Analysis Report of LAB 3 for EECE5554

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1. The Analysis for stationary data:

One data correction place is outside the ISEC, with some buildings playing as partial occlusions and reflections, and the other is at the playground part beside the campus that is very clear.

1.1 At Spot with occlusions and reflections:

1.1.1 Stationary Dataset

Location : a spot outside the ISEC building.

Weather: Clear in sky, and Warm

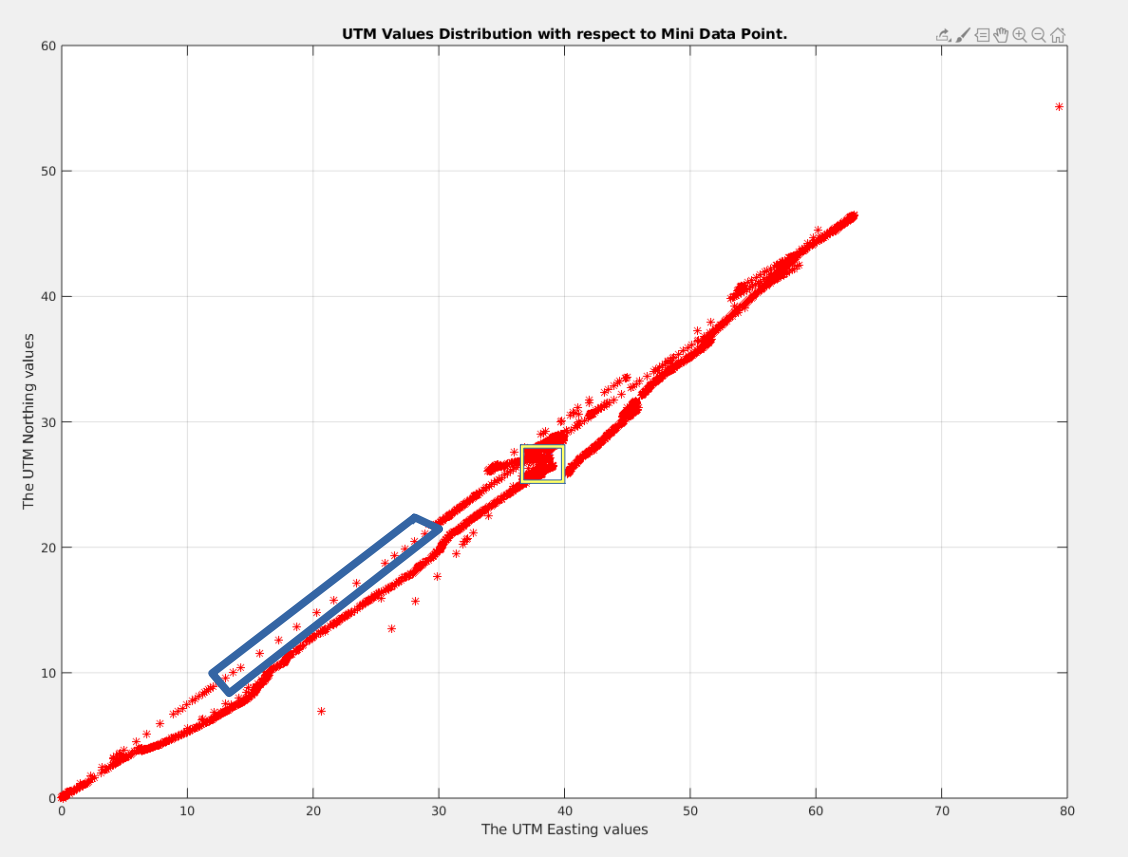


Figure 1. The UTM Data Distribution with respect to minimal data point (Occlusions & Refection)

What we could see above is the UTM data point distribution with respect to minimal data point. The values of UTM easting and northing of each point here are UTM values subtracting to the minimal values because the original values of UTM are very large, which brings difficulty to view and analyze. **We could notice that at some time the position of spot changes a lot and rapidly, as showed in blue rectangle, whereas the point changes little and be very stable at other time, as showed in yellow square.**

What shows below are UTM Easting and Northing Value Distributions separately, and the UTM values are also respect to minimal data like before.

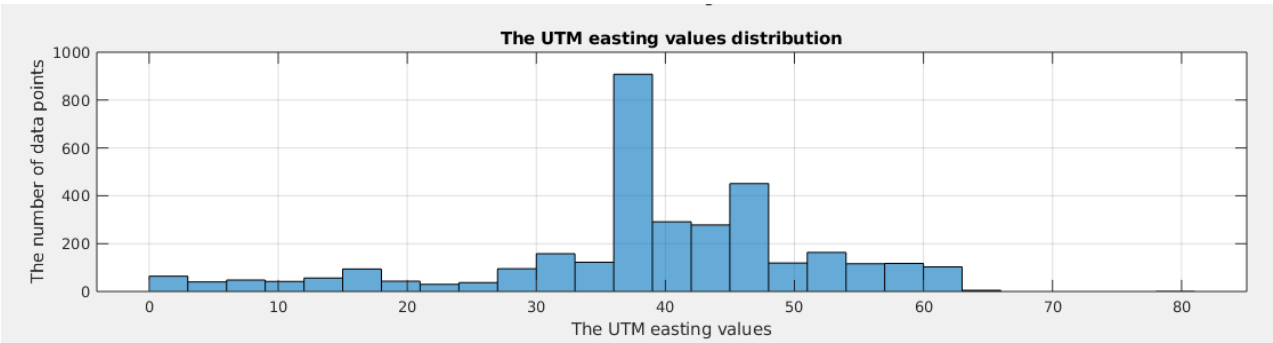


Figure 2. The UTM Easting Value Distribution (Occlusions & Refection)

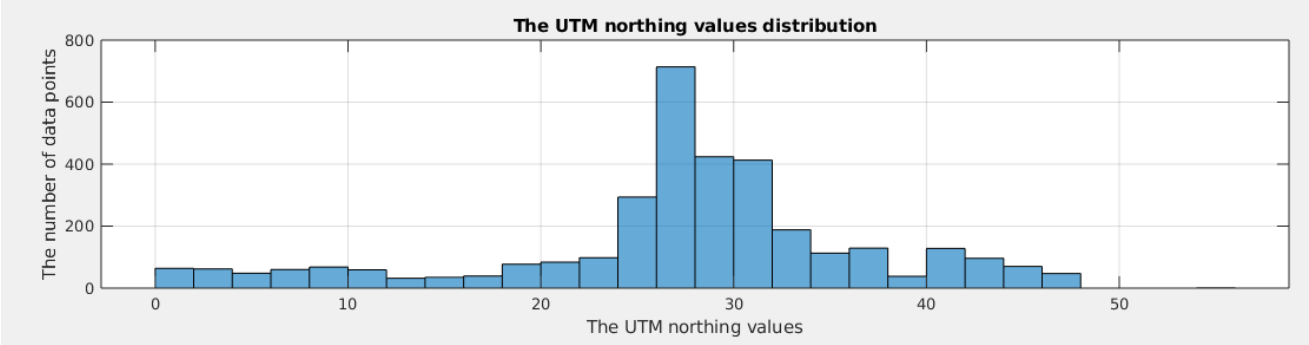


Figure 3. The UTM Northing Value Distribution (Occlusions & Refection)

