EECE5554 – Robotics Sensing and Navigation

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Lab2 Report

Introduction to RTK:

Real Time Kinematic is a technique used to increase the accuracy of GNSS (GPS, Glonass, Galileo, BeiDou) signals by using a fixed base station which wirelessly sends out corrections to a moving receiver (rover). By using these corrections, the RTK GNSS receiver can fix the position of the antenna to within 1-2 cm.

RTK GNSS vs GNSS:

RTK (Real-Time Kinematic) and standard GNSS (Global Navigation Satellite System) positioning are two techniques for obtaining position information from satellite-based systems. They differ in the following aspects:

Accuracy: GNSS positioning, also known as standalone or single-point positioning, provides positional accuracy in the order of several meters. RTK is a differential GNSS technique that provides positional accuracy in the order of centimeters.

Methodology: GNSS positioning determines the user's position by measuring the time of flight of signals from satellites to the receiver. RTK improves the accuracy of GNSS positioning by using a network of fixed reference stations with known positions.

Therefore, the main difference between RTK and GNSS positioning is that RTK achieves a higher level of accuracy by using real-time corrections from reference stations, while GNSS positioning depends only on satellite signals and provides less accurate positioning information.

Sources of error in RTK GNSS:

There are many sources of error in RTK GNSS which are discussed below:

1. Base Station Location Accuracy - The accuracy of the known location of the base station is crucial for RTK GNSS accuracy.

2. Satellite Visibility and Availability - Buildings, terrain, and other obstructions can block the line of sight between the receiver and the satellites.

3. Antenna Phase Center Variation - The point on the antenna where the GNSS signal is assumed to be received. Variations in this point can lead to errors.

4. Dilution of Precision - Poor geometric arrangement of the satellites in the sky can result in less accurate measurements.

5. <u>Satellite Clock Errors</u> - The satellite clocks are not perfect and can have slight timing errors. This can result in errors in the calculated distances.

Stationary Data (Open):

