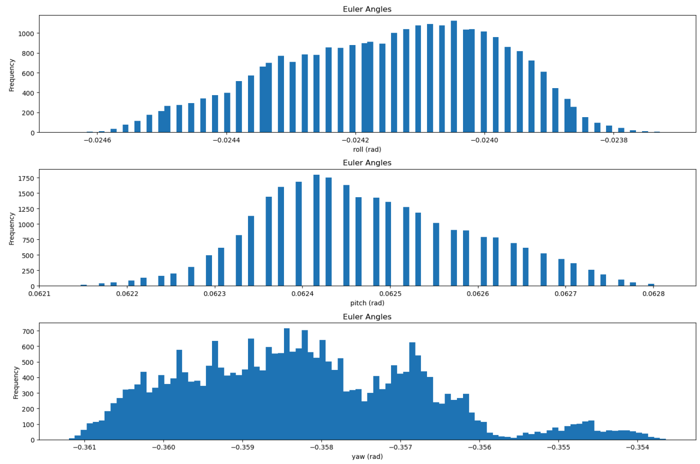
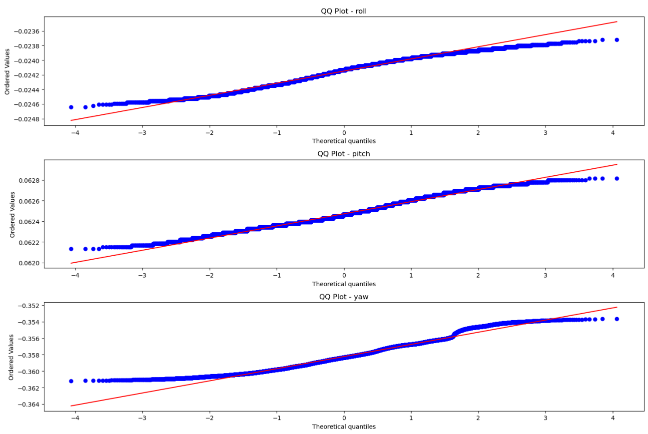
Mostafa Ibrahim

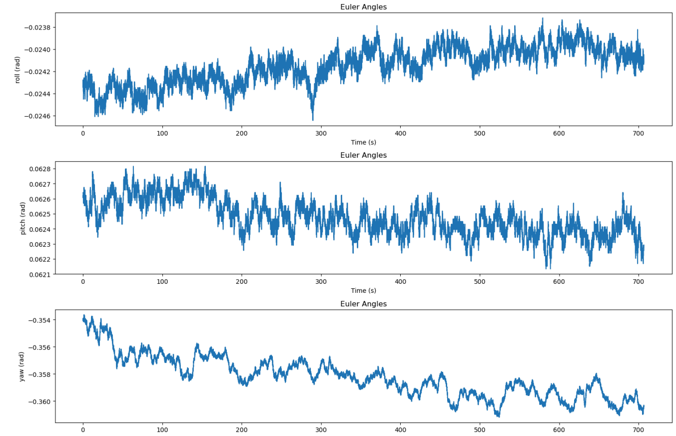
Lab 3 Report

Roll, Pitch and Yaw (Respectively in the plot)

The histogram plots show the existence of what seems like uniform noise in all the movements. As time goes, the roll shows an overall increase in the value while both pitch and roll showed an overall decrease. It is to be noted that the noise is very minor; however, a trend is shown. The QQ plots aid in visualizing the uniformity of the data. Although they are all roughly uniform, during the first and last quantities, the data doesn't seem to be uniformly distributed.