From the value distribution, we could compute that : **the means of easting and northing here** are **38.7122** and **27.2458** respectively, which corresponds to **the mean original UTM values [3.2806e+05, 4.6893e+06]**. The standard deviation of UTM easting is **12.9296**, and of UTM northing is **9.7086**. The standard deviation of northing is less than that of easting, which means that the northing is relatively more stable than easting. Also, the value range of northing is less either.

There are Noise Distributions of the UTM Easting and Northing respectively, and the distribution of GNSS Fix Quality.

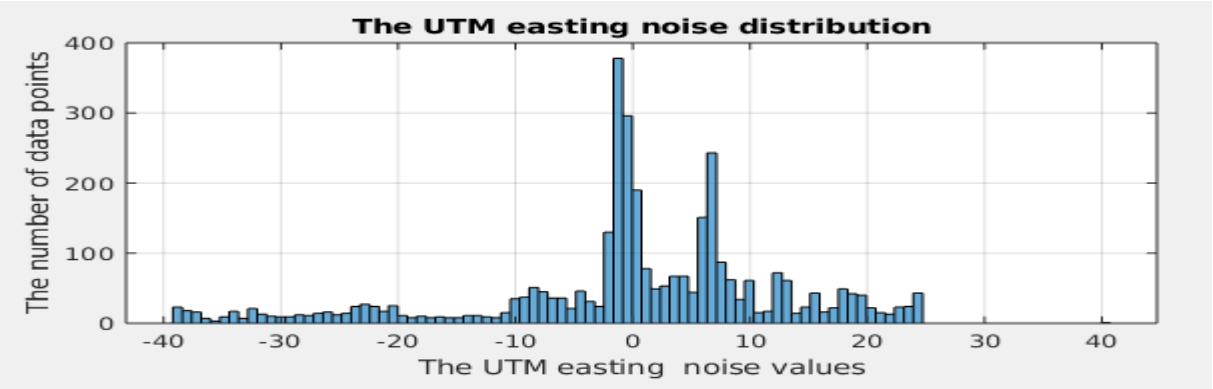


Figure 4. The UTM Easting Noise Distribution (Occlusions & Refection)

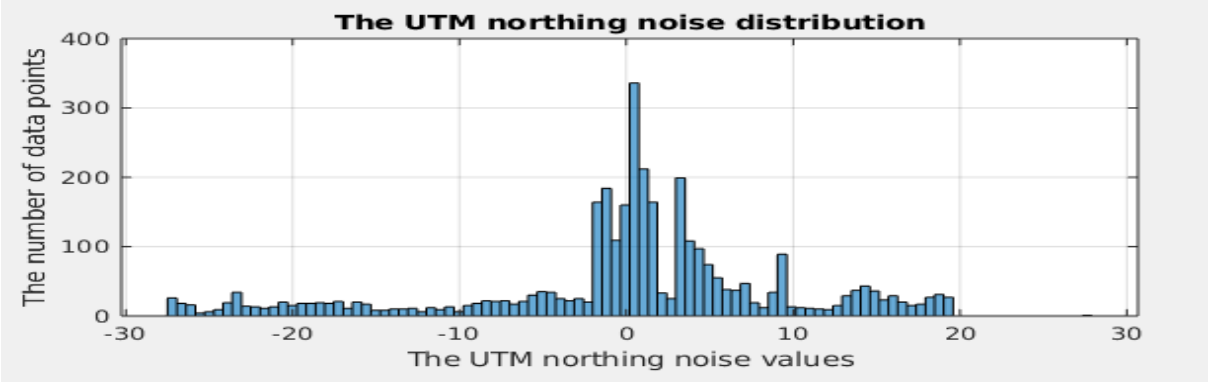


Figure 5. The UTM Northing Noise Distribution (Occlusions & Refection)

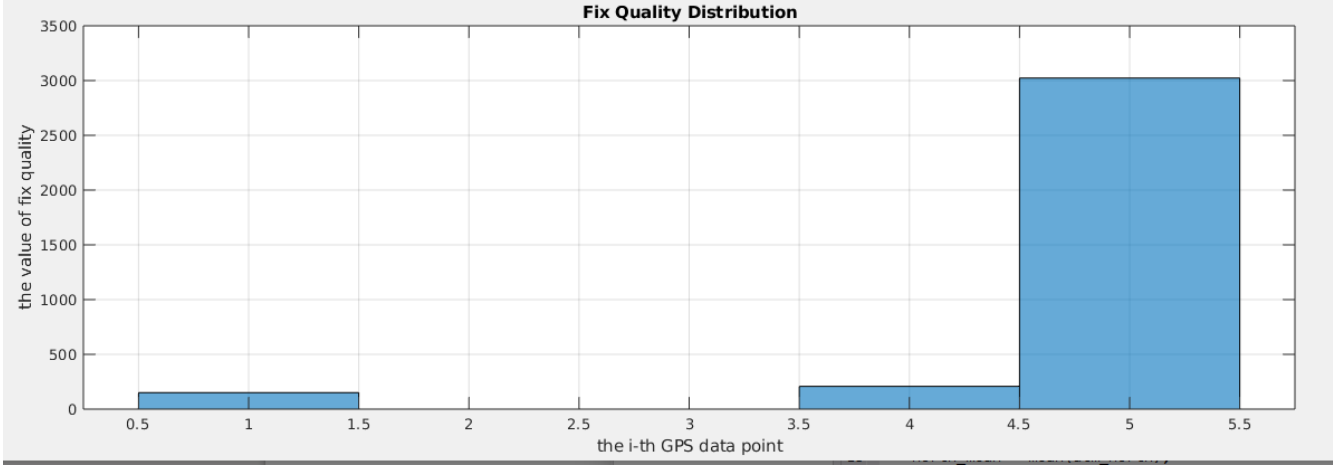


Figure 6. The Fix Quality value distribution

The noise value, or error value in other words, **are computed by subtracting the mean of UTM easting & northing from the original UTM values**, based on the assumption that the mean [Easting

Northing] is the estimated position of the spot. **The mean noise values are [0.5839e-9 -0.5553e-9], and the standard deviations are [12.9296 9.7086], of easting and northing respectively.**

From the Fix Quality distribution plot, at most time the Fix Quality always 5 representing RTK float, whereas at some time the Fix Quality is 4 representing RTK Fix, or even 1 just representing GPS Fix. When the Fix Quality is 1 the fix is not good, which leads to a relatively worse correction leading to some bigger noise like 15 or 20. **The reason why of this perhaps is, there are buildings around as influence sources, and at those time the reflection affect the signal seriously, which in result influenced the correction computation. Also other influence sources may make difference here too.** When the Fix Quality is 4 or 5, the fix is good, which may be one reason that at most of time the noise value is small and around the mean.

