LAB 2 Report

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For better viewing of plots view in the analysis folder, plots added here are re-sized to fit in the documents.

Stationary Data Analysis

GPS

What is GPS? It is the Global Positioning System launched by the U.S. Other countries, like Russia, call it GLONASS, while China refers to it as BeiDou, but the underlying methodology is the same. GPS works by triangulating signals from multiple satellites to determine a precise location on Earth. A minimum of four satellites is required for accurate GPS functioning.

RTK GPS vs GPS

RTK GPS provides centimeter-level accuracy by using real-time corrections from a nearby base station, making it ideal for applications like surveying and precision agriculture. In contrast, normal GPS typically offers accuracy within 5 to 10 meters without such corrections, suitable for general navigation. Similarly, RTK GNSS enhances positioning precision to centimeter levels through real-time kinematic techniques, while GNSS systems deliver varying accuracy based on satellite signals alone, generally within several meters. Thus, RTK systems are essential for tasks requiring high precision, whereas standard GPS and GNSS are used for more routine positioning needs.

In GNGGA data, the "Fix Quality" field indicates the type of GPS fix achieved, representing the reliability and accuracy of the positioning data. Possible fix values include: 0 for no fix (invalid), 1 for standard GPS (5-10 meters accuracy), 2 for Differential GPS (DGPS) with improved accuracy (1-3 meters), 4 for Real-Time Kinematic (RTK) fixed, providing centimeter-level precision, and 5 for RTK float, offering decimeter-level accuracy. These fix types are crucial for understanding the precision of GPS data in applications ranging from basic navigation to high-accuracy tasks like surveying.

Source of Error

Sources of error in RTK GNSS can significantly impact positioning accuracy. Key factors include poor satellite geometry, which can lead to increased errors, and multipath effects where signals reflect off surfaces before reaching the receiver. Atmospheric interference, such as delays from the ionosphere and troposphere, also plays a role. Additionally, inaccuracies from the base station's known position, variability in receiver quality, and network errors can further compromise results. Lastly, physical obstructions like buildings or trees can block satellite signals, degrading accuracy. Addressing these issues is essential for improving the reliability of RTK GNSS positioning.

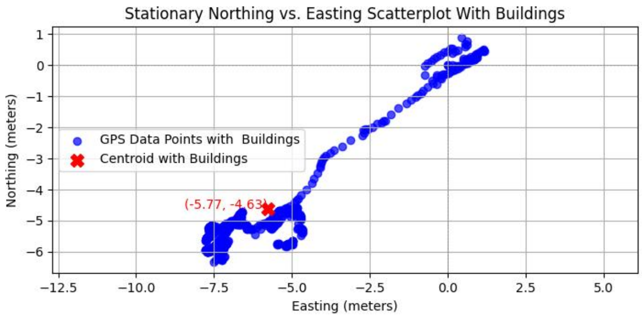
Implementation

The objective of this lab2 is to modify the GPS driver created in the previous lab1 and create a ros bag file for analysis of data the data recorded from the RTK GPS.

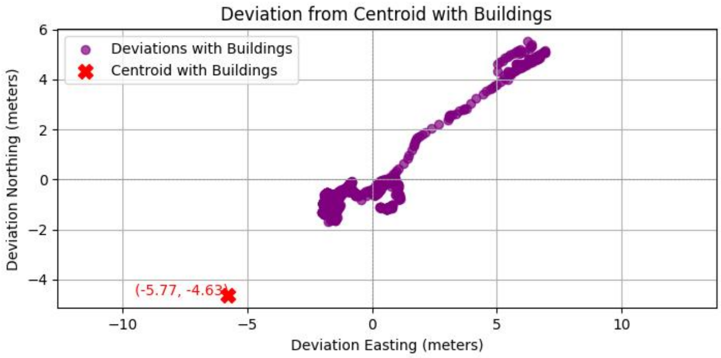
In the lab1 we read data from serial port, for this lab we will be reading data from ubx file which has been created from the u-centre application. Then modify the ros msg type and also ros driver to read data from the ubx file and publish it as an topic. Then record the data using ros bag and analysis. The data is collected if two type based on locations and movements. The location types are are open and occluded, and based on movement it is stationary and walking in square path. Thus after collection of data we will be having 4 types of data. This was the method suggested in the lab2 handout. For this report and lab2 followed the same methods suggested in the lab2 but this can be done in multiple ways as mentioned below.

The data from the RTK GPS can be directly read by the serial port. To do this, first set the baud rate in u-centre app, then connect the RTK GPS after make a few small changes like port number, baud rate, and add gps fix msg and ros bag data can be recorded directly. Sample snippet to read data from serial port is given in the driver file(github). It is also possible to do this even without ros bag data. After reading data from u-centre app, the recorded ubx file can be directly read as text file line by line and the phrased data can be converted to required data to plot as followed in gps driver and the data can be plotted. In the second case we only need recorded ubx file and the analysis script where all the process can be completed in the same script.

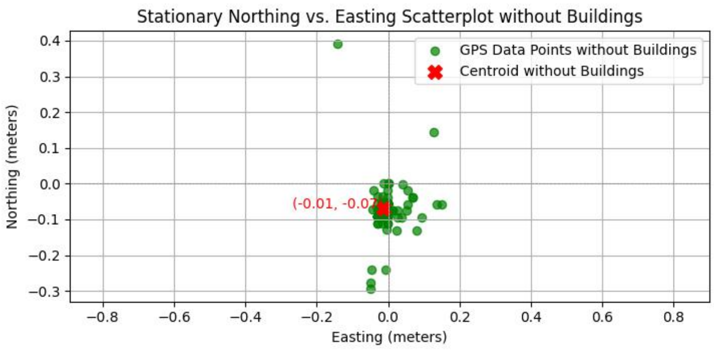
Below are the few plots and its analysis.



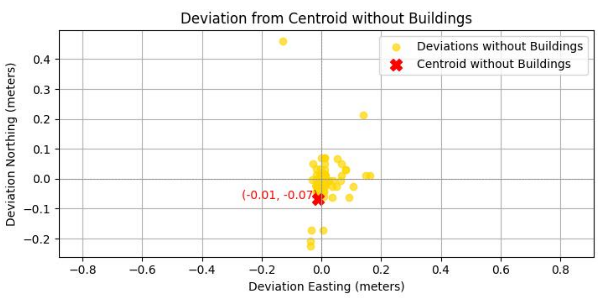
The above plotted data is stationary data of Northing VS Easting with buildings. The centroid of the collected data is -5.57 and -4.63. It can be seen the data plotted are scattered around with tolerance of plus or minus 4 meters. Which proves that there is more chance of getting noises when there are more buildings. Even in lab 1 we got the same amount of scattering.



