EECE 5554 Lab_3 Report

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Hardware / Sensors:

- 2x GNSS/RTK Processing boards
- 2x GNSS Antennas
- 2x 915 MHz Telemetry Radios

1. Stationary data at clear area (*stationary_clear_data.csv*)

1.1 UTM data results and analysis

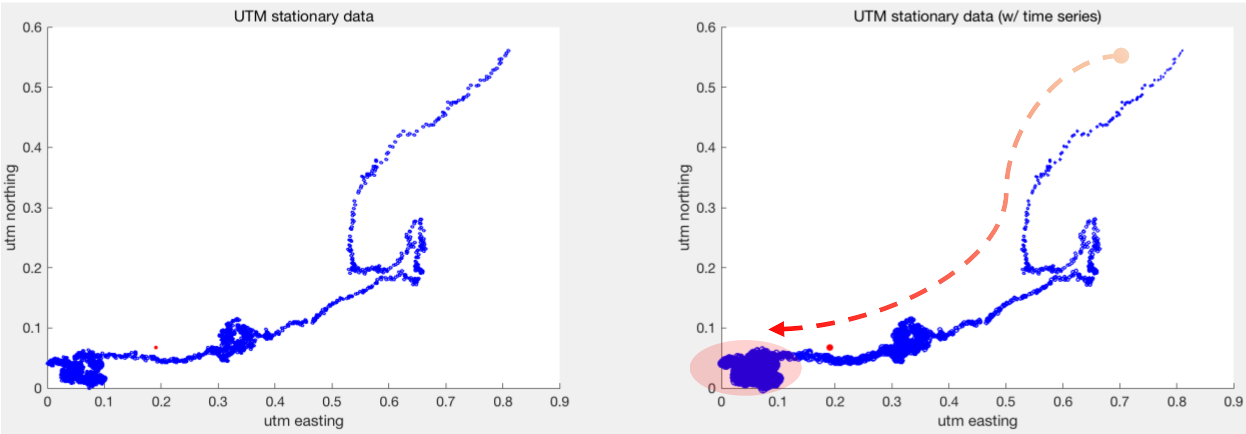

Figure 1: Stationary data at clear area

Figure 1 shows the UTM measurements of stationary data collected at clear area. For better visualization, all the data points are pre-processed by subtracting the minimum value. **All the data points generally form an irregular shape due to the measurement errors.** In the right plot, the area of points is increasing as time goes by. **We can observe that the measurements deviate more from the mean value at first, and then gradually lingered in a certain area** (shown as the red area).

