Use of Network RTK using VRS for a Cadastral survey on Islands

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Key words: Cadastral Survey, Island, Network RTK, VRS, Registration

SUMMARY

The Republic of Korea, a peninsula completely surrounded by oceans on three sides, has a lot of islands. However, minor outlying islands and valueless islands were not registered or registered inaccurately in a cadastral record as the record was made out in a condition of inferior surveying technology and poor economic situation in 1910. The recent growth of economy and development of tourism and leisure have brought interests of islands even an uninhabited island, it led to the necessity of registration of islands with a definite position. But for the exact registration, it could happen a dispute over land ownership and enhancement of squatted area and environment for the islands.

It is difficult to register as a definite position in islands using electronic plane table surveying because of the weak positional characteristics of islands such as isolated, small and narrow, geographical weakness. Therefore, a network RTK method using VRS for a cadastral survey on islands has been introduced these days. This method is proper for the cadastral survey on islands as it calculates network corrections for systematic errors based on real-time data from all reference stations and it can survey in any places without environmental limitations.

This paper analyzed the surveying results for network RTK using VRS on islands and presented several expectation effects such as effective island development, protection of expansion of cadastral business, citizens' property rights and realization of multipurpose cadastral surveys by suggesting the alternative of network RTK using VRS in order to record exact registration and cadastral survey on islands.

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1. INTRODUCTION

The Republic of Korea, a peninsula completely surrounded by oceans on three sides, has 3,201 affiliated islands. Islands including uninhabited islands have a key role in terms of tourism, marine resources and military works. Even though these valuable islands are needed accurate and systematic management, in the past, positions of islands were registered inaccurately or omitted in cadastral and forestry maps which are national ledgers. Especially, uninhabited islands where are located far from the land were not registered mostly.

The registration of cadastral data for islands was accomplished mostly during land and forestry survey projects in 1911-1918, but minor outlying islands and valueless islands were not registered in a cadastral record as the record was made out in a condition of inferior surveying technology and poor economic situation at that time. Then, some of the omitted islands in the cadastral record were registered in accordance to 'Investigation guidelines for whole uninhebited islands' which were conducted by Ministry of Interior in 1978. Furthermore, in March 2009, the Ministry of Land, Transport and Maritime affairs established 'A plan for a cadastral registration project on unregistered islands over the country' and planned to conduct from 2009 to 2011 by using established cadastral maps and aerial photos.

A definite positional registration of islands is the most important thing in order to manage a national territory accurately and push ahead with the islands development effectively so a suitable survey method for conditions of islands has to be selected above all to do this difinite positional registration. In case of cadastral survey using electronic plane table, whichi is total station, it takes a long time to establish control points on islands due to absence of control points. Though the existing control points are there, conducting the difinite positional registration would be difficult as errors are inhered in most of them which were destroyed by various development on islands.

The paper analyzed the surveying results for network RTK using VRS on islands and presented application for definite positional registration, installation and repair of control points and cadastral survey etc. using RTK survey based on VRS network to settle the above problems. Through this network RTK method using VRS, difficulties for repair of control points which were already destroyed and time consuming by control points surveying and client complaints can be solved. Furthermore, utilization possibilities have been presented in terms of expansion of cadastral business, effective development on islands, protection of citizens' property rights and realization of multipurpose cadastral surveys as suggesting the alternative method of network RTK using VRS.

2. THE CURRENT CADASTRAL STATUS ON ISLANDS

2.1 Geographical characteristics and current status on islands

Islands described on Act of Island Development Facilitation mean that they are all islands on oceans except for Jeju main island. Article 2 of Island Development Facilitation enforcement ordinance defines that all islands on oceans are territories surrounded by oceans on four sides at high tide.

The Republic of Korea has 3,201 islands all over the country, and among them there are 482 inhebited islands where almost 260 thousand people live. 3,201 islands which total area is 3,765.81km^2 covering 3.76% of the whole country which is 100,032km^2 in area. The total number of household on islands is 278,720 which counts for 0.62% of that of household in the whole country(12,961,138 households). <Table 1> shows the current status on islands investigated(Kim, 2006).