After calculation of deviations then the data has been sifted right which in results increase of tolerance to -1.5 meters to 6.5 meters. So if we measure the gps data the accuracy will be plus or minus of 6.5 meters.

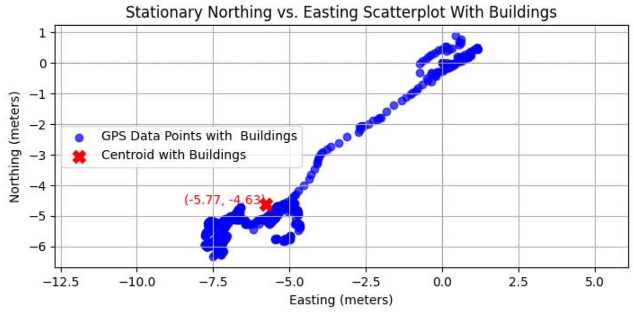


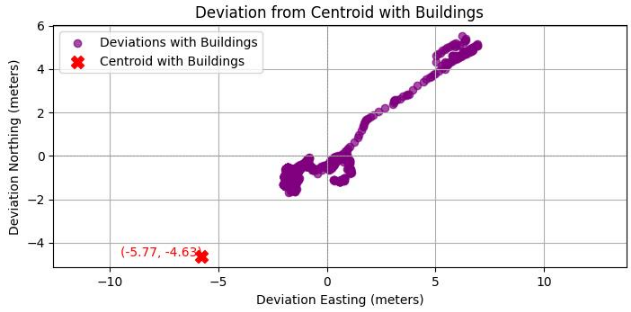
The above given data is collected without building and we observe that the data is scattered very less when compared to with buildings. The centroid is -0.01 and 0.02. The tolerance is plus or minus of 0.1 meters or in less than 10 centimeter, which is less than with buildings.

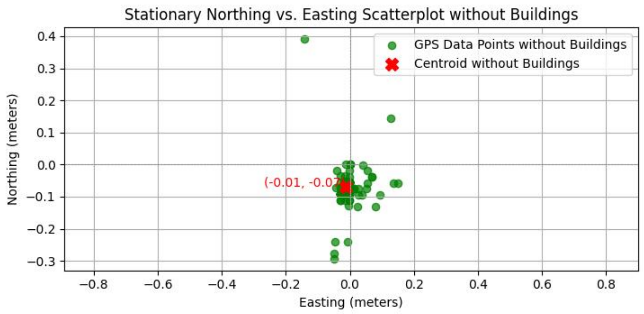


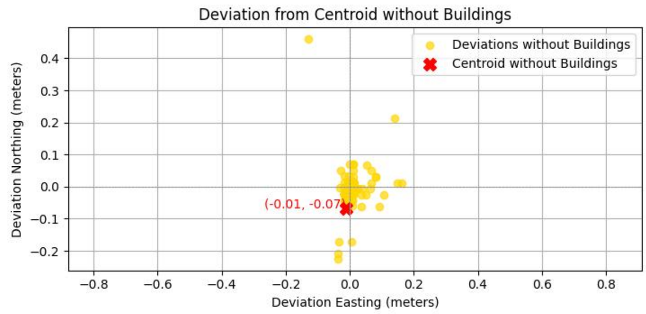
After calculation of deviations there the data has been very little right which in results increase of tolerance to -0.1 meters to 0.1 meters. So if we measure the gps data the accuracy will be plus or minus of 0.15 meters or less than 15 centimeters. Form the above plot we can understand that data collection will be more accurate when it is collected without buildings.

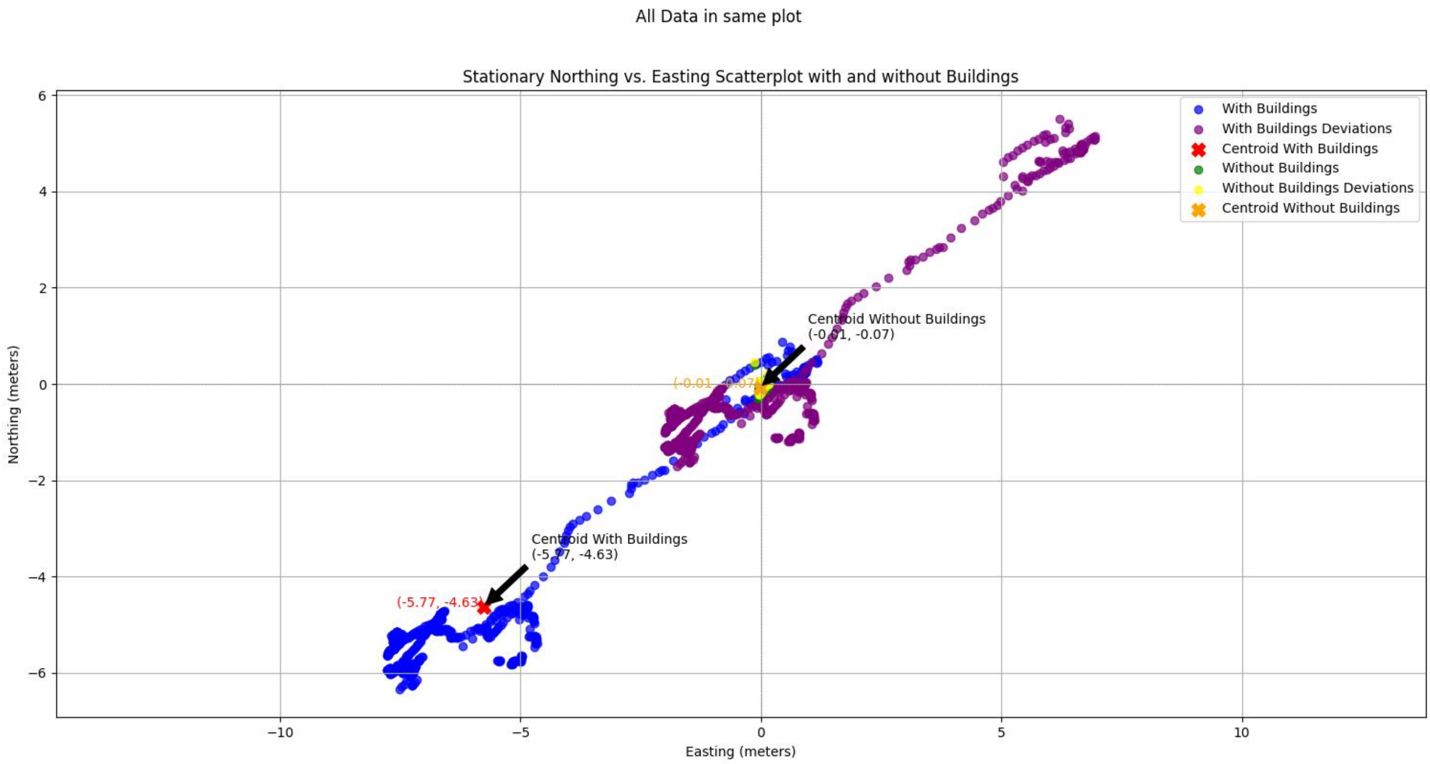
For better comparison the all the above shown data is plotted in single graph got better understanding.