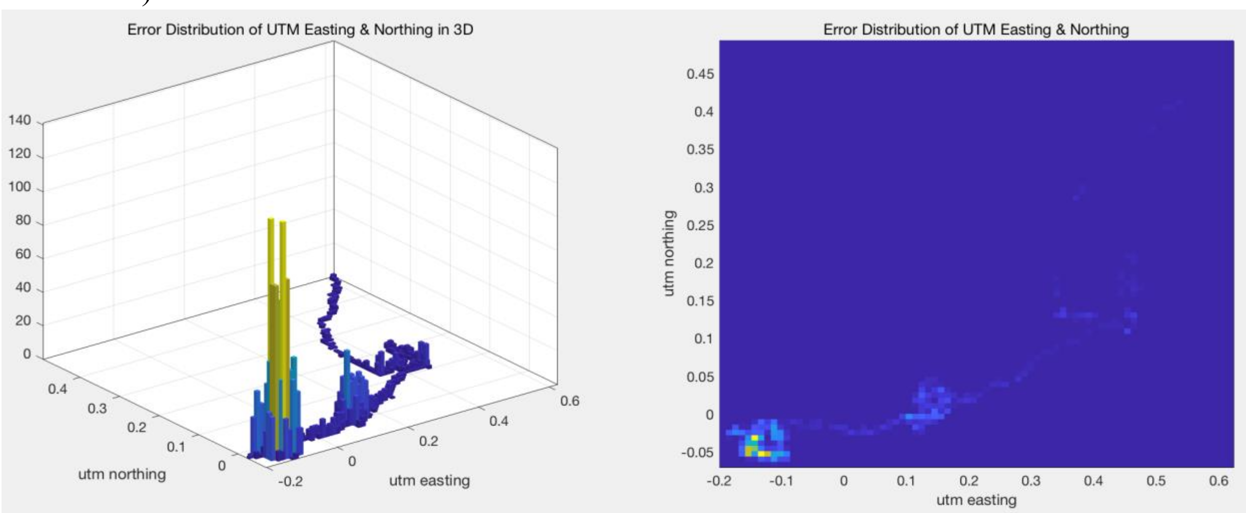

Figure 2: Noise distribution of stationary data at clear area

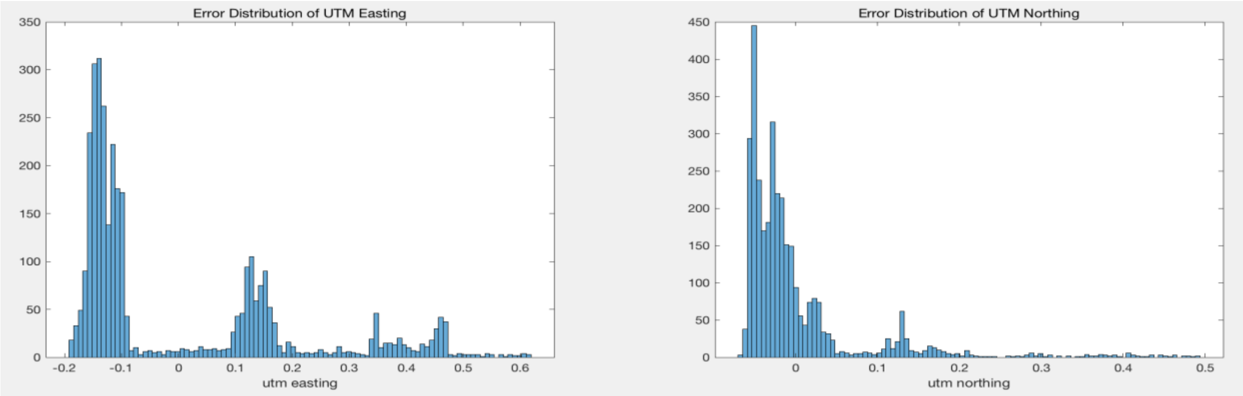

Figure 3: Noise distribution of stationary data at clear area

Figure 2 and figure 3 show the noise distribution of clear area stationary data from different perspectives. Further analysis about noise-distribution will be discussed at Part 1.3.

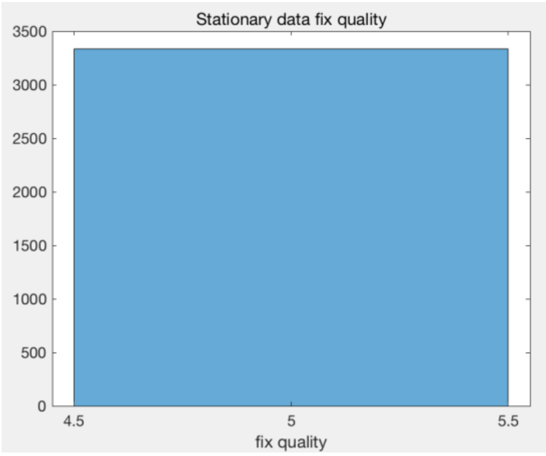

Figure 4: Fix quality of stationary data at clear area

All the data points are collected with the *fix-quality = 5* (as shown in figure 4), which means the measurement is RTK float with decimeter precision. **The reason why it doesn't receive the RTK fix coordinate may because of the low number of satellites visible, poor satellite constellation geometry or low signal strength.**

Compared with the fix-quality of clear area data collected in Lab 1 using general GPS system *(fix-quality = 2:* DGPS fix*)*, **it is reasonable to expect more accurate measurements.**

- **Comparison of *standard deviation* between Lab3 RTK GPS data and Lab1 GPS data.**

	Std of reflection area		**Std of clear area**	
	easting	**northing**	**easting**	**northing**
Lab1 GPS data	7.460073	5.900717	1.645809	1.061633
Lab3 RTK GPS data	12.929626	9.708634	0.194479	0.081462

Table 1: Standard deviation between Lab3 RTK GPS data and Lab1 GPS data

- **Comparison of *mean of error* between Lab3 RTK GPS data and Lab1 GPS data.**

	Mean-error of reflection area		Mean-error of clear area	
	easting	northing	easting	northing
Lab1 GPS data	-1.7693e-10	2.1595e-09	-5.4618e-12	-6.3744e-09
Lab3 RTK GPS data	5.3002e-15	-1.0037e-13	6.8132e-17	1.6499e-15

