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Downtown Area Cadastral Boundary Surveying Using Real-time GPS/GLONASS Combination

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Abstract

To manage national territory and cadastral data efficiently, accuracy and cost-efficiency in cadastral boundary surveying is inevitable. The efficient management of cadastral data is a very important element in national land management. Survey techniques are being introduced. Recently, improvements in survey techniques have been made with the development of satellite surveying, Allowing accurate and fast surveys. If we can calculate the output accurately in real-time in survey fields, it will open a new method in cadastral detail surveying. According to the classification on Law of cadastral surveying, Cadastral surveying can be divided into cadastral control point surveying and cadastral detail surveying. The control point survey can be divided into cadastral triangulation surveying and cadastral traverse surveying. The detailed survey is usually perform by plane surveying. Among these, cadastral detail surveying will be reviewed in this study. In this study, the combination of the satellites, such as US managed GPS and Russian managed GLONASS was used. In the satellite survey in downtown, data interruption symptoms arose(according to the mask angle of the satellite). Therefore; we combined the satellites to get date more accurately. A block of Haewoondae New City in Busan, Korea, which has Numerical Cadastral Law was selected as the sample area for this study. Block II and III are surrounded by high rise apartments. One side of Block I and IV is level ground and the other side is full of high rise apartments. Especially, Block II is surrounded by high rise apartment houses with 20 meters width. In the results of the study Block II did not satisfy the allowable precision, while Block I, II and IV satisfied the allowable precision of the enforcement regulations of Cadastral Law. Therefore, it is judged that the traditionally used Total Station method should be used for supplementary survey on Block II, in stead.

Keywords : *GPS, GLONASS, Cadastral Boundary Surveying, HDOP, Data Rate*

1. Introduction

Nowadays, interest in the quantitative technology of cadastral surveying has increased dramatically. Especially in Korea, it has developed rapidly under the purpose of the cadastral re-surveying projects. However, there have been significant research only in numerical cadastres, which have been done graphically. Therefore, Total Station and GPS(Global Positioning System) became noticed for numerical cadastre.

With the government's support, cadastral triangulation, topographic control surveying and detail surveying at GPS observation centers(full-time observation station). But, in the downtown, it is impossible to survey because the minimum 5 visible satellites for surveying GPS cannot be secured.

In this research, detail surveying was tried in the downtown by assembling GPS controlled by the USA and GLONASS(Diggelen, 1997) controlled by Russia (David, et al, 1995). The center of the city is concentrated with 25 story buildings, and visible satellites are very few. To increase visible satellites, a survey was done at a distance of 5m to 10m from the cadastral boundaries, and its results were analyzed.

2. The Summary of GPS and GLONASS

2.1 The Theory of GPS and GLONASS

NAVSTAR GPS(NAVigation System with Time And Ranging Global Positioning System) is a system

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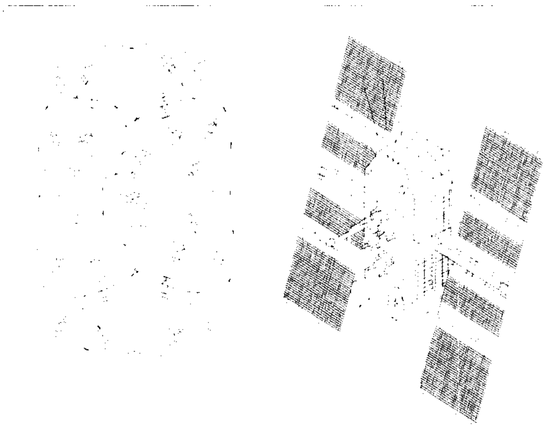

Fig. 1. GPS orbits and its Satellite.

