Lab 2: Analysis of RTK GPS Data

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Setting up the hardware for the collection of the RTK GPS data involved the setting up of the base station and the rover. The idea is to eliminate the common noise that is present in the base station (which is fixed at a single point) and rover GPS data. After data collection was complete, four datasets were analyzed.

Stationary Data – Free Space (No Occlusions)

Stationary Data was collected on the rooftop of Columbus Parking adjacent to ISEC. The GPS hardware was placed away from any obstructions. There were no physical obstacles, and the data was collected on a clear day. A key observation made during the collection of stationary data was the impressive accuracy in the position over the data collection period of 10 minutes. Over this period, a total of 609 data points were recorded. The data was recorded in an open space with no obstructions in the immediate vicinity, as can be seen in Figure 1.

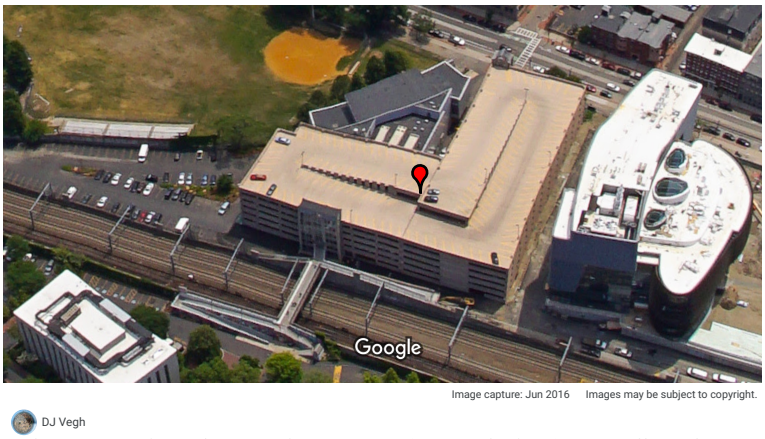

Fig 1 – Location where Stationary Data (No Occlusions) was collected

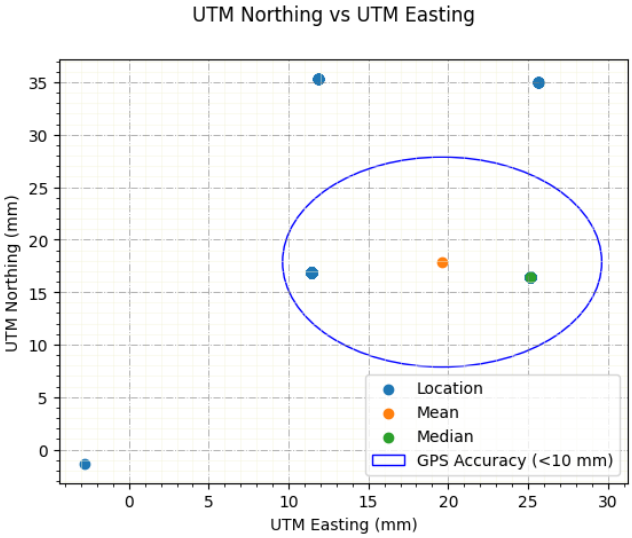

Fig 2 – Data collected - Stationary Data (No Occlusions)

In Figure 2, the data collected is very accurate, with the accuracy of the data collected within few mm. The GPS board used, which is the simpleRTK2B – mPCIe based on the u-blox ZED-F9P module, has an accuracy of <10mm with the presence of a base station.

It is to be noted that during the collection of this dataset, a constant RTK fix was achieved.

Analysis of Stationary Data

By observing the data that has been collected, it can be said that the level of precision of position data is accurate to a few mm. The analysis of this data initially by calculating the mean of all the data points collected. In Figure 2, the mean is plotted. As mentioned in the GPS module spec sheet, an accuracy of 10mm is denoted in the figure by plotting a circle around the mean.

However, an additional point that must be noted is that out of the 609 points collected ~85% of the points overlap on the median, plotted as a green point on the graph. This means that probabilistically it can be inferred that this point is the true GPS position, neglecting the mean, as statistically, the median proves to be a more realistic point denoting the true GPS value.

On further analysis, the Root Square Mean Error is calculated for Easting and Northing values. On evaluation, the RSME for Easting is 6.789mm and for Northing it is 4.7588mm.

```
For UTM Easting,
upper bound : 5.992384116877979
mean: 19.624743329579765
lower bound : 22.37676193307602

For UTM Northing,
upper bound : 17.46137084191656
mean: 17.86742775017405
lower bound : 19.215843475107196
```

Combining the errors of both Easting and Northing a single parameter is obtained, which accommodates for the errors across both Easting and Northing. The accuracy of the GPS data from this dataset is obtained to be 6.7mm ~ 7mm.

This accuracy in the dataset shows an improvement of 30% to the data mentioned in the datasheet of the GPS module.

