Development of RTK-GPS Field Quality Checking Module for Korean Cadastral Resurvey Project

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Key words: RTK-GPS, NMEA, Quality checking module, PDA, Cadastral surveying

SUMMARY

Real-Time Kinematic Surveying (RTK-GPS) provides the surveying results in the field, but there is a no reliable way to verify the reliability of surveying results obtained by RTK-GPS.

Therefore, cadastral surveyors can not make best use of RTK-GPS in cadastral surveying that demands high accuracy level. If surveying data has some mistake or error in RTK-GPS surveying, we have to resurvey to check the distance between RTK-GPS and Total Station (TS) at the same field.

The purpose of this study is to verify the quality of RTK surveying results by NMEA data obtained by RTK-GPS and to develop a method in order to enhance the reliability of cadastral surveying so that it could be applied to field surveying. For this, the module which can verify the quality of RTK-GPS surveying results in the field was developed. In the testing module, $GPLLQ data suppling location information can be identified during surveying operation through the PDA screen and RTK-GPS data could be received with the permitting the accuracy and the number already set, calculating standard declination and storing average measurements as decisive coordinates. In order to evaluate the efficiency of the verification module, the results of pilot surveying by TS surveying were compared and analysed. As a result, it is illustrated that the quality verification module of RTK-GPS surveying results could be applied to cadastral surveying very usefully.

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1. INTRODUCTION

RTK-GPS stands for real-time kinematic surveying using GPS and RTK surveying finds increasing applications in cadastral control point surveying or detail surveying, as it can measure location in a narrow area with high level of accuracy. However, GPS is mostly used to survey control point in post-process static surveying method where field surveying is performed for 1~2 hours and control point result is determined in office work. RTK-GPS is not utilized in cadastral supplementary control surveying or detail surveying.

The reason why RTK-GPS is not used actively in cadastral surveying is because, although RTK-GPS surveying can acquire surveying results promptly on site in 1:N arrangement, not requiring visibility, there is no method to verify reliability of its surveying results, making it difficult to utilize RTK-GPS in cadastral surveying that requires maximum level of accuracy.

Notably, as each control point is surveyed independently in cadastral control surveying, it is hard to verify surveying results on site and, if errors are found subsequently in surveying results, surveyors need to make the field trip again and re-survey control points by TS.

In detail surveying as well, errors can be confirmed visually to some extent by comparing digital files of cadastral map and actual surveying results files on site. However, if such errors are in the range of several meters, there is no way to detect them. This study is intended to ensure reliability of RTK-GPS surveying by developing a module that can verify surveying results on site to address such shortcomings as in the above and provide reliable surveying results.

To meet such purpose effectively, the scope of study herein is limited to the following in terms of contents and area. Firstly, in terms of contents of study, field quality checking module that enables surveyors to determine accuracy of real time transmission data on site is to be developed. Secondly, in terms of area of study, an area that encompasses rural area, urban area and mountainous area is to be selected as pilot surveying site.

As for study method, survey points are marked on selected surveying site. Then pilot surveying using RF modem is conducted by RTK-GPS field quality checking module. Then, TS surveying is performed on the same conditions and static GPS surveying is conducted. Lastly, pilot surveying results are analyzed to evaluate viability of RTK-GPS field quality checking module for field surveying application.

2. QUALITY CHECKING MODULE DEVELOPMENT

2.1 NMEA

The following LLQ has been used in the field quality checking module among NMEA-0183 data types for RTK-GPS.

