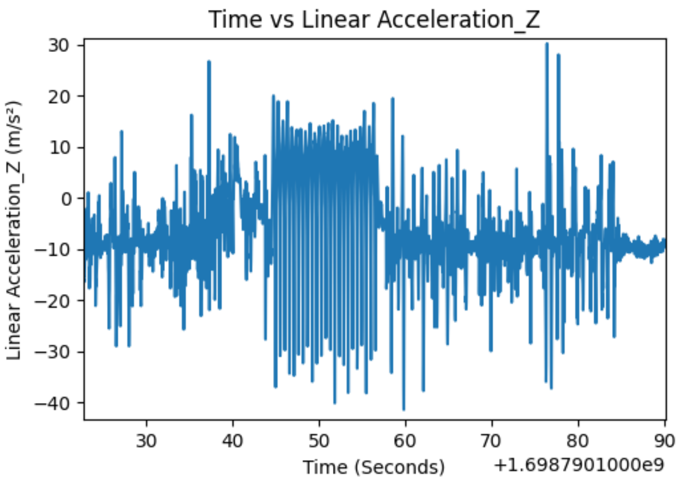


Before the above movement, Junnan moves the IMU sensor in clockwise direction. Thus, we can see a spike in the Angular Velocity in Y.





Looking at the plot of Linear acceleration in Z we can see that there was a steady data from the sensor from 45 – 55 secs. This is because Junnan was only moving the sensor in x and y direction. This tells us about the accuracy of the sensor.



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 is very limited and could be thermal noise, mechanical noise, or the electrical noise. (Mean, Median and Distribution has been mentioned 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 we can infer that the imu data is very accurate and the noise level.

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

   Compared to the datasheet, the data was very accurate with moderate 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 could be from multiple sources like mechanical noise, electronic noise, environmental noise. These errors could be broadly classified into systematic and unsystematic. Systematic errors have similar or proportional values for every measurement, while unsystematic errors are very random and unpredictable. Effects of temperature, humidity, axis orthogonally, scale factor, etc.

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?

   To match the Allan deviation (AVAR) plots to the locations/conditions, I would consider the following factors:

   Slope of the AVAR plot at low frequencies: A slope of -0.5 indicates angle random walk noise, which is caused by random changes in the orientation of the sensor over time. A slope of 0.5 indicates rate random walk noise, which is caused by random changes in the angular velocity of the sensor over time. A slope of 0 indicates bias instability noise, which is caused by a constant offset in the sensor's output.

   Magnitude of the AVAR plot at low frequencies: The magnitude of the AVAR plot at low frequencies indicates the overall level of noise in the sensor output. A lower AVAR indicates a less noisy sensor.

Shape of the AVAR plot at high frequencies: The shape of the AVAR plot at high frequencies can be used to identify specific sources of noise, such as quantization noise, thermal noise, and vibration noise.

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

   To understand the best sensor performance possible, it is important to measure Allan variance under conditions that minimize noise. This means measuring the sensor in a quiet, vibration-free environment. It is also important to measure the sensor for a long enough period to reduce the effects of random noise.

   some specific tips for measuring Allan variance:

   - Place the sensor in a quiet, vibration-free environment.
   - Mount the sensor securely to prevent vibration.
   - Use a high-quality data acquisition system.
   - Sample the sensor data at a high frequency (at least 100 Hz).
   - Collect data for a long period of time (at least 1 hour).

7. If you were trying to characterize a new sensor with unknown performance, briefly

   To characterize a new sensor with unknown performance, I would measure the sensor's Allan variance in a quiet, vibration-free environment to understand the sources of noise in the sensor and environment. I would then compare the sensor's Allan variance to the Allan variance requirements of the sensor's operating conditions to determine if the sensor is suitable for the application.