**Lab Goal:**

Analyze the data collected by RTK GNSS setup, and understand the error distribution along with major sources of error in this setup.

**Methods:**

Our team setted up a stationary base station and a rover using an RTK hardware board that uses RF to communicate with each other. Then we collected a total of 4 sets of data (2 with stationary Rover and 2 with moving Rover) in an open field area (McLaughlin Park, ) and a partially occluded area (Columbus Avenue, outside ISAAC building).


(Image1- Moving data at McLaughlin Park, Image2 - Moving data at Columbus Ave outside ISAAC)

**Data Analysis:**

For each data set, we have calculated a bounding radius to define precision of the RTK module under different conditions. For calculation of bounding radius, we are assuming that 95% of measured data points will lie within a circle of bounding radius (‘r’).

STATIONARY DATA:

For analysis of stationary data we are considering three plots -

**Plot 1**: Sensor measurements in 2D plane with easting and northing as x and y axis respectively. This plot reflects the measured location of RTK-Rover in UTM Coordinates.

**Plot 2:** Deviations from mean easting and northing position with data point as X axis, deviations as Y axis and Fix quality as Y2 axis. In this plot, deviations are calculated by estimating the distance of each point from the mean easting and northing coordinates. It reflects change in deviation from mean position with time and how it is related to the Fix-quality.

$$e = \sqrt{(x - \bar{x})^2 + (y - \bar{y})^2}$$

**Plot 3:** Error Distribution with number of data points on Y axis and standard deviation on X axis. (Note - 1 bin [0-0.713] reflects 1 standard deviation). This plot reflects how errors are distributed across the mean and standard deviation.

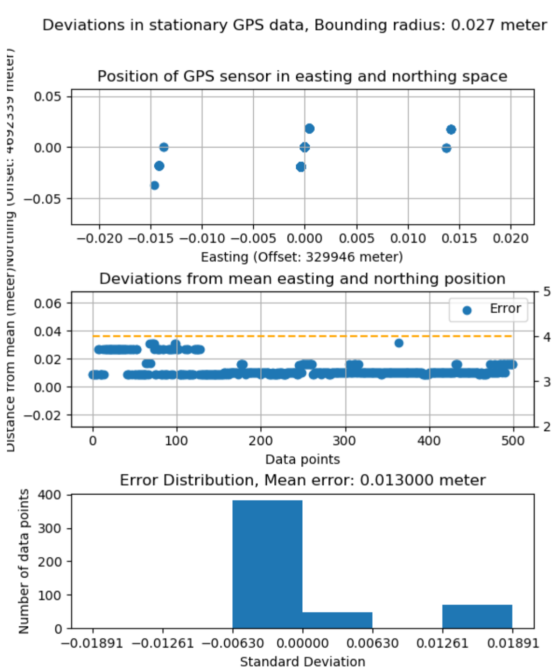
MOVING DATA

**Plot 1**: Sensor measurements with easting and northing as X and Y axis respectively along with Estimated northing positions corresponding to easting data. In this plot, Estimated northing positions are calculated by predicting a linear regression model between easting and northing data for each straight line walked. This plot reflects the measured location of RTK-Rover in UTM Coordinates along with the best fitted trajectory.

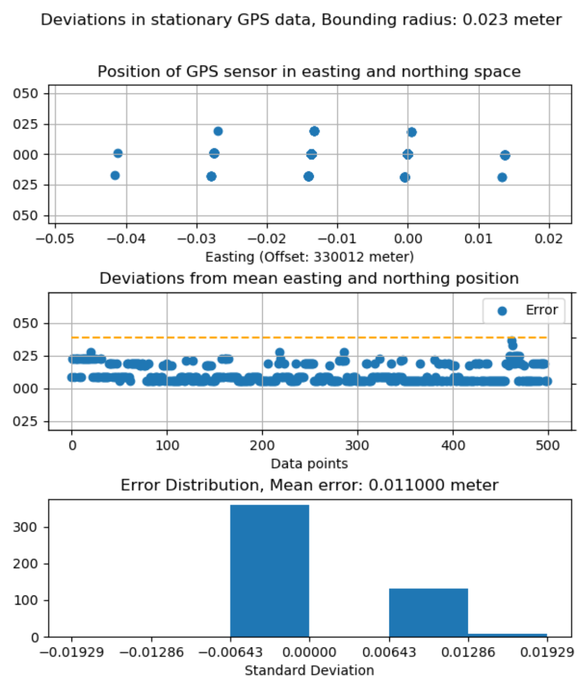
**Plot 2:** Deviations with deviation on Y axis and data points on X axis. In this plot, deviations are calculated by evaluating the distance of measured northing from estimated northing corresponding to each easting value. This plot reflects trends in difference between RTK Rover measurements from an estimated straight path (Assumption - RTK rover is moved in a perfect straight line).

**Plot 3:** Error Distribution with number of data points on Y axis and standard deviation on X axis. (Note - 1 bin [0-0.713] reflects 1 standard deviation). This plot reflects how errors are distributed across the mean deviation value and standard deviation.

