Using Network-RTK for Cadastral Reform In Republic of Korea

Jongmin Lee, Byeongun Park and Dekkie Tcha
Republic of Korea

Key words: GNSS, Network-RTK, Coordinate System, Cadastral Reform

SUMMARY

In 2011, National Assembly of South Korea enacted a law dealing with Cadastral System Reform. It is important changes to existing cadastral system which sustained for 100 years from land management system to surveying technology. And central government established general plans that introducing three-dimensional digital Cadastre system, integrated real estate information books and advanced surveying technologies such as aerial photogrammetry and GNSS RTK positioning.

Accuracy of GNSS positioning have improved in the last thirty years using various reinforcement method so that the latest navigation satellites allow users to determine true positions to within a few centimeters in real time. One of the main issues in Cadastral Reform is establishing control point network which is integrated triangulation points and bench marks because height information is essential part of future cadastral system.

In this paper, we present new 3D cadastral control points model which is able to use for digital map by surveyor. Moreover, we investigate the possibility to using GNSS surveying technology, especially Network-RTK for cadastral reform project in order to acquire 3D positions and improve productivity of surveying tasks.

Using Network-RTK for Cadastral Reform in Republic of Korea

Jongmin Lee, Byeongun Park and Dekkie Tcha
Republic of Korea

1. INTRODUCTION

Cadastral information is closely related to the right of ownership because cadastral documentation defines location and boundary of land parcels. Nowadays, advanced information technology can able to integrate land information and spatial data on the web as well as mobile device. However, Cadastral System of Republic Korea was established about one hundred years ago with low survey technique skills during Japanese colonial period. Current cadastral map is limited in ability of boundary relocation, various uses with geospatial data and appropriate provision of the people's need.

Since 1980, rapid industrialization and urbanization of Korea lead a landowner to complex land use. In addition to the change of land usage, government needs new land administration strategy and policy. National Assembly of South Korea finally enacted a law dealing with Cadastre system reform in 2011. Ministry of Land, Transport and Maritime Affairs (MLTM) which is project main department plans to basic direction of Reform: high precision digital cadastral information, integration with geo-spatial data, and registration of 3 dimensional. Basic plan signified resolving current cadastral system and establishing new land information system in accordance with legal cadastral system.

In technical parts, one of the main changes is transition of geodetic coordinate system from local to world datum. Current paper based map are drawn in local datum as well as several different coordinate system. This makes it difficult to join

2. CADASTRAL SYSTEM OF KOREA

2.1 Current Cadastral System Status

Korea cadastral system is created by surveying parcel boundary and ownership all over the nation. As economy grew, most nation's cadastral system pursue multipurpose Cadastre in terms of land administration and management. Korea, like other country, endeavor to utilize land information for establishing effective land use plan and provide accuracy land information to people. As land use sophisticated, government and the public needs not only various land information but also spatial data related to land.

2.2 Difficulties and Problems

As I mentioned before, Korea cadastral system was established between 1910 and 1916 for fiscal reasons. Survey techniques for constructing geodetic network do not have sufficient accuracy compare with current technology. In addition to low survey technique, more than 70% of control points were destroyed by Korean Civil War in 1950. As a result, inhomogeneous geodetic network lowers quality of cadastral survey results of boundary relocation.

At the time of land investigation project in 1910, each parcel was registered by the graphical way on paper. As time goes on, paper map are deformed for several reasons so that graphical map cause border dispute and related social problems continuously. It is another problem that each map sheet does not match with surroundings which are
Several different coordinate systems and scales are also obstacles for realizing legal and multipurpose cadastral system. Due to non-consistent coordinate and scale, surveyor had to transfer to other coordinate and adjust dislocated boundary, causing a great deal of inconvenience. It is difficult to exploit cadastral information integrated with various geo-spatial data. Table 1 show that there are 7 different scales according to the region.