<Table 1> Current status of islands

(UNIT : km^2)

CONTENTS	TOTAL	INHABITED ISLANDS	UNINHABITED ISLANDS
NUMBER	3,201	482(15.2%)	2,719(84.8%)
AREA	3,765.81	3,681.25(97.8%)	84.56(2.2%)

Valueless islands where were difficult to live and small were not registered in Korean cadastral record as the record was made out in a condition of inferior surveying technology and poor economic situation in 1910. Positions of most islands are still not registerd accurately after the registeration set with inaccurate position due to geographical conditions of islands during the land survey project. At that time cadastral surveys were not conducted using triangulate network connected with land areas, so the result of registration is now inaccurate.

As most of islands were isolated geographically and undeveloped socioeconomically, population of islands are getting decreased. Korean government has promoted big and small 3,072 development business on islands which were invested approximate 7,560 trillion US dollars from 1988 to 1997 after enacting Act of Island Development Facilitation in 1986. Interests of islands which landscape are beautiful are growing with economic growth and development of tourism and leisure industries in recent days. Problems such as disputes over land ownership and unplanned development are concerned by these situations. Nowadays, applications of cadastral boundary relocation surveying are getting increase and an interest of definite positional registration projects on islands where were not yet registered are growing.

2.2 Difficulties of cadastral survey on islands

Even though Korea Cadastral Survey Corporation(KCSC), performs various business related

with cadastre as a public organization, has 203 local offices distributed all around the country, it has difficulties to survey on islands in terms of geographical, economic and manpower problems. First of all, most of islands are located far from the land geographically, so surveyors cannot go for the islands survey often. A statistic of KCSC's cadastral survey works on islands says that surveyors visit islands once a month on average, clients appeal inconvenience due to postponement of surveying. When going to an island once to survey, surveyors usually go on a business trip for several days to survey at once. As a result, these matters have brought serious loss to Korea Cadastral Survey Corporation in terms of economic and manpower sides.

Another problem is that most of control points on islands have been disappeared or damaged by unplanned development and improper maintenance. If a cadastral survey is done using total station in this situation, it would take additional time to establish control points again. So, in most cases, cadastral actual state surveys were conducted as measuring arbitrary points based on present condition without cadastral control point surveying. Results of those cadastral actual state surveying have been reflected at the time of site condition so these results might be different from the result registered in the cadastral record due to continuous change of boundaries. These factors make decision on surveying result difficult and bring out inaccurate results conclusively. Even though cadastral control point surveying is preceded in order to get accurate results, it needs considerable economic and time cost because of geographical condition of islands where are difficult to access and isolated.

3. NETWORK RTK USING VRS

Most of islands form coast, forest and farmland not having high-rise or fixed buildings like in urban areas. This environmental condition is proper for GPS reception as it is fairly free from errors and wave interference caused by multi-path error happened in urban areas. As mentioned above, islands are isolated and small areas and cadastral control points on the islands have not been managed systematically. Therefore a network RTK method using VRS is suitable for cadastral survey on islands which can make full use of advantages of GPS survey.

3.1 Concept of RTK

RTK(Real Time Kinematic) is a revolutionary method which can decide a position with high accuracy of centimeter(cm) level in real time. This was originally developed to get quickly precise coordinates of measured points distributed a wide range as doing an alteration survey as well as to compute results which have similar precision acquired from post processing of data. The RTK method makes results of surveying precise and various spatial data needed for mapping acquire in real time. Nowadays it is applied to a variety of fields such as cadastral survey, other surveys, GIS and navigation equipment of flight, ship or car. A principle concept of RTK makes users obtain measured values in real time by using carrier phase measurements of control points which secure precise position. A RTK system uses a single base station and a mobile station. A single base station needs additional means of communication to send measured or corrected data to mobile stations and a mobile station

also needs means of communication to receive these data respectively.
A standard RTK method which is operated by one single base station has a disadvantage limiting a distance of 10~20km between a based station and a mobile station in order to calculate reliable unknown integers quickly. The reason of limiting a distance between receivers is that errors depending on a distance such as orbit errors, ionospheric and tropospheric delay and satellite clock errors increase according to an increase of distance and are not cleared these increased errors properly.