Table 2: Mean of error between Lab3 RTK GPS data and Lab1 GPS data

- **Comparison of RTK GPS stationary data error distribution between clear and reflection area**

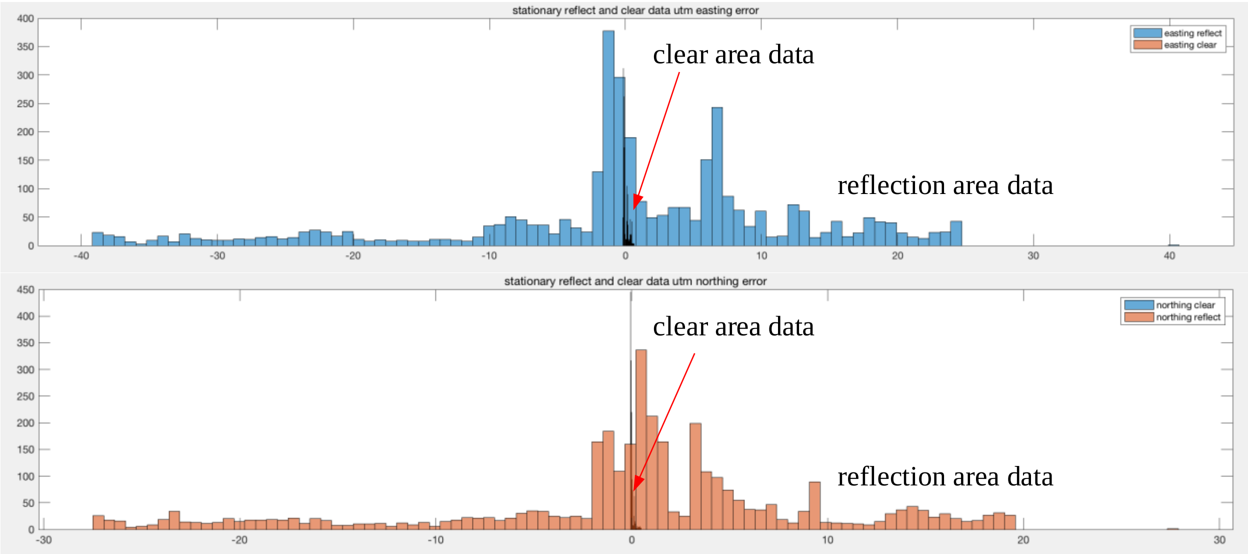

Figure 5: Noise distribution of two datasets

1.2 What does this say about RTK GNSS navigation?

From the above results and table 1, we can see that RTK GNSS navigation data have a smaller standard deviation than general GPS system's at clear area, which means the measurements tend to be more concentrated. But for reflection area data, it is surprised to see the opposite result. Further data collection and analysis for reflection area cases still need to be done.

From table 2 and figure 5, **the mean-error of RTK GPS data is much smaller than general GPS data for both clear and reflection area**, which means a higher accuracy obtained. **For RTK GPS data itself, it is reasonable to see that the standard deviation and mean-error for clear area measurements are both significantly less than the reflection area data.**

RTK GPS does give us more accurate measurements, especially in open areas. However, there are still various sources of error influencing the GNSS system accuracy. Ionospheric & tropospheric errors, satellite clock errors, multipath error, receiver quality and so on could both have obvious influences.

1.3 What can you say about the distribution of noise in the signal?

The distribution of noise in the signal doesn't have any specific type and it is hard to tell any specific kind of distribution. There could be some type of noise from various sources combined with some random noises generated by unavoidable factors. Although we can't control some of the noise, it would be better if we could minimize the noise from the device itself, like thermal noise or antenna noise and so on.