<Table 1> cadastral map scale

class	Scale	District	Sheet number
Cadastral Map	1:500	urban	40,495
	1:600	urban	15,136
	1:1000	Farm	142,889
	1:1200	Farm	513,136
	1:2400	sub-farm	23
Forestry Map	1:3000	mountain area	14,890
	1:6000	mountain area	44,964
Total			771,533

3. GENERAL PLAN OF CADASTRAL REFORM

3.1 Conversion to World Geodetic System

Existing Korea cadastral map was created by local datum which adopting Bessel 1841 ellipsoid and astronomical longitude and latitude. Local system is different about three hundred meters in location as well as difficult to use with other geospatial data.

3.2 Registration of 3D cadastral information

The increasing use of land from above-ground to under-ground causes various dispute such as ownership, easement, superficies etc. In addition, the laws related to real estate are dispersed at diverse agency concerned so that adopting and applying 3 dimensional cadastral concepts are difficult. One of the main purpose of Cadastre reform is building 3D cadastral system.

3.3 Adoption of advanced survey method

Recently, development of science improves accuracy of aerial photogrammetry and GPS surveying. In order to reduce resurvey cost and increase utilizing ability of cadastral information, MLTM determined to introduce new and advanced techniques such as aerial photogrammetry and RTK-GPS. These techniques have more work efficient as well as ripple effect to geospatial industry. Specific spatial area already adopts these skills however cadastral area required reliable and precise results is not yet. Since advanced survey technique is essential for carrying out Cadastre reform successfully, a number of researches find appropriate way to apply techniques.

Table 2 show strategic plan of Cadastre Reform in point of parcel resurvey basis.

<Table 2> Stretegic Plan of Cadastre Reform

Category	2020 year		2030 year		Cost (million dollar)
	Parcel number (million)	Ratio	Parcel number (million)	Ratio	
Creating Numerical Cadastral map	300(6,000)	8 %	400(8,000)	11 %	N/A
Non-coincidence resurvey	282(3,100)	7 %	550(6,130)	15 %	509.3
National land resolution	188(9,000)	5 %	564(25,000)	15 %	(378.7)
Coordinate Transformation	1,111(31,900)	30 %	2,295(61,907)	59 %	25.5
Total	1,881(50,000)	50 %	3,761(100,037)	100 %	8,021(913.4)

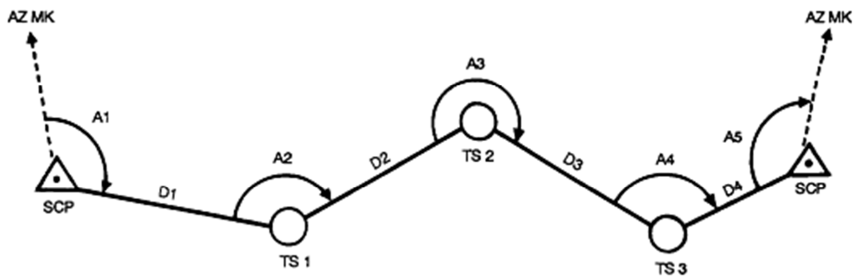
4. NETWORK-RKT VS TRADITIONAL SURVEY

4.1 Traditional Survey Method

Most of the control network and detail cadastral surveying in Korea are carried out by total-station equipment computing relative positioning with respective to fixed points. This method is the same as previous when land was initially registered in 1910s.

4.1.1 Control Point Network

Cadastral ordinance of Korea defines surveying method of establishing control network by both static GPS observation and traverse surveys. Due to the development of GNSS surveying technology, first and second-order control points were usually established by static GPS observation whereas third-order control network was usually installed by traverse method using total station equipment. Traverse survey is a familiar and simple method to Korean cadastral surveyors. This conventional method relatively needs more human resource and is slow compare with Network-RTK survey. Moreover, local geodetic network established 100 years ago with lower accuracy causes large misclosure as well as different results according region.