1.1.2 What can say about the distribution of noise in the signal ?

According to estimated noise distributions, **the noise distribution is not a Gaussian distribution,** because the value ranges from mean to the maximal one and to the minimal one are not the same. The value of most noise points are around the mean point, whereas there are also some big noise distributed. The sources of noise could be various, for instance, the radio inference or signal obstructions.

1.2 At Spot with Clear Environment:

1.2.1 Stationary Dataset

Location : a playground located at Tennis Courts close to NEU

Weather: Clear in sky, and Warm

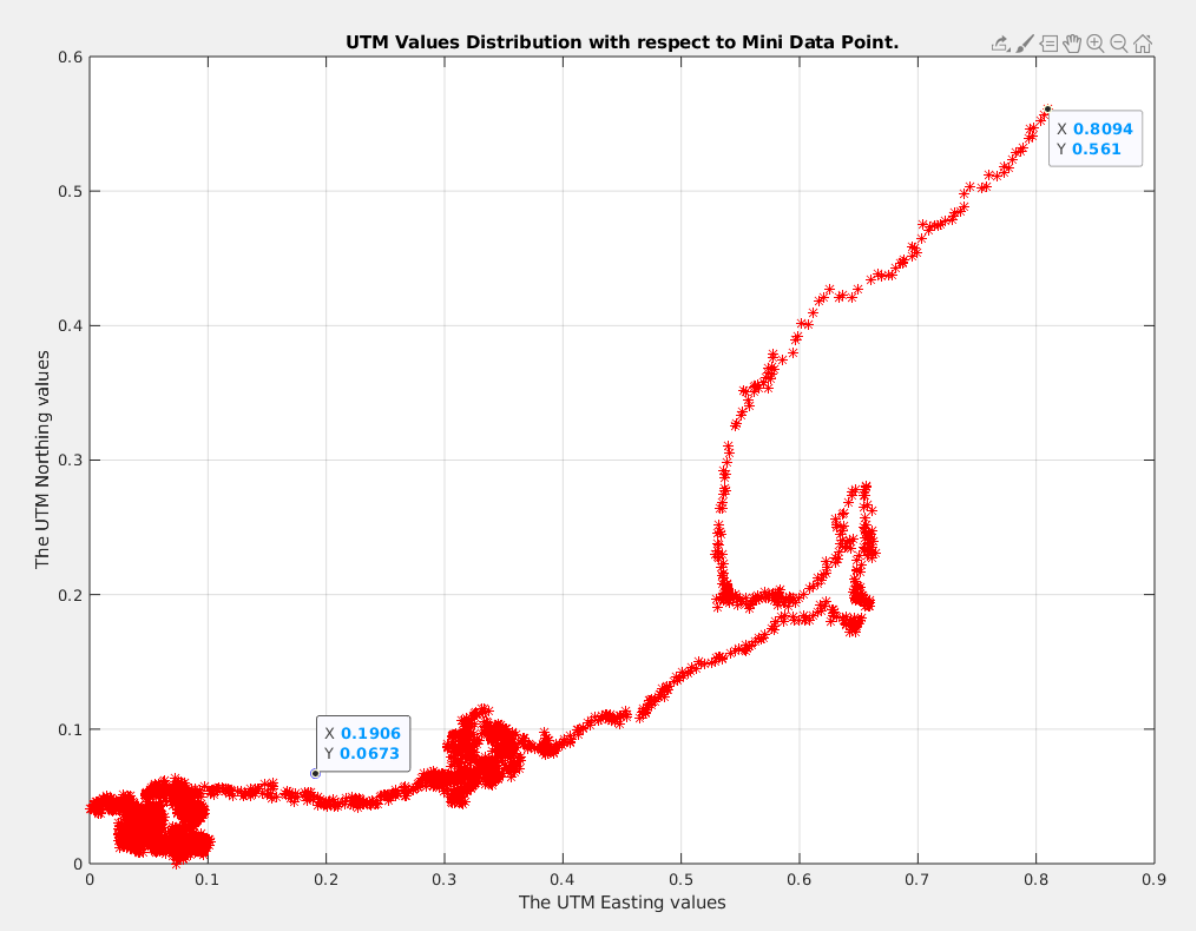


Figure 7. The UTM Data Distribution with respect to minimal data point (Clear)

What we could see above is the UTM data point distribution with respect to minimal data point. The values of UTM easting and northing of each point here are also UTM values subtracting to the minimal values. Compared to UTM data distribution about data collected in spot with reflection, the UTM data points collected in clear environment has far less changing range, that largest values of easting and northing are [0.8094 0.561] (with respect to minimal data point). Although the accuracy is higher than before, the data still has noise which is not constant.

What shows below are UTM Easting and Northing Value Distributions separately, and the UTM values are also respect to minimal data like before.

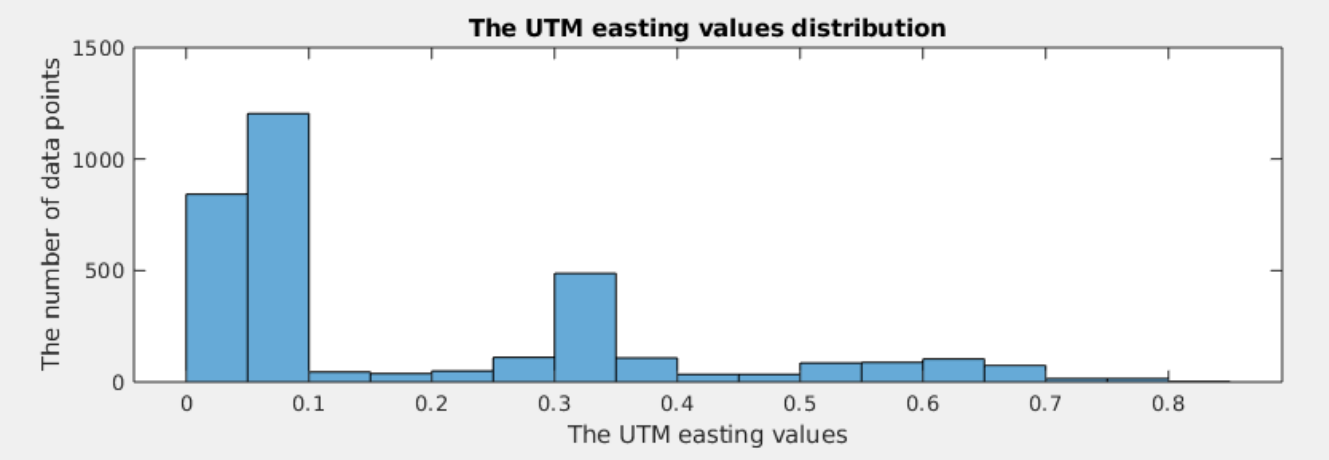


Figure 8. The UTM Easting Value Distribution (Clear)