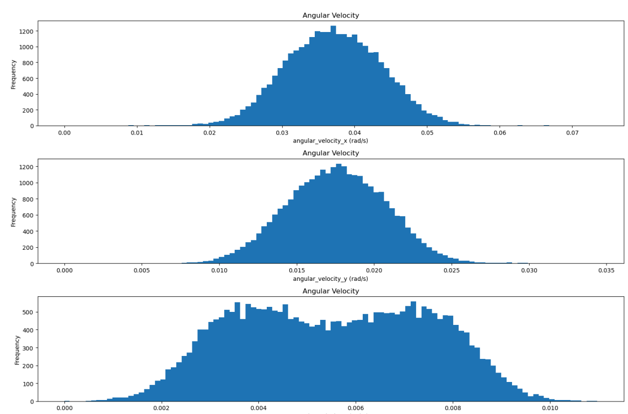


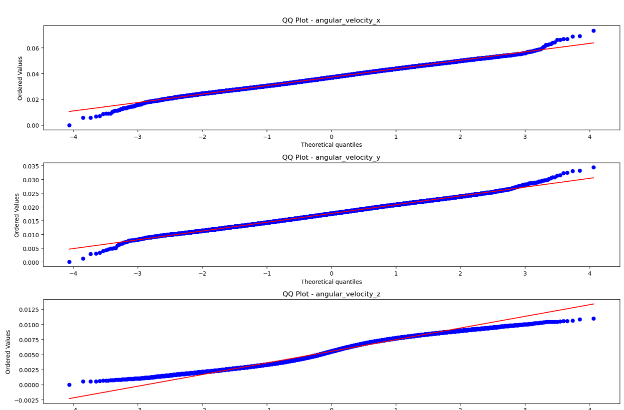


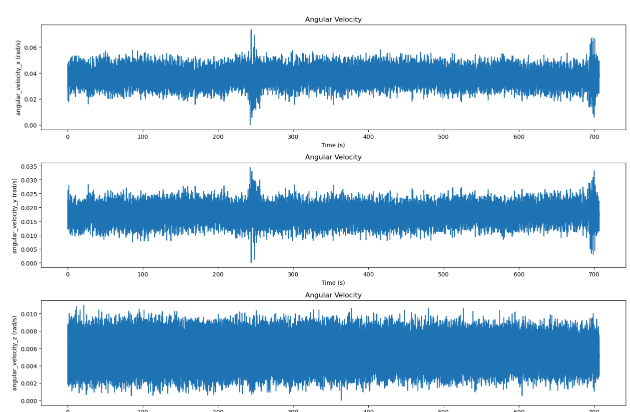


Angular Velocity XYZ (Respectively)

The angular shows a much better uniform distribution in all axes while it is showing a double peaked distribution in the z-axis. The noise in the z-axis doesn't seem to have a Gaussian distribution as much as the other two axes. There seems to be two instances where noise severely affected the x and the y axes and this could be due to a movement next to the sensor or a specific vibration. While the z axis seems to have the most noise and this could be due to vibrations of the surface the sensor was on.







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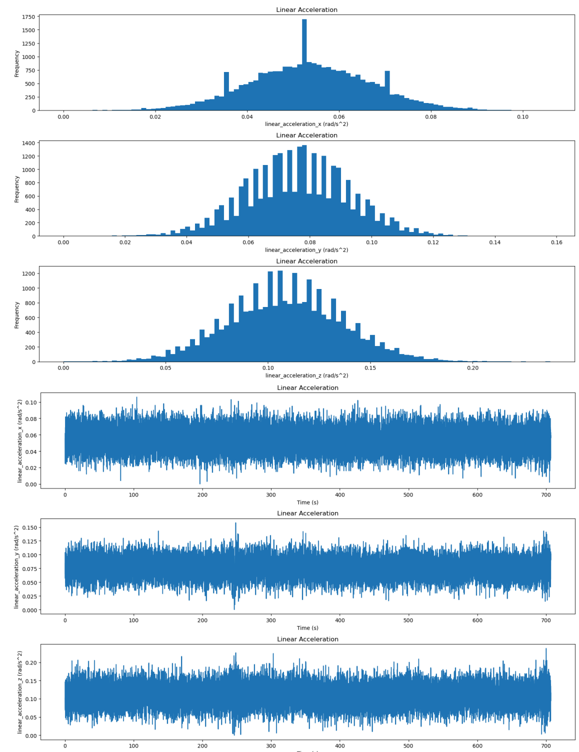
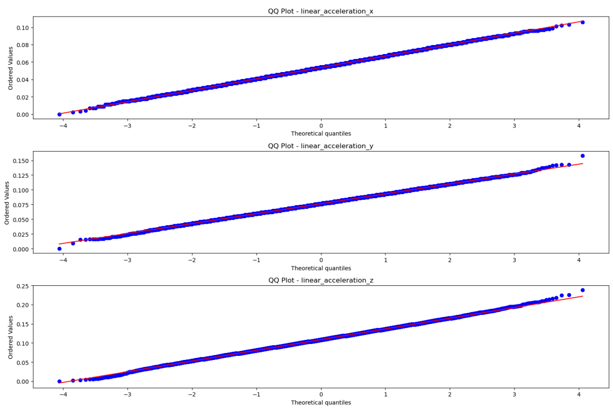
Linear Acceleration