LLQ - Leica Suppling local location and accuracy information

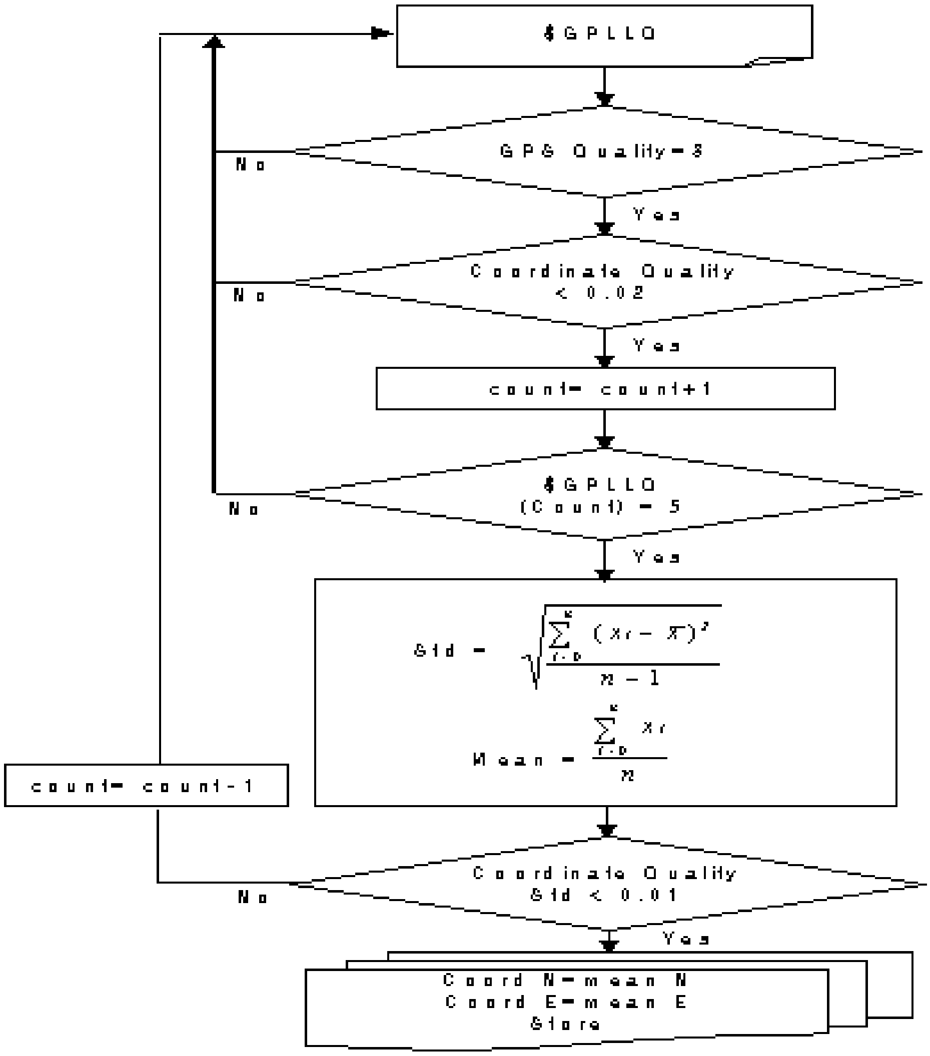
$GPLLQ,020520.00,043008,193122.623,M,446277.260,M,3,07,0.021,-777.952,M * 1D

$GPLLQ Header including Talker ID
020520.00 UTC time of position(02:05:20.00)
043008 UTC date(mmddyy)
193122.623 Horizontal Y coordinate
M Unit of coordinate : Meter
446277.260 Horizontal X coordinate
M Unit of coordinate : Meter

3 GPS quality
0 = Invalid
1 = GPS Nav Fix
2 = DGPS Fix
3 = RTK Fix
07 Number of satellites used in computation
0.021 Coordinate quality
-777.952 Altitude of Antenna
M Unit of altitude : Meter
*1D checksum

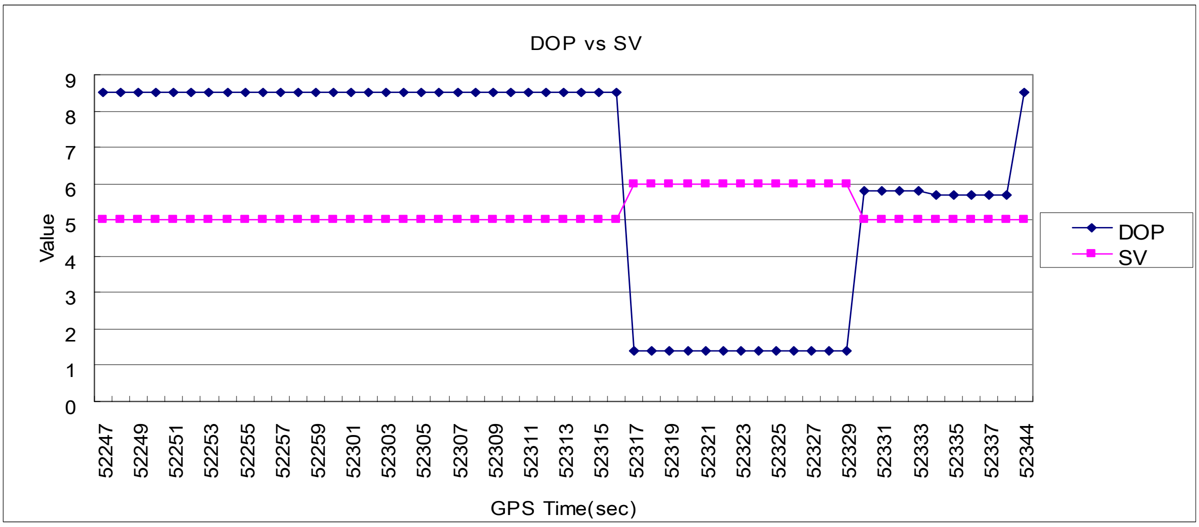
2.2 Developing Field Quality Checking Module