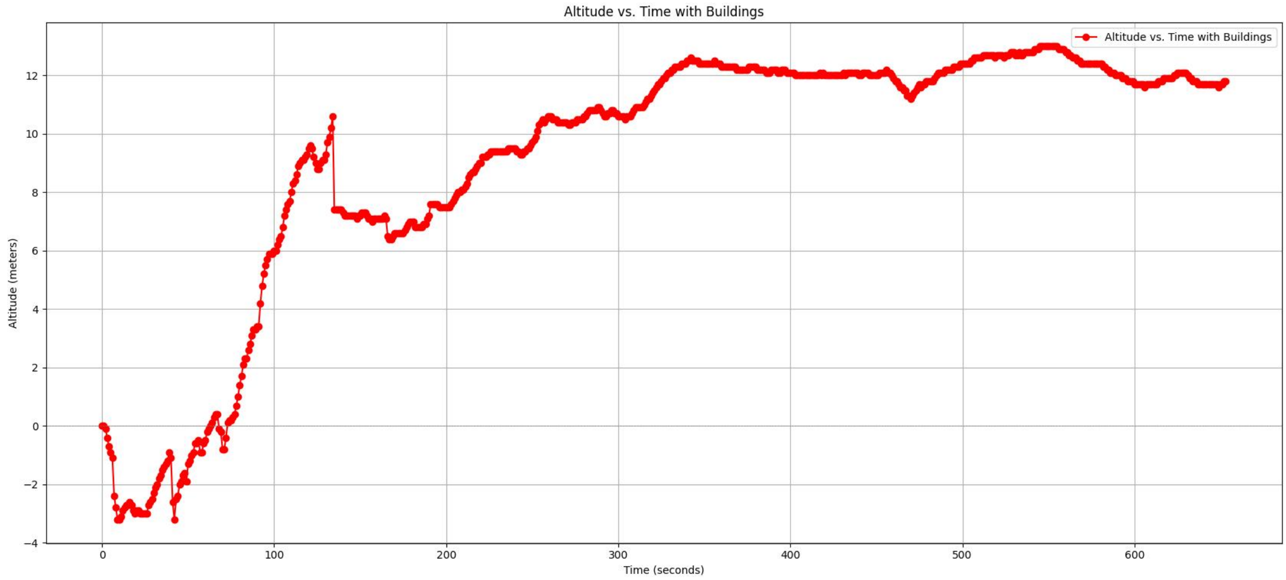




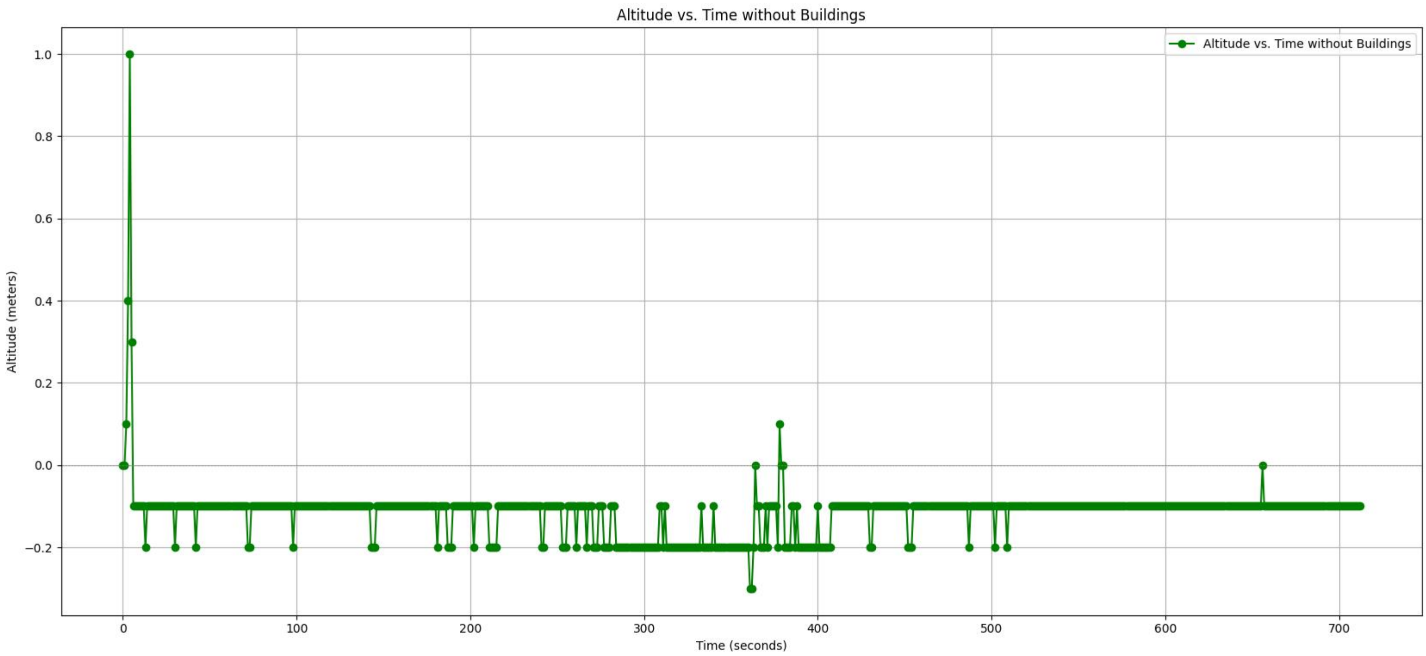




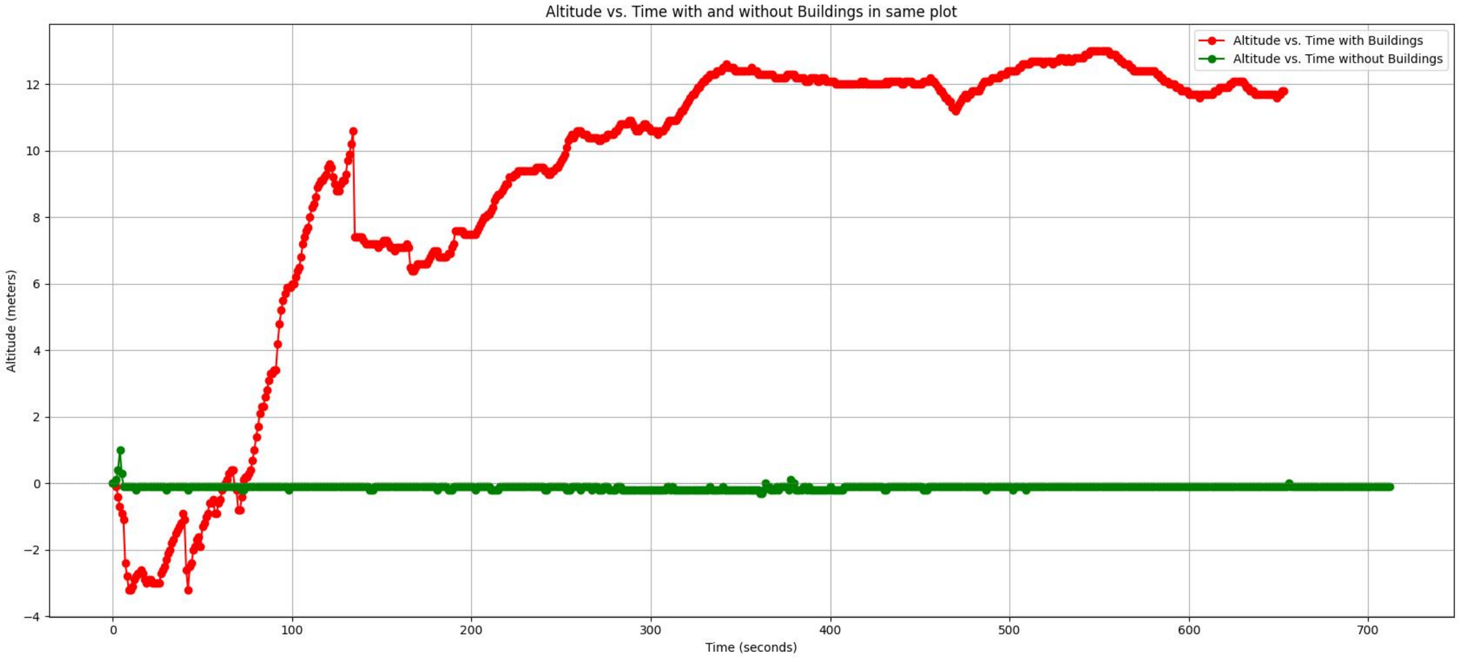
The below given data is Altitude VS Time when collected with buildings and it can be seen the data is continuously increasing. This is because we are holding the gps in hand and also default error from gps data due to buildings.

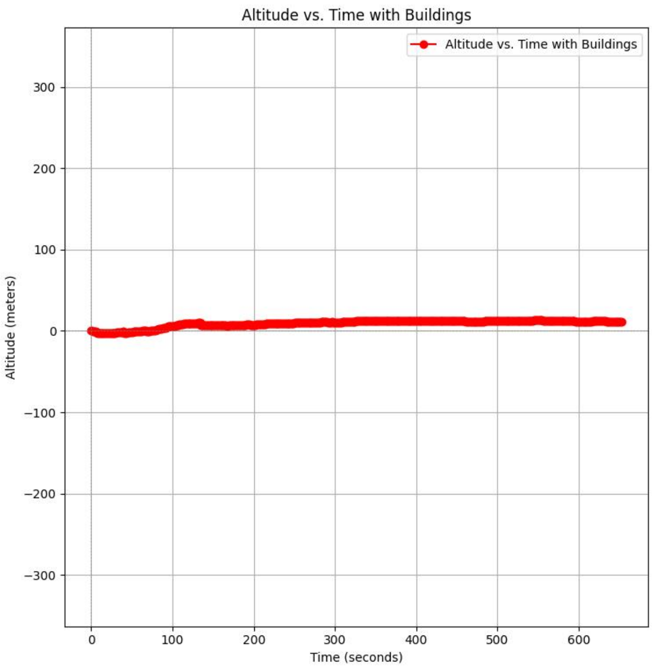


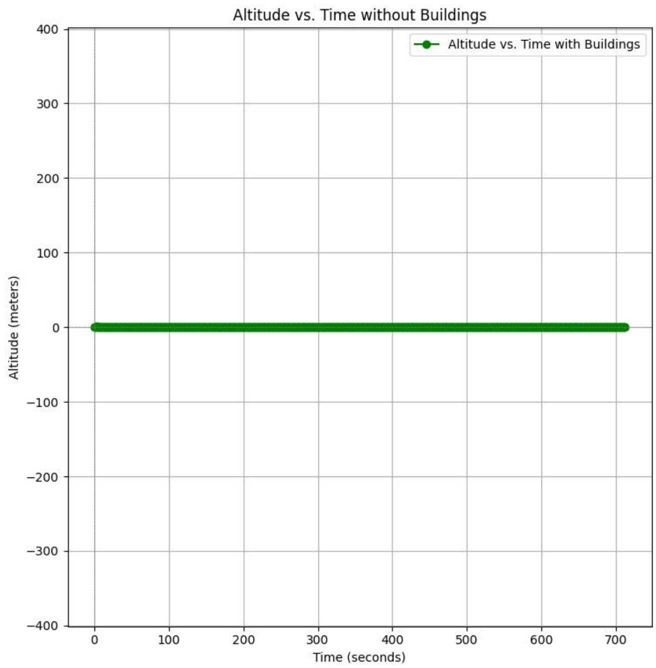
The below plotted data are collected without building and it can observed that data is being stable for some time and again changes some time due the sensor was holding in hand but it can be seen the map over a period after receiving correction data it is stabilizing again. This shows that altitude from without buildings are more accurate.