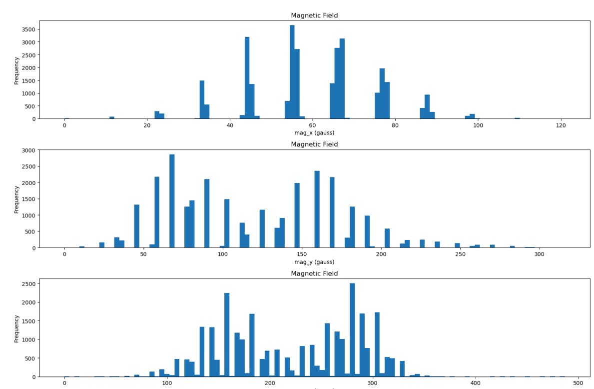
The histogram and the QQ plot of the linear acceleration shows uniform Gaussian distribution for all axes with some extra peaks or noise that were there at random times. The chart shows how the noise is distributed over time. However, through observation a low pass filter could smoothen the linear acceleration values and show accurate readings.

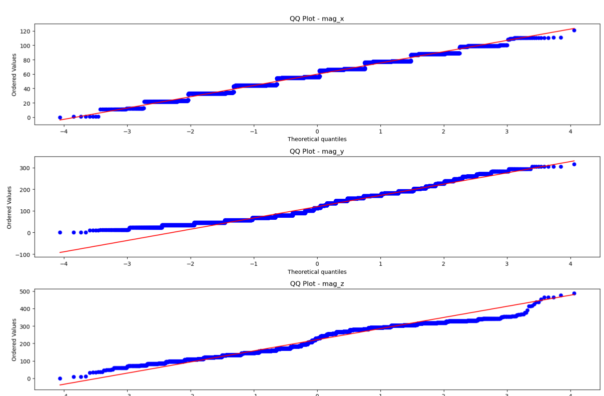


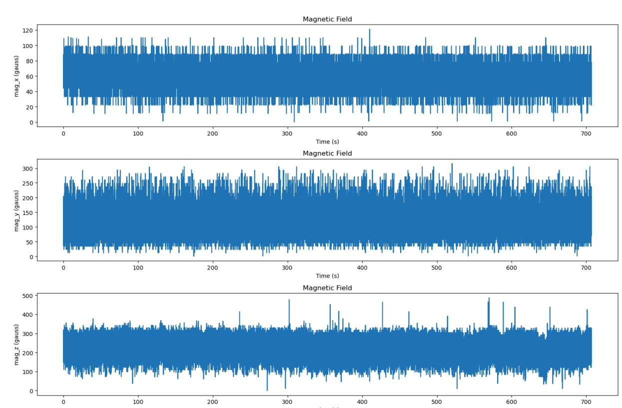


Magnetic Field

The distribution of the magnetic field is odd and full of noise.
In the x-axis magnetic field it shows a uniform distribution with gaps in the middle while the other axes have gaps in the readings too, but the distribution is not necessarily uniform. The QQ plots show the x-axis magnetic field as steps while the rest have slightly curved lines with a non-strict uniform shape. The noise in the magnetic field sensor seems to be the highest and this could be due to a minor magnetic interference with the devices and electronic equipment in the room. Note that the IMU was put in a table in the room which probably had iron support which could have contributed to the bias. **Note:** the magnetic field units were converted from Tesla to Gauss in the data analysis part. The driver has been edited to convert it during the data collection.