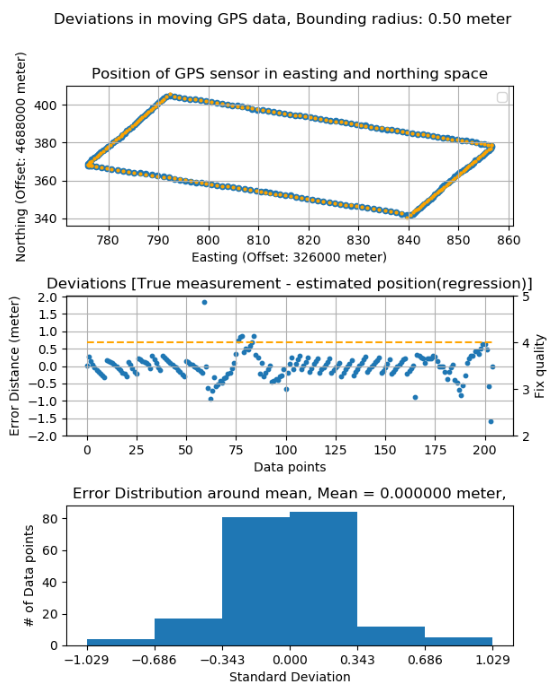
PLOTS



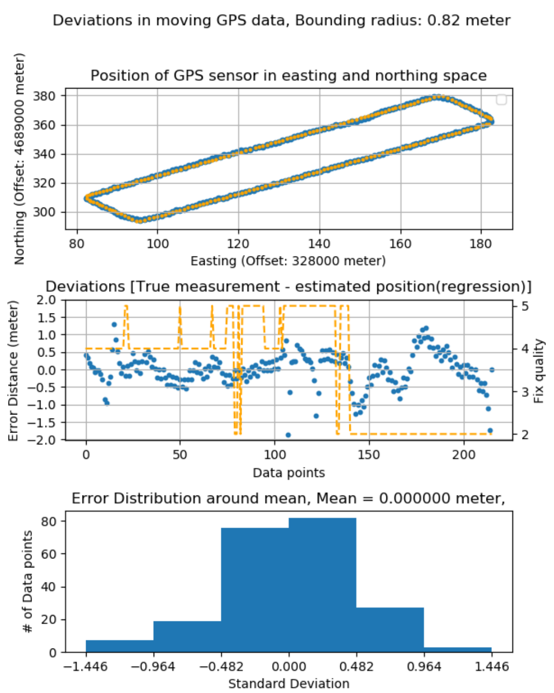

(a)




(b)




(c)




(d)

(Plot (a) - Stationary data - Open field, Plot (b) - Stationary data - Occluded area, Plot (c) Moving data - Open field, Plot (d) Moving data - Occluded area)

**Results**

Precision for RTK setup are in the following decreasing order with lower value of bounding radius in brackets reflecting higher precision - Stationary open field (~0.025 m), stationary occluded area (~0.025 m), moving open field (~0.50 m), and moving occluded area (~0.85 m). Also, for an RTK Setup, we can assume the error distribution to be a gaussian distribution in a moving rover as approximately reflected by the error distribution graphs in Plot c and Plot d. Additionally, the results suggest major sources of error in RTK setup is signal blockage from satellites and failed transmission between base station and rover due to obstructed line of sight.

**Discussion:**

In these experiments, we evaluated the precision of RTK setup for different conditions. Comparing the precision (bounding radius) of RTK setup with a GPS receiver for stationary and moving data in a similar environment (open field) shows that RTK GNSS navigation has a much higher accuracy and precision compared to GPS receiver especially with stationary data - Stationary, RTK: 0.025m vs GPS: 2.25m and Moving, RTK: 0.50m vs GPS: 1.25m. This improved performance is majorly contributed by increased satellite visibility and better spatial geometry from additional satellites (GPS and GLONASS navigation systems). Also, RTK setup compensates for the effect of atmospheric ionization by sending corrections, which is one of the major sources of error in GPS systems. However, the setup is unable to compensate for the signal blockage and multi-path errors [1]. As suggested in the study for effects of Multipath errors in RTK setup [2], the system is prone to a maximum of 5cm error and an average of 3cm error due to Multipath errors in a general urban setting in which the receiver is not completely obstructed. This aligns with our observation for stationary data as reflected by graph 1 in plot a and plot b. Therefore, major sources of error in RTK setup must be obstructed signals from satellites or failed communication between base station and rover. If we observe Deviations vs Fix quality w.r.t data points graph (2nd graph) in each plots, data points for which the quality factor dropped to 2 (no RTK) deviations escalated to GPS receiver levels - Plot (d) Graph 2, in case of moving data error values reach [-1m , 1m] which is similar to GPS receiver errors. Thus, the effect of line of sight between RTK and Base station has a huge impact on the errors generated by the RTK setup, as the setup uses RF transmission between base station and rover to communicate for corrections. Additionally, if we compare the error graphs (graph 2) in plot c and plot d, effect of signal blockage could be observed which leads to large errors of upto 1.5m in case of moving data in partially obstructed regions. These observations align with our theory for major sources of errors - Signal blockage and failed communication between base station and rover.

**References:**


1. Li, T.; Zhang, H.; Gao, Z.; Chen, Q.; Niu, X. High-Accuracy Positioning in Urban Environments Using Single-Frequency Multi-GNSS RTK/MEMS-IMU Integration. *Remote Sens.* **2018**, *10*, 205. https://doi.org/10.3390/rs10020205
2. Mekik, Çetin & Can, Özer. (2010). Multipath effects in RTK GPS and a case study. Journal of Aeronautics, Astronautics and Aviation, Series A. 42. 231-240