LAB1 Report

Note: Due to faulty hardware and bad weather condition, we are submitted Lab1 late. We received new hardware on deadline day from TA Skanda and the weather was also extremely bad last weekend which made it tougher for us to collect data. Please consider our delayed submission and I kindly request you not to give us late penalty for this.

Real-Time Kinematic (RTK)

- RTK stands for Real-Time Kinematic, which is a satellite-based positioning system that uses radio signals to determine the precise location of a receiver on the Earth's surface. RTK works by using a base station that is located at a known location and a rover that is moved to an unknown location. The base station receives signals from Global Navigation Satellite System (GNSS) satellites, such as GPS, and uses these signals to determine its own position.
- The base station then sends corrections to the rover receiver in real-time, which allows the rover to calculate its own position with high accuracy. RTK can achieve centimeter-level accuracy, making it ideal for applications such as surveying, construction, and precision agriculture. RTK is also used in autonomous vehicles and drones for precise navigation and control.

GNSS vs RTN GNSS

- GNSS stands for Global Navigation Satellite System, which is a constellation of satellites that provides signals to receivers on the ground, allowing them to determine their location, velocity, and time. GNSS includes various satellite systems such as GPS and GLONASS
- RTN GNSS or Real-Time Network Global Navigation Satellite System is a more advanced and precise positioning system that uses a network of GNSS base stations and a rover receiver to determine the position of the rover in real-time.
- While both GNSS and RTN GNSS use satellite signals to determine position, the key difference between the two is that RTK GNSS utilizes a network of base stations that provide real-time corrections to the rover receiver, resulting in higher accuracy and precision. GNSS can achieve accuracy levels of around 1-5 meters, while RTN GNSS can achieve sub-centimeter-level accuracy. Hence it is used in applications such as land surveying, engineering, and construction.

Sources of Error in RTK GNSS:

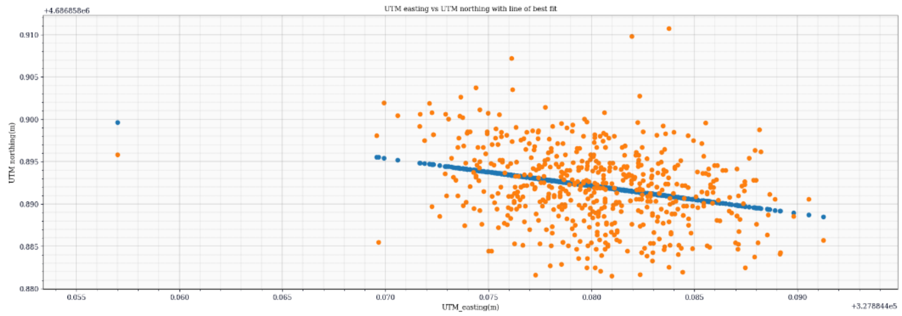
- Orbit errors
- Satellite clocks
- Ionospheric delay
- Tropospheric delay
- Noise in Receiver
- Multipath

Open Stationary:

The Scatter Plot tells us that most clusters are formed withing 2cm range which is highly accurate. The Mean and Median Error values are the same which tells us that the distribution of points in pretty uniform. If we look at the Error values, they are in range of 6-10 meters but this is mostly due to the fact that our known location might be a bit different than the location we got on our receivers. We use Google Earth for known co-ordinates and even a difference in second can cause a huge difference. If we take a median data point as known location instead of google earth, the error values are low in range of 5-10 cm.

Error Type	Error Value(m)	Error Type	Error Value(m)
Mean Easting	6.48	Mean Northing	10.89
Median Easting	6.48	Median Northing	10.89
Deviation Easting	0.004	Deviation Northing	0.0045

The Deviation in Altitude was from 2-4 cm which is highly accurate.



