Lab 1: GPS Data Analysis

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I. Introduction

This report analyzes GPS data collected using a GPGGA puck in both stationary and dynamic conditions. The aim is to evaluate the performance of GPS in terms of accuracy and error when the device is stationary, moving in a straight line, and walking through a dynamic environment. The data has been converted to UTM coordinates, and statistical analyses have been performed to assess the reliability of GPS under these conditions.

II. Data Collection

Three sets of GPS data were collected:

1) **Stationary Data:** The GPGGA puck was placed in a fixed location for an extended period.
2) **Straight-line Walking Data:** The puck was carried while walking in a straight line.
3) **Dynamic Walking Data:** The puck was carried while walking through a dynamic environment with changing obstacles.

The GPS data was recorded and parsed into UTM coordinates (easting, northing) and altitude.

A. Statistical Analysis

The following error statistics were computed for the UTM (Universal Transverse Mercator) easting and northing data:

- **Mean (Easting):** 328082.55 m
- **Variance (Easting):** 1.04 m
- **Root Mean Squared Error (RMSE) (Easting):** 1.02 m
- **Mean Absolute Error (MAE) (Easting):** 0.87 m
- **Mean (Northing):** 4689323.42 m
- **Variance (Northing):** 3.70 m
- **Root Mean Squared Error (RMSE) (Northing):** 1.92 m
- **Mean Absolute Error (MAE) (Northing):** 1.65 m

These results indicate that even when stationary, the GPS introduces small errors, mainly due to atmospheric conditions, satellite geometry, and multipath effects. The low variance and RMSE indicate that the GPS system is relatively stable when the puck remains stationary.

B. Error Bounds and Sources

The calculated RMSE and variance provide insight into the typical GPS error bounds for stationary conditions. Sources of error include atmospheric disturbances and signal reflection, both of which contribute to the noise observed in the GPS readings. While the RMSE values are relatively low, these errors could affect accuracy in applications requiring high precision.

III. Walking in Dynamic Environment

A. Overview

A total of 259 GPS messages were collected during a walk through a dynamic environment with potential obstacles and variations in terrain. The goal was to assess how these factors affect the GPS's ability to provide accurate location data.

B. Statistical Analysis

The following statistics were calculated for the UTM easting and northing data:

- **Mean (Easting):** 328005.52 m
- **Variance (Easting):** 2319.93
- **RMSE (Easting):** 48.17 m
- **MAE (Easting):** 44.36 m
- **Mean (Northing):** 4689406.23 m
- **Variance (Northing):** 3011.83
- **RMSE (Northing):** 54.88 m
- **MAE (Northing):** 46.78 m

The error values in the dynamic environment are significantly higher than those observed in stationary conditions. The variance and RMSE are considerably larger due to the movement and potential obstacles causing multipath effects and increased signal distortion. This data suggests that GPS accuracy deteriorates when the puck is moved through varying environmental conditions.

IV. Straight-line Walking Data Analysis

A. Overview

The straight-line walking scenario involved collecting 130 GPS messages. The data was analyzed to determine how accurately the GPS could track movement in a controlled, linear trajectory.

B. Statistical Analysis

For the UTM easting and northing coordinates, the following statistics were computed:

- **Mean (Easting):** 327867.67 m
- **Variance (Easting):** 1521.39
- **RMSE (Easting):** 39.00 m
- **MAE (Easting):** 34.02 m
- **Mean (Northing):** 4689637.18 m
- **Variance (Northing):** 426.98
- **RMSE (Northing):** 20.66 m
- **MAE (Northing):** 17.48 m

While the error statistics are lower than in the dynamic environment, they are still significantly higher than in the stationary scenario. This confirms that even in controlled linear movement, the GPS introduces substantial noise, particularly in the UTM easting data. The RMSE and MAE values are within expected bounds for consumer-grade GPS systems.