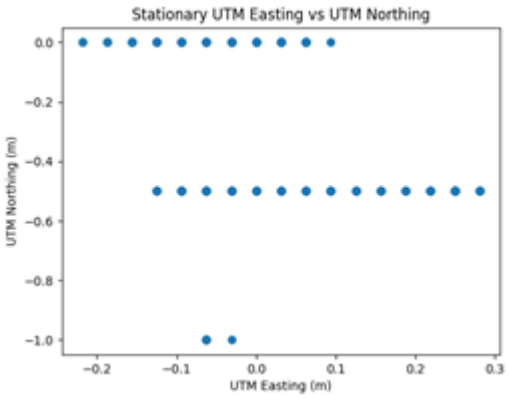

Figure 1: Northing vs Easting Scatter Plot

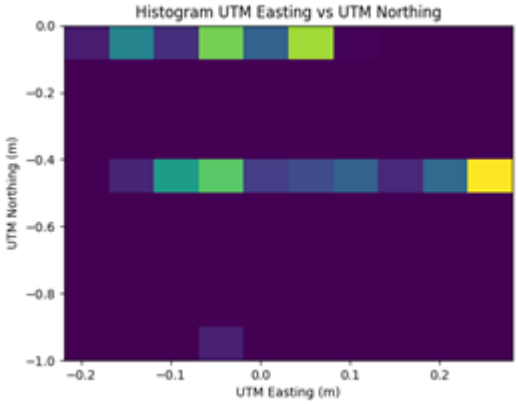

Figure 2: Northing vs Easting Histogram

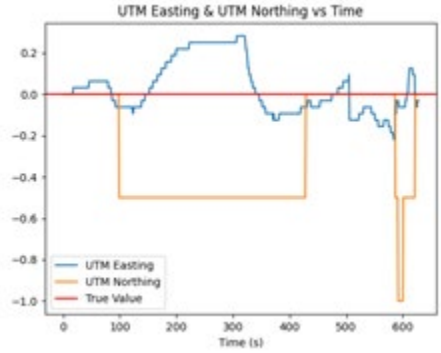

Figure 3: Easting & Northing vs Time Line Plot

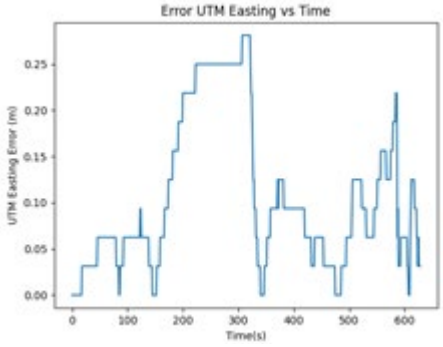

Figure 4: Error Easting vs Time Line Plot

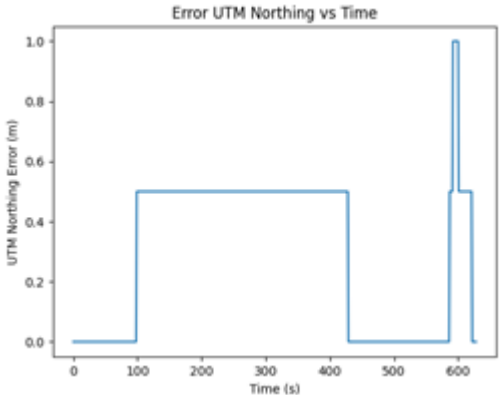

Figure 5: Error Northing vs Time Line Plot

Figure 1 gives us the Easting and Northing data in stationary condition. Figure 2 is a histogram plot of the same. The data has been plotted relative to the first reading of Easting and Northing values obtained from RTK GNSS:
First Reading of Easting: 328252.65625
First Reading of Northing: 4689524.5
There is a deviation of 0.3 m in the Easting value and 1 m in the Northing value even though the RTK was stationary. Figure 2 is a histogram plot of the same.

Figure 3 is a plot of Easting and Northing values w.r.t. time. We have assigned the first relative reading (0) as the true value. Error calculations shall be done w.r.t. this value. The variation of Easting and Northing values w.r.t. time matches with the Figure 1 graph.
Figure 4 & 5 show the error functions of Easting and Northing w.r.t. time. Error is calculated by subtracting the true value from the respective readings. The deviation of Easting value is less, but the values are continuously changing with multiple peaks in the given time period. The deviation of Northing value is very high as compared to Easting; however, the rate of change is quite low in the same time. When values do change, there is a sudden spike in the readings.

The average and standard deviation have been calculated from the error curves for error analysis:
Mean Error (Easting): 0.106
Standard Deviation (Easting): 0.081
Mean Error (Northing): 0.297
Standard Deviation (Northing): 0.259

