Procedures for Quality Control of GNSS Surveying Results Based on Network RTK

Limin WU, vice Director of Surveying & Mapping Institute of Kunming, RP China
Anna Feng Xia Li, Graduate Student of Kunming University of Technology, RP China
Joel van Cranenbroeck, Business Development Manager for GNSS Network, Leica Switzerland

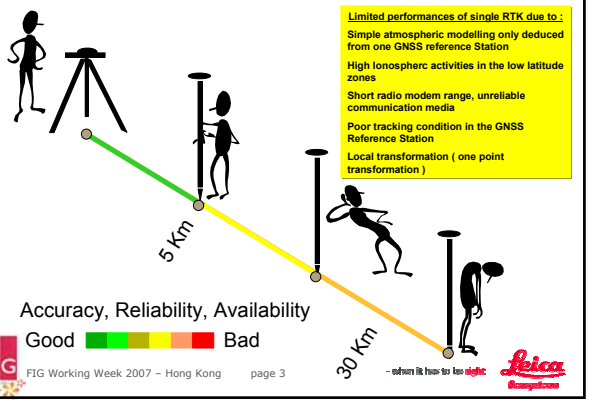
GNSS RTK is intensively used for surveying

Nowadays, the GNSS RTK technique is intensively used for surveying applications and even compete with the Total Station in many areas.
There are several reasons for that evolution :

1. GNSS signal can be used independently of field atmospheric conditions
2. GNSS signals can be used day and night
3. GNSS signals is now tracked and processed from light equipment and with an easy to use users interface
4. The operators can access immediately the coordinates of surveyed points in local datum
5. There is no need of line of sight between the base reference station and the rovers, etc.

But the performances of GNSS RTK operations have also some limitations !

GNSS RTK



Limited performances of single RTK due to :

- Simple atmospheric modelling only deduced from one GNSS reference Station
- High Ionospherc activities in the low latitude zones
- Short radio modem range, unreliable communication media
- Poor tracking condition in the GNSS Reference Station
- Local transformation (one point transformation)

Contribution of GNSS Network RTK

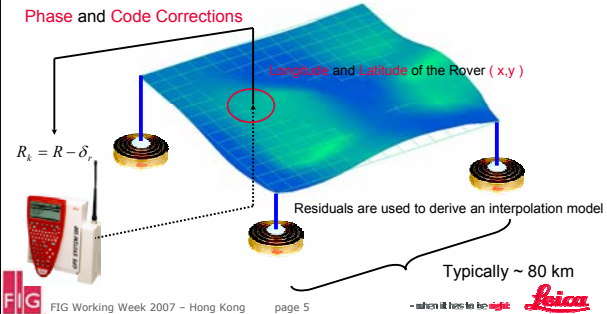
It is well recongnized today that to overcome the limitations of the GNSS single RTK performances, a network of continuous operating GNSS stations can be very beneficial :

1. Reduced time to first fix the ambiguities on the rover side
2. Improved accuracy, reliability and availability
3. Homogneous results over the area covered by the GNSS Network RTK
4. Multi-applications possibility (not only for surveying tasks but also for GIS, traffic management, weather forecasting, structural monitoring, machine guidance, etc.)
5. Better transformation of WGS84 coordinates to fit the local datum definition
6. Positioning Infrastructure benefits (power supply, security, only one rover is needed, etc.)

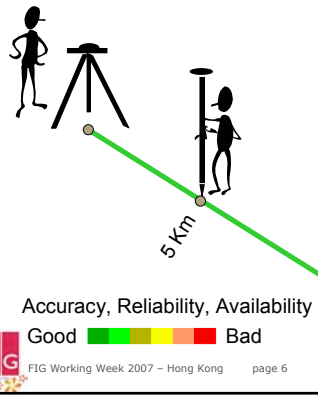
Derived Observation Corrections

$$\delta_{r0} = \alpha\left(N_0(\varphi-\varphi_R)+E_0(\lambda-\lambda_R)\cos(\varphi_R)\right)$$

$$\delta_{r1} = \beta\cdot H\left(N_1(\varphi-\varphi_R)+E_1(\lambda-\lambda_R)\cos(\varphi_R)\right)$$



GNSS Network RTK



Contribution of a GNSS Network RTK :

- Regional atmospheric modelling deduced from the network of GNSS reference Stations
- High Ionospherc activities in the low latitude zones mitigated by modelling.
- Advanced communication GSM, GPRS, CDMA, ...
- Ideal tracking condition in the GNSS Reference Station
- Global transformation (« n » point transformation)

GNSS RTK Network in Kunming
Surveying & Mapping Institute

GPS RTK Network in Kunming
Surveying & Mapping Institute

Quality Control of GNSS RTK Surveys

The fascination of the GNSS Network RTK technology should not hidden the importance to have quality control on the end results obtained much more easily than before by other technics.