However, these errors can be modeling accurately by using measured data acquired from a base station(GPS reference station) located around a mobile station. This standard RTK method can be improved on accuracy and efficiency by extending a single base station to several base stations, and it is called a network RTK method.

3.2 Virtual Reference Station

There are two methods developed RTK based on network up to now, which are virtual reference point method and MAC(Master Auxiliary Concept) method. The virtual reference point method has three different ones, which are multi reference, FKP and VRS. A word of virtual from VRS(Virtual Reference Station) is started from a concept building up measured values of virtual base stations which are not existed in reality using real base stations within a network. The VRS method elevated performance of existing RTK, which eliminates a spatial correlation of errors as a length of a base line becomes longer, solving a decline problem of positional precision at mobile stations.

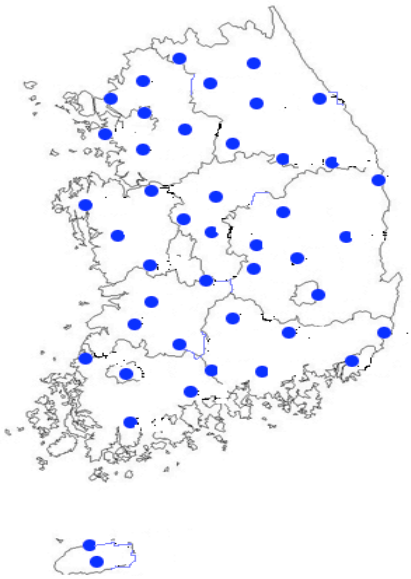
The following contents include a measuring process of a network RTK using VRS(National Geographic Information Institute, 2003).

- GPS data collected from control points within a network of GPS reference stations and positional data of mobile stations using mobile communication units are sent to a main control station, managed by National Geographic Information Institute in Korea. After that, the main control station decides positions of more than 3 control points from neighboring areas of mobile stations.
- The main control station combines measured data of control points and mobile stations and then produces an error model. Created positional information of virtual reference points and created correction data are sent to a receiver of a mobile station.
- Finally, users decide an accurate position based on information received from both correction data sent by a main control station and data sent by GPS satellites.

So, data of VRS are created by integrating data of GPS reference stations within a network and interpolating positions of virtual mobile reference stations which are already separated from statistical errors caused by ionospheric and tropospheric effects etc. The separated errors are interpolated using weight based on a distance between a virtual reference point and a real reference point and corrected values of virtual reference points are created. This data process of VRS is shown in <Figure 1> and <Figure 2> presents an example of installation of RTK.

44 GPS reference stations are distributed all over the country, and <Figure 3> presented the distribution in south Korea.

<Figure 1> Data process of VRS(Vollath, et al, 2002)



<Figure 2> GPS Reference Stations in south Korea
(www.gps.ngii.go.kr)

<Figure 3> Installation of RTK

The method of network RTK using VRS has advantages, it makes effects on statistical errors decrease comparing to an existing RTK method and has high reliability and accuracy and quick initialization time as securing a wide survey range. This VRS method which is possible to obtain quick and accurate results without additional control point surveying may be helpful to improve an efficiency of cadastral survey on islands where control points were already destroyed and located inaccurately. Furthermore, a survey can be conducted everywhere if there are VRS receivers, and unnecessary manpower and cost for surveying can be reduced by using the VRS method.