<u>Stationary Data (With Occlusion):</u>

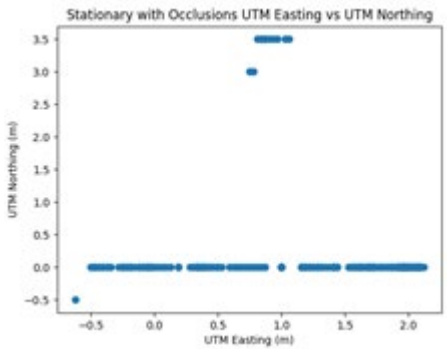

Figure 1: Northing vs Easting Scatter Plot

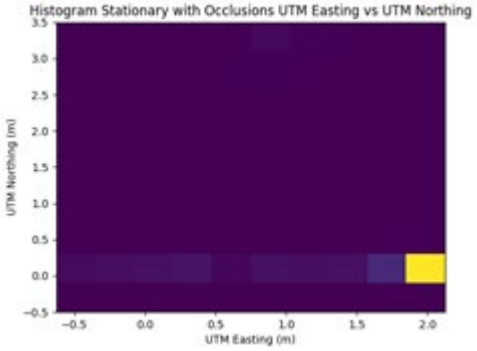

Figure 2: Northing vs Easting Histogram

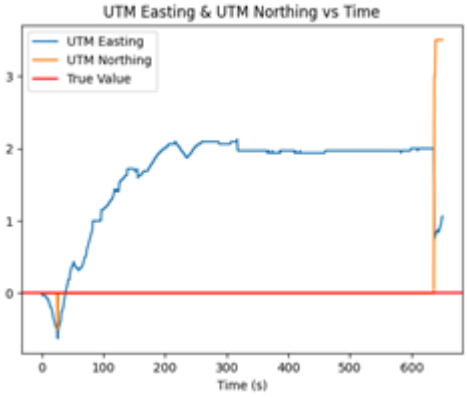

Figure 3: Easting & Northing vs Time Line Plot

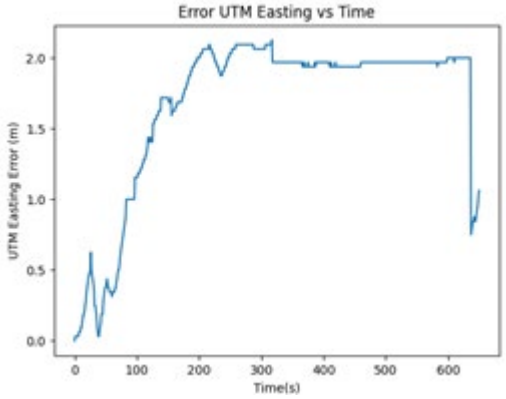

Figure 4: Error Easting vs Time Line Plot

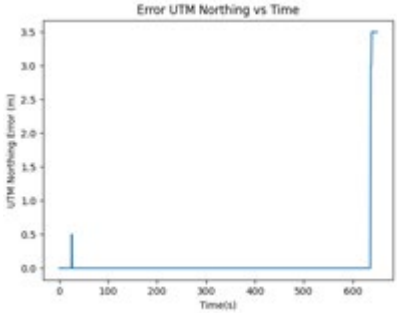

Figure 5: Error Northing vs Time Line Plot

Figure 1 gives us the Easting and Northing data in stationary condition with occlusion. Figure 2 is a histogram plot of the same. The data has been plotted relative to the first reading of the Easting and Northing values obtained from RTK GNSS:
First Reading of Easting: 328067.46875
First Reading of Northing: 4689334.0
There is a maximum deviation of 2.125 m in the Easting value and 3.5 m in the Northing value even though the RTK was stationary.

Figure 3 is a plot of Easting and Northing values w.r.t. time. We have assigned the first relative reading (0) as the true value. Error calculations shall be done w.r.t. this value. The variation of Easting and Northing values w.r.t. time matches with the Figure 1 graph.

Figure 4 & 5 show the error functions of Easting and Northing w.r.t. time. Error is calculated by subtracting the true value from the respective readings. The Easting error values are changing continuously till they reach the peak, after that the curve is almost flat. The error for Northing values is mostly zero, although it does peak at the last.

The average and standard deviation have been calculated from the error curves for error analysis:
Mean Error (Easting): 1.671
Standard Deviation (Easting): 0.579
Mean Error (Northing): 0.074

Standard Deviation (Northing): 0.498

Walking Data (Open):