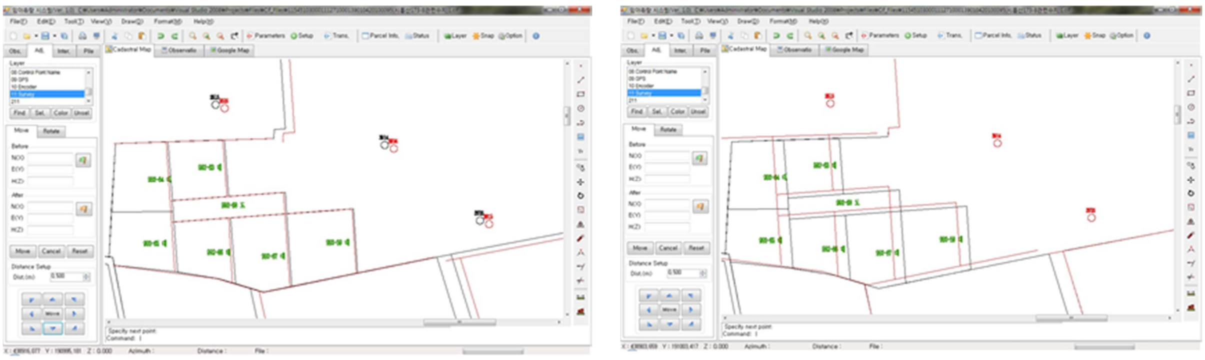
<Figure 1> Closed Traverse

4.1.2 Detail Survey

Most of the detail cadastral surveys are performed by graphical cadastral survey method which means that decision of parcel boundary is based not on physical but on legal boundary. Graphical survey method has large allowable tolerances which vary depending on the map scale so that consistent results of survey cannot be guaranteed. Table 3 shows allowable tolerance according to the map scale. Many European countries adopt the concept of reflecting real physical boundary as a legal boundary whereas Korea cadastral system defines boundary registered on cadastral map as a legal boundary by regulation (Figure2). Thus difference between physical and legal boundary occurs and increases the number of boundary disputes.

<Table 3> Allowable tolerance in graphycal Cadastre

Control Points			Boundary	
Class	Tolerance(m)		Map scale	Tolerance(m)
1st-order	Graphical	0.20m	1/500	0.15
2nd-order	Graphical	0.25m	1/1,000	0.30
3rd-order	Numerical	0.15m	1/1,200	0.36
	Graphical	0.25m	1/3,000	0.90



<Figure 2> difference between physical and legal boundary

4.2 Network-RTK Survey in Cadastral Reform

Network-RTK (Real Time Kinematic) technology was developed in the mid-1990s. It is able surveyor to determine centimeter level accuracy positioning in real-time. Field rover receives raw measurements or corrections from reference station via communication equipment and resolve carrier phase ambiguity.

4.2.1 Benefits

Network based RTK complements weakness of single base RTK, which are distance dependent biases caused by satellite orbit error, ionospheric signal refraction and tropospheric signal delay. Single-RTK can get reliable accuracy when distance between a base and a rover is 10 km or less. On the other hand, the accuracy of Network-RTK is maintained over large inter-station distances up to 70 km. Therefore, fewer reference stations are required in order to use Network-RTK system compared to the number of base station of single-RTK.

No need to carry out process of coordinate transformation. Since cadastral map is based on local datum, positions measured with GPS survey are determined by transformation process. According to general plan of Cadastre Reform, world geodetic system is reference datum adopting GRS80 ellipsoid and ITRF2000 coordinate. WGS84 regard world geodetic system as almost the same at working-level so that computed coordinates using Network-RTK directly become resurvey results without any transformation operation.

Another advantage of using Network-RTK in cadastral resurvey is effective operation of human resources and survey equipment. Network-RTK system does not need to set up base station and surveyor just carry a pack of rover. Above factors have more merit than using Single-RTK and traditional survey methods.

4.2.2 Analysis of Accuracy

In this paper, study area is located in Youngjong Island near Incheon International Airport. Published values are authorized coordinates that is computed by static GPS observation and registered on cadastral book. Network-RTK value is average of 2 session and measuring time is 30 epoch. Accuracy analysis was carried out comparing published values to Network-RTK measurements. The largest difference in the comparison was 0.18m on the x-axis and the y-axis (Table 4). Standard deviation was less than 0.01m. This result is in the range of allowable tolerance so that Network-RTK can be applied to survey method for installing third-order control network.

