Introduction:

Real-Time Kinematic (RTK) is a positioning system that uses satellite technology to provide real-time centimeter-level accuracy for various critical applications. The system highly depends on Global Navigation Satellite System (GNSS) technology to determine precise positioning information and is commonly used in fields where high-precision positioning is of utmost importance.

Differences between GNSS and RTN GNSS:

GNSS and RTN GNSS are two different positioning systems with some notable distinctions. RTN GNSS refers to a network of permanently installed GNSS receivers that are maintained and monitored by a service provider and are capable of providing high-precision real-time positioning data to users. This technology is particularly useful in areas where traditional GNSS measurements can be affected by obstructions. In contrast, GNSS is a satellite-based positioning system that offers global coverage and does not rely on any ground-based infrastructure. The fundamental difference between RTN GNSS and GNSS is that while RTN GNSS is based on a network of ground-based receivers, GNSS is solely reliant on satellite signals. Due to this reliance on different technologies, RTN GNSS can offer higher positioning accuracy in locations where GNSS signals are obstructed or weak.

Error sources of RTK GNSS:

There are a few factors that can cause errors when using RTK GNSS which are:

1)**Atmospheric conditions:** Variations in atmospheric conditions, like ionospheric delays, can negatively affect the GNSS signal, leading to inaccuracies in positioning data.

2) **No. of satellites connected to:** The number and placement of GNSS satellites in view can impact the quality of positioning data obtained. Generally, the more satellites that are within view, the more accurate the measurements will be.

3) **Receiver noise:** The quality of the GNSS receiver used can also affect the accuracy of positioning data. If a low-quality receiver is used, it can introduce noise into the signal and reduce the accuracy of measurements.

4) **Multi-path interference:** When the GNSS signal bounces off surfaces such as buildings or trees, it can cause multi-path interference and produce incorrect positioning information.

5) **Improper configuration:** When the base and rover are not properly configured and are not communicating with each other properly, this results in the reading not having a fixed quality.

Questions:

a. What do the error (if you used a "true" position) or deviation (if you didn't) tell you about the accuracy of RTK GNSS navigation, as compared to standalone GNSS without RTK?

