Robotics Sensing and Navigation (EECE5554)

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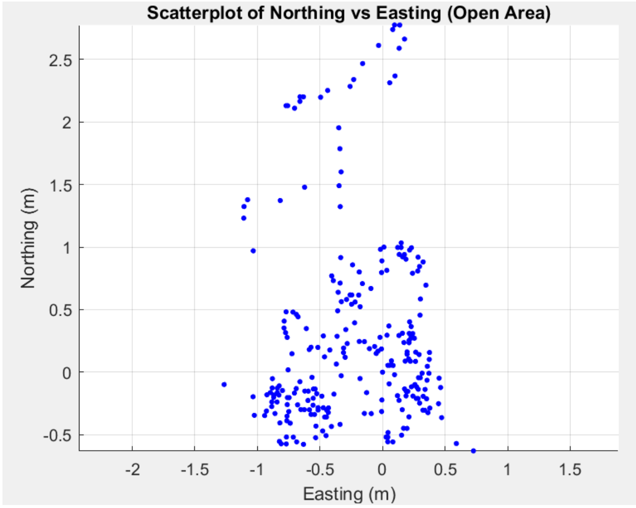


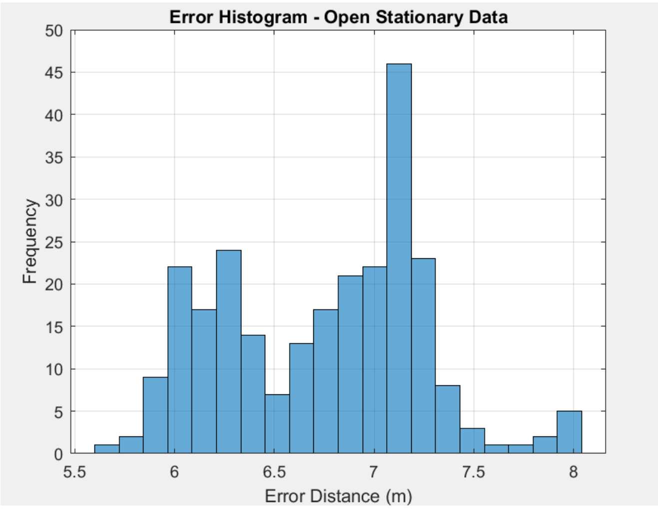
GPS data collected in a stationary open area

Scatter Plot of Northing vs Easting

- The clustering of points suggests that the GPS device is stationary. The spread of points suggests that the GPS signal is fluctuating around a central position. These variations in measurements are due to normal GPS errors, such as atmospheric effects, satellite geometry, and multipath errors.

Histogram of Position Errors

The histogram shows a distribution of position errors, with most errors concentrated in a specific range.



The errors are distributed symmetrically, resembling a Gaussian (normal) distribution. The histogram shape indicates that most errors are within a certain range (5.5-8 meters)

To estimate the error quantitatively, we use the Root Mean Square Error (RMSE) from the known position. From the histogram the error distances range between approximately 5.5 m and 8 m.

The most frequent errors are clustered around 7 m, with a gradual decline in frequency as the error increases. The mean error distance, as calculated, is 6.76 m

To calculate a single error value:
Root Mean Square Error (RMSE):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(e_i - e_{\text{mean}})^2}$$

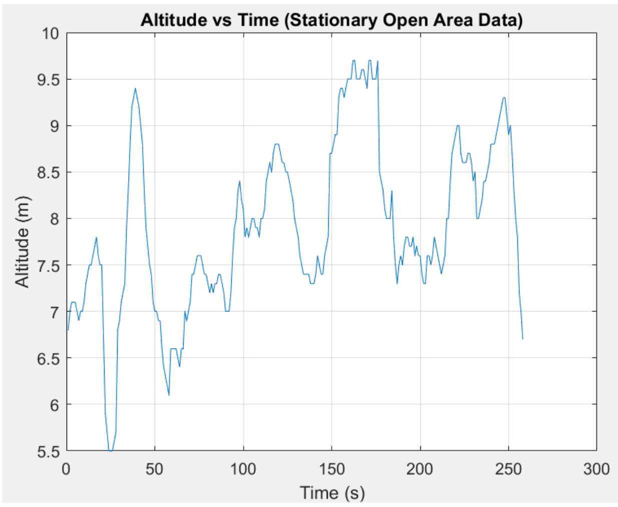
The mean HDOP value is 0.94620, which is excellent and indicates good satellite geometry and high positional accuracy.

Does This Error Make Sense Given HDOP and GPS Accuracy?

In ideal conditions, GPS errors typically range between 3–10 meters in open areas with good satellite visibility and low HDOP values (<1.0). My HDOP values range between 0.87 and 1.37, with a majority of values close to 1.0. So, the GPS receiver had good satellite visibility and geometry, which should result in high accuracy.
The observed mean error of **6.76 m** falls well within this range, suggesting that the GPS puck performed as expected under ideal conditions. The error is probably because the known reference position used for comparison could be slightly inaccurate, thereby slightly inflating the measured error or local environmental factors like atmospheric delays could contribute to this deviation. These reading were taken on a very windy day. The quantitative error estimate (RMSE), is consistent with the expected error given the low HDOP value in an open environment.