2. Stationary data at reflection area (*stationary_reflect_data.csv*)

2.1 UTM data results and analysis

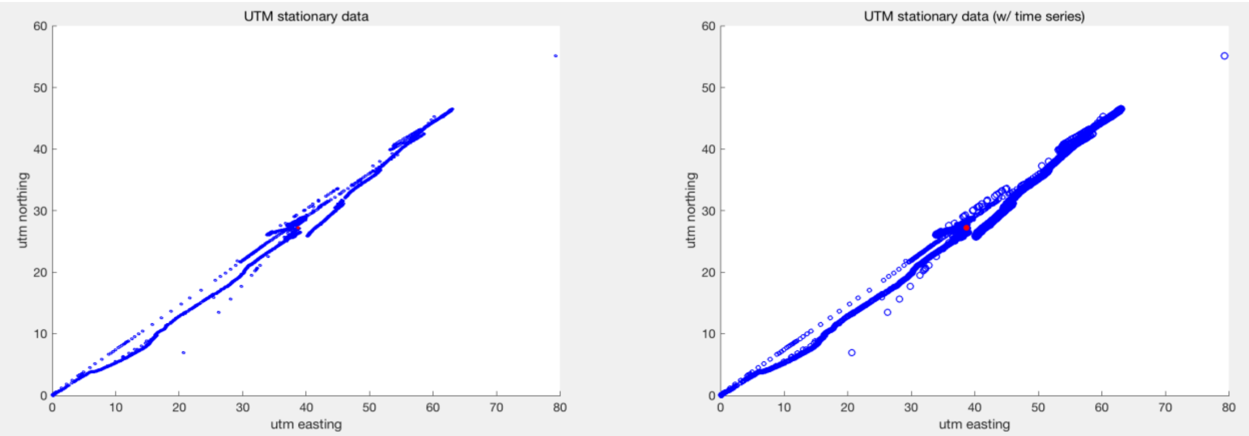

Figure 6: Stationary data at reflection area

Figure 6 shows the UTM measurements of stationary data collected at reflection area. For better visualization, all the data points are pre-processed by subtracting the minimum value. It is interested to observed that **all the data points generally form a diagonal distribution shape.** In the right plot, the area of points is increasing as time goes by. **We can observe that the measurements vary continuously around the mean, but only with the diagonal direction.**

Further data collection and detailed analysis are required for this feature.