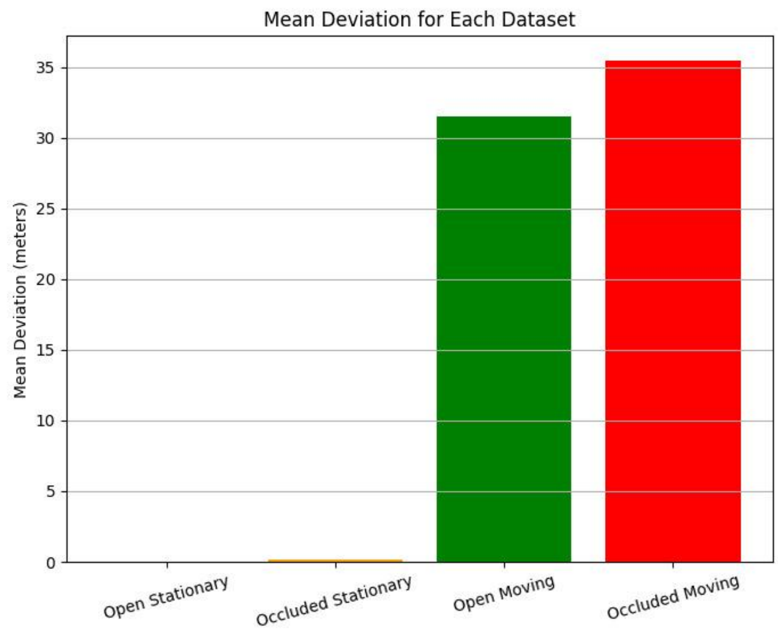


Fig1: GNSS with RTK

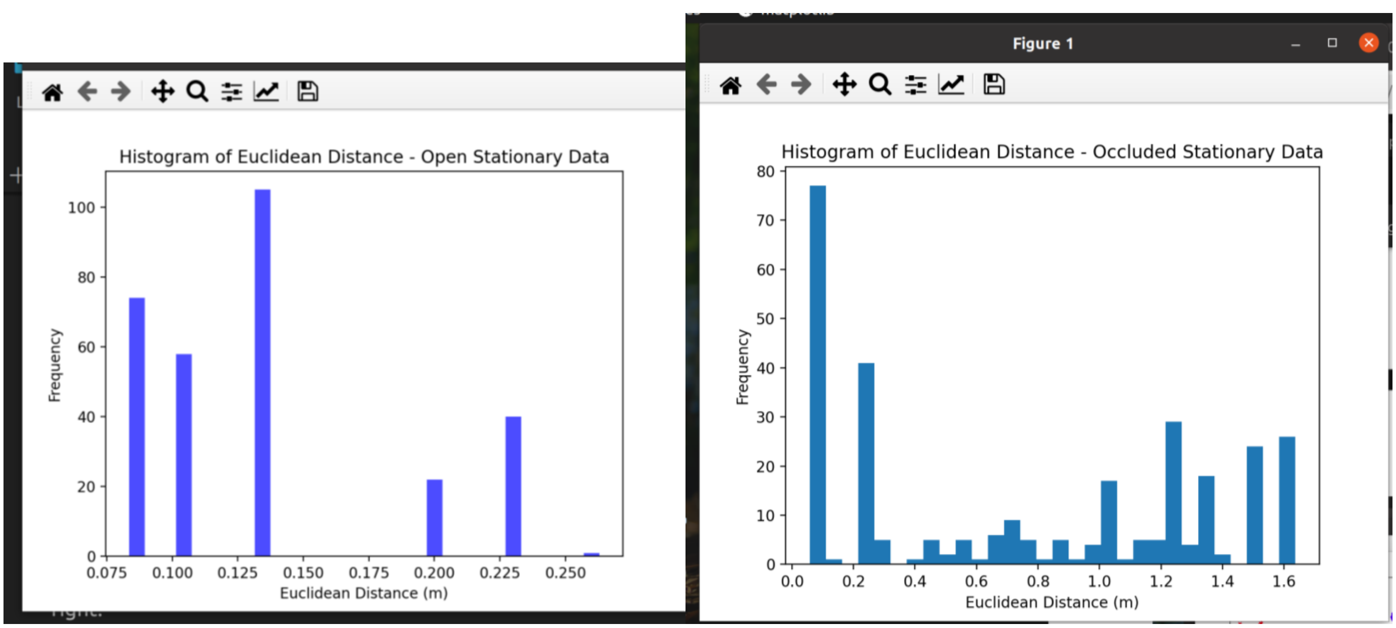


Fig2: GNSS without RTK

According to fig1, it shows the mean deviation of open & occluded stationary & moving data. The deviation for GNSS with RTK's open & occluded stationary is almost non-existent compared to GNSS without RTK, almost 0 & 0.01.

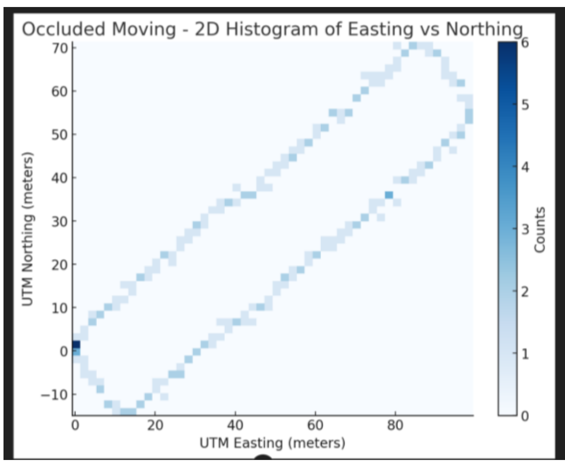
Comparing both fig. shows GNSS with RTK has significantly lower error values compared to GNSS without RTK. This shows that RTK GNSS offers higher precision & accuracy in areas where GNSS signals are usually weak & obstructed (e.g. Occluded spaces). It achieves this by utilizing a network of ground-based receivers that constantly monitors and corrects the GNSS signal, reducing the impact of potential sources of error, which are more likely to occur in urban and suburban environments.

