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# RSN LAB 2 - GPS RTK

## Analysis of Stationary Data

### 1. No Occlusion

This data was collected under clear sky on the top of the Columbus parking lot for a duration of 10 minutes. RTK quality 'Fix' was observed throughout the entire duration of the data collection. The error in this data is estimated to be 1.37 cm . The error was calculated in the following fashion:

$$\sqrt{(max(utm\ e)\ -\ min(utm\ e))^2\ +\ (max(utm\ n)\ -\ min(utm\ n))^2}$$

The reason for calculating error according to the above formula is that it relates the range of error obtained in UTM easting to UTM northing by treating them as dependent quantities. As only two distinct points are observed, the error when calculated as above simply translates to the distance between the two points

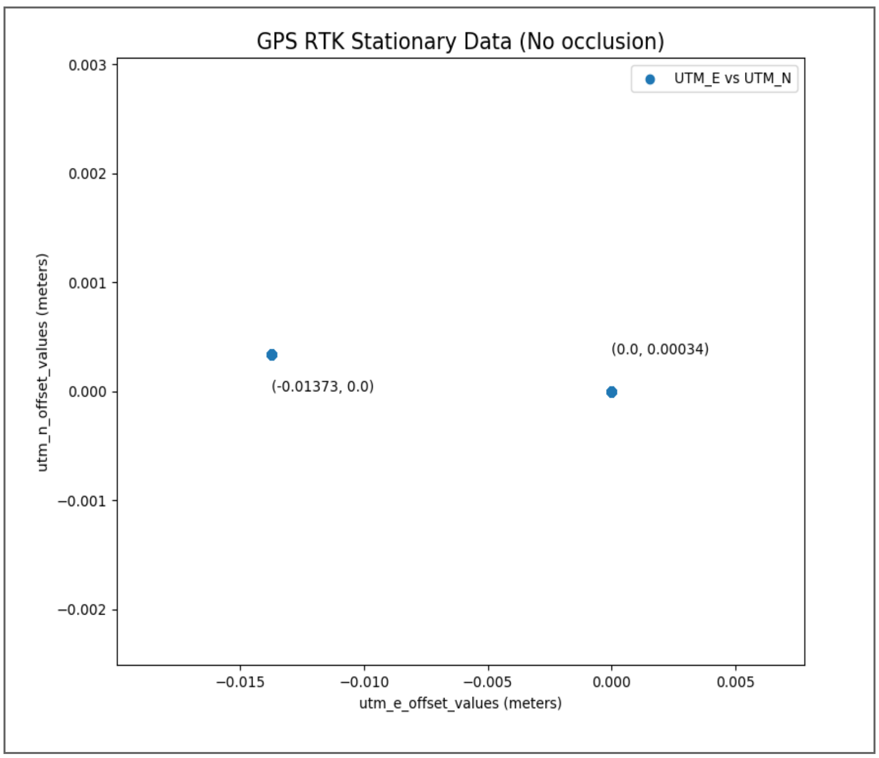



*Fig. 1: Plot of stationary data (no occlusion)*

There are about 600 observations recorded in the duration of 10 minutes, and only two distinct points are observed with a frequency distribution of about 50% data overlapping on each point. If we draw circles of radius 1 cm (considering that the least change GPS can measure is 1 cm) with the centers as the two distinct points as seen above, the overlapping region may be the one having highest probability of containing the true location.

## 2. With Occlusion

The stationary data with occlusion was collected in front of Snell library. The weather was clear on the day of collection and RTK quality 'Fix' was observed throughout. It is observed that there are many more distinct points recorded in this data as compared to the one with no occlusion. I plotted a histogram to quantify how many points are overlapping for every distinct point.