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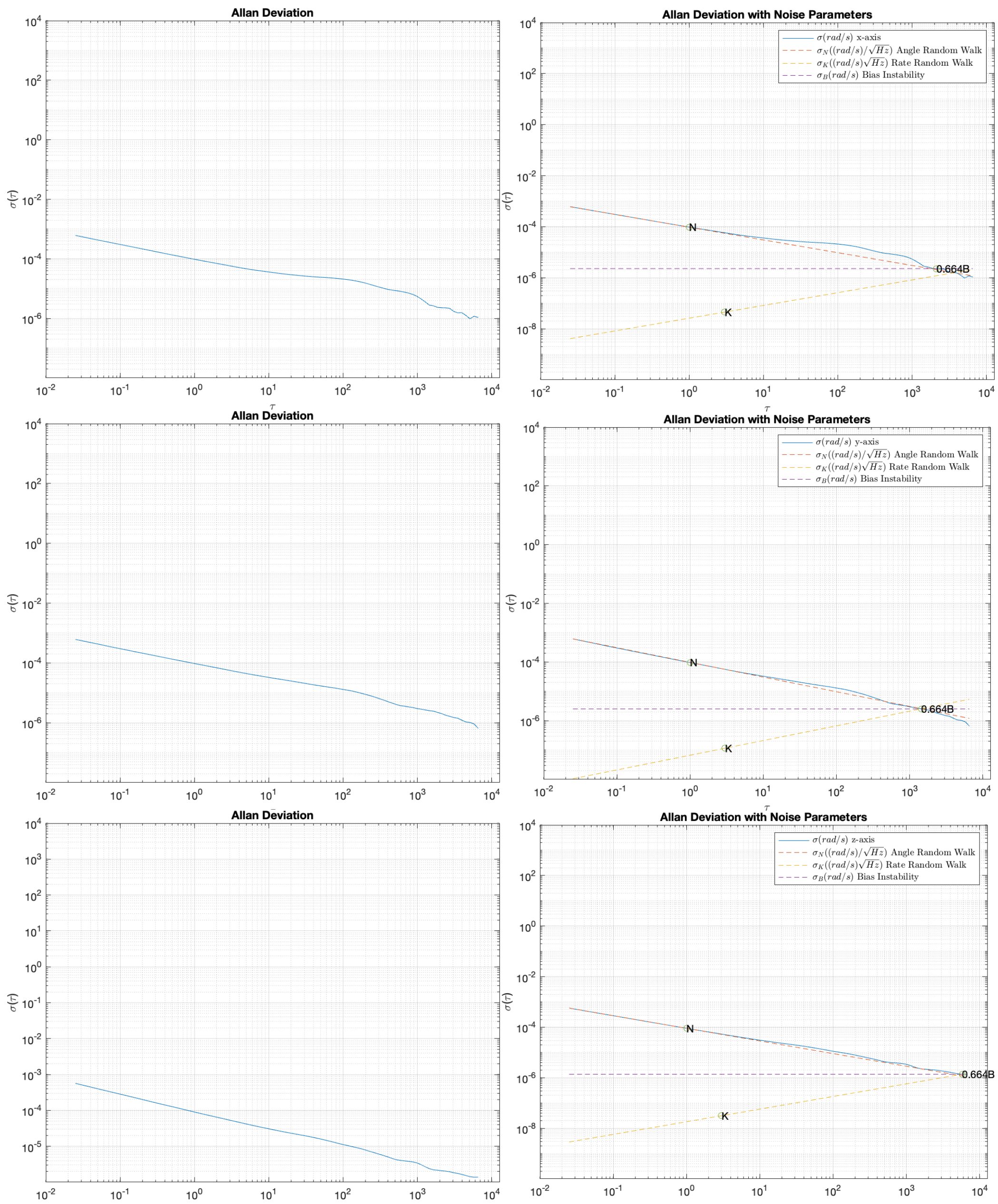
Allan Variation



Errors/sources of noise present

According to the analysis the errors arise from Angle Random Walk (ARW), Bias Instability (BI) and Rate Random Walk (RRW). The ARW error is represented by the negative gradient line in the graph, and it shows the white noise affecting the gyroscope. The positive gradient line represents the RRW which is the red, Brownian noise spectrum of the gyroscope. The BI error is represented by the flat line, and it's the flicker noise of the gyroscope.

Measuring and Modeling the Errors

The main function to obtain a noise parameter for the gyro is as follows $\sigma^2(\tau) = 4\int_0^\infty S_\Omega(f)\frac{sin^4(\pi f\tau)}{(\pi f\tau)^2}df$ by substituting the power spectral density (PSD) function of each noise.

The ARW is modeled as a white Gaussian noise with PSD $S_\Omega(f) = N^2$ that is proportional to the square root of the time step of the gyro $\sigma^2(\tau) = \frac{N^2}{\tau}$. We obtain this function by substituting the PSD in the first equation. The ARW is measured at short intervals usually with a line of +0.5 slope and it has a value of 9.7211e-05.

For the RRW the model is $S_\Omega(f) = (\frac{K}{2\pi})^2\frac{1}{f^2}$ and the noise parameter is $\sigma^2(\tau) = \frac{K^2\tau}{3}$. This noise is measured on longer intervals and is shown in the -0.5 line on the plot; it has a value of 1.1556e-07. The BI is modeled as a random bias that drifts and adds up over time. The PSD is $S_\Omega(f) = \begin{cases} (\frac{B^2}{2\pi})\frac{1}{f} & : f \le f_0 \\ 0 & : f > f_0 \end{cases}$ yielding a value of $\sigma^2(\tau) = \frac{2B^2}{\pi}\ln 2$ where B is the bias. This bias is measured as a line with a slope of 0 when plotted on a log-log plot. It is measured as 3.8170e-06 rad/s which is scaled by a factor of 0.664. These values could be related to the VN-100 model given the initial calibration of the device. The actual numbers of the noise are not given for comparison.

5 Hours ROS bag

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