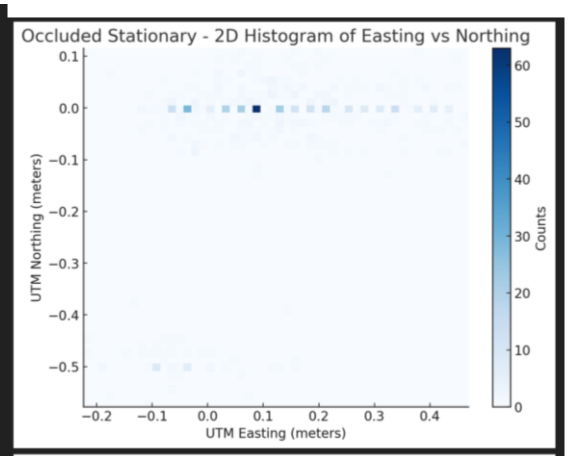
Whereas GNSS without RTK relies solely on satellite signals, which are susceptible to various sources of error, resulting in higher deviation values. While GNSS provides global coverage, it may not deliver the same level of accuracy, especially in areas where obstructions or interference exist. (e.g. Occluded spaces, like forests or skyscrapers).

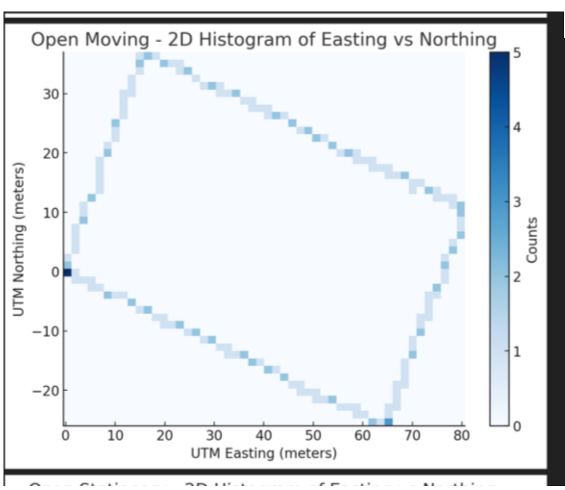
b. What can you say about the ranges and shapes of your position in Easting and

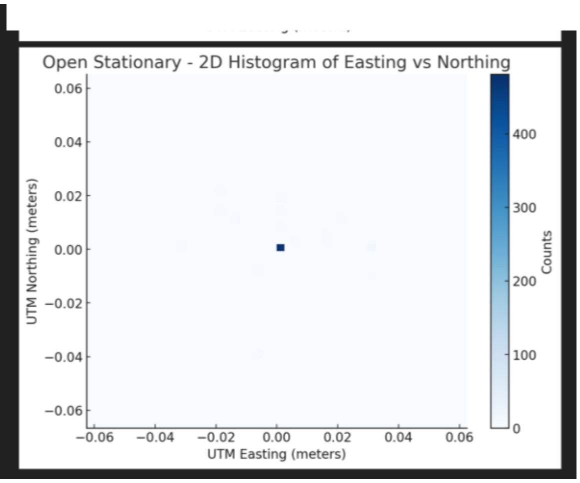
Northing from RTK GPS? (Make a 2D histogram, state the deviations of Easting and Northing,

and draw additional conclusions about these data).









1. **Occluded Moving**:
   a. Mean Easting: 48.28 meters, Std Dev: 30.34 meters.
   b. Mean Northing: 27.31 meters, Std Dev: 24.44 meters.
   c. Shape: rectangular. The average counts are between 1-3 mostly.