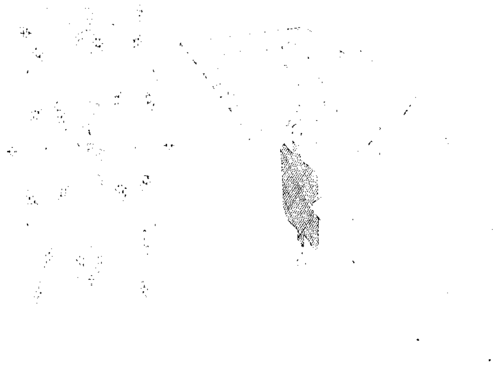

Fig. 2. GLONASS orbits and its Satellite.

Table 1. The Comparison between GPS and GLONASS System

Parameter	GPS	GLONASS
No. of satellite	21+3 spares	21+3 spares
No. of orbital planes	6	3
Orbital inclination	55°	64.8°
Orbit altitude	20,180km	19,130km
Period of revolution	11hr 58m 40s	11hr 15m 40s
Geodetic datum	WGS 84	SGS 85
System time correction relative to	UTC[SUNO]	UTC[SU]
Frequency band L1	1.575MHz	1.602～1.615MHz
Frequency band L2	1.228MHz	1.246～1.256MHz
Codes	same for all satellites C/A-code on L1 P-code on L1, L2	different for all satellites C/A-code on L1 P-code on L1, L2

for precise navigation and 3 dimensional positioning using radio waves from satellites made by the Department of Defense of the USA since 1973(Leick,A, 1995). This system is composed of Space Division with 4 satellites in 6 orbits, controlling division and user division including receivers. The shape of the orbits and satellites of GPS are shown in Figure 1.

The Soviet Union also developed GLONASS (GLObal NAvigation Satellite System) similar to GPS after 1970^{th}(Zhodzishsky, M., et al,1999). In 1988, the Soviet Union started to dissolve information data, and provided the system for international use. GLONASS was also composed of space division, control division and user division. The shape of the orbits and satellites of GLONASS are shown in Figure 2, and the comparison between the systems is shown in Table 1(Lee In-soo, 2001).

2.2 Performances of GPS and GLONASS

The GLONASS system began in 1982 with its first satellite launched in August 30 thatyear. A full constellation of 24 satellites was reached on Jan 18, 1996. The Russian authority, for one reason or another, has failed to maintain the full constellation after a year (Holmes et al., 1998). A possible lack of funding for launches together with an aging satellite population put the system operating with 10 to 16 healthy satellite since September 1997. Another explanation for lack of urgency to launch new satellites thereby maintaining a full constellation is that most of the current satellites are operating well(with more than 80% of Russia covered) even though many of them have exceeded their design lifetime of three years. Figure 3 shows that the number of GLONASS satellites is always two to four lesser than the number of GPS satellites in the Boston area at 42.5o N latitude and 71.3o W longitude.

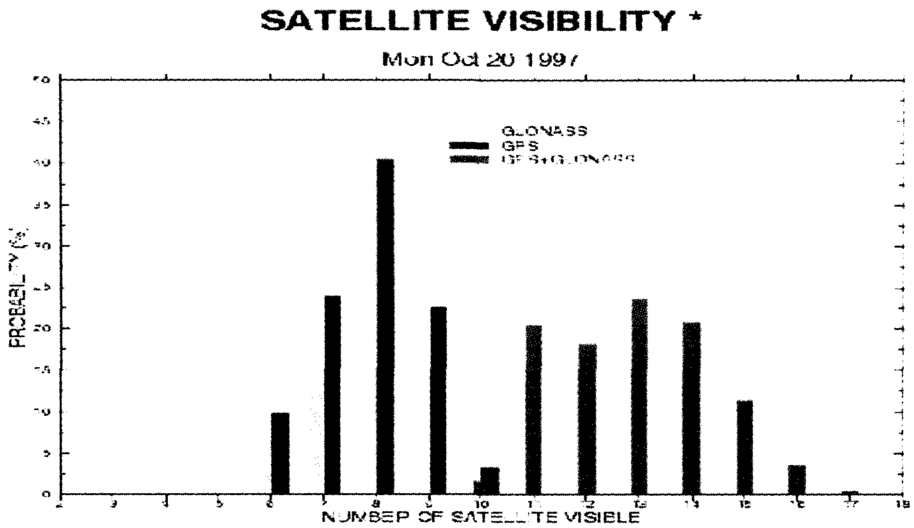

Fig. 3. GPS and GLONASS Satellite Visibility on October 1999.

