Real Time Kinematic GNSS

Lab 2 Report

EECE5554: Robotics Sensing and Navigation

Group 4:

Wondmgezahu Teshome (me)
Kanishk Kaushal
Matthew Kazan
Sam Milhaven

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1 Introduction

Real-Time Kinematic (RTK) GNSS is an advanced positioning technology that significantly enhances the accuracy of standard Global Navigation Satellite System (GNSS) receivers from meter-level to centimeter-level precision [1], [2].

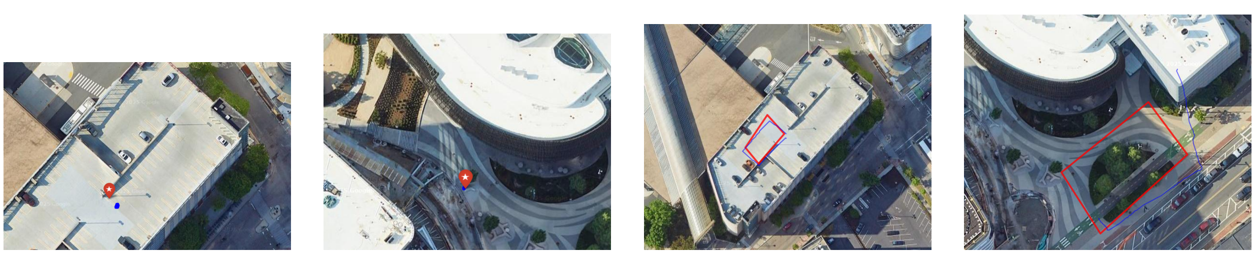
Real-Time Kinematic (RTK) positioning enhances standard GNSS technology by utilizing a network of fixed reference stations that continuously transmit correction data for satellite signals, enabling mobile receivers to achieve centimeter-level accuracy rather than the meter-level precision of standard GNSS[2]. While standard GNSS relies solely on direct satellite signals and measures the time it takes for these signals to travel to the receiver, RTK employs a differential positioning technique that compensates for atmospheric delays, satellite clock errors, and other inaccuracies through real-time corrections from known reference points[2]. This fundamental difference in methodology makes RTK ideal for precision applications like surveying, construction, and autonomous vehicles, whereas standard GNSS positioning suffices for general navigation and location-based services where extreme accuracy isn't required[2].

2 Data Collection

We collected four RTK GNSS datasets following the lab manual requirements. The equipment used included a SimpleRTK2B GNSS/RTK Board, GNSS Antenna, USB cable, and a Windows laptop. Data was collected at two locations: the Columbus parking garage rooftop (open air) providing unobstructed sky view, and near the ISEC building (partially occluded) with building structures and vegetation creating signal challenges. At each location, we recorded:

- **Stationary data**: we collected 10-minute continuous recording with the receiver at a fixed point (marked with red stars in the images below)
- **Moving data**: Rectangular path with approximately 1 minute per side, returning to the starting point (highlighted with red rectangles)

All data was saved as text files containing NMEA sentences, with GNGGA sentences extracted for analysis as required.



(a) Open Air: Columbus (b) Occluded: ISEC (c) Open Air Square (d) Occluded Square

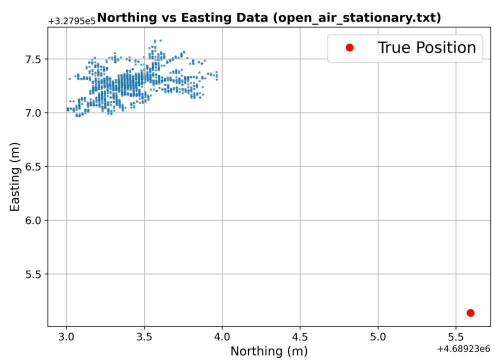
Figure 1: Data Collection Locations and Paths

