Lab 1 Report for EECE5554: Robotics Sensing and Navigation GPS Data Collection and Analysis

Wondmgezahu Teshome

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1 Introduction

This report presents an analysis of GPS data collection and analysis of the collected data under different environmental conditions. The experiment utilizes a GPS receiver to collect position data in three distinct scenarios: open-air stationary, occluded stationary, and walking trajectory. Through this analysis, we examine how environmental factors and motion affect GPS measurement accuracy, which is crucial for understanding GPS reliability in various robotics and navigation applications. The data collection and analysis were conducted by Group 4 using a GPS puck.

2 Data Collection

Data was collected in three different scenarios around Northeastern University campus:

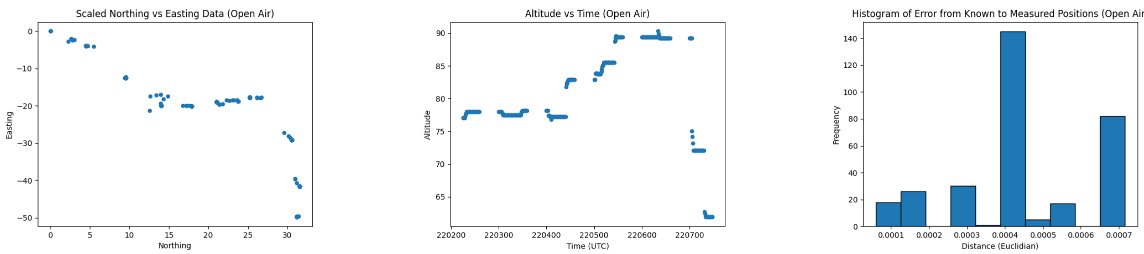
- Open-Air Location: Data collected near Whole Foods Market on Westland Avenue, chosen for minimal obstruction to sky visibility, providing optimal GPS signal reception conditions.
- Occluded Location: Data collected near Churchill Hall, where surrounding buildings created significant sky obstruction. This location was selected to analyze GPS performance under typical urban conditions with limited satellite visibility.
- Walking Data: A straight-line walk along the Christian Science Center's Reflecting Pool, chosen for its clear linear path of approximately 210 meters. This location provided an ideal setting to analyze GPS tracking during motion with a well-defined reference path.

Figure 1: Visualization of GPS measurements: (left) Open-air, (middle) Occluded conditions, and (right) Walking data.

3 Results and Analysis

3.1 Stationary Data Analysis

- Open Area Results
  - **Plots:** The following plot shows the different plots for the open area results.



(a) Northing vs Easting

(b) Altitude vs Time

(c) Histogram

Figure 2: Open Area Analysis Plots

  - **Discussion:**
    The open-air GPS measurements reveal several interesting patterns in position accuracy and stability. The **Northing vs Easting** scatter plot demonstrates a gradual position drift over the 5-minute collection period, with data points forming distinct clusters rather than a continuous spread.

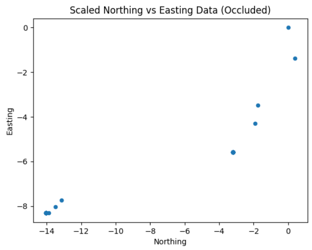
    The **altitude measurements** show marked step changes over time, varying between 70m and 90m, with distinct plateaus. These abrupt changes, rather than gradual transitions, indicate potential shifts in the satellite geometry or processing adjustments in the receiver's position solution.

    The **error distribution histogram** shows a multimodal pattern, with major peaks at approximately 0.0004 and 0.0007 Euclidean distance units, and several smaller modes throughout the distribution. This multimodal characteristic,suggests that the position solution experiences different systematic biases during the collection period. While the majority of measurements cluster around 0.0004 units from the known position, the presence of multiple modes indicates that the receiver's position solution shifts between different bias states, possibly due to changing satellite configurations or varying atmospheric conditions.

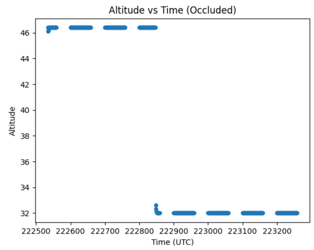
    The **position error estimate** was calculated in open-air conditions, which showed a mean error of 0.00045 degrees and with a standard deviation of 0.00017 degrees. The errors ranged from 0.00006 to 0.00072 degrees, indicating variation in position estimates despite unobstructed conditions.

    In conclusion, these observations, while within typical GPS performance specifications , demonstrate how even in open-air conditions, GPS measurements are subject to various **error sources** including atmospheric effects, satellite geometry changes, and receiver processing characteristics. The multimodal error distribution particularly highlights the dynamic nature of GPS accuracy even in stationary, unobstructed conditions.