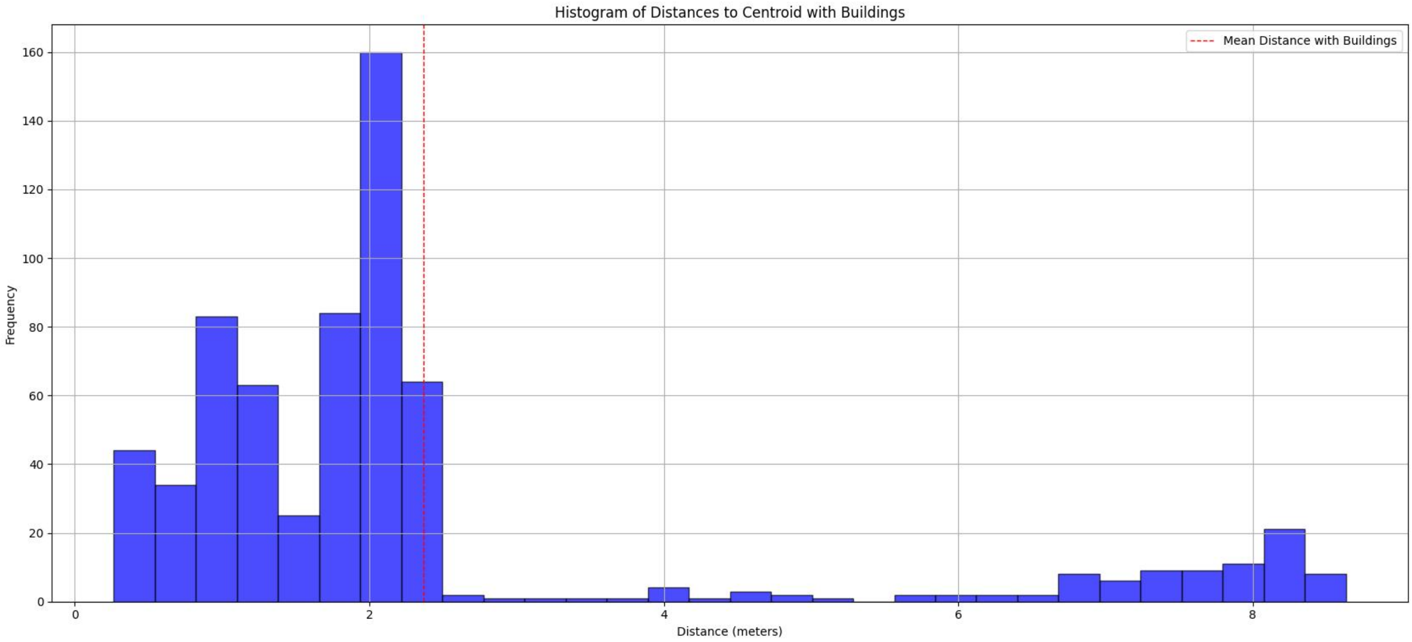
For better understanding and comparison both altitude plots are given in the same plots.