Altitude vs Time

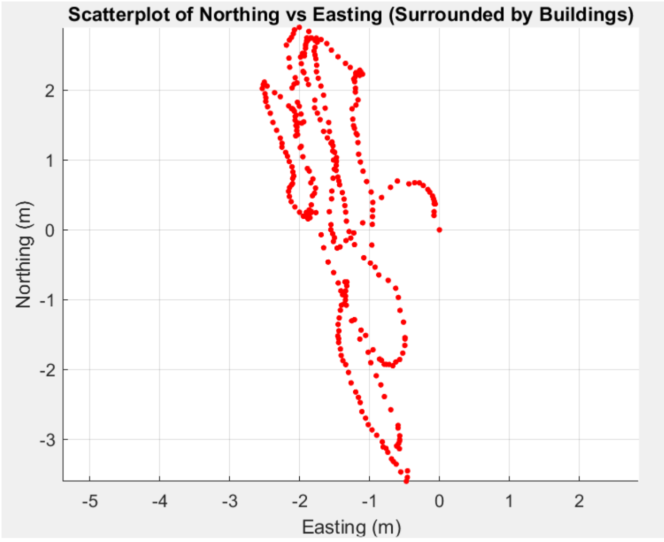
The altitude plot shows fluctuations over time, even though the device is stationary. The fluctuations are relatively small and consistent, staying within a range of about 3.5 meters. There is no clear trend, as the GPS puck is stationary, and the variations are random. The altitude readings are relatively stable, indicating good satellite visibility and minimal environmental interference.



GPS data collected in a stationary environment surrounded by buildings

<u>Scatter Plot of Northing vs. Easting</u>

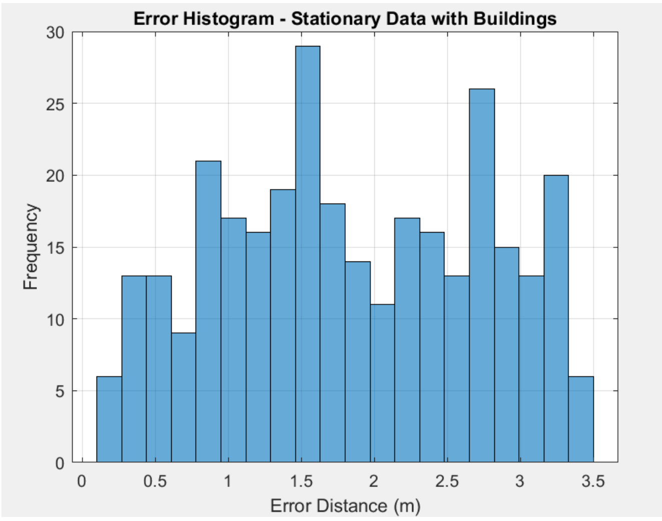
- The scatter plot shows significant variability in the GPS measurements, forming a loose cluster with irregular loops and deviations.
- The spread of the points indicates that the GPS device struggled to maintain consistent measurements, likely due to environmental factors. In an environment surrounded by buildings, multipath effects (GPS signals reflecting off nearby buildings before reaching the receiver, leading to inaccurate position fixes) and signal blockage can cause inaccuracies.
- The irregular shape and spread are typical for stationary data collected in urban or obstructed environments.



<u>Histogram of GPS Position Errors</u>

The histogram represents the distribution of error distances for GPS data collected in an occluded area (surrounded by buildings) are Mean HDOP: 3.2778, RMSE: **2.05 m**

The error distances range between approximately 0 and 3.5 meters, with the most frequent errors occurring around 1.5 meters. This variability reflects the challenges of GPS accuracy in urban environments. Multipath effects and poor satellite geometry (high HDOP values) contribute to larger errors. The presence of outliers indicates moments where the GPS signal was particularly degraded or obstructed.



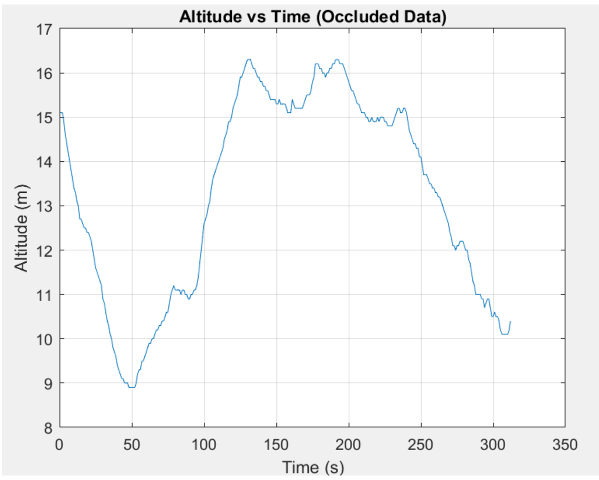
There is a positional error of 2.05m. Considering the high HDOP value, this RMSE is relatively low, indicating that while the environment was challenging, the GPS receiver still performed reasonably well.