The large deviations & lack of count in graph suggest considerable variation in positioning, which is due to obstructions affecting signal reception while moving.

2. **Occluded Stationary**:
    a. Mean Easting: 0.11 meters, Std Dev: 0.14 meters.
    b. Mean Northing: -0.05 meters, Std Dev: 0.15 meters.
    c. Shape: line. Range: -0.1 to 0.4. The average counts is between 10-30 mostly. At 0.11 easting we get the highest count.

    The small deviations indicate relatively stable positioning despite obstructions, since the data was stationary & good reception of GPS satellites.

3. **Open Moving**:
    a. Mean Easting: 40.64 meters, Std Dev: 26.30 meters.
    b. Mean Northing: 5.33 meters, Std Dev: 18.65 meters.
    c. Shape: rectangular. The average counts are between 1-3 mostly.

    Although the open environment reduces noise, there is still noticeable variability due to the movement.

4. **Open Stationary**:
    a. Mean Easting: 0.00 meters, Std Dev: 0.01 meters.
    b. Mean Northing: 0.00 meters, Std Dev: 0.01 meters.
    c. Shape: dot. Range: none. At 0.01 easting we get the highest count 400.

    Extremely low deviations show high precision and stability when stationary in an open environment. High count shows strong reception of multiple GPS satellites signals.

c. Is the shape or range of your histogram different than your dataset collected in Lab 1?

Yes, it's shape & range of open stationary & moving Lab2 data is more precise & smaller respectively, compared to Lab1 which was scattered around & had more deviation around the centroid.

Lab2 data range:

Occluded stationary: Range: -0.1 to 0.4.

The points are closer to the centre point & the shape is highly accurate, less scattered. The open stationary gives highly accurate GPS data.

Occluded moving: The points show a less precise GPS data path of the entire data collection path. Even though the GPS accuracy is less precise, we can see good reception of GPS data during the data collection, it's still better than Lab1's data. There is less deviation of GPS data from the collected data path.

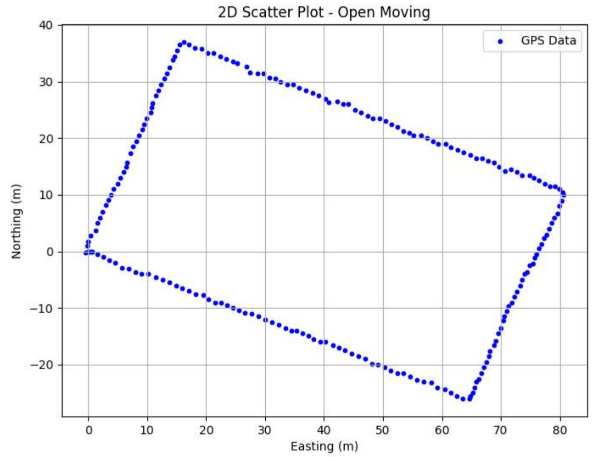
Lab1 Data range:

Occluded stationary: Range: -1.5 to 1.5.

The points are scattered away from the centroid & shape is haphazard.

Occluded moving: The point only shows it received GPS data on one point accurately while taking data the entire path.

d. Give quantitative comparisons for how your moving data differ in the open and occluded cases, including error/deviation estimates? Does this have anything to do with GNSS fix quality?