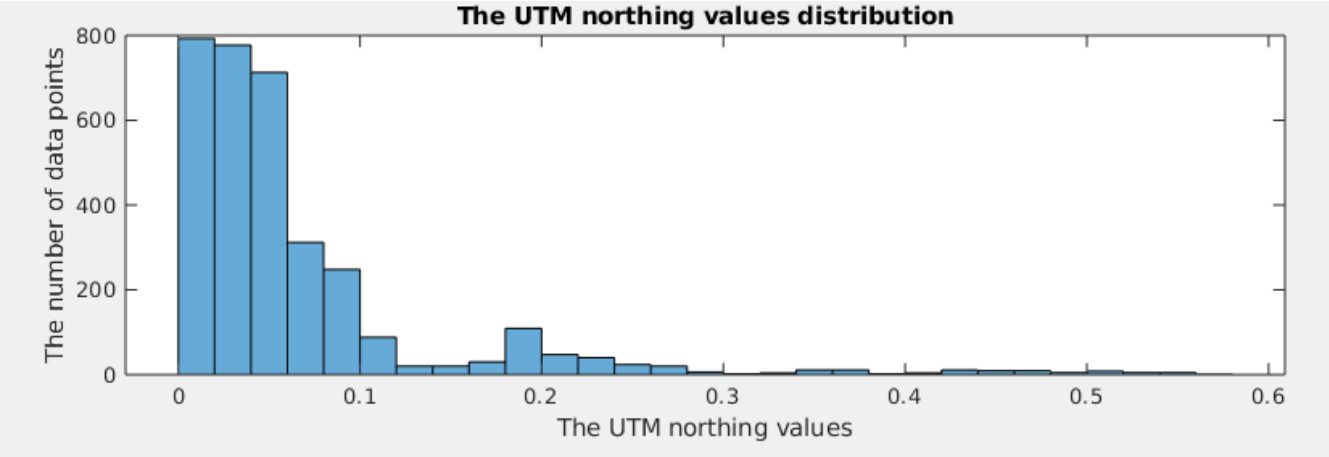


Figure 9. The UTM Easting Value Distribution (Clear)

From the value distribution, we could compute that : **the means of easting and northing here** are **0.1906** and **0.0673** respectively, which corresponds to **the mean original UTM values [3.2828e+05, 4.6895e+06]**. The standard deviation of UTM easting is **0.1945**, and of UTM northing is **0.0815**. We could notice that the distribution variance of northing is less that easting, which means that the value of northing is more stable, although both of them changes in a very little range and frequency.

There are Noise Distributions of the UTM Easting and Northing respectively.

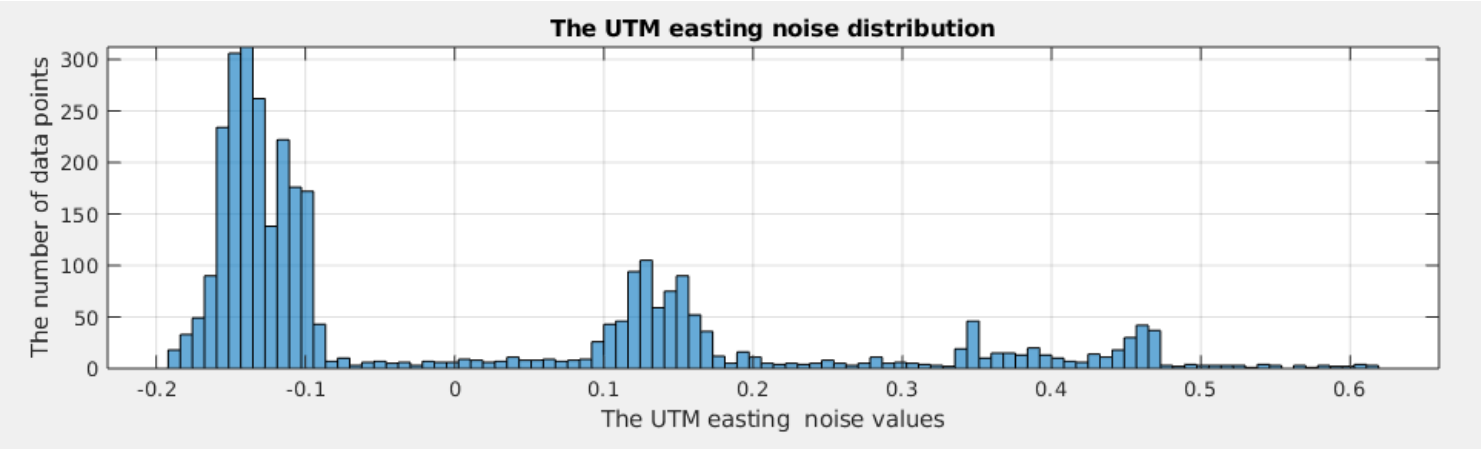


Figure 10. The UTM Easting Noise Distribution (Clear)