RTK-GPS surveying field quality checking module is developed by "Visual Studio 2008 of Microsoft" and <Figure 1> shows the program process flow of the module. First, acquire $GPLLQ data selectively from GPS receiver among NMEA data of RTK-GPS. Second, select RTK Fix data for which GPS quality is 3 from $GPLLQ chosen in the above. Third, select $GPLLQ data for which Coordinate Quality falls within user-specified accuracy range (Ex.: CD<0.02) from the above data. Fourth, repeat data acquisition until specified quantity (Ex.: 5) of data is selected consecutively. Fifth, calculate standard deviation and mean of location coordinates from 5 $GPLLQ data selected as described in the above. Sixth, if standard deviation is within specified accuracy range (Ex.: Std<0.01), add calculated coordinates and divide the sum by the number of data used for calculation (5) and save final results as determined coordinates. If surveying conditions are not favorable and specified accuracy range is exceeded, the user can decide whether to go on with surveying or not, as the program keeps acquiring data every second until the user saves data. Furthermore, the user can set up accuracy range and data acquisition quantity, depending on locale and purpose of survey.



<Figure 1> Program Process Flow

<Figure 2> shows actual data surveyed in test surveying area, indicating DOP and number of satellites per hour. As high-rise apartment complex was situated in the vicinity and trees were located right next to the survey site, the location of the site were not favorable for RTK GPS surveying. As the graph shows, 5 satellite signals were received for about 70 seconds after survey started and PDOP was 8 or more, indicating poor data quality. Then, for about 12 seconds, 6 satellite signals were received and PDOP changed close to 1 before number of satellite signals fell and PDOP began to rise again.



<Figure 2> DOP and number of satellites per hour

RTK-GPS field quality checking module is designed to ensure reliability of RTK-GPS surveying by selecting only coordinates of good quality for calculation based on data received for 12 seconds of stable reception period even if overall reception status is unstable.

Even if GPS Quality and Coordinate Quality are good, reliable RTK-GPS surveying data may not be acquired. For example, even if the user moves antenna pole momentarily from a certain survey station while surveying, GPS Quality and Coordinate Quality values that fall within user-specified range can still be received. However, data measured when antenna pole is moved always corresponds to the point right below the center of antenna. Accordingly, if mean value is calculated blindly, other values may be affected, therefore, standard deviation is calculated and data corresponding to antenna movement is excluded to enhance accuracy of surveying product.

Furthermore, as RTK-GPS field quality checking module uses PDA, it is lightweight and mobile, not needing Rover Controller. Thus, even a beginner can check survey progress with ease by viewing NMEA data reception information right on PDA display on site. It is designed to be easy to use and produce reliable surveying product.

2.3 Performance Evaluation on Field Quality Checking Module

Yeouido Ecology Park that has features of both urban district and mountainous area was selected as pilot survey area of this study in consideration of varying impacts that specific site conditions may have on RTK-GPS surveying.

To conduct pilot surveying, 4 control points (do1~do4) were confirmed first and 11 observation points (p1~p11) were marked in consideration of site conditions and visibility for TS, static and RTK surveying. Leica System 500 was used as survey equipment with SR530 receiver, AT502 antenna and RF wireless modem. For testing, the module was installed in PDA which was connected in place of Rover Controller.