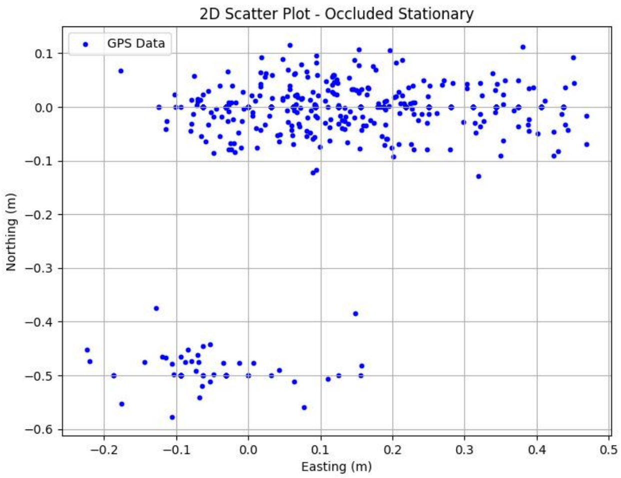
According to the 2d scatterplot, RTK GPS measurements are generally more precise and accurate in open spaces compared to occluded areas which show decreased accuracy and precision because in an open space, GPS signals travel through more of free space with fewer obstacles, enabling tracking of more satellites and resulting in more precise fix. By contrast, occluded areas have higher chances of signal blockage or reflection. Thus, it results in a less accurate fix.

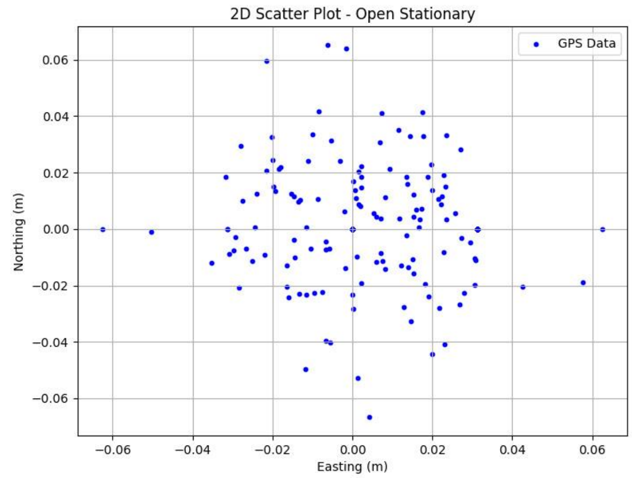
In other words, the quality of the GNSS fix, or "RTK Fixed," is an indication of the quality of the satellites being tracked and it affects the accuracy of the measurements. However, other factors such as atmospheric conditions and receiver errors might interfere with the quality of the measurements.

Further, the Quality value obtained in Open locations is 4, meaning RTK fixed, while occluded spaces have Quality values of 5, indicating RTK float. Although this is an excellent reading, it is nevertheless subpar compared to RTK fixed; 4 shows the GPS has got centimeter–accurate positioning whereas 5 shows it's yet to determine centimeter–accurate positioning.

Hence, we can note that the most deviated data comes from occluded and walking data owing to continuous movement and obstructions simultaneously. In open conditions, the case is not so, and the signals received are strong and without much break or interruption; thus, the deviation from the path travelled will be lesser. Also, we can notice that the start and stop point in the case of an open condition is the same but not in the case of an occluded space.

e. How are your stationary data different in the open and occluded cases, including numerical error/deviation estimates? Does this have anything to do with GNSS fix quality?





From the figure above, the occluded stationary has deviation from –0.2 to 0.5m for Easting & -0.5 to 0.1m for Northing. Whereas open stationary points are mostly in the center with a minimal deviation of –0.04 to 0.04m for both Easting & Northing. Typically, the quality of the GNSS fix is higher in open spaces, while in occluded areas, the quality of the GNSS fix is lower due to blocking of the signal, thus yielding less precise measures.

It should, however, be further emphasized that the quality of the GNSS fix alone is not the sole determining factor affecting the accuracy of a stationary RTK GPS measurement. Multipath interference, noise in the receiver, and even atmospheric conditions may also introduce additional sources of error, further worsening precision even when there is clear open space with a high-quality GNSS fix.

Also, it is important to mention that the value of Quality received in Open locations is 4, while at occluded spaces, the value of quality obtained is 5, meaning RTK float, which although is an excellent reading is subpar with respect to RTK fixed, which in itself states that the accuracy in open conditions is higher than in occluded spaces. We can also realize that, in this case, with the rover being stationary and in an open environment, we record almost a negligible error compared to occluded and stationary, where some occlusions to the signals are present.