This discrepancy might be due to short periods of improved satellite visibility during data collection.

Overall, while the error value does not fully align with general expectations for high HDOP values, it demonstrates that the GPS puck performed surprisingly well under challenging conditions.

<u>Altitude vs. Time</u>

The altitude varies between approximately 9 m and 16 m, with larger peaks and valleys compared to the open area. The fluctuations are more pronounced and there is a noticeable pattern of larger deviations, which could indicate multipath effects or reduced satellite visibility. Therefore the occluded environment significantly impacts GPS accuracy for altitude measurements.



Moving Data

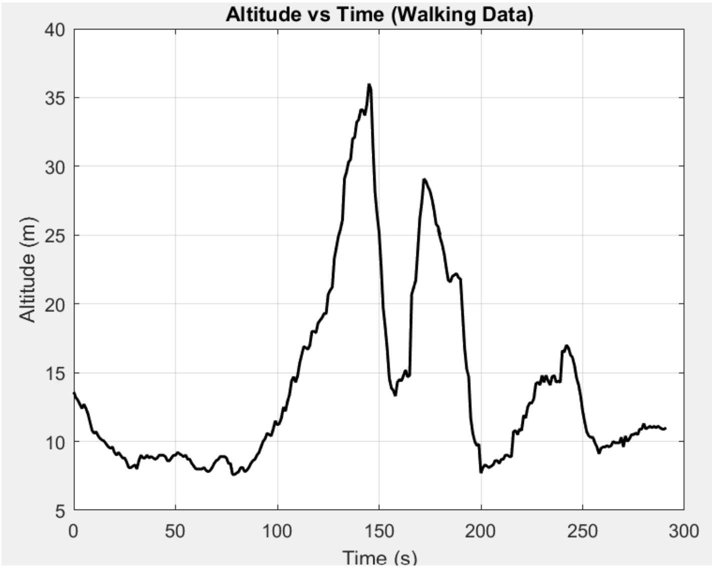
Scatter Plot of Northing vs. Easting

The scatter plot shows a general straight-line trend, indicating that the movement was approximately linear, as expected. However, there are noticeable deviations and wiggles along the path, which suggest inaccuracies in GPS measurements.

The deviations from the straight-line path could be due to GPS noise, multipath effects, or minor variations in actual movement.

The mean error of **3.8668 meters** is consistent with typical GPS performance and reflects expected deviations due to inherent limitations of consumer-grade GPS receivers.

Altitude vs. Time



The altitude plot shows significant fluctuations over time, with peaks and valleys despite moving along a nearly straight line. The fluctuations reflect actual elevation changes in the terrain as you walked. These fluctuations could result from poor satellite geometry or environmental factors or noise. These readings were captured along a slight slope from Ruggles to Marino.

How do your estimated error values change for stationary vs. moving data?

- For stationary data (e.g., in an open area or surrounded by buildings), the errors are typically smaller and more concentrated because the GPS receiver remains in a single location. The scatter plots for stationary data show tight clusters. This reflects minimal variability in position measurements.
- For moving data the error falls between the stationary errors. When moving, GPS receivers can use smoothing algorithms and motion models to correct errors. Unlike stationary data, random errors tend to average out, leading to a more consistent tracking performance. However, multipath effects (from buildings, trees, or terrain) still caused fluctuations. The scatter plot of Northing vs. Easting shows deviations from the straight-line path. These deviations arise because the receiver must continuously update its position, leading to greater variability.

Can you explain why this result is the case? What does this say about GPS navigation when moving for our receiver?

GPS performs better when moving compared to being stationary in an open area because movement allows for error filtering. Stationary positions suffer from drift over time, making long-term GPS tracking less reliable unless additional corrections are applied. In occluded areas, GPS might appear stable, but accuracy can be deceptive due to signal loss or reliance on a small subset of satellites.

What are physically likely source(s) of error in these data sets?

Multipath Effects: Signals reflecting off nearby surfaces (e.g., buildings or the ground) can cause inaccuracies by introducing delays in signal reception. This is particularly evident in urban environments or areas surrounded by obstructions.

Satellite Geometry (HDOP): Poor satellite geometry (high HDOP values) reduces accuracy by increasing uncertainty in position calculations.

Signal Noise: Atmospheric conditions, such as ionospheric and tropospheric delays, can distort GPS signals and contribute to errors.

Receiver Processing Errors: Consumer-grade GPS receivers may introduce errors due to limitations in hardware or software algorithms used for position calculations.

Environmental Factors: Moving data is more prone to errors caused by obstructions (e.g., trees, buildings) and dynamic changes in satellite visibility.