Moving Data – Free Space (No Occlusions)

Moving Data was collected on the rooftop of Columbus Parking adjacent to ISEC. The GPS hardware was placed away from any obstructions. The data was collected by moving in a rectangular pattern. There were no physical obstacles, and the data was collected on a clear day. The data was collected over a period of a few minutes, over this period, a total of 211 data points were recorded. The data was recorded in an open space with no obstructions in the immediate vicinity, the plot of which can be seen in Figure 3.

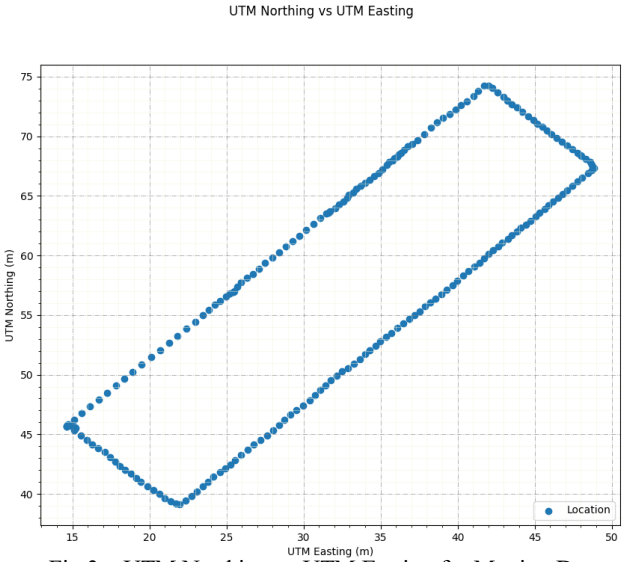

Fig 3 – UTM Northing vs UTM Easting for Moving Data – No Occlusions

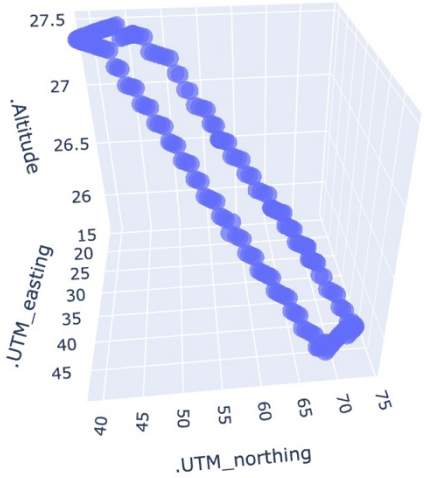

Fig 4 – UTM Northing vs UTM Easting vs Altitude for Moving Data – No Occlusions (All axes are in m)

The path that was traced in a rectangle was not on flat ground. The accuracy of the collection of data was so precise that the gradient of the slope of the Columbus parking rooftop can be seen in the 3D plot in Figure 4.

It is to be noted that during the collection of this dataset too, a constant RTK fix was achieved.

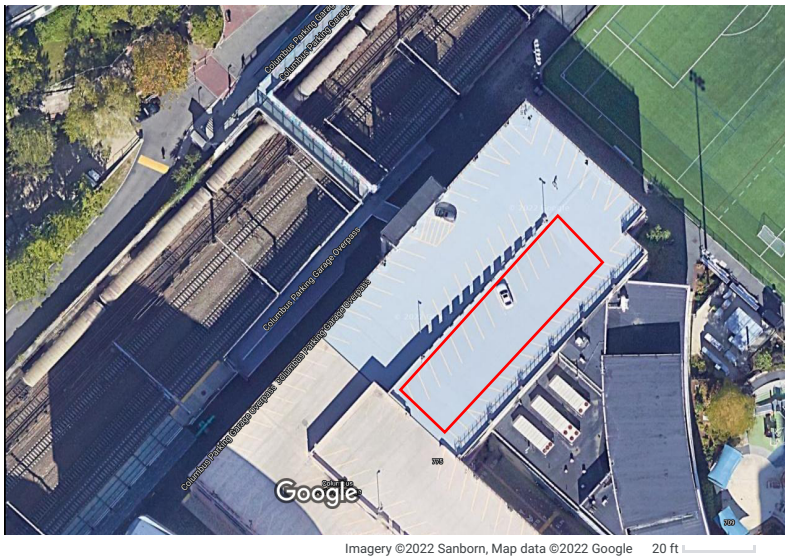

Fig 5 – Location of Collection of Moving Data – Columbus Parking Rooftop

Analysis of Moving Data

The path traced during the data collection is a rectangle, but for analysis, it cannot be considered as a rectangle. During the data collection, at the site of collection, the path traced was taken with the reference of walking on the guidelines marked on the floor of the site, which was parallel to each other. It can thus be safely approximated that the errors of the entire path can be calculated as a combination of 4 straight lines that form a quadrilateral.