V. Conclusion

This analysis highlights the varying degrees of GPS accuracy in different scenarios. When stationary, GPS data exhibits minimal noise and error, but as the puck is moved through dynamic or controlled environments, the error increases significantly. The RMSE and MAE values show that movement introduces additional noise into the GPS readings, especially in dynamic environments with obstacles. Overall, the analysis provides a useful understanding of the limitations of GPS systems under different conditions.

VI. Figures

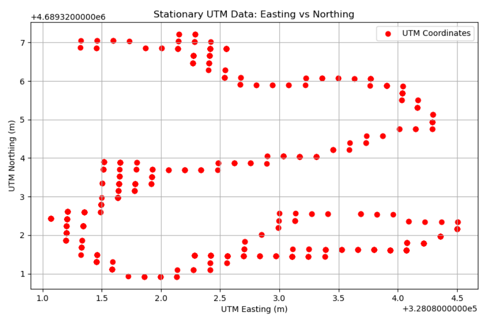

Fig. 1. Stationary UTM Data: Easting vs Northing.

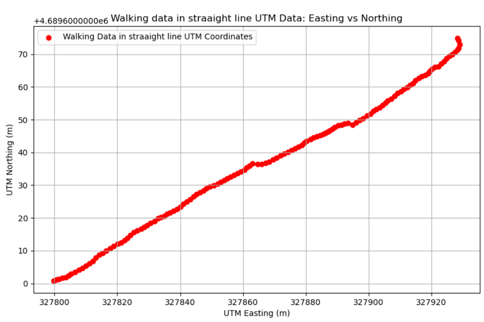

Fig. 2. Straight-line Walking UTM Data: Easting vs Northing.

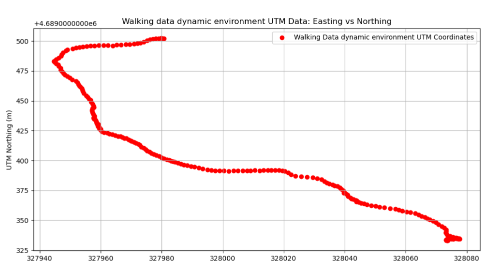

Fig. 3. Dynamic Walking UTM Data: Easting vs Northing.

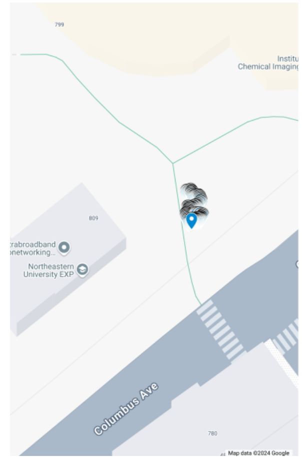

Fig. 4. Stationary Map: GPS Trajectory in Fixed Location.

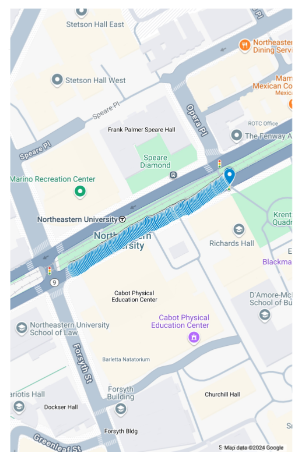

Fig. 5. Straight-line Walking: GPS Trajectory in a Linear Path.

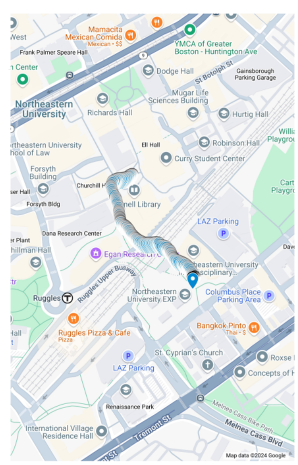

Fig. 6. Dynamic Walking: GPS Trajectory in a Dynamic Environment.