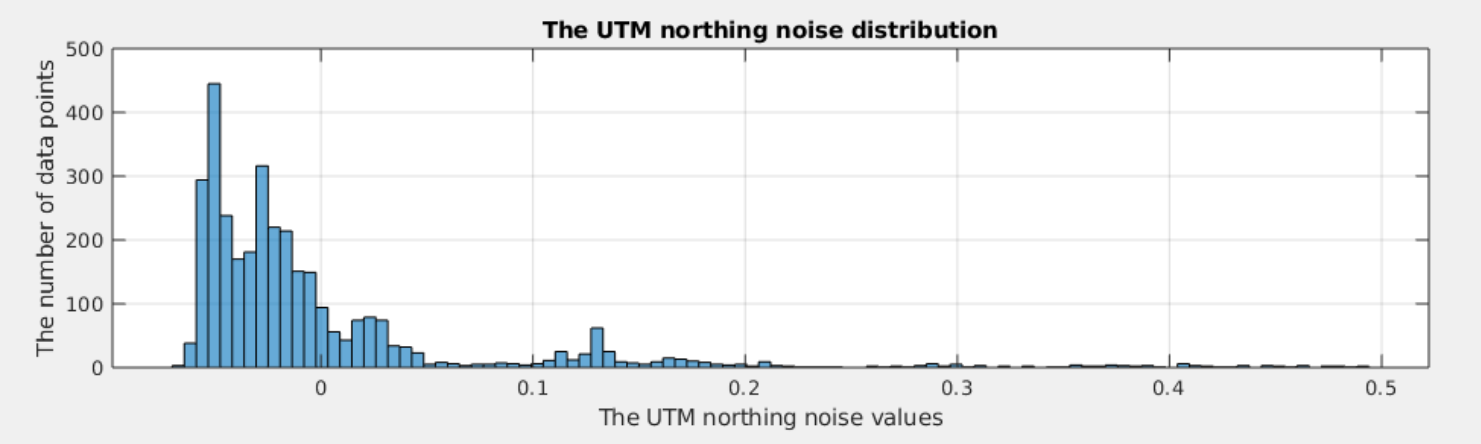


Figure 11. The UTM Northing Noise Distribution (Clear)

Figure 12. The UTM Northing Noise Distribution (Clear)

The noise value are computed by subtracting the mean of UTM easting & northing from the original UTM values, based on the assumption that the mean [Easting Northing] is the estimated position of the spot. **The mean noise values are [0.0017e-7 -0.1428e-7], and the standard deviations are [0.1945 0.0815], of easting and northing respectively.**

From the Fix Quality distribution plot, the Fix Qualitys always 5 representing *RTK float*, which means that the fix quality is good all time during this collection in clear place. So the correction computed is very well leading to very little noise in rover's data.

We could notice that the means of noise are very close to zero, and the standard deviations are also very small, which means that the noise value is very stable, changing just a little bit around the zero, so the correction computed in correction is good, which in returns leads to more accurate localization in rover. **Perhaps**, it is because at the clear collection place there are few influence sources, like building causing undetectable reflection for instance, so the signal from satellite to RTK is almost not affected, that the base is able to locate its position accurately in initialization, then the correction would be computed well which in return leads to a more accurate position information in rover.

1.2.2 What can say about the distribution of noise in the signal ?

According to estimated noise distributions, at the spot where is clear, **the noise distribution in clear correction environment is not a Gaussian distribution, and not any linear pattern either**. **For noise of northing**, the noise values of most data points are around the mean point, which is close to zero. Just a few of them have some non-zero values, but also very small, and the larger the noise the less the number of such noise. **For noise of easting,** the majority of values are around the mean, and some of others are about in range **[0.1 0.2]**, while the rest have other values but are small in number.

1.3 What to say about RTK GNSS navigation ?

We could notice that **generally speaking, the RTK GNSS navigation brings higher localization accuracy with lower error compared with GPS method, with the help of base station which gives rover the correction information for fixing.** According to our noise distribution, the noise standard deviation is also smaller than that in GPS lab, which may mean that the noise value is more stable in RTK. Although, the data from RTK also has noise either.

We could also see that **in different places, with or without influence sources around like tall buildings for example, the accuracy of navigation and the error value could be different.** For instance, in clear spot the error is very small which leads to a high position accuracy.

2. The Analysis for Moving data:

One data correction place is outside the ISEC, with some buildings playing as partial occlusions and reflections, and the other is at the playground part beside the campus that is very clear.

2.1 At Spot with occlusions and reflections:

2.1.1 Moving Dataset

Location : Outside the ISEC building.

Weather: Clear in sky, and Warm

Actual Trajectory Shape : a rectangle

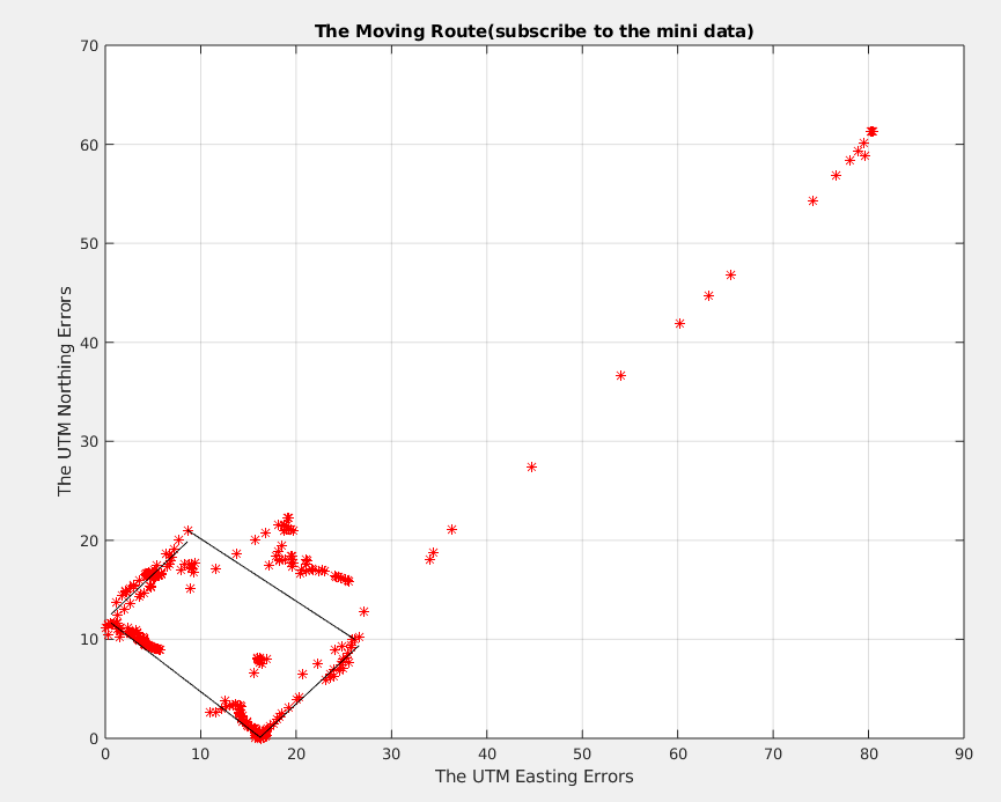
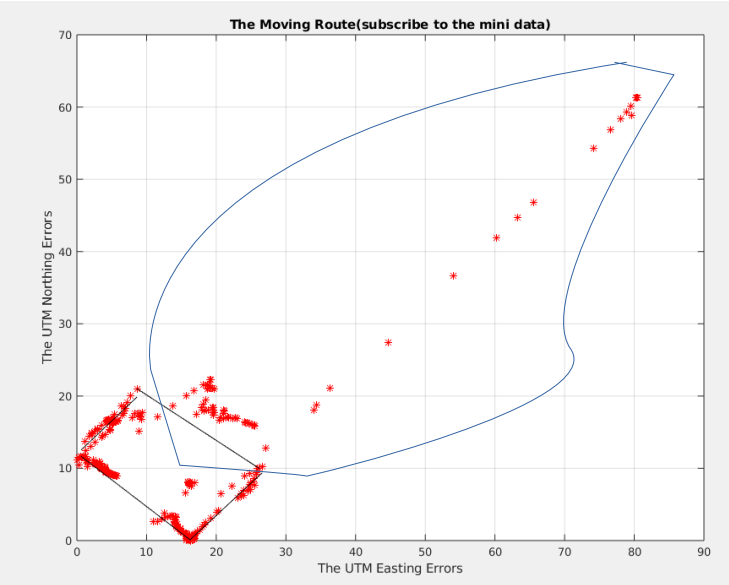
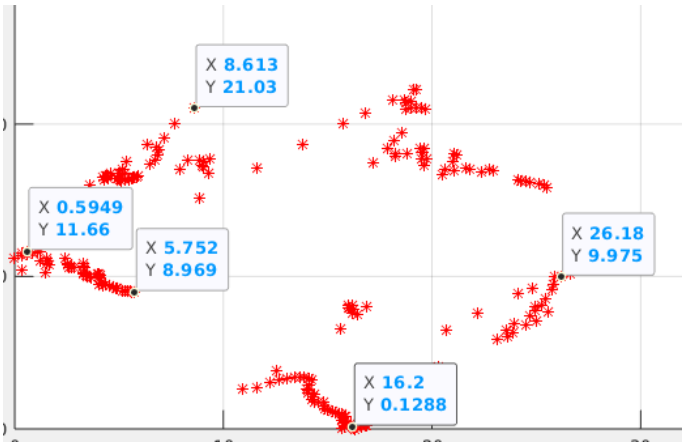