Assuming the path traced is a quadrilateral, the four sides are straight lines, and that the start and origin point are the same, we can proceed with analyzing the data.

On further analysis, the Root Square Mean Error is calculated for Easting and Northing values. On evaluation, the RSME for Easting is 10.39mm and for Northing it is 10.467mm.

```
For UTM Easting,
upper bound : 16.85377562943442
mean: 31.989697523987235
lower bound : 17.35120121947428
For UTM Northing,
upper bound : 17.221141862749207
mean: 57.02192758855308
lower bound : 17.897656904467297
```

Combining the errors of both Easting and Northing a single parameter is obtained, which accommodates for the errors across both Easting and Northing. The accuracy of the GPS data from this dataset is obtained to be 10.46mm ~ 11mm.

This accuracy in the dataset shows a 10% decrease in accuracy to the data mentioned in the datasheet of the GPS module. This lower accuracy can be expected due to the initial assumptions made regarding the path that was traced and the errors that might arise due to multipath, while moving, as the environment keeps changing and is not fixed as in case of stationary data.

Stationary Data – With Occlusions

A key observation made during the collection of stationary data with occlusions was the eventual drift in the position over the data collection period of 10 minutes. Over this period, a total of 630 data points were recorded. The data was recorded outside ISEC in Northeastern University, which is an occluded space with many obstructions in the form of trees, buildings in the immediate vicinity. This was a reason for many multipath interferences to affect the GPS, which led to the collection of very unreliable position data.

During the collection of this dataset, an RTK Fix was not observed, due to the several obstructions present in the vicinity.

In Figure 2, all the values converge into distinct points. However, as it can be seen in Figure 7, the data collected does not converge, and shows the drift in the position. Data for stationary GPS position has an overall change of 5.8m in Northing and 6.1m in Easting. However, there is a gradual drift in the position even when recording stationary data.

Fig 6 – Location of Collection of Stationary Data – Just Outside ISEC

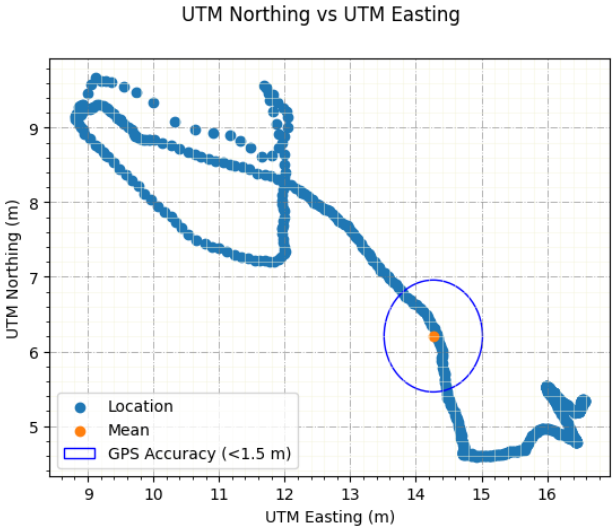

Fig 7 – UTM Northing vs Easting – Stationary Data with Occlusions

Figure 6 shows the location where this dataset was collected. As it can be seen, there are a lot of tall buildings and trees that affect the signals that reach the GPS module from connected GPS satellites.

Analysis of Stationary Data with Occlusions

As previously done, a circle is plotted around the mean to denote the accuracy of 1.5m which is present in the datasheet when there is an RTK Float status. There is a lot of drift in the position due to errors.
The major source of these errors is from multipath which is the interference of signal with surroundings like trees and buildings which lead to the reflected or altered signal that is being received.

On analysis, the Root Square Mean Error is calculated for Easting and Northing values. On evaluation, the RSME for Easting is 2.394m and for Northing it is 1.573m.

```
For UTM Easting,
upper bound : 2.302723750203759
mean: 14.266111776268199
lower bound : 5.462403611373711
For UTM Northing,
upper bound : 3.4660953945672466
mean: 6.2067124702775525
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```
lower bound : 1.6206564818316744
```

Combining the errors of both Easting and Northing a single parameter is obtained, which accommodates for the errors across both Easting and Northing. The accuracy of the GPS data from this dataset is obtained to be 2.394m ~ 2.4m.

Moving Data – With Occlusions

As done in previous sections, the data was collected by tracing a rectangular path in front of Snell Library at Northeastern University. Over the period of a couple of minutes, 126 data points were collected. The area of data collection was well occluded with buildings trees and many occlusions. As in the case of stationary data collection with occlusions, similarly in this case too, the data collected is noisy and erroneous. Just like the previous case, the data is affected due to multipath.

In this case too, the data collection was done with a status of RTK float, due to multipath interferences. As can be seen in Figure 8 the occlusions affect the signal received by the GPS hardware.