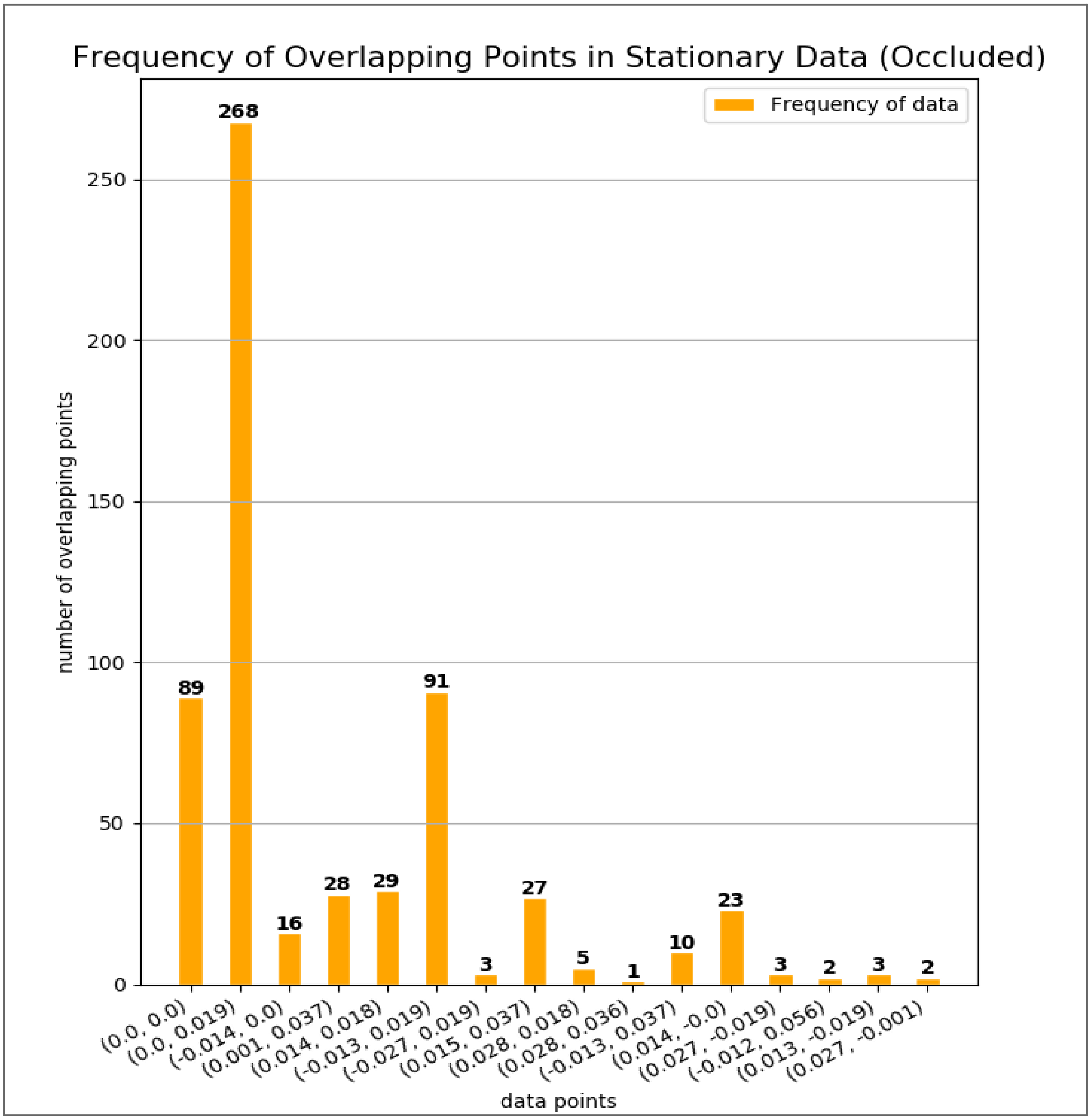
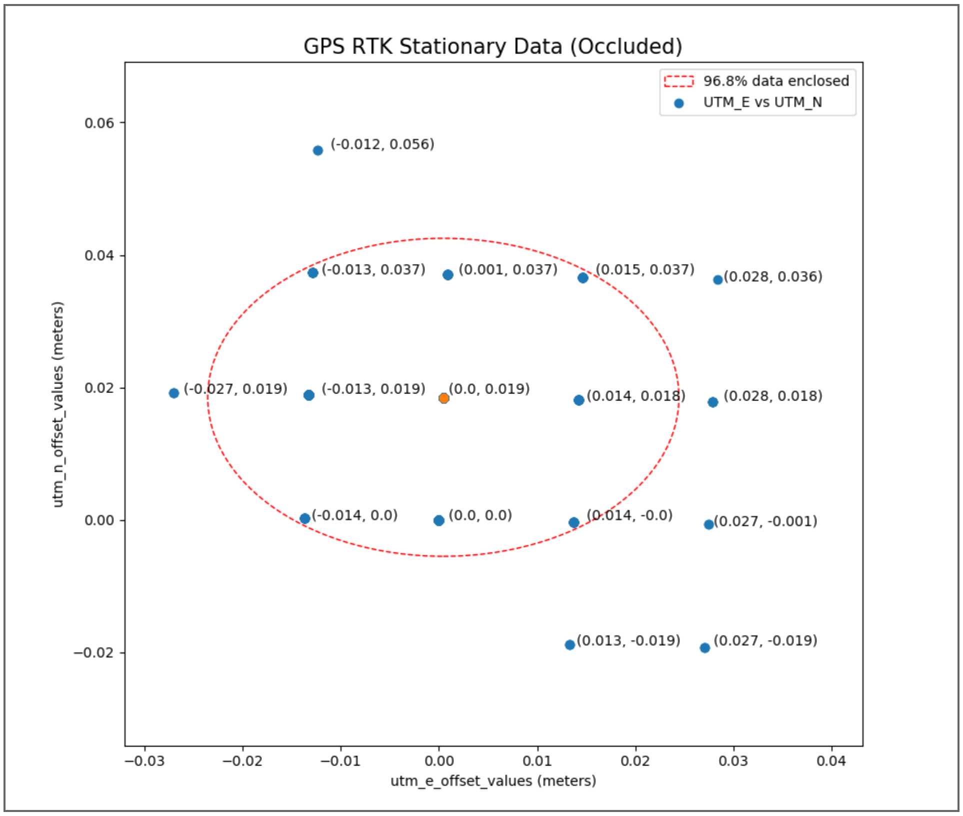