Figure 13. The Moving Trajectory and Turning points in spot with reflection

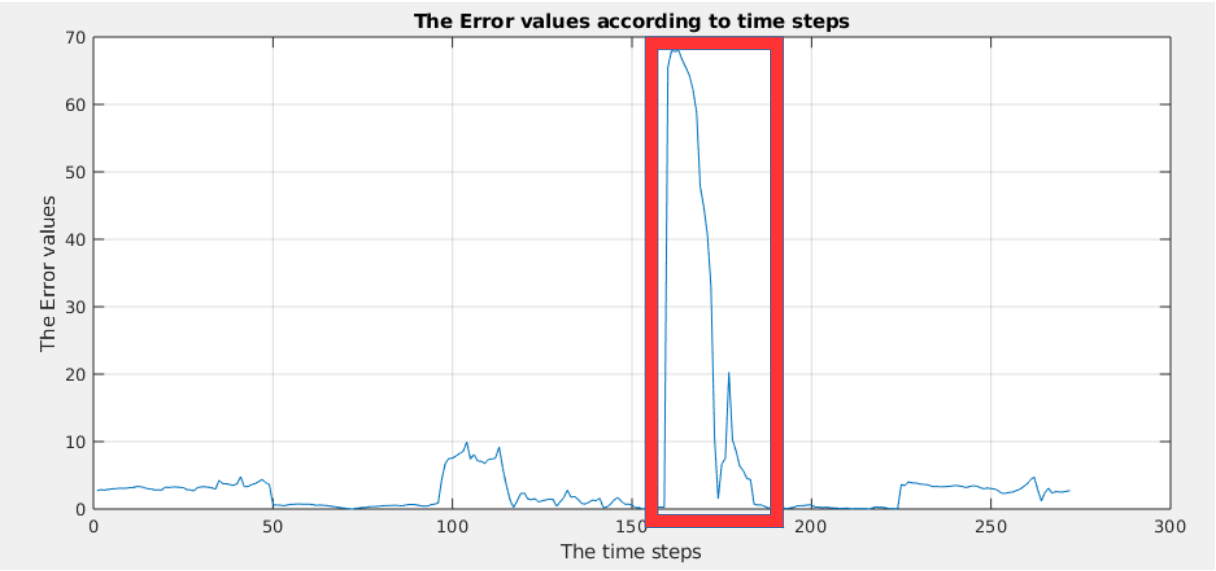


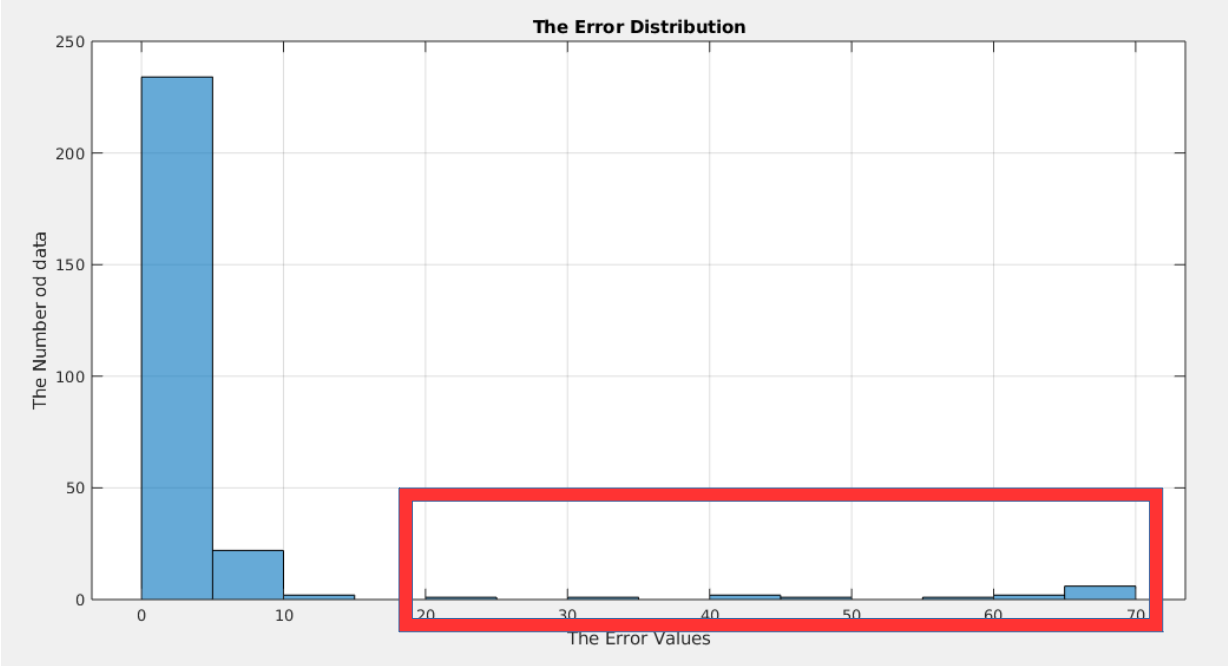


The left plot above shows the Moving Trajectory in reflection space with respect to minimal data point, and the black fit lines represent the approximately estimated real moving trajectory. The right figure shows the coordinates of points where taking turns. From data points in the left-down region, we could see a square-like trajectory, but with some errors. However, as what inside the blue polygon shows in left figure, the data points here varies a lot with very huge error. **Perhaps, it is because the reflection of signal greatly affected the signal, which influenced the correction computation and also affect the localizing in rover. Also, other kind of influence sources could affect too.**