Despite some of the less-than-encouraging news from the recent GLONASS constellation, there is however a number of inherent advantages GLONASS has over GPS. The most beneficial one is that GLONASS has no SA or any other technique implemented to purposely degrade its ranging accuracy. No SA mode in GLONASS played an important role in many stand-alone GLONASS applications. In terms of accuracy, the UERE of GLONASS has been reported at 10 metres level(Daly & Misra, 32 1994). Compared to the 25 metres UERE from GPS with SA on(7 metres UERE with SA off), GLONASS is advantageous. It is hence able to meet the requirements of many users in Russia and world-wide. In terms of coverage, users in higher latitude areas, such as Canada, obtain better GLONASS derived dilution of precision(DOP) than that of GPS. This is due to the high inclination angle of GLONASS: 64.8 degrees compared to 55 degrees for GPS.

3. Field Observation

3.1 The area to be observed

The Area to be observed is a sector in Haewundae Busan Korea. The survey was done for 6 days from February 4 to 9, 2002. Figure 4 shows the cadastral map of this area.

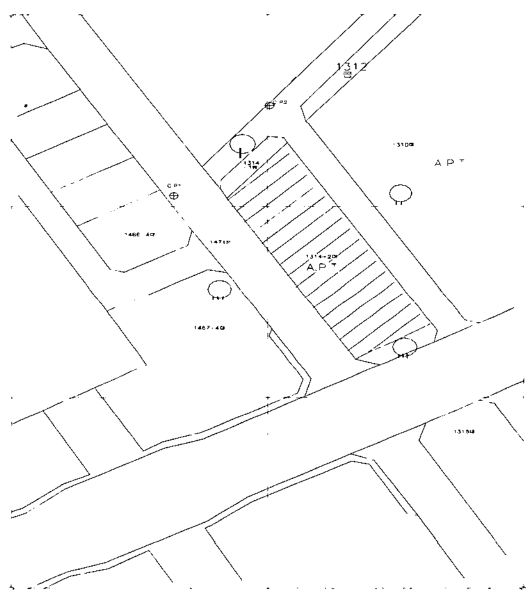

Fig. 4. The Observation area of the cadastral map.

3.2 Devices For Observation

Receivers are L1/L2, C/A-code, P-code and a JAVAD product, which can receive carrier waves with 20

Table 2. Specification of the surveying devices

Tracking Specification			Performance Specification	
Tracking	Signals Tracked	Measure Mode	RTK Mode	
			H	V
40 L1 channels, 20 L1+L2 channels GPS/GLO (optional)	L1/L2 (L1-C/A &L1/L2 Full Cycle Carrier, P1/P2)	Static Kinematics RTK DGPS	10mm+1.5ppm (×Base) for 2 freq.	20mm+1.5ppm (×Base) for 2 freq.

channels. A Legant was used as an antenna. The specification of these devices is shown in Table 2.

4. The Results of the Observation and its Analysis

4.1 The Results

Using RTKGPS and RTKGG(GPS/GLONASS), the target area was surveyed along the cadastral boundaries. As shown by Figure 5, the data acquisition rate was only 24%, due to a shortage of visible satellites. So, surveying was impossible.

However, when RTKGG(GPS/GLONASS) was used, the data acquisition rate was 76%, which was enough to do surveying.

The target area was surveyed by assembling RTKGPS and RTKGLONASS, and the area was subdivided into 4 areas. Figure 6 shows these areas and the cadastral boundaries.

As shown by Figure 7, in Area I, apartments with H = 75m are located at the right side 10m from the cadastral boundary, and the left side is flatland. The survey results along the cadastral boundary are shown in Table 3. In Area II, the intervals between both the cadastral boundaries and higher buildings are 1.0m and 3.0m respectively, and the intervals between the 75m-height building and other building around is approximately 14m. Visible satellites of RTK GPS or RTK GLONASS were too few to measure.