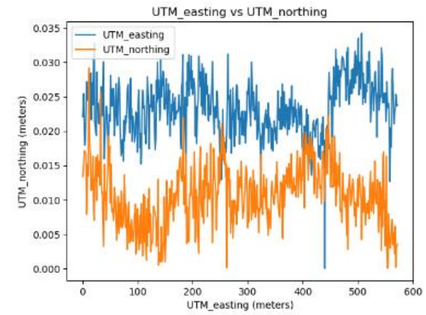


Fig: Scatter Plot

Fig: UTM Easting vs UTM Northing

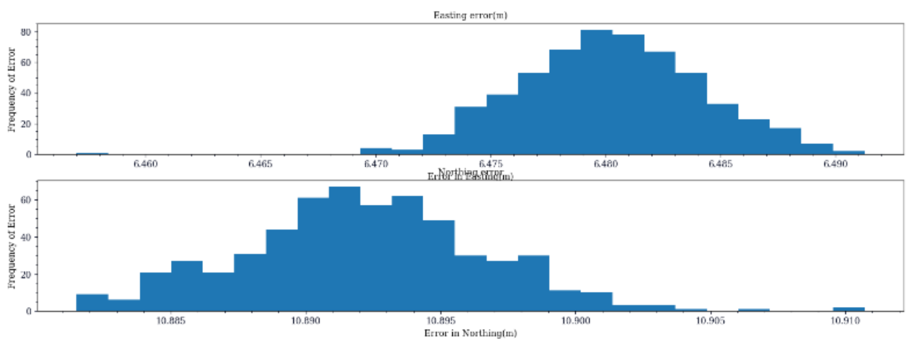


Fig: Error vs Frequency of Error (Histogram) for Easting and Northing

Open Walking:

The following are the values for Errors in Open Walking Data

Error Type	Error Value(m)	Error Type	Error Value(m)
Mean Easting	0.27	Mean Northing	0.04
Median Easting	-3.01	Median Northing	-0.38
Deviation Easting	7.745	Deviation Northing	7.84

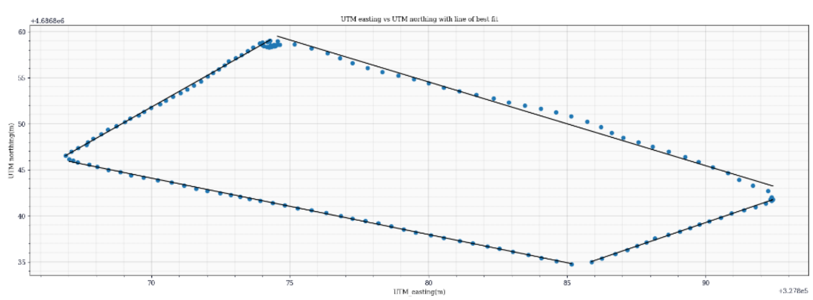
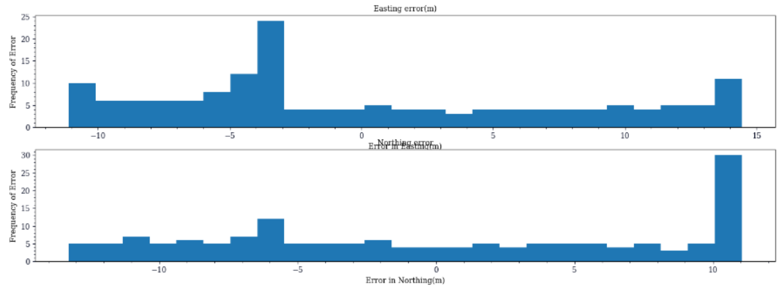
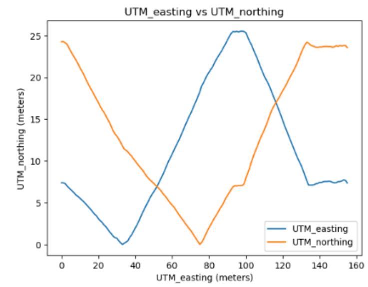