As for equipment installation, reference was installed at a random point marked and rover was installed on tripod to check accuracy.

For conversion of area coordinates, cadastral control points of the pilot test area were identified as shown in <Table 1>.

<Table 1> Published coordinates of cadastral control points(Supplementary) in the pilot test area

Control Name	X coordinate(m)	Y coordinate(m)
d1	446113.24	193406.64
d2	446195.88	193229.10
d3	446285.59	193050.44
d4	446470.46	192728.41

In case of surveying by RTK-GPS field quality checking module, GPS data was received for around 30 seconds per each of the 4 cadastral control points for coordinate conversion and for around 10 seconds per each observation point to ensure accuracy in comparative analysis. After all, all survey points were saved when a message that surveying was performed as intended by field quality checking module (F.Q.C.M) on PDA display before moving to the next point.

To determine viability of RTK-GPS surveying in consideration of survey site conditions, adjacent area where trees and building were located was also surveyed and RTK-GPS was fixed after 10 seconds elapsed in general and, depending on surveying hour band, there was significant difference in time passed before RTK was fixed.

<Figure 3> Correction data not transmitted

<Figure 3> shows a state where correction data is not transmitted from Reference, which indicates initial surveying state. PDA display shows 6 satellites but GPS quality is 1, indicating GPS Nav Fix status.

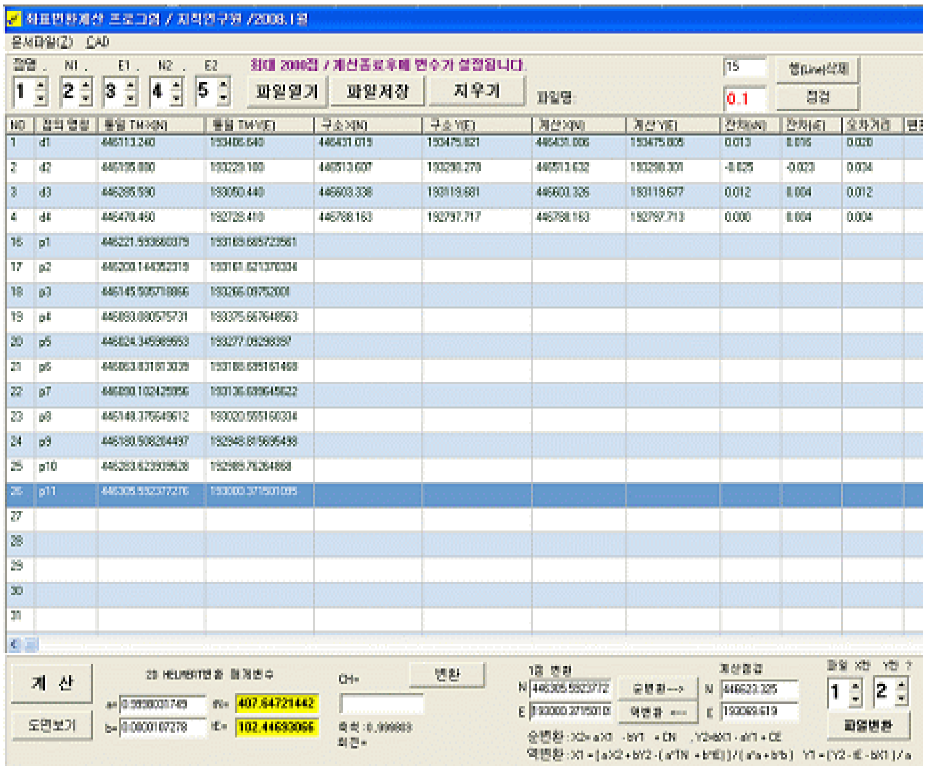
<Figure 4> indicates that RTK-GPS surveying is in progress as usual. As the PDA display shows, 7 satellites are used for calculation and GPS quality is 3, indicating RTK Fix status. OK sign is shown at the bottom left of the PDA display, indicating that location coordinates in the pilot test area are within specified tolerance range and surveying product quality is acceptable. Furthermore, 'Good' message shown at the bottom right indicates that wireless communication quality is good.