3 Results and Analysis

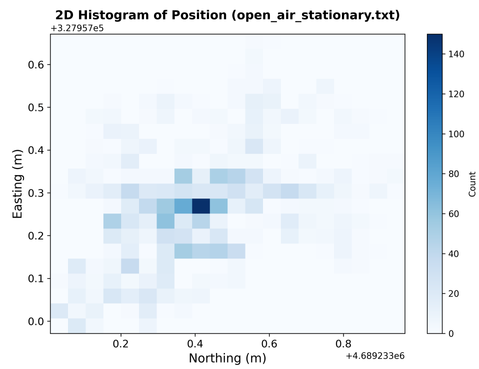
3.1 Stationary Data Analysis

- **Open Area Results**

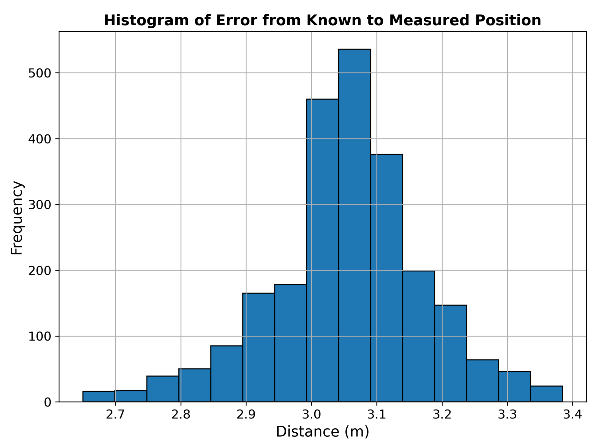
  – **Plots:** The following plots show the analysis results for the stationary open area data.



(a) Northing vs Easting



(b) 2D Histogram of Position



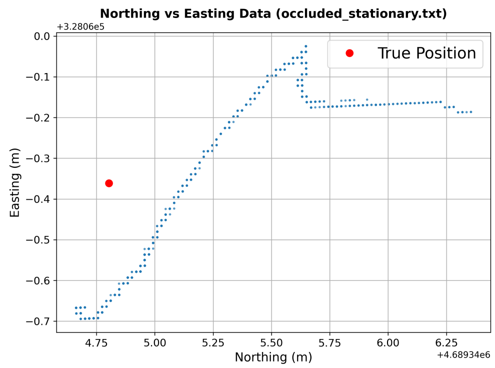
(c) Histogram of Error

Figure 2: Open Stationary Area Analysis Plots

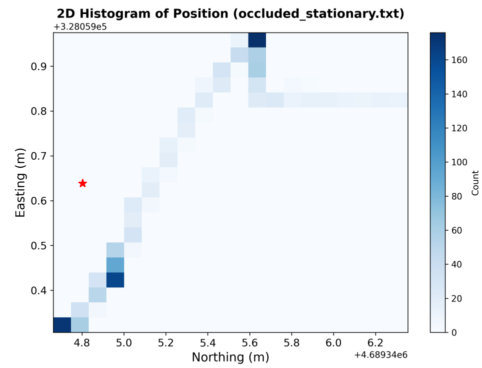
  – **Discussion:**

  The open-air stationary data shows a consistent clustering of position measurements with a mean error of 3.055 meters from the true position and a standard deviation of just 0.118 meters. The Northing-Easting plot and 2D histogram shows a scatter measurements concentrated around a specific area. The error histogram shows a near-normal distribution centered at approximately 3.1 meters.

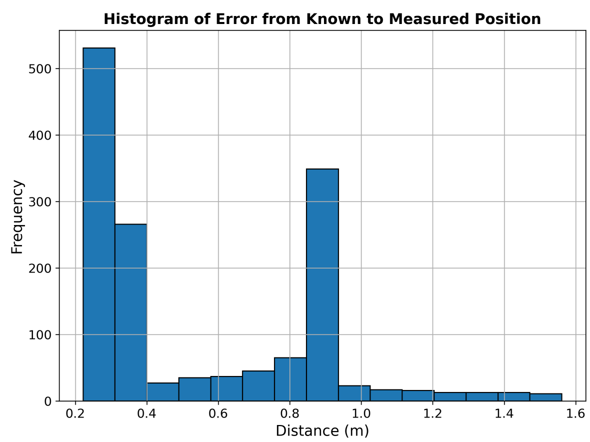
- **Occluded Area Results**
  - **Plots:** The following plots show the analysis results for the stationary occluded area data.



(a) Northing vs Easting



(b) 2D Histogram of Position



(c) Histogram of Error

Figure 3: Occluded Stationary Area Analysis Plots

  - **Discussion:** The above plots for the occluded stationary scenario shows a linear drift pattern rather than the clustered distribution seen in open-air conditions above. Despite the signal obstruction, the mean position error improved to 0.548 meters (compared to 3.055m in open-air), though with increased standard deviation of 0.325 meters reflecting lower precision. The 2D histogram in Figure (b) shows position measurements spreading diagonally across the plot, with concentration points at both ends of the trajectory. Most notably, the error histogram in Figure (c) displays a bimodal distribution with peaks at approximately 0.3m and 0.9m.