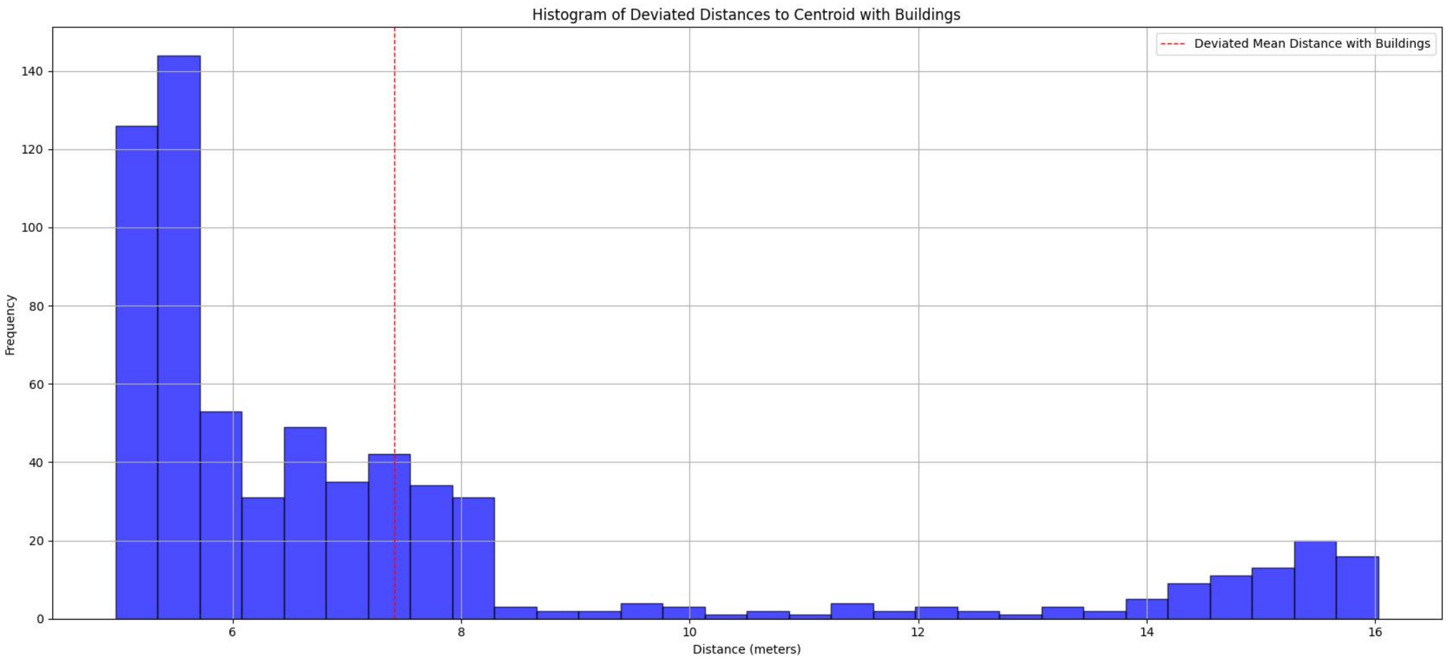




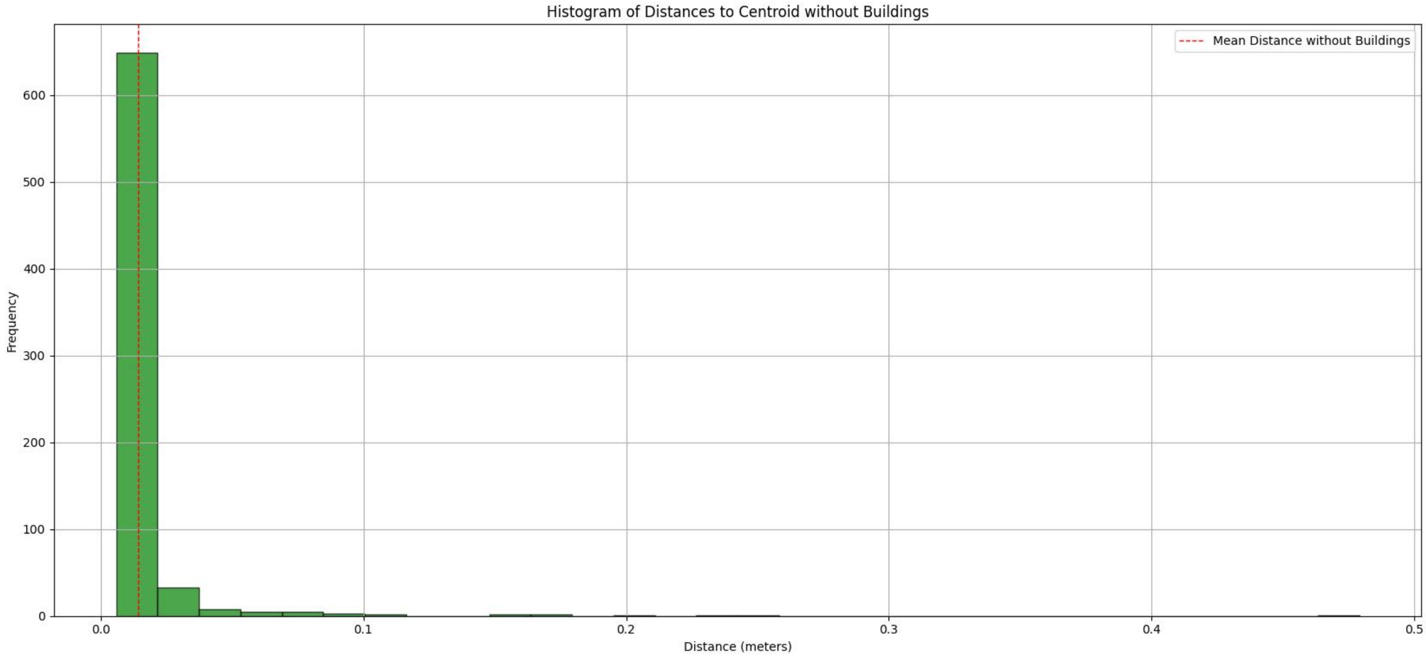
The below given image is the Histogram of Distance to Centroid with buildings. The data is plotted are calculated using euclidean distance. The formula is $d = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$. The mean is more shifted towards right from the origin which shows that are less accurate with buildings.



The below given plot is calculated from the points that are deviated from centroid. With buildings it can be seen that mean is more shifted from the origin. Thus the data is less accurate.