<Figure 4> GPS surveying data received accurately on PDA

If 'Good'message is shown at the bottom right, indicating good wireless communication quality and RTK-GPS survey progress as usual, but, location coordinates are out of specified range, 'Moved' message is shown in the left, urging the user to wait rather than fixing data or observe data again. In addition, if measured coordinates are out of user-specified accuracy range and communication quality is poor, Moved in place of OK will be displayed at the bottom left and 'Bad' will be shown at the bottom right.

As described in the above, the field quality checking module is designed to enable even a beginner to understand surveying status with ease while conducting RTK-GPS surveying in the field or switch to TS surveying if site conditions do not permit RTK-GPS surveying at all.

In the pilot surveying, coordinate error range was set at 5cm or less and wireless communication error range was set at 2cm or less given site conditions. As such, stable surveying products were acquired in both OK and Good status. <Figure 5> shows determined point coordinates based on coordinate conversion values.



<Figure 5> Determined point coordinates based on coordinate conversion values.

2.3.1 Surveying Results Verification by TS

TS surveying was performed to verify the results produced by the module in the pilot survey. As for surveying equipment, Sokkia SET230R, two pole and pole tripods were used. Observation was made by the 3 repetition method and calculation was conducted by the SIP system (Survey Information Processing System) developed by Korea Cadastral Survey Corporation in 2008. Calculation results showed that observation had been performed with good quality given that connection error was 0.05m when tolerance range was ±0.23m.

Furthermore, azimuth angle of given point and distance calculation result are shown in <Table 2> and determined coordinates by repetition angle observation and distance measurement by TS are indicated in <Table 3>. In case of determined coordinates, as azimuth angle of arrival calculated for given point d3→d4 is 299-51-32.9 and azimuth angle of arrival for which observed value is 299-52-15, 42.1 seconds out of tolerance =±108 seconds are assigned to observation angle of each survey point.

<Table 2> Azimuth and distance calculation

Name	X(m)	Y(m)	Direction	Azimuth	Distance(m)
d1	446113.24	193406.64	d2→ d1	114-57-38.5	195.83
d2	446195.88	193229.10			
d3	446285.59	193050.44	d3→ 4d	299-51-32.9	371.32
d4	446470.46	192728.41			

<Table 3> Determined coordinates by repetition angle observation and distance calculation

Survey Points	Target Points	Observation Angle	Horizontal Distance(m)	Azimuth	Determined Coordinates	
					X(m)	Y(m)
d2	d1			114-57-38	446195.88	193229.10
d2	p1	178-27-42	64.77	293-25-17	446221.63	193169.67
p1	p2	87-07-29	22.94	200-32-37	446200.15	193161.62
p2	p3	97-04-18	117.91	117-36-53	446145.49	193266.11
p3	p4	177-57-42	121.50	115-34-33	446093.04	193375.71
p4	p5	299-32-34	120.17	235-07-05	446024.31	193277.13
p5	p6	238-57-01	96.84	294-04-04	446063.80	193188.71
p6	p7	182-44-54	58.26	296-48-54	446090.08	193136.71
p7	p8	179-49-50	130.01	296-38-42	446148.37	193020.52
p8	p9	177-28-48	78.62	294-07-27	446180.50	192948.77
p9	p10	267-33-03	110.98	21-40-28	446283.62	192989.76
p10	p11	184-02-38	24.41	25-42-58	446305.61	193000.35
p11	d3	266-04-23	53.94	111-47-17	446285.59	193050.44
d3	d4	8-04-15		299-51-32		

<Table 4> shows the comparative verification results of RTK surveying results with TS surveying results.

<Table 4> RTK surveying results verification with TS surveying results (unit: m)

Survey Points	RTK		TS		RTK-TS		Misclose vector
	X(N)	Y(E)	X(N)	Y(E)	△ X	△ Y	
p1	446221.594	193169.666	446221.63	193169.67	-0.036	-0.004	0.036
p2	446200.144	193161.621	446200.15	193161.62	-0.006	0.001	0.006
p3	446145.506	193266.098	446145.49	193266.11	0.016	-0.012	0.020
p4	446093.081	193375.668	446093.04	193375.71	0.041	-0.042	0.059
p5	446024.346	193277.093	446024.31	193277.13	0.036	-0.037	0.052
p6	446063.832	193188.695	446063.80	193188.71	0.032	-0.015	0.035
p7	446090.102	193136.700	446090.08	193136.71	0.022	-0.01	0.024
p8	446148.376	193020.555	446148.37	193020.52	0.006	0.035	0.036
p9	446180.508	192948.816	446180.50	192948.77	0.008	0.046	0.047
p10	446283.624	192989.763	446283.62	192989.76	0.004	0.003	0.005
p11	446305.592	193000.372	446305.61	193000.35	-0.018	0.022	0.028
RMSE					0.0224	0.0260	0.0166