4. CADASTRAL SURVEY ON ISLANDS APPLYING A NETWORK RTK USING VRS

An application of aerial photogrammetry method can be considered one of approaches for a definite positional registration on islands. A registration on islands by aerial photogrammetry can be brought approximate survey results comparing to results of control point surveying on

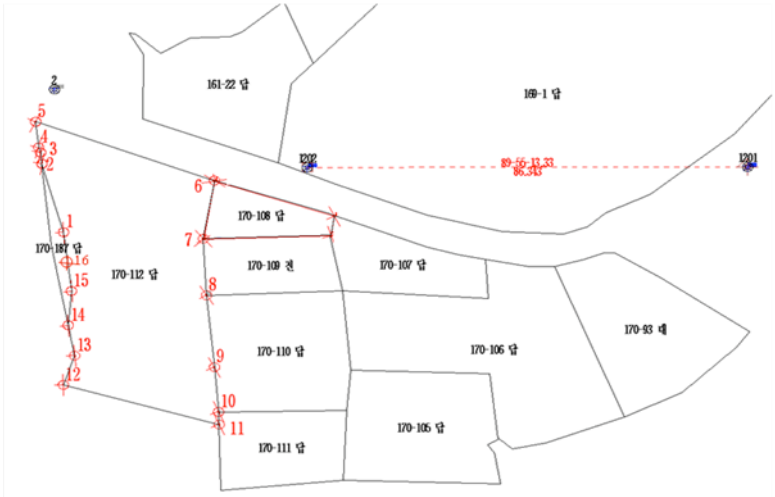
lands. However, errors for registered areas can be occurred as the sea level change according to shooting time is not reflected in the topographic map of aerial photogrammetry. Another limitation is that an error range of positional registration is almost 1^{m} much less than cadastral survey outcome standard needed in Article 27 of Cadastral Survey Act(Kim, 2009). An error range of cadastral survey outcome standard in numerical areas has to be less than 10^{cm} which is specified in Cadastral Survey Act. But a maximum error limitation of aerial photogrammetry results is 28^{cm} regulated in Article 54 of Aerial Photogrammetry Task Regulation. So, it is not precise using aerial photogrammetry on islands because the accuracy of aerial photogrammetry is not satisfied with one of cadastral survey.

And aerial and satellite images are conducted a security clearance process targeting main military facilities and major facilities in terms of security etc. in south Korea. This security clearance is abided by security management regulations such as Geographic Information Security Management Regulation and Security Task Regulation etc. These regulations are hindrances to use aerial and satellite images.

On the other hand, GPS cadastral survey can be conducted regardless of time, weather condition and mutual communication etc. and derive results of centimeter level even on islands far from a land. Therefore, a network RTK method using VRS can be used efficiently for the definite positional registration on islands. For a definite performance evaluation, an accuracy analysis between a network RTK method and total station one which is an original method for cadastral survey was conducted.

4.1 Performance Analysis of a network RTK using VRS

An experimental area for this study was Yeongjong island, Incheon Metropolitan City, located on the west coast. Results of boundary surveying using total station method and the VRS one were compared to analyze validity of a network RTK survey method on islands. <Figure 4> shows the experimental area, especially, a specific parcel which consisted of 16 boundary points was chosen for the performance analysis, and <Table 2> contains measurement results of these 16 boundary points by total station and VRS survey.



<Figure 4> An experimental area(Yeongjong island)

<Table 2> Result of an experiment

(UNIT : m)