The below given image is the histogram of distance to centroid without buildings. The mean is very less shifted from origin when compared to data collected with buildings and also it looks more close to align with the origin. Which states that the data are more accurate when collected without buildings.



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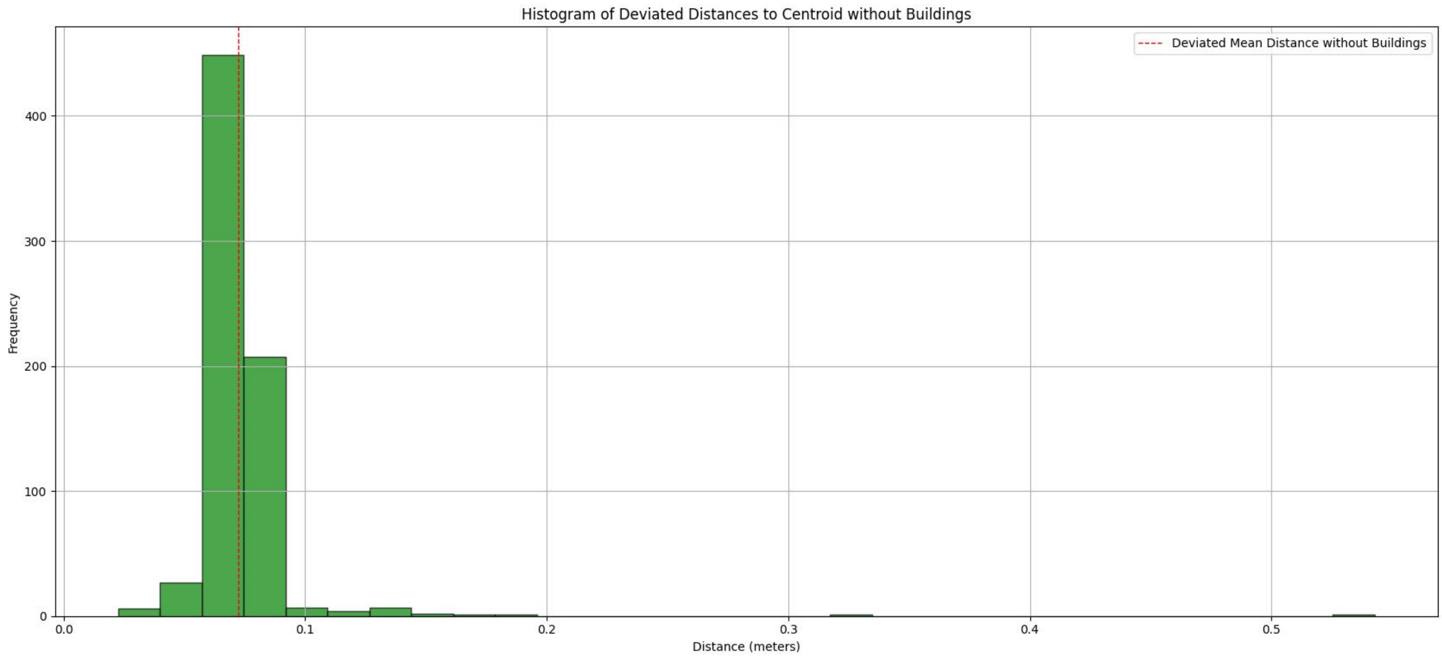
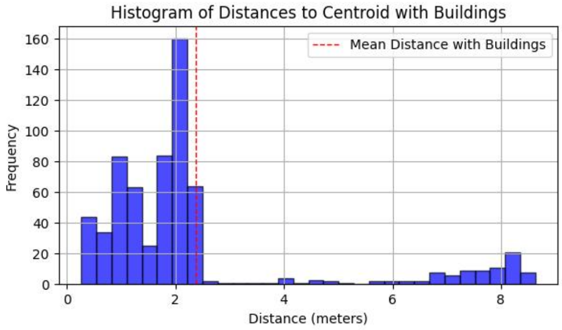
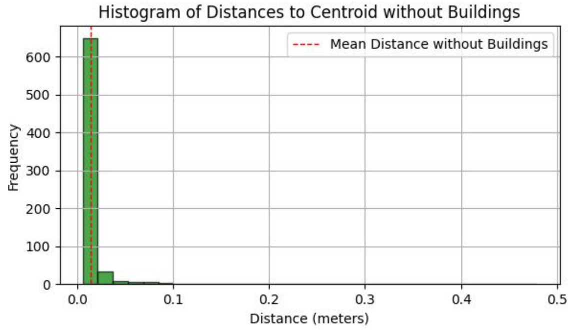
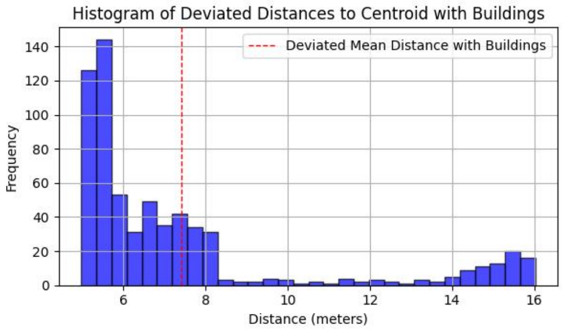
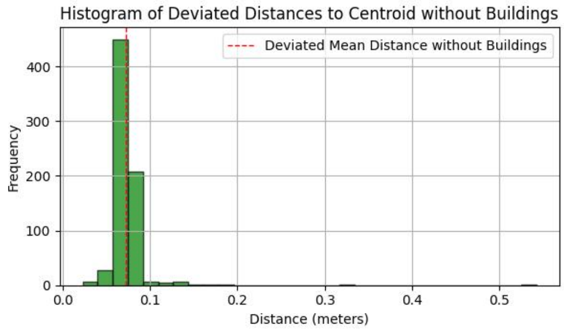