As the table indicates verification results of RTK surveying results by module with TS surveying results, □X showed an error of less than 1cm at survey points of p2, p8, p9, p10 and □Y showed an error of 1cm or more at p1, p2, p7, p10 and both □X and □Y at other survey points showed an error of 5cm or less. Connection errors at p2 and p10 were almost the same with each other while it was the biggest at p4 as 5.9cm. In addition, standard deviations of □X, □Y and misclose vector were estimated to be 2.24cm, 2.6cm and 1.66cm respectively, indicating that the surveying results had no problems and the field quality checking module was effective.

2.3.2 Surveying Results Verification by STATIC

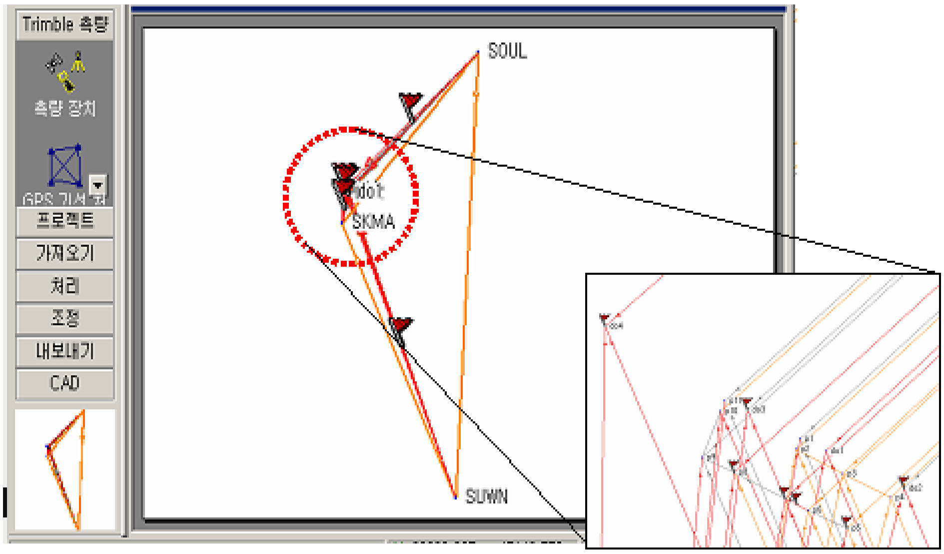
To verify the quality of RTK surveying results by F.Q.C.M, pilot surveying by STATIC was conducted in addition to TS surveying. Leica System 500 was used as survey equipment with two SR530 receiver and AT502 antennas. Observation time was 30 minutes for each survey point.

Trimble Geomatics Office was used to process observed values and Korea Cadastral Survey Corporation 1998/10/30 VERSION 2.1 was used as Korean coordinate system for conversion with GPS (WGS84) coordinate system. Fixed point used for calculation was calibrated accurately by data based on fixed network of GPS observation stations at SUWN (Suwon), SOUL (Seoul) of National Geographic Information Institute and SKMA (Seoul) of Korea Astronomy and Space Science Institute. Surveying products at the GPS observation stations used herein are as shown in <Table 5>

<**Table 5**> Published surveying results at the GPS observation stations used herein