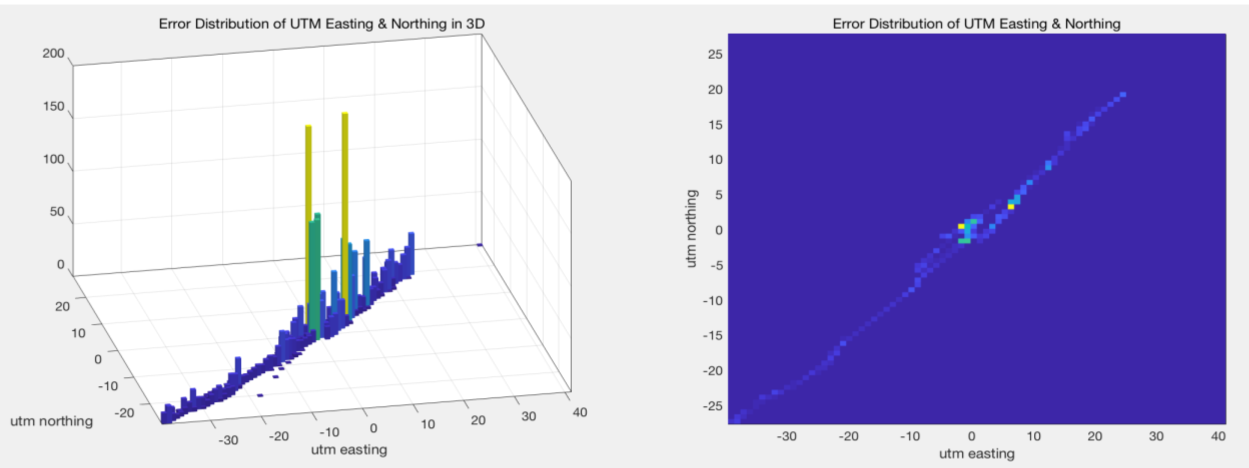

Figure 7: Noise distribution of stationary data at reflection area

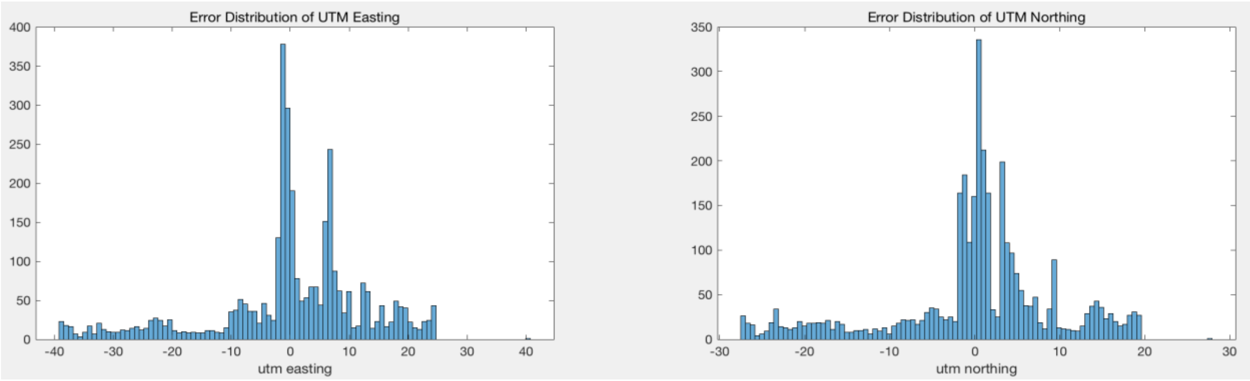

Figure 8: Noise distribution of stationary data at reflection area

Figure 7 and figure 8 show the noise distribution of reflection area stationary data from different perspectives. Further analysis about noise distribution will be discussed at Part 2.3.

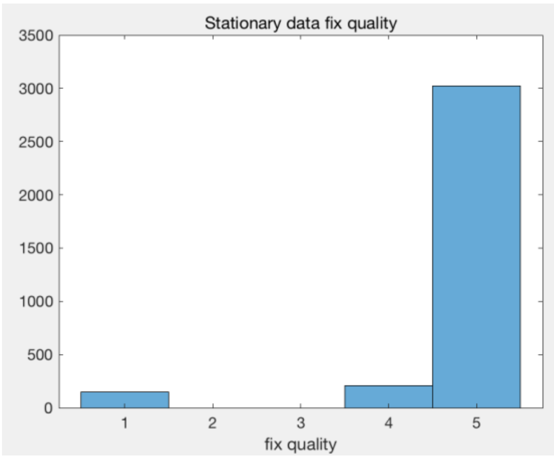

Figure 9: Fix quality of stationary data at reflection area

As shown in figure 9, most of the data points are collected with the *fix-quality = 5*, which means the measurement is RTK float with decimeter precision. Only some of them are with *fix-quality = 4* which is RTK fix with centimeter precision. **It's worth noting that there are also 150 points that are collected with *fix-quality = 1* indicating the uncorrected coordinate. This could be influenced by multipath error, the number of satellites visible or satellite constellation geometry.**

Compared with the fix-quality of reflection area data collected in Lab 1 using the general GPS system *(fix-quality = 1:* GPS fix for most measurements*)*, **it is reasonable to expect the more accurate measurements.**

2.2 What does this say about RTK GNSS navigation?

From table 2, we can observe that **the mean-error of RTK GPS data is much smaller than general GPS data at the reflection area, although the error is still much larger than the clear area's measurement error. RTK GPS does provide more accurate measurements.**

There are still various sources of error influencing the GNSS system accuracy. Ionospheric & tropospheric errors, satellite clock errors, multipath error, receiver quality and so on could both have obvious influences.

2.3 What can you say about the distribution of noise in the signal?

The distribution of noise in the signal doesn't have any specific type and it is hard to tell any specific kind of distribution. There could be some type of noise from various sources combined with some random noises generated by unavoidable factors. Although we can't control some of the noise, it would be better if we could minimize the noise from the device itself, like thermal noise or antenna noise and so on.