For better understanding and comparison all the histogram plots are plotted in the same plot.







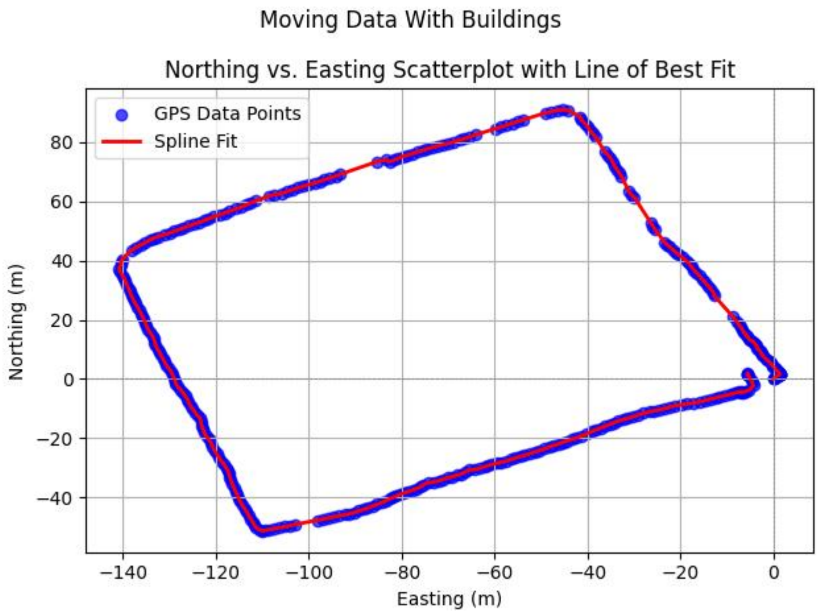


Comparison of stationary lab1 and lab2 data

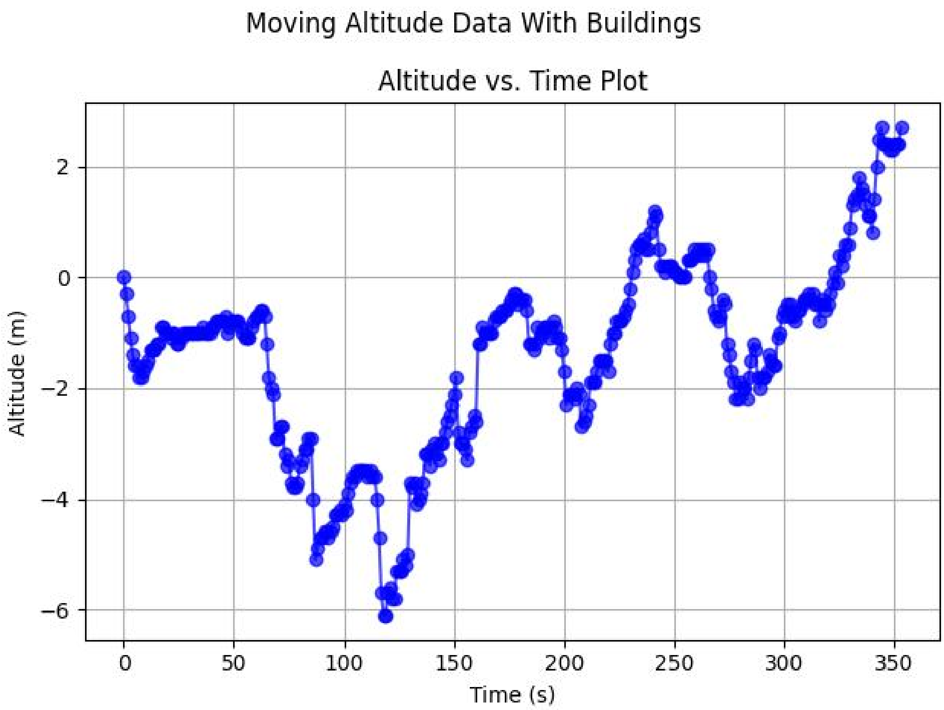
When we observe the data from lab1 and lab2 it is very clear that the RTK GPS is more accurate than normal GPS data. It is explicitly stated that open stationary data is having the more accuracy than occluded and even through there is some noise it can be corrected when ever a new fix message is received.

Moving Data Analysis

The below given plots is collected when walking with gps in hand in a straight line and forming a square path. With the collected data is plotted as a scatted plot and drawn an best fix straight line in square format to check the straightness of the collected data. With the noise in sensor there is a little bit of deviations but the plot looks like a straight line and it forms a square with loss of data in a few section. This is due to the reason because the gps wasn't able to gps fix when we pass close to or under the buildings.