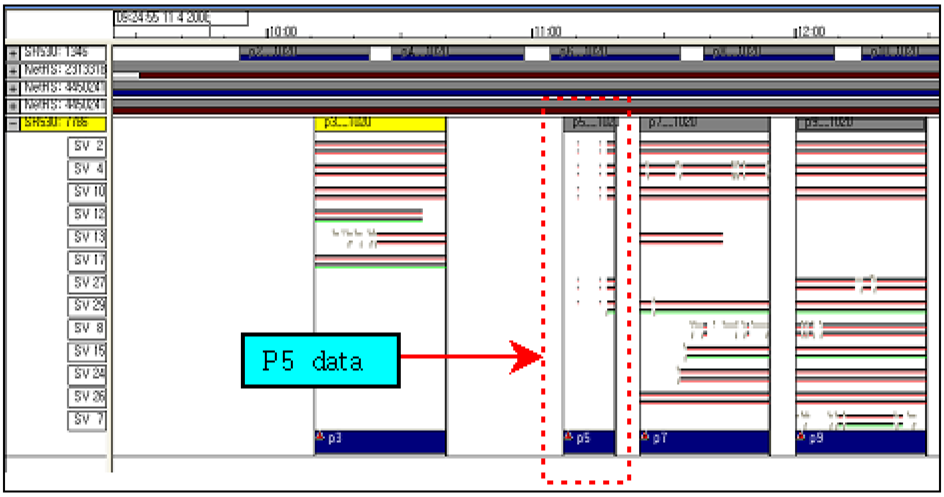
Station Name	GRS80				Owner
	Latitude	Longitude	H	Origin	
SUWN (Suwon)	37-16-31.8529	127-03-15.2638	83.816m	Middle	NGII
SOUL (Seoul)	37-37-46.8973	127-04-47.0067	59.109m	〃	〃
SKMA (Seoul)	37-29-36.70257	126-55-04.79368	61.697m	〃	KASSI

<Figure 6> shows data processed by TGO program with 3 GPS observation stations fixed.



<**Figure 6**> data processed by TGO program with 3 GPS observation stations fixed.

As excessive error occurred at survey point P5 among surveying products calculated by 3D network adjustment, reception data status was analyzed. GPS data was received without any problem at all observation points for 30 minutes. However, it was not received at P5 for the first 20 minutes before being received for around 10 minutes later. Therefore, as reception time at P5 was relatively shorter than other survey points, it was analyzed in the data processing stage that excessive error occurred. <Figure 7> indicates analysis result of data received at P5 in the field.



<Figure 7> Analysis result of data received at P5 in the field.

Coordinates conversion was conducted to convert the coordinates of each survey point in WGS84 datum determined by static surveying to local coordinates in Bessel datum. 4 common points were used for coordinates conversion and conversion was made using surveying results at supplementary control points from d1 to d4. In case of survey point p5, gross error was propagated as was even after data processing.

<Table 6> shows coordinates conversion results of coordinates conversion program developed by the Cadastral Research Institute. As the mean square an error is ±0.028m, determined conversion Parameter is believed to be reliable.

<Table 6> Coordinates conversion results.

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        우리나라 좌표계와 GPS(WGS84)좌표계간의 변환계산
          지적기술연구소. 1998/10/30 VERSION 2.1
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1.관련정보

  1) 지역명등 : 여의도 관측데이터 처리
  2) 측 량 자 : '김준식'
  3) 고정점명 : '성과점검-관측소3점고정망조정결과'
  4) 사용기종 : '라이카'

2.입력정보 |

  1) 총 점 수 :  15
  2) 사용점수 :   4
  3) 변환변수 :   6
  4) 고정변수 :   1

3.계산처리

1) 변환파라메터 :  4 점을 이용하여  6 변환계수를 구함. 뒤 1 변수는 고정치임.

   (X0)      (Y0)      (Z0)       (RX)      (RY)      (RZ)     SCALE
 119.846  -568.379  -568.987     4.533     0.272    10.995    -6.662

2) 평방제곱근 오차 :   0.028

   * X-성분 :   0.022
   * Y-성분 :   0.017
   * Z-성분 :   0.003

3) 파라메터 오차

   (X0)      (Y0)      (Z0)       (WX)      (WY)      (WZ)     SCALE
 820.059 10700.031 10607.604   428.752   148.800   181.232     0.000

 * 다음의 결과는 변환파라메터의 결정에 활용치  않은 점들의 계산성과임

   p1        446221.619   193169.609        15.82
   p2        446200.144   193161.586         7.31
   p3        446145.507   193266.052         7.19
   p4        446093.074   193375.612         6.72
   p5        446025.406   193277.071         4.64
   p6        446063.847   193188.649         4.97
   p7        446090.091   193136.703         4.96
   p8        446148.363   193020.538         4.95
   p9        446180.536   192948.765         4.85
   p10       446283.640   192989.761         7.03
   p11       446305.607   193000.329        15.70

      ==================== !! 계산종료 !! ====================
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<Table 7> shows comparative quality verification results between coordinates determined by RTK-GPS surveying and coordinates at each survey point determined by static GPS surveying.