<Table 4> Control Pont Accuracy

Control Points	Published value (A)		Average Network-RTK(B)		Error	
	X	Y	X	Y	dx	dy
3188	547825.384	156876.685	547825.380	156876.680	-0.004	-0.005
3187	547815.384	156966.761	547815.390	156966.740	0.006	-0.021
3186	547787.525	157053.704	547787.530	157053.690	0.005	-0.014
3190	547757.195	157111.694	547757.200	157111.680	0.005	-0.014

Control Points	Published value (A)		Average Network-RTK(B)		Error	
	X	Y	X	Y	dx	dy
3191	547715.877	157163.597	547715.870	157163.580	-0.007	-0.017
3192	547608.462	157229.214	547608.470	157229.210	0.008	-0.004
3196	547583.663	157129.122	547583.650	157129.110	-0.013	-0.012
3199	547519.014	157048.113	547519.010	157048.110	-0.004	-0.003
3179	547445.925	157046.618	547445.930	157046.600	0.005	-0.018
3180	547483.181	157008.455	547483.170	157008.440	-0.011	-0.015
3181	547560.208	156957.054	547560.190	156957.062	-0.018	0.008
3182	547626.874	156928.892	547626.870	156928.880	-0.004	-0.012
3183	547693.615	156912.605	547693.620	156912.590	0.005	-0.015
3184	547750.651	156910.833	547750.660	156910.830	0.009	-0.003
3185	547714.825	157037.82	547714.830	157037.820	0.005	0.000
3193	547678.353	157098.502	547678.370	157098.500	0.017	-0.002
3194	547633.709	157071.486	547633.7190	157071.495	0.01	0.009
3195	547605.138	157092.554	547605.130	157092.550	-0.008	-0.004
3197	547682.674	156973.117	547682.680	156973.120	0.006	0.003
			Average Error		0.001	-0.007
			Standard Deviation		0.009	0.009

Table 5 shows another experiment results focus on parcel boundary. Network-RTK values are average of 2 sessions and measuring time is 15 epoch at each point. Standard deviation of difference is X = 0.033 m, Y = 0.034 m and maximum difference between published values and Network-RTK measurement is 0.077 m in x-direction and 0.026 m in y-direction. Experiment results for boundary points also were satisfied with an inspection regulation of error range. However, maximum error and standard deviation are larger than control point's.

The reason for bigger error is because environment around rover location. Generally, site of third-order control point was selected by several specific conditions such as good line-of-sight, low signal noise and so on. Therefore, it is natural that network-RTK get reliable results at a control point rather than boundary points.

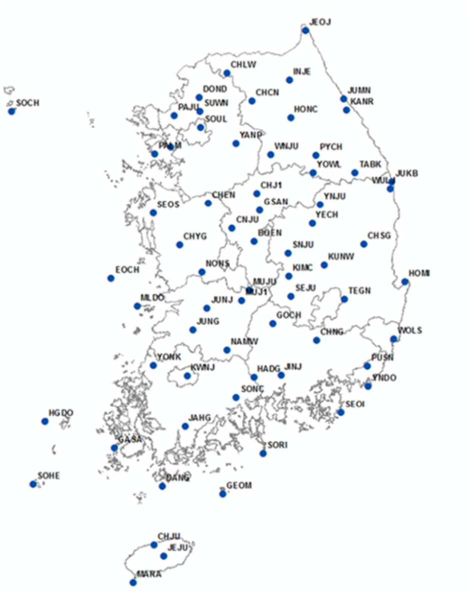
<Table 5> Parcel Boundary Accuracy

Boundary Points	Published value		Network-RTK		Error	
	X	Y	X	Y	dx	dy
1	547677.67	157992.47	547677.701	57992.455	0.031	-0.015
2	547668.89	157012.86	547668.93	157012.88	0.040	0.02
3	547662.40	157025.98	547662.374	157026.041	-0.026	0.061
4	547655.26	157038.78	547655.286	157038.836	0.026	0.056
5	547647.6	157051.25	547647.615	157051.32	0.015	0.07
6	547641.19	157060.93	547641.148	157060.936	-0.042	0.006
7	547634.87	157052.43	547634.88	157052.375	0.01	-0.055
8	547628.87	157052.64	547628.947	157052.603	0.077	-0.037
9	547597.94	157012.89	547597.932	157012.899	-0.008	0.009
10	547599.29	157007.04	547599.276	157007.035	-0.014	-0.005