Fig: Scatter Plot with Line of Best fit for each path





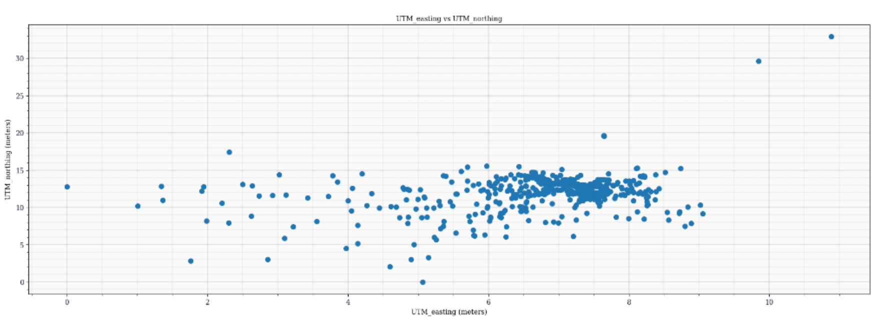
Altitude Mean Error	0.329	Root Mean Square Error (Line of Best Fit)	0.155m

Fig: Error Histogram Plot Fig: UTM easting vs UTM northing

The Root Mean Square Error for Open Walking through line of best fit for each path is around 15.5 cm which is extremely accurate in comparison to Occluded Walking. The data was collected as RTK Fix so it makes sense for this data to be extremely accurate. We cannot consider the deviation for UTM easting and northing as this is walking data so it is better to rely on mean error. The mean error for easting was 27 cm and for northing it was 4 cm which further confirms that fix RTK gives higher accuracy.

Occluded Stationary:

The Scatter Plot shows that most points are clustered withing 15-20 cm, some outliers are twice as far which can be accounted for noise. The Occluded Stationary Data was collected for 5m of accuracy and 60 second survey. We received RTK Float which was mostly due to bad weather.



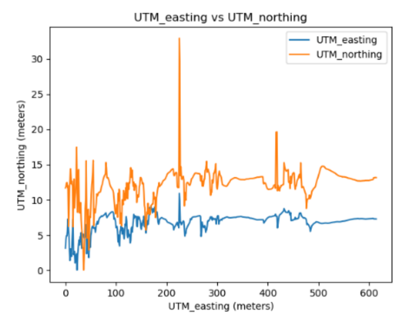


Fig: Scatter Plot Easting vs Northing Fig: UTM easting vs UTM Northing

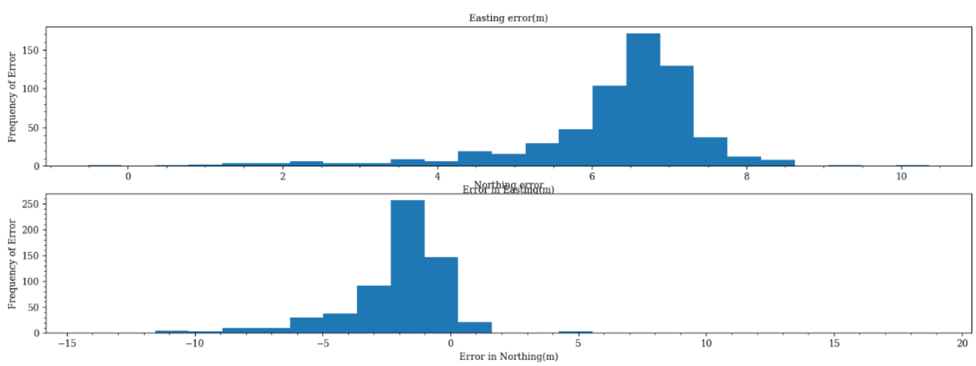


Fig: Error vs Frequency of Error (Histogram) for Easting and Northing

Error Type	Error Value(m)	Error Type	Error Value(m)
Mean Easting	6.28	Mean Northing	1.98
Median Easting	6.64	Median Northing	1.47
Deviation Easting	1.26	Deviation Northing	2.379

Occluded Walking: Collected in RTK Float

The following are the error calculated for the data set:

Error Type	Error Value(m)	Error Type	Error Value(m)
Mean Easting	-1.83	Mean Northing	25.41
Median Easting	0.718	Median Northing	22.82
Deviation Easting	11.075	Deviation Northing	18.3469