2.1.2 What can say about the distribution of noise in the signal ?

There are Plots about Error value change along the time and about Error Distribution.



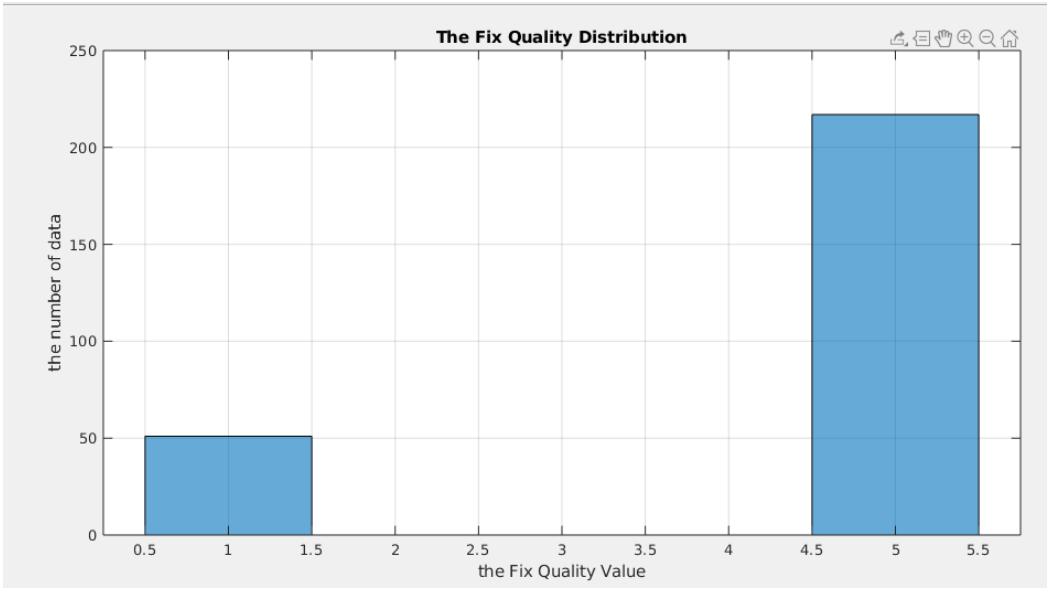


According to Error Value distribution, **the noise distribution in clear correction environment is not a Gaussian distribution.** The sources of error could be variant, including reflection affect from buildings or obstacles around.

The information in red square in Error Value Change corresponds to that in red square in Error Distribution, and both two square correspond to polygon in Trajectory Plot. According to the **Error Value Change** with respect to time step, the error is very large than others in time steps between about **[160 180]**, which brought great distortion in localization information, whereas error in other time steps is not so big, and is relatively less variant in comparison.

According to the **Error Distribution**, the most of error are less than 10 and are around the mean, while a few of error values are big but very small in number (appear in seldom in other words).

There is the Distribution of Fix Quality Value.



From the Fix Quality distribution, **the value at many of time is 1,** representing just GPS Fix, which means that the GPS data is not fixed well at those time. This may be one reason that the error at some point is very huge due to bad fixing. At other time, the fix is good which leads to relatively smaller error.