3. ROVER moving data at clear area (*move_clear_data.csv*)

3.1 UTM data results and analysis

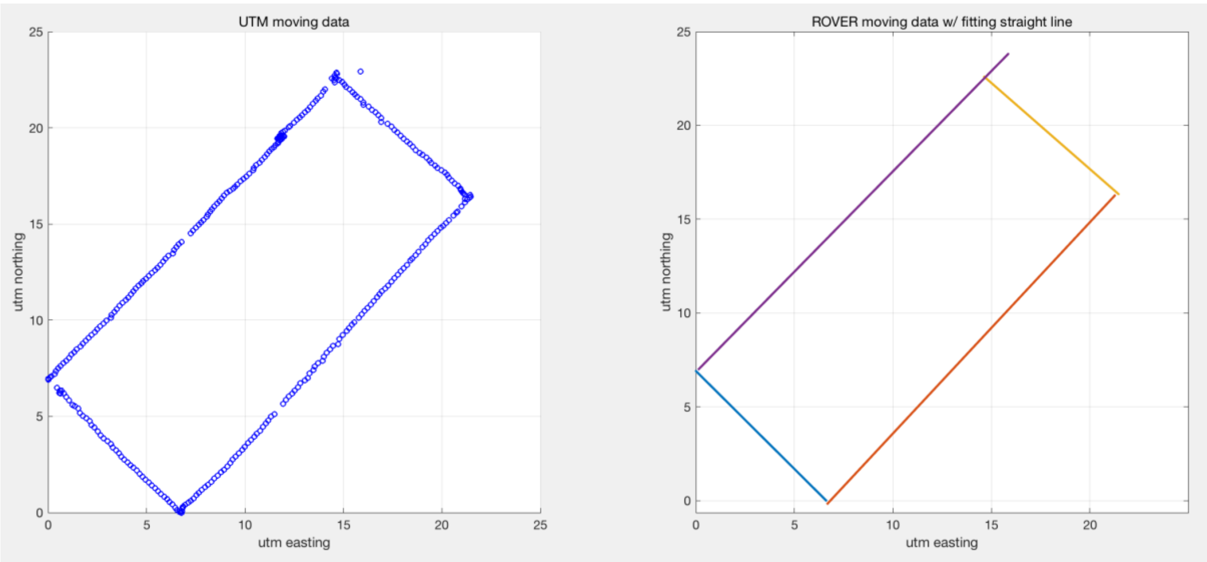

Figure 10: ROVER moving data at clear area

Figure 10 shows the ROVER moving data collected with a rectangle path. For better visualization, all the data points are pre-processed by subtracting the minimum value. The right plot is the fitted straight lines of each side. The four vertices of rectangle are chosen manually from the left plot. **It is clear that the measurements appear as a relatively accurate rectangle shape.**

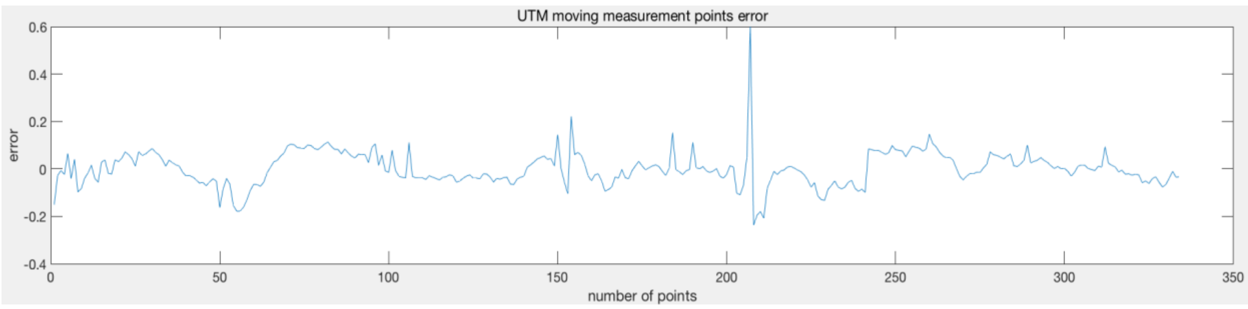

Figure 11: ROVER moving clear area data error

Figure 11 plots the error of each measurements in ROVER moving clear area data. The mean value is: *mean(abs(error)) = 0.0525*.