Point	Original Coordinates (A)		Total station (B)		VRS (C)		Error (A-C)		Error (B-C)	
	X	Y	X	Y	X	Y	ΔX	ΔY	ΔX	ΔY
1	442806.229	159036.799	442806.227	159036.79	442806.169	159036.852	0.060	-0.053	0.058	-0.062
2	442821.703	159032.557	442821.751	159032.544	442821.708	159032.604	-0.005	-0.047	0.043	-0.060
3	442824.277	159032.298	442824.295	159032.301	442824.257	159032.361	0.020	-0.063	0.038	-0.060
4	442825.413	159031.923	442825.394	159031.919	442825.358	159032.013	0.055	-0.090	0.036	-0.094
5	442831.251	159031.341	442831.197	159031.313	442831.164	159031.391	0.087	-0.050	0.033	-0.078
6	442817.923	159066.385	442817.915	159066.357	442817.87	159066.411	0.053	-0.026	0.045	-0.054
7	442804.753	159064.210	442804.810	159064.229	442804.753	159064.286	0.000	-0.076	0.057	-0.057
8	442791.922	159064.820	442791.978	159064.785	442791.959	159064.862	-0.037	-0.042	0.019	-0.077
9	442775.660	159066.395	442775.651	159066.350	442775.619	159066.419	0.041	-0.024	0.032	-0.069
10	442765.502	159067.190	442765.528	159067.180	442765.558	159067.230	-0.056	-0.040	-0.030	-0.050
11	442762.650	159067.285	442762.699	159067.265	442762.646	159067.348	0.004	-0.063	0.053	-0.083
12	442771.616	159036.749	442771.638	159036.756	442771.594	159036.828	0.022	-0.079	0.044	-0.072
13	442778.235	159038.970	442778.270	159039.001	442778.205	159038.981	0.030	-0.011	0.065	0.020
14	442785.140	159037.710	442785.076	159037.713	442785.099	159037.746	0.041	-0.036	-0.023	-0.033
15	442792.899	159038.346	442792.852	159038.350	442792.858	159038.362	0.041	-0.016	-0.006	-0.012
16	442806.229	159036.799	442806.227	159036.790	442806.169	159036.852	0.060	-0.053	0.058	-0.062

As shown in <Table 2>, maximum errors of differences between original boundary coordinates and VRS measurement values were 0.087m for X and 0.090m for Y. And maximum errors of differences between total station values and VRS measurement ones were 0.065m for X and -0.094m for Y. An error range of measurement differences was in less than 0.094m and was satisfied with an error range of outcome standard in Cadastral Survey Act.

And to check the influence of time and weather conditions, a network RTK survey was conducted two days in row. Target points were the same as boundary points of the above experimental area. <Table 3> presents a comparison of VRS surveying results measured in 29th and 30th June in 2009. Maximum errors of measurement results were 0.036m for X and 0.023m for Y. As a result, a difference of VRS surveying results measured in 29th and 30th June in 2009 was considered to be almost same.

<Table 3> Comparison of VRS measurement

(UNIT : m)

Point	29 June, 2009		30 June, 2009		Error	
	X	Y	X	Y	ΔX	ΔY
1	442806.169	159036.852	442806.162	159036.848	0.007	0.004
2	442821.708	159032.604	442821.680	159032.606	0.028	-0.002
3	442824.257	159032.361	442824.226	159032.350	0.031	0.011
4	442825.358	159032.013	442825.336	159032.007	0.022	0.006
5	442831.164	159031.391	442831.147	159031.389	0.017	0.002
6	442817.870	159066.411	442817.853	159066.409	0.017	0.002
7	442804.753	159064.286	442804.741	159064.263	0.012	0.023
8	442791.959	159064.862	442791.947	159064.862	0.012	0.000
9	442775.619	159066.419	442775.608	159066.403	0.011	0.016
10	442765.558	159067.230	442765.539	159067.219	0.019	0.011
11	442762.646	159067.348	442762.646	159067.368	0.000	-0.020
12	442771.594	159036.828	442771.558	159036.807	0.036	0.021
13	442778.205	159038.981	442778.194	159038.981	0.011	-0.000
14	442785.099	159037.746	442785.088	159037.754	0.011	-0.008
15	442792.858	159038.362	442792.834	159038.372	0.024	-0.010
16	442806.169	159036.852	442806.162	159036.848	0.007	0.004

4.2 Use of VRS survey in Various Projects

Experiments were performed to compare differences of VRS and total station measurement. And those results proved that errors from VRS survey were within the error range of Cadastral Survey Act. The network RTK survey using VRS has application possibilities on surveying on islands because structural errors and other variables like time, weather

conditions etc. of GPS are not limited respectively on islands. Therefore, this survey method can be applied in various ways as follows.