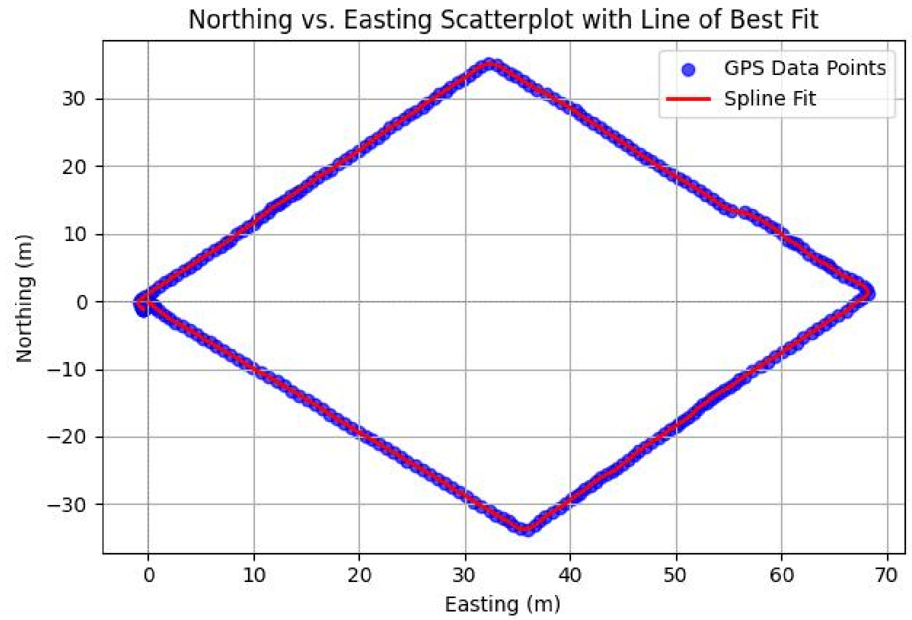


The below given plot is moving data altitude plot and it can be seen that the data altitude is varied over a period of time as it is due to height change in the plain while collection of data and also due to noise from the sensor and also one of the major reason for not above at-least one continuous point is as the gps wasn't able to receive data while passing close to or under the buildings and even though we received fix at a few locations the point was not continuous due to as it has been varied to earth surface height since we were moving continuously.



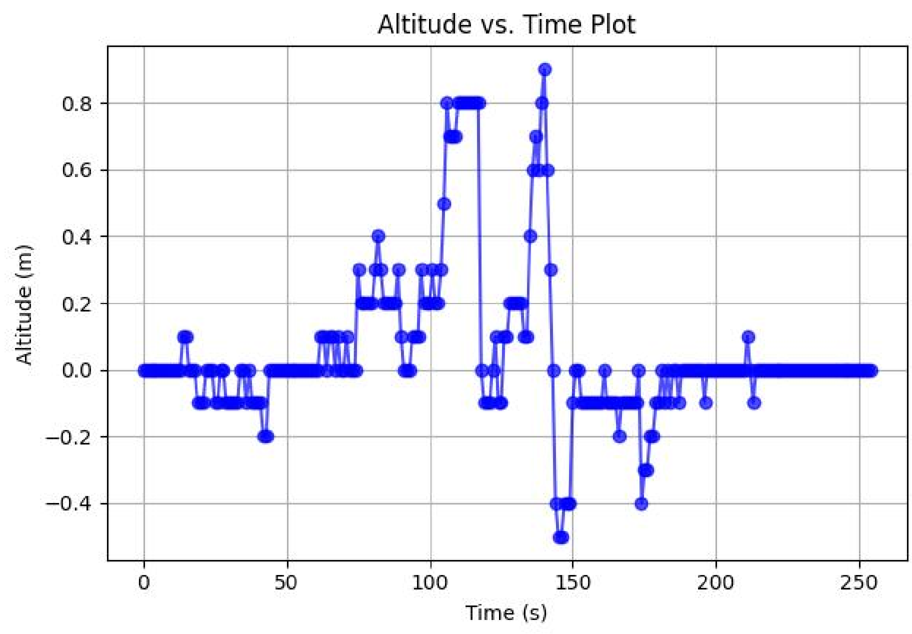
The below given plot is the data collected form open space while walking in a square distance. The data looks more accurate that the occluded data and also there is very less data loss and deviation. The deviation might be due to human error of walking with slight deviations instead of straight path.

Moving Data Without Buildings



The below given is the altitude data and it was recorded in a plain ground. Even though there was some deviations it is less than 0.8 meter or 80 centimeters. The majority of the data that line on the 0^{th} value, which means even though the sensor had its deviations after receiving the fix from base station it has be corrected to right value.

Moving Altitude Data Without Buildings



Comparison of open lab1 and lab2 data
It very clear that RTK gps data is more accurate than normal gps, this comparison is drawn from by comparing the data walked in straight line vs data walked in square path. Even though we walked in straight line in open area but still was not straight as compared to the straight line we got from rtk gps data. Both sensors has it own deviations but it has been fixed when the data is received with fix.

A) Error of stationary data open and occluded

```
kamal@kamal:~/catkin_ws/src/lab2/analysis$ python3 stationary_analysis_with_and_
without_building.py
With Buildings Centroid: (-5.77, -4.63)
Without Buildings Centroid: (-0.01, -0.07)
Min Altitude with Buildings: -3.20 m
Max Altitude with Buildings: 13.00 m
Mean Altitude with Buildings: 9.13 m
Min Altitude without Buildings: -0.30 m
Max Altitude without Buildings: 1.00 m
Mean Altitude without Buildings: -0.12 m
Error with buildings: 2.37 m
Error without buildings: 0.01 m
```

Error in moving data open and occluded

```
kamal@kamal:~/catkin_ws/src/lab2/analysis$ python3 moving_data_analysis_with_and
_without_buildings.py
Min Altitude With: -6.10 m
Max Altitude With: 2.70 m
Mean Altitude With: -1.42 m
Min Altitude Without: -0.50 m
Max Altitude Without: 0.90 m
Mean Altitude Without: 0.05 m
Error with buildings: 1.1233421932768312e-14
Error without buildings: 4.929975595327259e-15
```

Even though the RTK GPS has it own deviations after receiving the fix value the base station it was able to correct to original position it can observed from the plots.

B) The shapes of Easting vs Northing the mean of data collected in the open much closely aligned with the origin.

C) Yes there is a difference in-between the data collected from lab1 and lab2. the deviation from the origin in normal gps data is 5 meters with building and 2.3 meters without building. But where as the data collected from RTK GPS has deviation of less than 5 with building and 0.1 meter without building. Achieving centimeter level accuracy us phenomenal.

D) When we are collecting moving data it can be observed that not all the time we where able to get gps fix. Sometimes it was not receiving gps, from this we can understand that gps fix affected with buildings. The data loss and noise is more similar with and without building when stationary, but when moving it can be seen the error has be high some times due to no fix from base station.

E) The stationary data is also more accurate when collected from open field. Even though the sensor was kept static but still sue to no fix from base station some times with buildings the data was scattered a lot when compared to data collected form open field. In the open field data it was get the fix continuosly and able to get centimeter level accuracy.

Summary:

It has been observed that this sensor has lots of noise while collection of data has been reduced by the fix from the base station. When compared to lab1 data, the lab2 data has lesser noise and more accuracy. And the Data collected without buildings are more accurate than with buildings. To increase the accuracy of sensor fusion with IMU, and EKF (Extended Kalman Filter) can be used. And also multiple GPS can used to collect data and it can fused together with sensor fusion.