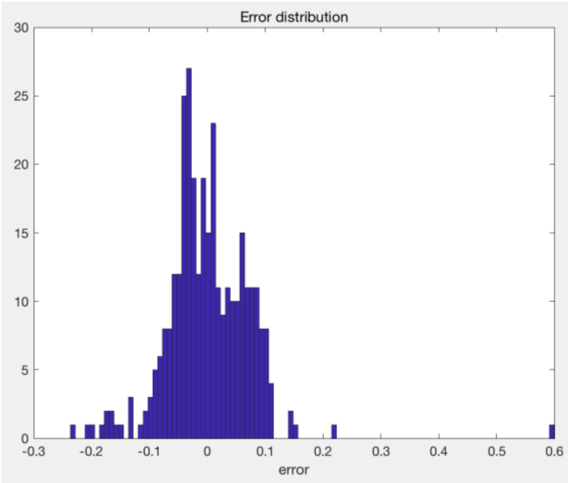

Figure 12: ROVER moving data error distribution at clear area

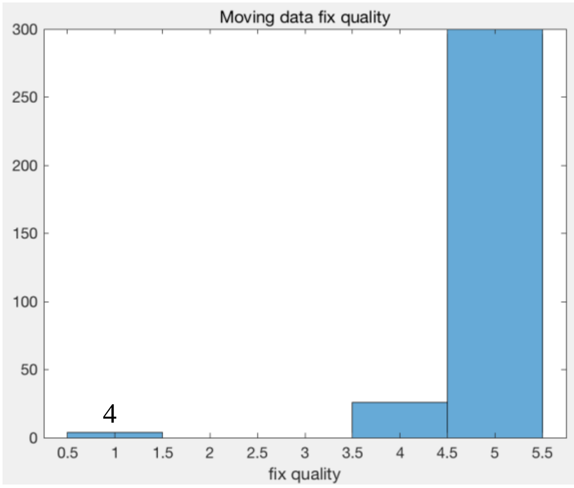

Figure 13: Fix quality of moving data at clear area

Figure 12 shows the error distribution of clear area moving data, **it is hard to see any particular distribution type.**

From figure 13, we can see most of the data points are collected with the *fix-quality = 5*, which means the measurement is RTK float with decimeter precision. Some of them are with *fix-quality = 4* which is RTK fix with centimeter precision. **It's worth noting that for some unknown reason there are also 4 points that are collected with *fix-quality = 1* indicating the uncorrected coordinate.**

3.2 What does this say about RTK GNSS navigation?

From above figures, we can observe that **the RTK GPS measurements at clear area have very high precision and the plot almost exactly matches the actual path.**

There are still some small errors in the GNSS system. Ionospheric & tropospheric errors, satellite clock errors, receiver quality and so on could both have obvious influences.

3.3 What can you say about the distribution of noise in the signal?

From figure 12, although the error distribution mainly focuses around zero, **it is still hard to say it's a Gaussian distribution because of the asymmetry of data. Except for the region around 0, the errors seem to distribute randomly.**

4. ROVER moving data at reflection area (*move_reflect_data.csv*)

4.1 UTM data results and analysis

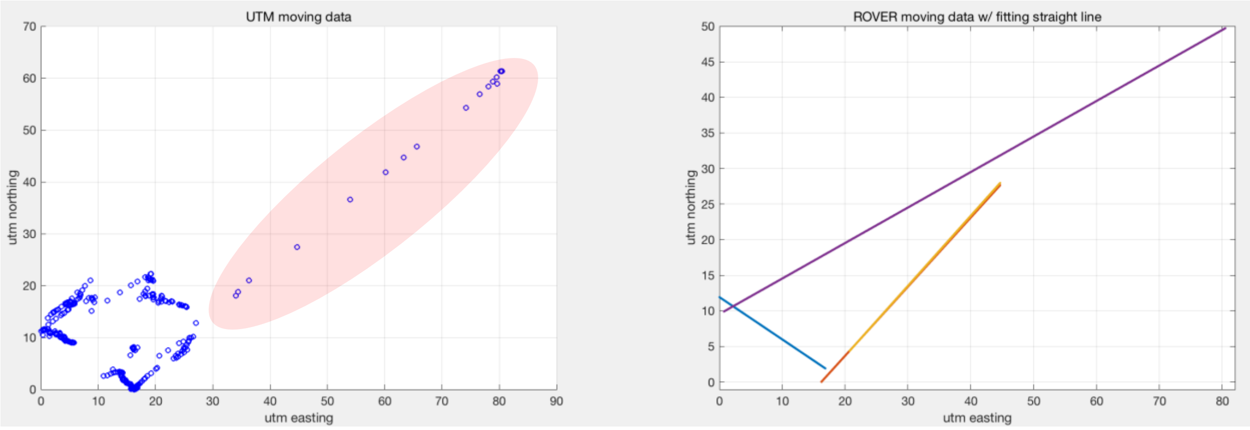

Figure 14: ROVER moving data at reflection area

Figure 14 shows the ROVER moving data collected with a rectangle path at reflection area. For better visualization, all the data points are pre-processed by subtracting the minimum value. The right plot is the fitted straight lines of each side. The four vertices of the rectangle are chosen manually from the left plot. **However, due to the large error values, it is even hard to fit a rectangle shape.**