The boundary of Area III is apart from the 75m-height building. Table 3 shows the surveying results of RTKGG. The right side was not included in this research. As shown by Figure 7, the left cadastral boundary is only 12m apart from high buildings, and the right boundary is only 2m apart from buildings. So, surveying was impossible. Table 3 shows the result of surveying the center line of a road which is 7m apart from the buildings.

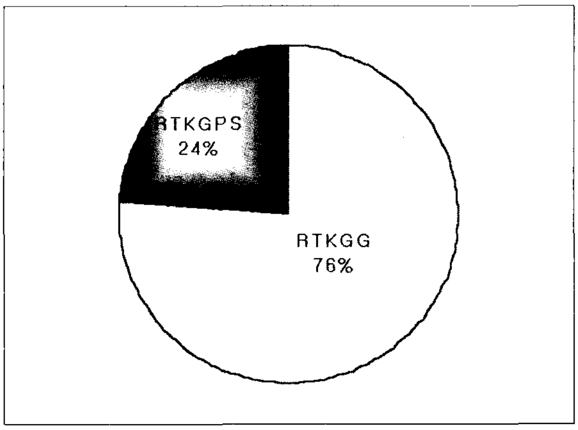

Fig. 5. The data acquisition rate of GPS and GLONASS.

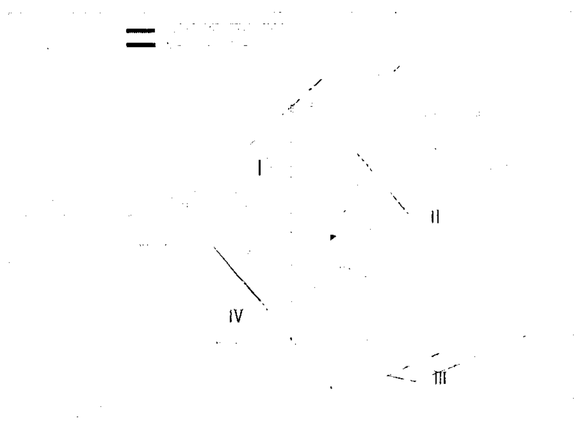

Fig. 6. The target area divided by satellites.

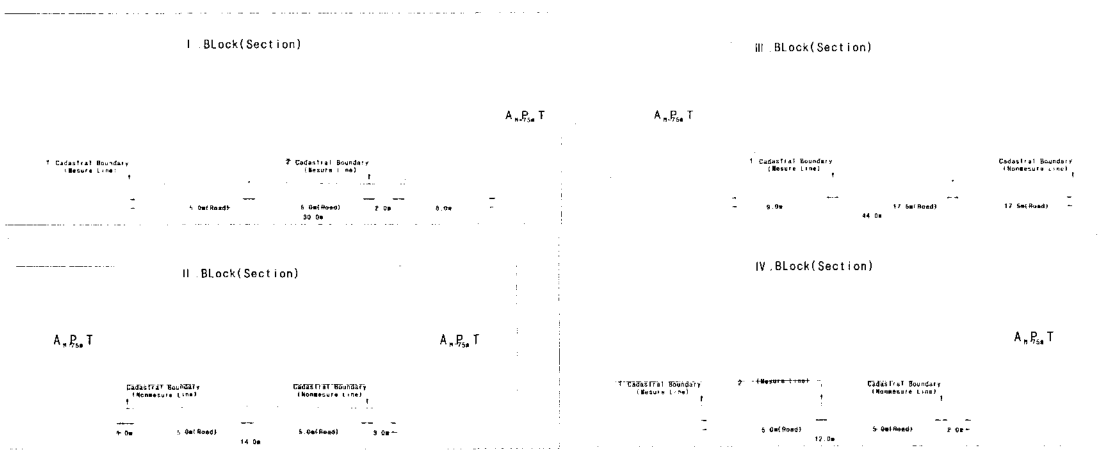

Fig. 7. Sectional drawings.