3.2 Moving Data Analysis

- **Open Area Results**
  - **Plots:** The following plots show the analysis results for the moving open area data.

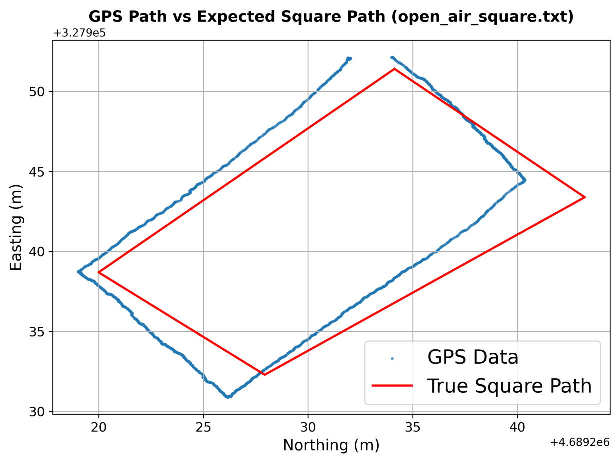


Figure 4: Northing vs Easting

- **Occluded Area Results**
  - **Plots:** The following plots show the analysis results for the moving occluded area data.

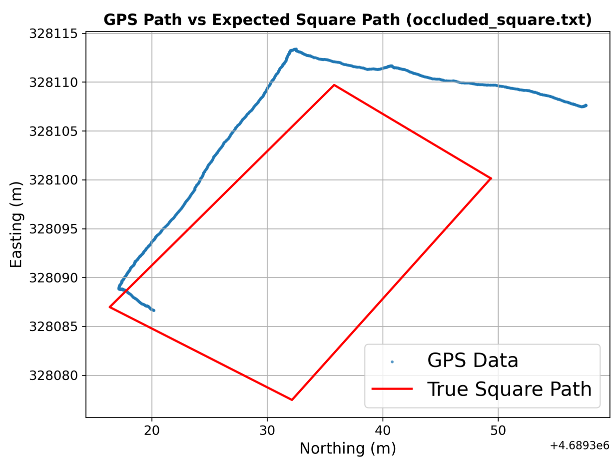


Figure 5: Northing vs Easting

- **Discussion** The square path data shows a significant differences between open-air and occluded environments. In open-air conditions, the RTK GNSS tracked the square path with reasonable accuracy, maintaining the overall geometric shape while exhibiting a mean path deviation of only 0.972 meters and standard deviation of 0.561 meters. The plot shows consistent tracking with well-defined corners, though slightly with some gap in the initial position compared to the true square path. In contrast, the occluded environment resulted in significantly degraded performance with mean path deviation of 3.971 meters and standard deviation of 2.905 meters , indicating both decreased accuracy and precision. The occluded path shows substantial distortion, particularly in the northing direction, with the receiver struggling to complete the square pattern.

4 Conclusion

In this lab, we do the GPS data collection and analysis using the RTK GNSS, which is better than the standard GPS. The position distributions evolved from scattered, multimodal clusters in Lab 1 to more structured, tightly grouped patterns in Lab 2, particularly visible in the Northing vs Easting plots of stationary open-air area. Open-air RTK measurements shows precision (SD=0.118m) despite a 3-meter offset, while occluded environments surprisingly delivered better absolute accuracy (0.548m) though with increased variability shown by the diagonal pattern in position plots. The error histograms widely dispersed distributions in Lab 1 to more normally distributed errors in Lab 2, representing an order-of-magnitude improvement. RTK GPS tracking works well in open areas, with errors under 1 meter when following set paths. However, buildings and obstacles increase errors to about 4 meters. This shows RTK provides good accuracy for navigation when it has clear view of satellites, but performance drops significantly in cluttered environments. While our stationary occluded dataset maintained 100% RTK fixed quality (5) with good accuracy (0.548m), the open-air stationary data showed predominantly quality 2 readings , yet maintained high precision (SD=0.118m). This indicates that while fix quality is important, environmental factors significantly impact RTK GNSS performance even when optimal fix status is achieved.

References

[1] Emlid. “Rtk introduction.” (2025), [Online]. Available: https://docs.emlid.com/reachrs3/rtk-quickstart/rtk-introduction/ (visited on 02/28/2025).

[2] D. O’Donohue. “What is gnss rtk.” (2025), [Online]. Available: https://mapscaping.com/what-is-gnss-rtk/ (visited on 02/28/2025).