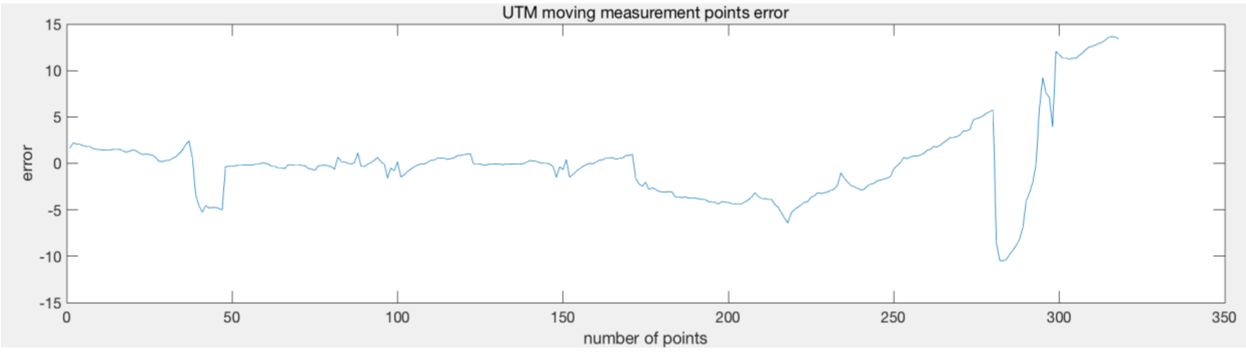

Figure 15: ROVER moving reflection area data error

Figure 15 plots the error of each measurements in ROVER moving reflection area data. The mean of absolute error value is: *mean(abs(error)) = 2.6890*.

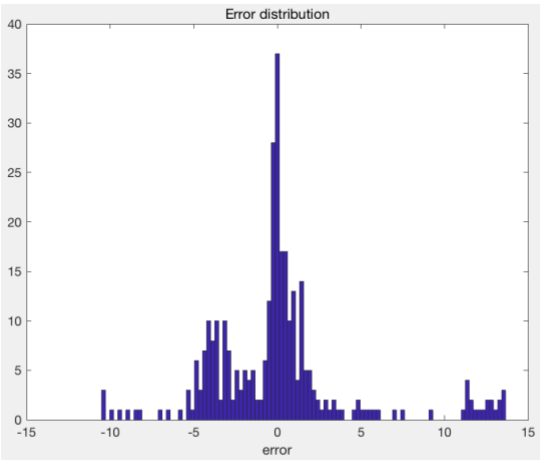

Figure 16: ROVER moving data error distribution at reflection area

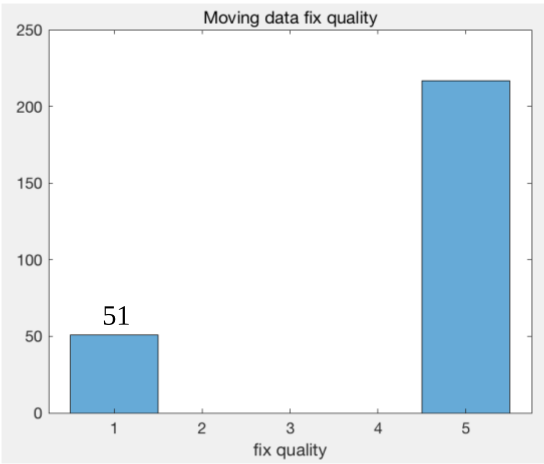

Figure 17: Fix quality of moving data at reflection area

Figure 16 shows the error distribution of the reflection area moving data, **it is hard to see any particular distribution type.**

From figure 17, we can also notice that there are 51 measurements collected with uncorrected coordinate (*fix-quality = 1*) **which could correspond to those large-drifting points (as shown in the red ellipse area)**.

4.2 What does this say about RTK GNSS navigation?

Although RTK GPS will provide us the more accurate measurements, **it is still very vulnerable to environmental impact, especially at the reflection area.**

4.3 What can you say about the distribution of noise in the signal?

From figure 16, although the error distribution mainly focuses around zero, **it is still hard to say it's a Gaussian distribution because of the asymmetry of data. Except for the region around 0, the errors seem to distribute randomly.**