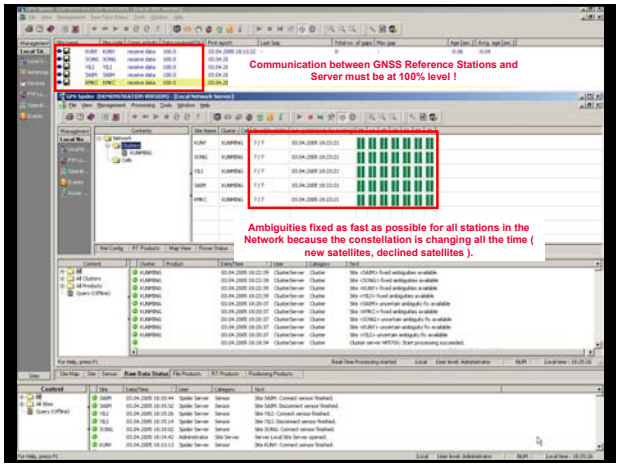
It's one of the major role of the Surveying & Mapping Institute of Kunming to control the quality of the production.

We cannot simply accept to integrate the results of GNSS RTK surveying production without a proper quality control process.

Based on extensive usage of GNSS RTK technics and long experience in geomatic production quality control (surveying, mapping, digitizing, etc.) , the Surveying and Mapping Institute of Kunming has developped some guidelines to ensure the GNSS RTK production is under control (quality, accuracy, availability) for every user who is operating in the network.

Normal working condition for GNSS Network RTK

a. Reference stations must track all satellites signals at the lowest elevation to ensure a complete coverage and must receive the signals from the same satellites the same time.
b. The communication network (Internet ADSL) must have no latency and no interruption in order to have 100% of data incoming the data center Network RTK server.
c. The common ambiguities level must be solved for the complete network in order to compute the appropriated corrections for any rover RTK users operating in the area of the network.
d. The corrections delivered must provide 99% availability. The users of a such infrastructure must have the same and even better performances than with standard RTK operations.
e. System reliability must reach more than 95% level of confidence.
f. When receiving the request information of rover (individualized corrections), it can provide correction data of network RTK immediately "on demand".
g. It must provide differential data with all kinds of formats.



Normal working condition for Rover RTK

a. The rover RTK can receive data (observations and corrections) from the data center managing the reference stations normally by GSM, GPRS, CDMA etc.
b. The rover RTK can process the correction values and fixed the ambiguities after receiving the network correction value.
c. Reference stations and rover can receive same signals of more than 5 satellites at the same time.
d. Rover can receive the same amount of differential signals of reference stations and satellite signals normally.
e. Rover can receive differential signals of reference stations and GPS satellite signals continually.
f. Data center of reference station and rover can communicate data without any delay.
g. There is no strong interference (radio jamming) around the reference station and the rover RTK, no severe multi-path effects.

Guidelines and good practices
Mission Planning is not obsolete !

Because the number of available satellite signals is normally enough and even greater than the minimum, it's still very important for the RTK user to consider the ideal time slots along the working hours.

There are still some critieria to fullfil :

1. **GDOP must be < than 4**
2. **Number of satellites signals effectively tracked must be > 6**
3. **Periods of sudden change in GDOP must be avoid**
4. **Constellation with GDOP < 4 but with only one satellite in the zenith should be highlighted in the production planning.**
5. **Periods where the number of satellites are > 6 but with pair of satellites on the same elevation/azimuth should be highlighted in the production planning.**
6. **Periods where the Ionosphere turbulences (Kunming is on low latitude) could be chaotic should be highlighted in the production planning and observations logged for re-processing.**

Quality Control of GNSS RTK results
Pragmatic approach

During the field operations, the user can control the results by using several checks :

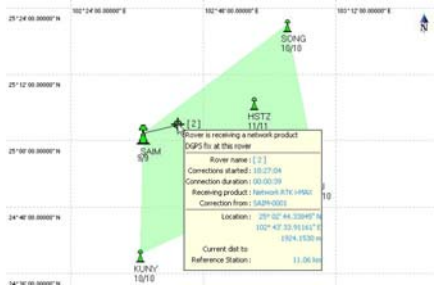
1. **When the initialisation has been succesful and the results are stored, the user can block the signals and force the GNSS receiver to track again and fix the ambiguities once more.**
2. **Double survey points with different satellites, different antenna heights.**
3. **Survey more than only one point ! Have different points (for orientation of TPS) that could be controlled after when using a Total Station for complementing the survey (Urban survey operations)**
4. **Another survey team is mandate to control some points independantly (sampling)**
5. **Fixed Rover that operate like a normal RTK user and installed in the network and check by the Network operator.**

Assisted Client-Server RTK Survey
The RTK rover user is not alone anymore !