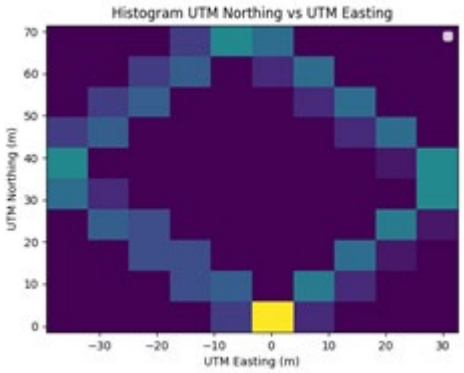

Figure 1: Northing vs Easting Histogram Plot

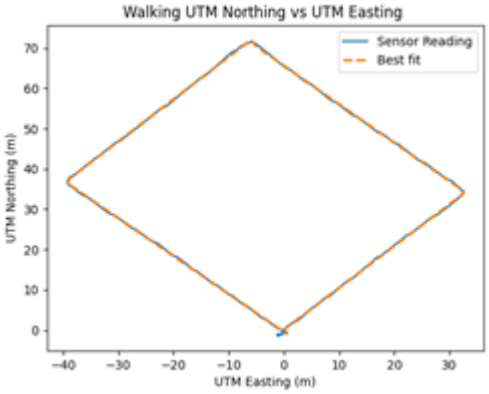

Figure 2: Northing vs Easting Scatter

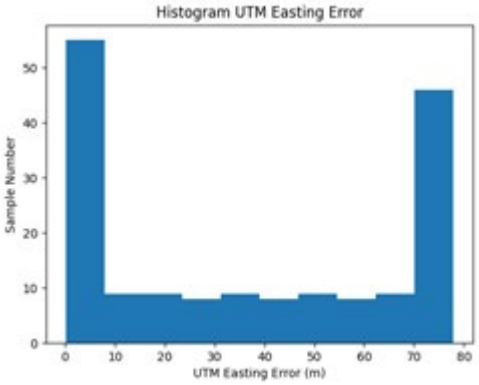

Figure 3: Easting Error Histogram

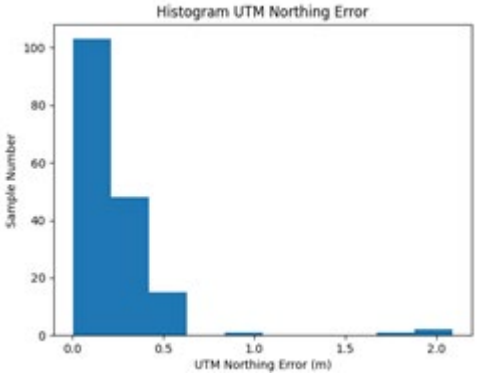

Figure 4: Northing Error Histogram

Figure 1 gives us the Easting and Northing data in walking condition. Figure 2 is a histogram plot of the same. The data has been plotted relative to the first reading of the Easting and Northing values obtained from RTK GNSS:
First Reading of Easting: 328255.90625
First Reading of Northing: 4689498.5
The Best fit line represents the true value. The readings obtained from the RTK GNSS track the best fit value along the closed path with minor deviations. The curve indicates that the readings were taken in a rectangular closed path.

Figure 3 & 4 represents the histogram for the Error Function of Easting and Northing values. Error is calculated by subtracting the true value from the respective readings. The Easting error is quite high. The Northing error is mostly zero, with minor peaks.

The average and standard deviation have been calculated from the error curves for error analysis:
Mean Error (Easting): 36.881
Standard Deviation (Easting): 31.182

Mean Error (Northing): 0.228
Standard Deviation (Northing): 0.275

Walking Data (Occlusion):

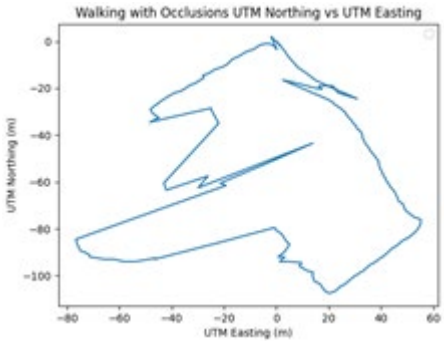

Figure 1: Northing vs Easting Line Plot

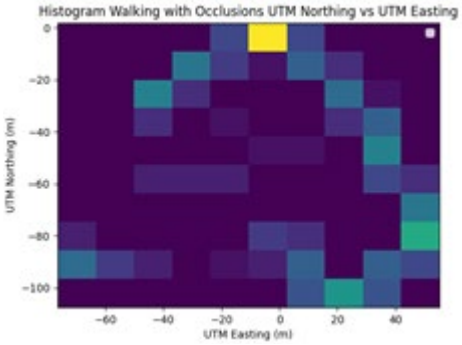

Figure 2: Northing vs Easting Histogram

Figure 1 gives us the Easting and Northing data in walking condition with occlusion. Figure 2 is a histogram plot of the same. The data has been plotted relative to the first reading of the Easting and Northing values obtained from RTK GNSS:
First Reading of Easting: 328269.62500
First Reading of Northing: 4689430.5

The shapes of the plots indicate a significant error in the readings. This indicates that the area where the readings were taken must be heavily surrounded by buildings or other structures which causes such a huge error.

Conclusions:

a. By using a true value for error measurement, it is clear that the performance of RTK GNSS is much better than that of Standard GNSS. The error in case of both stationary and walking conditions has been significantly reduced in RTK GNSS.

b. The deviations of the Easting and Northing Values for stationary conditions are:
1. Open Field - There is a deviation of 0.3 m in the Easting value and 1 m in the Northing value.
2. Occlusion - There is a deviation of 2.125 m in the Easting value and 3.5 m in the Northing value.

For Waking conditions, there are very small deviations when walking in an open field, whereas, when walking in an occluded area, the deviations are very high as seen from the plots. The shape of the histogram follows that of the plots. It is mostly straight in case of stationary conditions, and forms a closed path in case of walking conditions.

c. The shape as well as range of the histogram is different than the dataset collected in lab1. The shape is because in lab1 we were moving in a straight line instead of a rectangular path. Also, the range is different due to the difference in accuracies of RTK GNSS and standard GNSS.

d. The mean error and standard deviation for the case when walking in an open field are:
Mean Error (Easting): 36.881
Standard Deviation (Easting): 31.182
Mean Error (Northing): 0.228
Standard Deviation (Northing): 0.275
The deviation in the readings is very high for the case when walking in an occluded area as seen from the line plot and histogram.

e. The mean error for Easting in case of stationary conditions in open field is 93% lesser than that of occluded area. The standard deviation for Easting in open field is 86% lower than that of occluded area.
The mean error for Northing in case of stationary conditions in occluded area is 75% lesser than that of open field. The standard deviation for Northing in occluded area is 92% higher than that of open field.