These days Korea Cadastral Survey Corporation have exerted great efforts to diversification of projects such as overseas market development, flooding mark surveying and culture assets surveying etc. as workload of practical cadastral survey have been going down caused by an open-door market of cadastral survey and large-scale land modification like building apartments etc. In this respect, a network RTK method using VRS can be used effectively in those projects due to speed of work performance and accuracy and maintenance of data. As mentioned above, as interests of islands have been increased, the Ministry of Land, Transport and Maritime affairs(MLTM) made a decision to manage uninhabited islands at the government level and planned to promote a project which registers definite positions into a cadastral record for all islands over the country. MLTM conducted a pilot project targeted at Hong-Do, Jeollanam-do province in 2007 and started 'A cadastral registration project on unregistered islands' extending to other islands from 2009. The following <Table 4> presents current status on unregistered islands classified by administrative districts including all islands over the country.

<Table 4> Current status on unregistered islands over the country

(UNIT : km^2)

MUNICIPALITY · PROVINCE	UNREGISTERED ISLANDS	
	NUMBER	AREA
TOTAL	1,419	32,962,182
Gyeonggi-do(Incheon)	283	5,099,584
Gangwon-do	10	44,978
Chungcheonnam-do	261	3,169,910
Jeollabuk-do	121	262,584
Jeollanam-do	399	6,192,023
Gyeongsangbuk-do	23	159,090
Gyeongsangnam-do(Busan, Ulsan)	278	17,997,041
Jeju-do	44	36,972

MLTM turned out that there were 1,419 islands not registered in a cadastral record and expected an increase of the number of Korean islands counted to 4,410 after a completion of this project. The project has not only a significant meaning in terms of management of islands, but also additional effects for an ecosystem preservation project on islands, a coastal tourism promotion project etc. Therefore, a network RTK method using VRS can be used for the definite positional registration project on unregistered islands and it makes not only time efficient, but also accuracy improve. And the definite positional registration may improve administrational efficiency and contribute to protection of property right by preventing unplanned development and disputes over ownership.

The original surveying method using total station obtain just two dimensional coordinates(X, Y) not three dimensional ones(X, Y, Z) previously. In case an elevation value of a control

point is inputted into existing results of cadastral survey, Z coordinates can be applied, managed and updated in various fields. In the process of this development, a variety of studies on three dimensional cadastre have been conducting actively. In the process of this accelerating development, data acquired from the network RTK survey using VRS can be used as preliminary data to set a foundation of three dimensional cadastre and a base for cadastral survey and nationwide cadastral re-surveying project. These three dimensional data can make multi-purpose cadastre realization possible.

5. CONCLUSION

The Republic of Korea, a peninsula, has a lot of islands and interests of cadastral survey and systematic management on these islands have been growing due to development of tourism and lesuire industries. However, there are a lot of difficulties to manage islands systematically as most of islands were not registered at all or registered with inaccurate positions.

This paper analyzed accuracies comparion of VRS survey and total station one. Analysis results proved that accuracies of VRS survey were similar with ones of total station survey. And errors of VRS survey, in less than 0.094m, were within the outcome standard of Cadastral Survey Act. Therefore RTK survey based on VRS network is proper to survey on islands because it can help to register a definite position and conduct prompt and accurate cadastral survey in order to cope with civil complaints on islands.

Furthermore, as the survey is done quickly without an additional contorl point surveying and works out an accurate result of centimeter level, it is economic and efficient for areas where are difficult to survey using the origianl total station. The following contents present a summary of use of the network RTK method using VRS in various fields.

- As cadastral markets were opend in Korea a few years ago, Korea Cadastral Survey Corporation have made efforts to extend projects related to cadastre. As a part of those projects, a definite positional registration project on unregistered islands has been progressing. A use of the network RTK method using VRS can be an efficient and proper way to conduct this kind of project.
- An administrational efficiency can be improved by conducting prompt survey, definite positional registration on islands, as a result, unplanned development and disputes over ownerships on islands can be settled.
- Elevation values are obtained by the method, so these data can be used as preliminary data for studies on three dimensional cadastre and projects. These data will also make multi-purpose cadastre realization possible.

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BIOGRAPHICAL NOTES

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