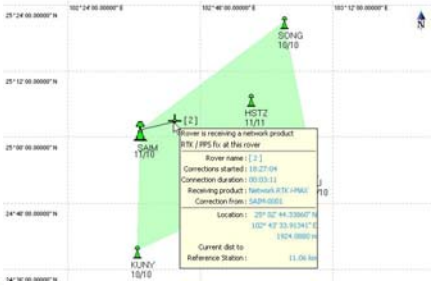
Thanks to the Client-Server architecture, a GNSS RTK user operating in a GNSS Network RTK can benefit of the support from the network operator.
The network operator is managing the various status of the server and can assist the users in their field operations as for instance :

1. **The network operator can advice the users of optimal time slots.**
2. **In case of long period of amb's initialisation, the operator can give an immediate feedback to the user about the reason of the poor performances (few common satellites tracked, less satellites than in the network, weak geometry resulting in large GDOP)**
3. **A report can be addressed after each survey project to the survey manager.**
4. **The user can complement his survey with static and post-processing techniques, the network operator will provide the RINEX files**
5. **Communication issues (GSM, GPRS, CDMA) can be solved directly when happen.**
6. **The RTK users are operating in a « Positioning Infrastructure » that delivers various services to support them.**

Assisted Client-Server RTK Survey
The RTK rover user is not alone anymore !



Assisted Client-Server RTK Survey
The RTK rover user is not alone anymore !



Assisted Client-Server RTK Survey
The RTK rover user is not alone anymore !

Site Name	Cluster / Cell	Fixed/Available	Last update	01	14	16	18	22	25	30
SONG	Kunming Network	7 / 7	26.05.2005 10:33:06							
SAIM	Kunming Network	7 / 7	26.05.2005 10:33:27							
KUNY	Kunming Network	7 / 7	26.05.2005 10:32:55							
YILI	Kunming Network	7 / 7	26.05.2005 10:33:06							
CHGO	Kunming Network	6 / 7	26.05.2005 10:33:27							
HSTZ	Kunming Network	6 / 7	26.05.2005 10:33:27							

The user RTK who has a the Master YILI is getting corrections from all satellites in view !

The user RTK who has a the Master CHGO will not get corrections from satellite 16 !

The user RTK who has a the Master HSTZ will get corrections for satellite 16 soon !

New Transmission Concept in Network RTK
The RTK user must access all real data's

To transfert the corrections, several « strategies » have been developped by the German Universities and applied by some manufacturers without using a standard exchange format.

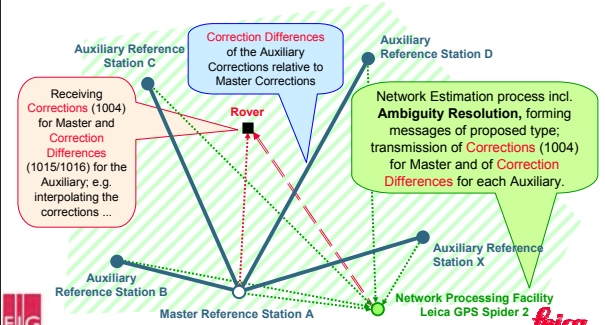
VRS was invented to speed up the GPS RTK processing by creating a « Virtual Reference Station » on the navigated user position and by broadcasting its **« virtual observations » without any indication on the quality of those new values.**

Since 2001, the RTCM commitee recognizing the huge increase of the GPS RTK users, has followed the Leica Geosystems proposal. **Now the whole GPS industry has adopted the new RTCM 3.1 Network Corrections format proposed by Leica Geosystems.**

One of the benefit is to have on the rover RTK side all the observations from the GNSS reference stations (cell concept) around the user position in a condensed format and to derive from those redundant informations quality indicators.

Network RTK Transmission Concept

One Master Reference Station + Several Auxiliary Reference Stations = One Network Cell



Conclusions

With the development and application of GNSS reference station technology, RTK surveying operations are going to be handled more and more by using the advantages of GNSS network RTK positioning infrastructures, and the operational efficiency will rise greatly.

At present time, by selecting appropriated GNSS Network RTK concepts and operational modes, by using all methods of quality control, the user can attain more stable and reliable positioning results than with the conventional single RTK.

The author's believe that the development of GNSS reference station technology must also include quality check procedures (statistical analysis) to ensure the RTK end user with indicators that will qualify his end results. At the end a GNSS Network RTK positioning infrastructure must also add this value to the user !

Many thanks for your kind attention and for your questions