*Fig. 2: Histogram of distinct points in stationary data (with occlusion)*

It is inferred from the plot above that the point (0.0, 0.019)[hereby referred to as point P1] has the highest occurrence i.e. 44.66% of the total recorded data. Below is a plot of the collected data:



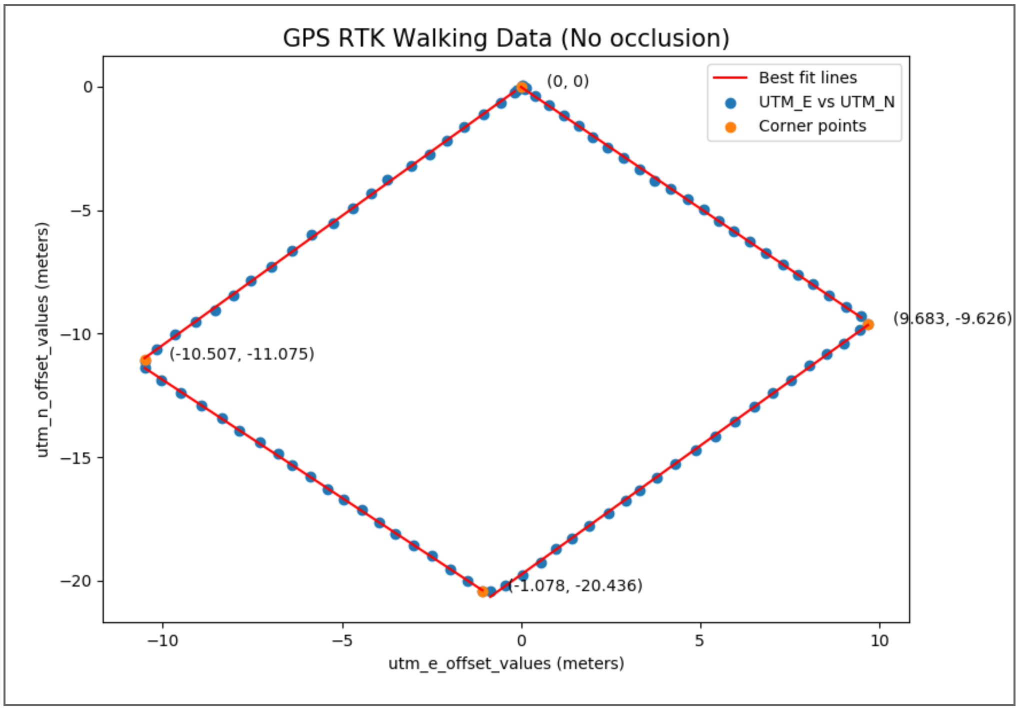

The error calculated for this plot (according to the expression mentioned earlier) is 9.33 cm. There is a significant rise in error from the data collected with no occlusion. I hypothesized that the points with the least occurrence would be the farthest from P1. It is clear from the histogram that there are 7 unique points in the data that each occur 5 times or less, and their total occurrence constitutes for only 3.1% of the whole collected data. Now, to classify the outliers, I decided to plot a circle with a radius that encompasses >95% of the data. The point P1 was chosen as the center of this circle, considering that it is the point that occurs most frequently.

The exact computed radius of the circle is 2.4 cm (The computational code can be found in the analysis script). This circle is plotted on the graph shown above. Thus it proved my hypothesis that the least occurring points are the furthest from P1, and their existence may be attributed to the occlusions present(snell building, overhead trees) which result in multipath errors. The reason that these points occur so rarely is that RTK base is constantly collecting data from a constellation of satellites and providing a real time solution for the rover to fix its position.

# Analysis of Walking Data:

## 1. Without Occlusion

The walking data was collected on top of the Columbus parking lot. The actual path traversed is a rectangle with dimensions (15.84 x 13.70 meters). Below is a plot of the collected data.