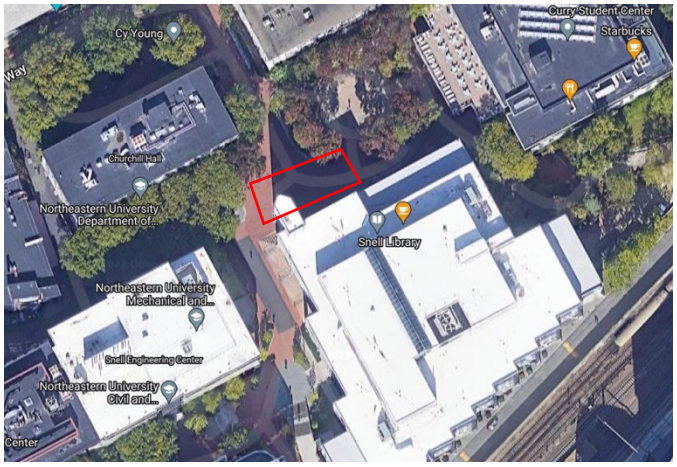

Fig 8 – Location of Collection of Moving Data – In Front of Snell Library

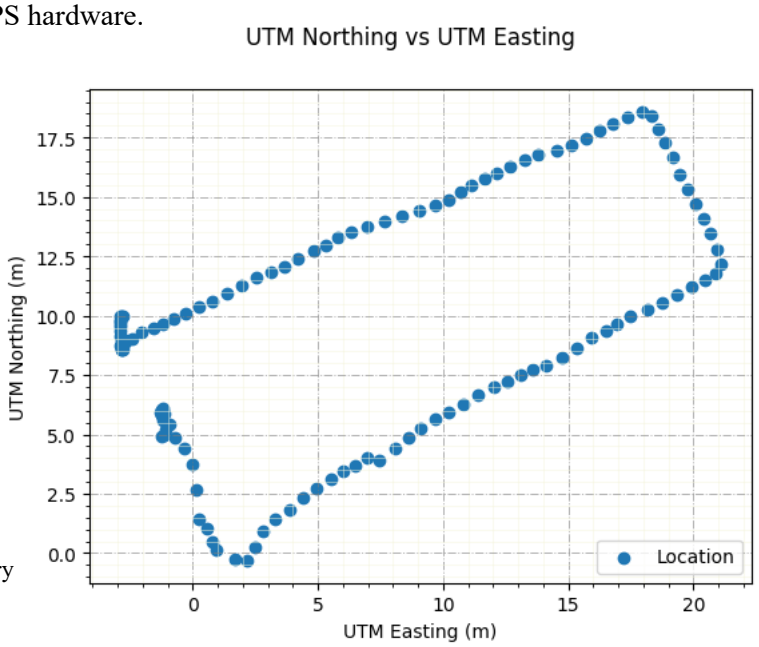

Fig 9 – UTM Northing vs UTM Easting for Moving Data - Occluded

In Figure 9, it can be observed that although the initial starting point and ending point was the same, it is not coinciding due to the multipath error.

Analysis of Moving Data with Occlusions

The path traced, although is not a regular polygon, does not appear to be a polygon at all as observed in Figure 9.

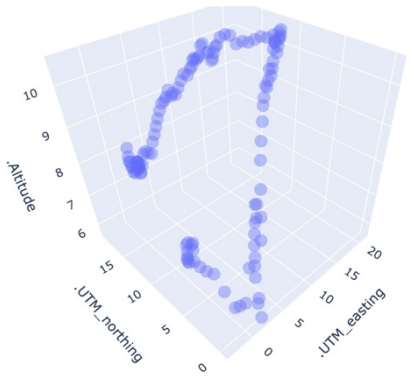

Fig 10 – UTM Northing vs UTM Easting vs Altitude for Moving Data – with Occlusions (All axes are in m)

When we add another dimension of altitude, as seen in Figure 10, the data is seen to be very erroneous.
The major source of these errors is from multipath which is the interference of signal with surroundings like trees and buildings which lead to the reflected or altered signal that is being received, just like in the stationary data with occlusions dataset.

On analysis, the Root Square Mean Error is calculated for Easting and Northing values. On evaluation, the RSME for Easting is 8.078 m and for Northing it is 4.82 m.

```
For UTM Easting,
upper bound : 14.499665470286143
mean: 6.6252738733730645
lower bound : 9.553062389937825
For UTM Northing,
upper bound : 9.144186195215239
mean: 9.440575757766114
lower bound : 9.746029520178185
```

Combining the errors of both Easting and Northing a single parameter is obtained, which accommodates for the errors across both Easting and Northing. The accuracy of the GPS data from this dataset is obtained to be ~ 8m.

Thus, from the datasets collected it can be safely said that RTK GPS with an RTK fix status is very reliable and precise to well under <10mm accuracy.