2.2 At Spot with Clear Environment:

2.2.1 Moving Dataset

Location : a playground located at Tennis Courts close to NEU

Weather: Clear in sky, and Warm

Actual Trajectory Shape : a rectangle

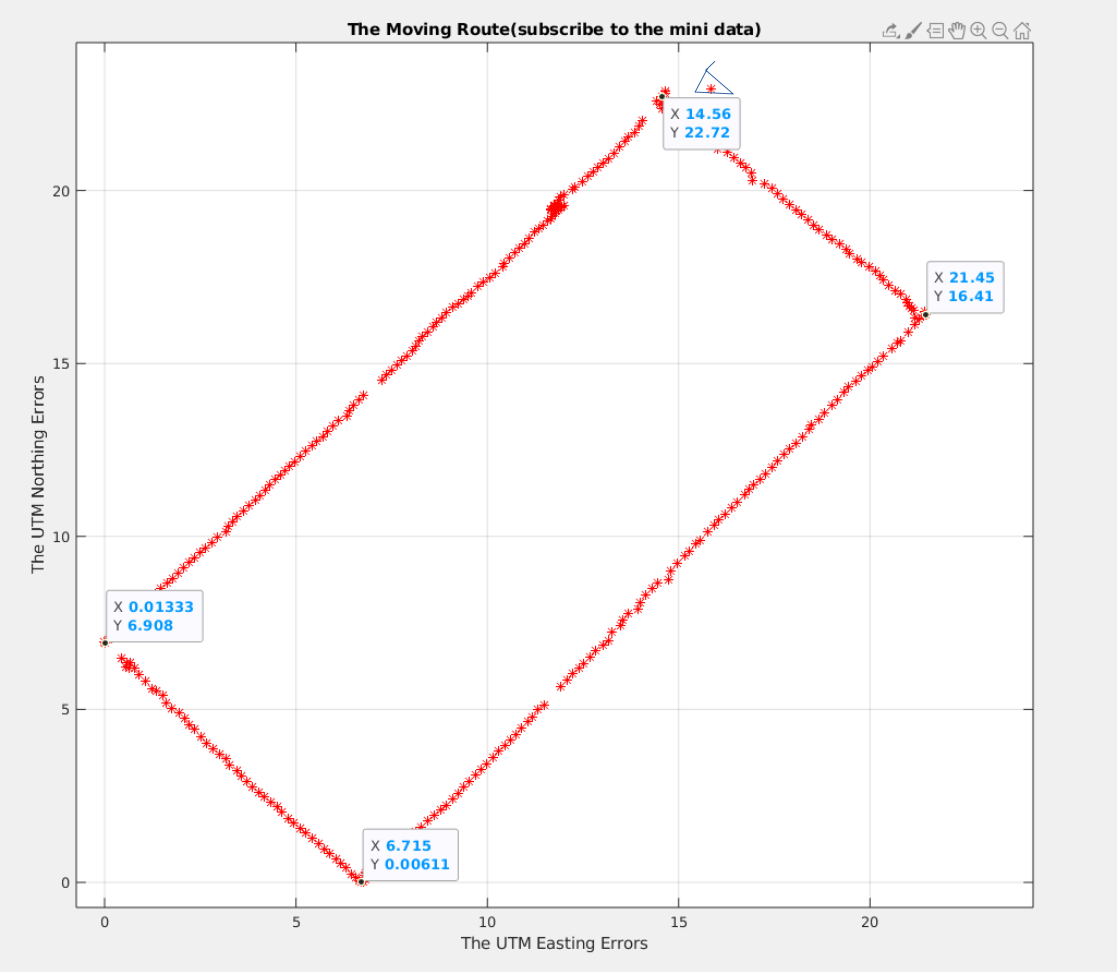
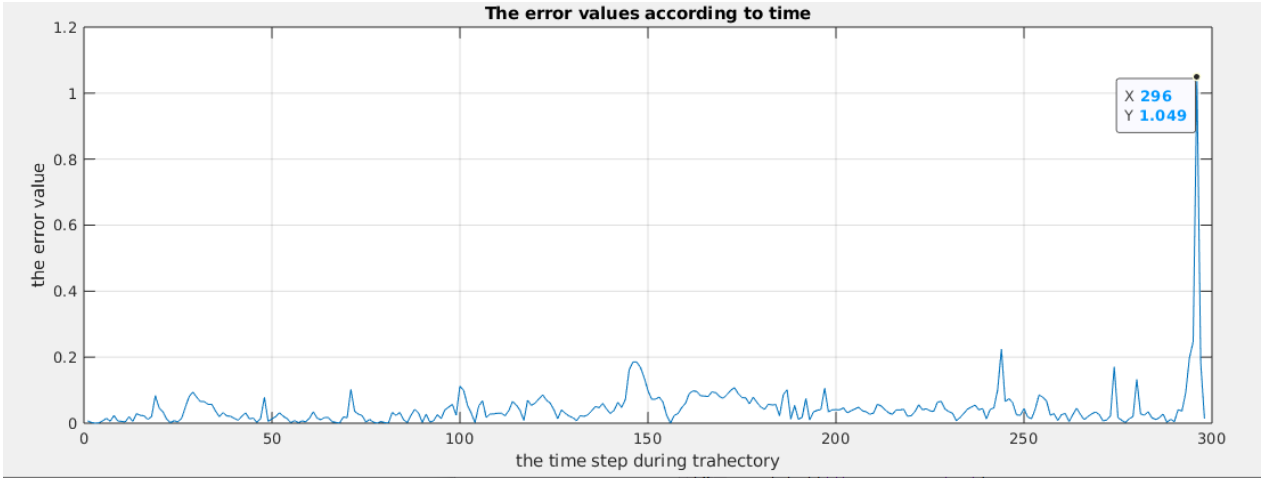


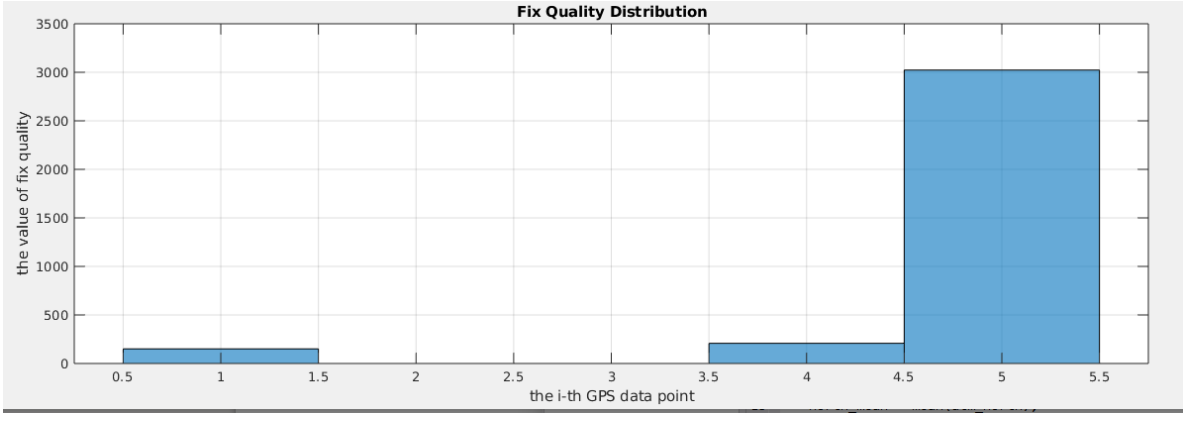
Figure 14. The Moving Trajectory and Turning points in spot clear

The plot above shows the Moving Trajectory in clear space , and the coordinates showed correspond to the spot where taking turns. From data distribution we could see the detected position information is very close to that of real trajectory. The gap between some points here due to that the moving velocity at that time is higher, whereas in other time with lower velocity the points are very close to each other. **However, there is a explicit noise data point circled in triangle, which may result from some unknown influence sources.**

2.2.2 What can say about the distribution of noise in the signal ?

There are Plots about Error Value Change, Error Distribution and Fix Quality Distribution.





According to Error Value distribution, **the noise distribution in clear correction environment is not a Gaussian distribution.** According to our experiment, the error in clear environment is very small with few signal influence sources.

According to Error Distribution, the average error is close to zero, and the error range is very small either. Most of error values are varying around the mean which is close to zero. **However, we could see a error whose value is more than one. This error corresponds to error which shows coordinates in Error Value Change plot, corresponding to the explicit noise point circled in triangle in Trajectory plot.** One reason probably could be that there is a unknown affect, or the error of the RTK device itself. **Also, another could be that, from the Fix Quality Distribution, at some points the Fix Quality is 1, which means the fix is not good that could result in relatively huge error.**

2.3 What to say about RTK GNSS navigation ?

We could notice that **generally speaking, the RTK GNSS navigation brings higher localization accuracy with lower error compared with GPS method, with the help of base station which gives rover the correction information for fixing.** According to our noise distribution and trajectory, the detected navigation route fit the real trajectory more, but still with some error.

According to our experiments, in different places, with or without influence sources, the accuracy of navigation and the error value could be different. For instance, in clear spot the error is very small which leads to a high position accuracy, so the trajectory detected is very close to the real one. However, in places with occlusions and reflections, the trajectory may have larger values even huge distortion at some points.