<Table 7> RTK surveying results verification by STATIC (unit: m)

Survey point	RTK		STATIC		RTK-STATIC		Misclose vector
	X(N)	Y(E)	X(N)	Y(E)	△ X	△ Y	
p1	446221.594	193169.666	446221.619	193169.609	-0.025	0.057	0.062
p2	446200.144	193161.621	446200.144	193161.586	0.000	0.035	0.035
p3	446145.506	193266.098	446145.507	193266.052	-0.001	0.046	0.046
p4	446093.081	193375.668	446093.074	193375.612	0.057	0.056	0.080

	RTK		STATIC		RTK-STATIC		
p5	446024.346	193277.093	446025.406	193277.071	-1.060	0.022	1.060
p6	446063.832	193188.695	446063.847	193188.649	-0.015	0.046	0.048
p7	446090.102	193136.700	446090.091	193136.703	0.011	-0.003	0.011
p8	446148.376	193020.555	446148.363	193020.538	0.013	0.017	0.021
p9	446180.508	192948.816	446180.536	192948.765	-0.028	0.051	0.058
p10	446283.624	192989.763	446283.640	192989.761	-0.016	0.002	0.016
p11	446305.592	193000.372	446305.607	193000.329	-0.015	0.043	0.046
RMSE		All			0.3030	0.0202	0.2932
		p5 exception			0.0141	0.0208	0.0207

<Table 7> indicates comparative verification between coordinates surveyed by RTK surveying and static surveying, □X values were exactly the same at survey point p2 and differed only by 1mm at p3, indicating that the coordinates surveyed by two different approaches were relatively identical to each other. However, the difference widened at p5 to 1.06m in X axis and 2.2cm in Y axis. As indicated in the above, such difference is attributable to failure to receive satellite signals as usual due to field troubles. Therefore, when data was processed in relation to other survey points for which data was sufficient, excessive error occurred in a certain direction due to inherent characteristics of GPS surveying such as satellite arrangement over time and elimination of common error by differential method. In case of □Y value, the smallest difference was 0.02cm at p10 and the biggest was 5.7cm at p1. Misclose vector equal to or bigger than 5cm appeared at 4 survey points including p5. In addition, except for p5 where excessive error occurred, standard deviations of □X, □Y and Misclose vector were estimated to be 1.41cm, 2.08cm and 2.07cm respectively. Therefore, except for □X at P5, surveying results determined by static surveying and RTK-GPS surveying did not show significant differences.

3. ISSUES IN THE NEAR FUTURE

Areas to be registered newly in cadastral records in the contexts of cadastral resurvey model project, land readjustment or farmland readjustment are expected to be registered by ITRF coordinates from 2010 and converting cadastral records of other areas to ITRF coordinates is under consideration. To ensure uniform registration by ITRF coordinates, promoting use of RTK-GPS that can provide uniform cadastral surveying products promptly is urgently called for.

However, RTK-GPS surveying is not actively used, as it is difficult for a beginner to use and there is no way to verify the quality of surveying products in the field. Accordingly, a module designed to enable even a beginner to use RTK-GPS surveying approach by displaying OK and Good messages on PDA screen in reference to user-specified quality range and verify survey data in order to ensure reliability of cadastral surveying products has been developed. However, the module still has room for further improvement.

Pilot surveying conducted as a part of this study has indicated that survey data may vary considerably, depending on time band, even if surveying is conducted at the same location and for the same period of time. Although with some difference across survey points, RTK-GPS data was fixed at some survey points in a minute following antenna pole installation. However, RTK-GPS data was not fixed even 10 minutes later at the same points when surveying was performed in different time band. What could be considered in relation is the satellite arrangement per time band and geometry of survey location. The module proposed herein will be developed further in consideration of time band, DOP and number of satellite signals received, etc. In addition, the module will be applied to cadastral resurvey model projects to identify further user requirements and incorporate such requirements in subsequent studies.

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