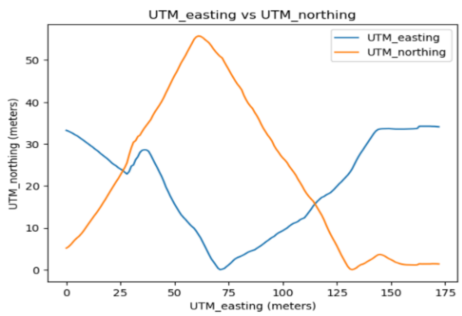


Fig: UTM easting vs UTM Northing

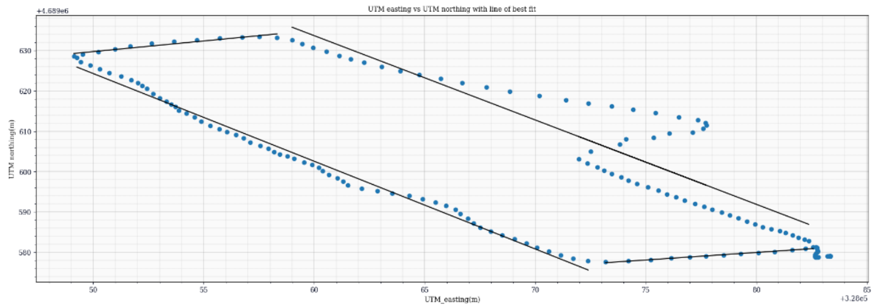


Fig: Line of Best Fit compared to actual Scatter Plot

Altitude Mean Error	12.404	Root Mean Square Error (Line of Best Fit)	2.25(m)

The values we got for Occluded Walking from Known Position were not as accurate or precise which might be due to taking the dataset in Float instead of Fix. Also you can notice a bulge in scatter plot due to noise and weak signal. We tried to walk as straight as possible but the bulge is almost as big as the width of rectangle which tells us that it was not due to human error but due to loss of signal.

Conclusion: RTK GNSS is highly accurate and precise in comparision to GNSS which makes it beneficial for us to use RTK GNSS in applications such as construction and Engineering. By using a combination of real-time measurements and correction signals, RTK GNSS is able to provide centimeter-level accuracy in positioning, enabling users to achieve greater efficiency, productivity, and safety in their operations. Depending on the quality of GNSS receiver we can reduce the noise, If set up in a perfect environment almost all errors except atmospheric delays can be reduced.

The Following questions are already partly answered in analysis, this is to summarize.

What do the error (if you used a “true” position) or deviation (if you didn’t) tell you about RTK GNSS navigation, as compared to GNSS without RTK?

- ➔ As seen from all cases except for occluded walking the deviation has been far less. It was as less as 2cm in some cases. The error value even though a bit high was mostly due to inaccuracy in known position. Compared to GNSS, this data is highly accurate, precise and reliable.

What can you say about the distribution of noise in the signal? It may be useful to make a scatterplot and plot something from there)

- ➔ The distribution of noise is far more uniform as we have almost same median and mean error in all our cases, the standard deviation is also in centimeters which makes this data have noise which is far more Linear than not. This also means that we should be able to rectify for the error in location far easily as a Linear Distribution is predictive.

Why is this distribution different from GNSS data collected in Lab 1?

- ➔ RTK GNSS utilizes a network of base stations that provide real-time corrections to the rover receiver, resulting in higher accuracy and precision. GNSS can achieve accuracy levels of around 1-5 meters, while RTN GNSS can achieve sub-centimeter-level accuracy. This was seen in the results of LAB2 if we look at the distribution with respect to Deviation which was in 10 cm range in most cases.

How are your moving data different in the open and occluded cases? Does this have anything to do with GNSS fix quality?

➔ Moving Data in Occluded case was far off than what we would have expected from RTK GNSS this was due to the fact that out fix quality for GNSS was float for occluded space. In open areas, the GNSS receiver can obtain a high-quality fix, allowing for accurate and precise measurements of position, velocity, and time. In occluded areas, however, the quality of the GNSS fix may be poor, leading to significant errors in the estimated position, velocity, and time. This was verified in the report.

How are your stationary data different in the open and occluded cases? Does this have anything to do with GNSS fix quality?

➔ Even Stationary data will be different depending upon the fix quality similar to moving data but with less Error and Deviation comparitively. We verified that our deviation for Open Stationary was around 2-4 cm whereas the deviation for Occluded Stationary was around 12 and 23 cm which is still pretty good for Fix Quality as Float. The Difference is not as drastic as the walking data.