Boundary Points	Published value		Network-RTK		Error	
	X	Y	X	Y	dx	dy
11	547592.64	156999.16	547592.632	156999.143	-0.008	-0.017
12	547603.14	156994.17	547603.171	156994.169	0.031	0.000
13	547616.54	156988.38	547616.549	156988.395	0.009	0.015
14	547630.15	156983.08	547630.167	156983.049	0.017	-0.031
15	547634.95	156978.29	547634.931	156978.25	-0.019	-0.04
16	547657.89	156974.01	547657.903	156973.992	0.013	-0.018
17	547672.45	156970.12	547672.478	156970.114	0.028	-0.006
18	547676.1	156966.7	547676.023	156966.679	-0.077	-0.021
19	547690.94	156950.92	547690.935	156950.96	-0.005	0.04
20	547687.12	156964.76	547687.09	156964.78	-0.03	0.020
21	547682.68	156978.71	547682.695	156978.703	0.015	-0.007
			Average Error		0.004	0.002
			Standard Deviation		0.033	0.034

4.2.3 Availability of Network-RTK in Korea

National Geographic Information Institute (NGII), Korean government organization, provides Network-RTK service from 2007. RTK network is composed of 50 permanent reference stations and cover whole South Korea. Basically, surveyor can use correction data generated by VRS method for free of charge so that anyone who have Network-RTK receiver can compute 3D location in real-time. Recently, NGII open new port to provide single base RTK and CMR/CMR+ corrections using existing reference stations.



<Figure 3> Permanent Reference Station and field experiment

5. CONCLUSION

Cadastral System Reform project will resolve a number of limitations to protect land ownership and use cadastral information with spatial data. Moreover, it will change existing Cadastre concept, adopt advanced information technology in order to satisfy needs of current society.

Building 3D digital Cadastral system is essential because land use becomes complicate and this cause social costs as using 3D paper cadastral map. To accomplish successful Cadastral Reform, advance survey techniques such aerial photogrammetry and RTK-GPS are considered.

In this study, accuracy analysis of Network-RTK measurements has enough to apply to third-order control points and parcel relocation survey. Work procedure for establishing control network is efficient rather than traditional method, traverse survey using total station equipment. Network-RTK system can determine 3D position with centimeter level accuracy in real time so that registration of building height, underground facilities and so on.

REFERENCES

Byeong-dal Hwang, 2010, Application of 3D Cadastral Control Points Using Network RTK, Journal of the Korea Cadastre Information Association.

Jong-young Son, 2011, A Study on the Driving Scheme for the Cadastre System Reform, Journal of Cadastre.

Jong-young Son, 2011, A Study on the Driving Scheme for the Cadastre System Reform, Journal of Cadastre.

Kam-rae Kim, 2009, Application of Network-RTK Using VRS to Cadastral Surveying, Journal of the Korea Cadastre Information Assiciation.

Chris Rizos, 2002, Network RTK Research and Implementation – A Geodetic Perspective, Journal of Global Positioning Systems.

Arbind Man Tuladhar, 2003, Reengineering Cadastre and Land Registration Systems and Business Opertunities, FIG Working Week 2003.

BIOGRAPHICAL NOTES

Jongmin Lee graduated from Purdue University in United State, earned Master's degree in Department of Civil Engineering. Since 2003, he work in Korea Cadastral Survey Corporation(KCSC)

CONTACTS

Jongmin Lee

Korea Cadastral Survey Corporation
4F, The K-Place, 27-8, 8-gil Gukjegeumyung-ro, Yeongdeungpo-gu
Seoul, 150-891
South Korea
Tel. +82-2-3774-2330
Fax + 82-2-3774-2319
Email: ljm0073@kcsc.or.kr
Web site: www.cari.re.kr