To compare the actual distance with the one observed in the plot, the length of each side of the rectangle on the plot is calculated to be 15.3 m, 13.28 m, 15.25 m, and 13.65 m. (starting with the point (0,0) and going in an anticlockwise direction). The difference in actual and calculated measurements are due to following reasons:

- Improper means to measure the actual distance on ground
- Human error in selecting the exact corner point from the plot

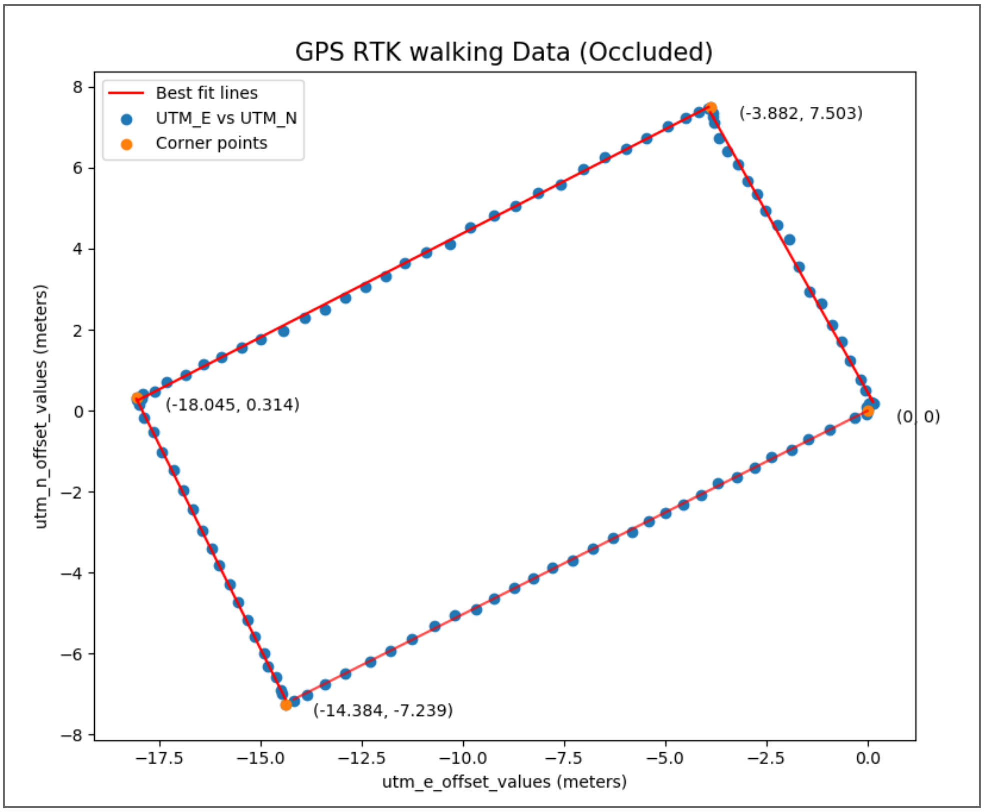
To better quantify the error, a best fit line is plotted for each of the sides of the rectangle, and the RMS error is calculated for each side. For every side, the error for individual point is calculated as the perpendicular distance from the point $\{(x_i, y_i) \mid i = 1 \; to \; n\}$ to the best fit line $ax + by + c = 0$. Further, the RMS error is calculated for each side and the net RMS error is calculated as:

$$RMS_{net} = (RMS_{side\ 1} + RMS_{side\ 2} + RMS_{side\ 3} + RMS_{side\ 4}) / 4$$

The net RMS error is calculated to be 3.79 cm for this plot.

## 2. With Occlusion

This data is collected in front of the Snell library. The actual path traversed is a rectangle with dimensions (16.0 x 8.26 meters). Below is a plot of the collected data:




To compare the actual distance with the one observed in the plot, the length of each side of the rectangle on the plot is calculated to be 16.10 m, 8.39 m, 15.88 m, and 8.44 m. (starting with the point (0,0) and going in an anticlockwise direction).

Similar to the previous plot, a best fit line is plotted for each of the sides of the rectangle, and the RMS error is calculated for each side. The net RMS error is obtained in similar fashion as mentioned above, and the same is calculated to be 4.32 cm for this plot

## Concluding Statements:

- Comparing the stationary data collected with RTK GPS with only GPS (as in Lab 1), it is clear that the precision of the data has increased significantly (almost 100 times)
- It is observed from the two sets of stationary data that occlusions can hamper the precision of data to a large extent. Nevertheless, RTK GPS still provides precision of upto 10 cm in occluded areas provided a fix solution is obtained
- The difference in the RMS error in walking data collected with and without occlusion is not very significant. The probable explanation of walking data being accurate even in occlusion may be due to the Kalman filter present in the GPS puck which is better able to predict the position when the GPS puck has certain velocity.