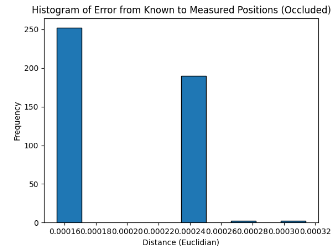
- Occluded Area Results
  - **Plots:** The following plot shows the different plots for the occluded area results.



(a) Northing vs Easting



(b) Altitude vs Time



(c) Histogram

Figure 3: Occluded Area Analysis Plots

- **Discussion:**

  The occluded area measurements show notably different characteristics compared to the open-air scenario. The **Northing vs Easting plot** shows a more linear drift pattern spanning approximately 14 units in northing and 8 units in easting. The data points form a roughly diagonal pattern with two main clusters at the extremes, suggesting a systematic bias in position estimation likely due to the reduced satellite visibility from nearby obstructions.

  The **altitude** measurements present a pattern with two distinct, stable levels - one at approximately 46 meters and another at 32 meters, with an abrupt transition between them. This 14-meter step change is particularly interesting as it remains stable at each level, unlike the gradual variations seen in the open-air scenario. This pattern suggests a sudden change possibly due to building obstruction blocking certain satellites.

  The **error histogram** shows a distinctly bimodal distribution with peaks at approximately 0.00016 and 0.00024 degrees of separation from the known position. The clearer bimodal distribution (compared to the multimodal pattern in open air) and the generally smaller spread of errors suggest that while the obstructions created systematic biases, they actually resulted in more consistent, although less accurate, position estimates.

  The **position error estimate** was calculated for occluded area with a mean error of 0.00020 degrees and with a smaller standard deviation of 0.00005 degrees. The error range was more compact, from 0.00015 to 0.00031 degrees, suggesting more consistent but not necessarily more accurate position estimates despite signal obstruction.

  In conclusion, these **observations** demonstrate the significant impact of urban obstacles on GPS performance, with interesting trade-offs between consistency and accuracy. The more structured error patterns, compared to the open-air scenario, indicate how building obstructions can create more predictable but biased position solutions.

3.2 Moving Data Analysis

- **Plots:** The following plots shows the Northing Vs Easting and the Altitude plots for the walking measured data.

(a) Northing vs Easting

(b) Altitude vs Time

Figure 4: Walking Analysis Plots

- **Discussion:**

  The Northing vs Easting plot shows three key elements: the measured GPS points, a polynomial fit of these measurements, and the true straight-line path (shown in black). The true path, defined by known start coordinates (UTM: 328256.10E, 4690068.53N) and end coordinates (UTM: 328403.14E, 4690219.59N), covers a distance of approximately 210 meters.

  The deviation between the measured path and the true straight line represents our position error during motion. The polynomial fit shows a deviation from the true path, particularly in the middle section where it curves away from the straight line. This deviation suggests that motion introduces additional position uncertainty beyond what we observed in stationary measurements.

  The **altitude plot** shows a total elevation change of approximately 45 meters (45m to 90m), captured in discrete steps. Given that this was a continuous uphill walk, the stepped pattern in altitude measurements indicates limitations in the GPS receiver's vertical position resolution during motion.

  The **moving data position error estimate** during walking was calculated as the perpendicular distance from each measured point to the known straight-line path. This path was defined by the start and end UTM coordinates, with error representing the shortest distance from each measured position to this reference line. Analysis shows a mean error of 12.22 meters with a standard deviation of 3.78 meters, ranging from 5.31 to 19.56 meters. These values represent the lateral deviation from the intended straight path while walking.

  In conclusion, the **measured path** shows deviations from the expected straight-line trajectory, which could be attributed to several factors including the receiver's sampling rate during movement, changes in tracked satellites, and potential signal interference along the walking route.

4 Conclusion

Through this GPS data collection and analysis task, we examined position accuracy under three distinct scenarios: open-air stationary, occluded stationary, and walking conditions. The open-air measurements showed mean position errors of 0.00045 degrees with notable variation, while the occluded location demonstrated more consistent readings with a mean error of 0.00020 degrees, though affected by signal obstruction. During the walking trajectory, position measurements deviated from the intended straight path with a mean error of 12.22 meters, highlighting the challenges of GPS tracking during motion. These findings demonstrate how environmental conditions and movement affect GPS measurement accuracy, with implications for applications requiring precise position information. The analysis provides valuable insights into the limitations and capabilities of GPS-based positioning systems under different real-world conditions.