Table 3. The surveying results for each section by RTKGG

NO	I		III		IV	
	X	Y	X	Y	X	Y
1	216102.3730	185838.5340	216163.6290	185738.4460	216084.0460	185784.3420
2	216102.6520	185838.5580	216163.9600	185737.8140	216083.4020	185785.4390
3	216102.6570	185838.5690	216163.9950	185737.8590	216082.8400	185786.5620
4	216102.6880	216164.6950	185736.3840	216082.1410	185787.6520	185787.6520
5	216102.6740	185838.5250	216165.0910	185735.5600	216081.3070	185788.9410
5	216102.6850	185838.4950	216165.1040	185734.7630	216080.6940	185790.0670
6	216102.7210	185838.5410	216164.7420	185733.9120	216079.8880	185791.2430
7	216101.1680	185836.8110	216164.4150	185732.7780	216079.2350	185792.1600
8	216099.5950	185834.7110	216164.2610	185731.7680	216079.2370	185792.1700
9	216095.6000	185829.7620	216163.9840	185730.4470	216094.3880	185766.4850
10	216095.0160	185829.0090	216163.6410	185729.5810	216095.2240	185765.0830
11	216102.4850	185838.4720	216162.4950	185728.7670	216096.1980	185763.4550
12	216101.8520	185837.6970	216161.6410	185728.2710	216096.9640	185762.0970
13	216100.3620	185835.7240	216158.0110	185724.9470	216098.0260	185760.4210
14	216098.6430	185833.4980	216160.6600	185727.7900	216090.5350	185772.3780
15	216097.9020	185832.5690	216160.4480	185727.3730	216091.4650	185771.0860
16	216096.9720	185831.4790	216160.4570	185726.4330	216092.5190	185769.4450
17	216096.2800	185830.6970	216159.5790	185725.6210	216093.3930	185768.0940
18	216094.3120	185828.2150	216148.7360	185720.9490	216105.3540	185747.9840
19	216083.7930	185815.0110	216156.6650	185724.2360	216106.1010	185746.6160
20	216082.8240	185813.9860	216155.5130	185723.6820	216107.0740	185744.9990
21	216081.8780	185812.7150	216154.1820	185722.9510	216107.8170	185743.7660
22	216080.9780	185811.5340	216153.1520	185721.8110	216108.7310	185742.1670
23	216079.8050	185809.9250	216151.4650	185721.3160	216109.5270	185740.8940
24	216078.8580	185808.5370	216150.4170	185721.5950	216110.3770	185739.4690
25	216078.5820	185807.9920	216149.9950	185721.5180	216118.5450	185725.8700

4.2 Analysis of Data

4.2.1 The Accuracy of the Digitizer

To express graphical cadastral maps numerically, original prints of the cadastral maps were digitized. One of the most important elements in digitizing is the conformity between cadastral maps and digitizers. In Affine conversion, RMS Error was 0.2376m, and Standard deviation was 0.0006m. It was a satisfying result. The surveyed data were analyzed using the RTKGG method, assuming the boundaries of numerical cadastral maps were true.

4.2.2 Errors in Detail Surveying of Numerical Cadastral Maps

Normally, geometrical elements such as distances and angles are used in numerical cadastres. But, because there is no reference about permissible error in detail surveying in Korea, Japanese regulations were referred as shown by Table 4(Kang Tae-seok, 1996). "Eul 1" was used in this research, and the values of "Eul 1" are that Mean RMSE(root mean square error) is 25cm and tolerance is 75cm.

Table 4. The error tolerance for an area

Classification	Positioning error of boundary corner	
	Error of average square(cm)	Allowable error(cm)
Gap1	2cm	6cm
Gap2	7cm	20cm
Gap3	15cm	45cm
Eul1	25cm	75cm
Eul2	50cm	150cm
Eul3	100cm	300cm

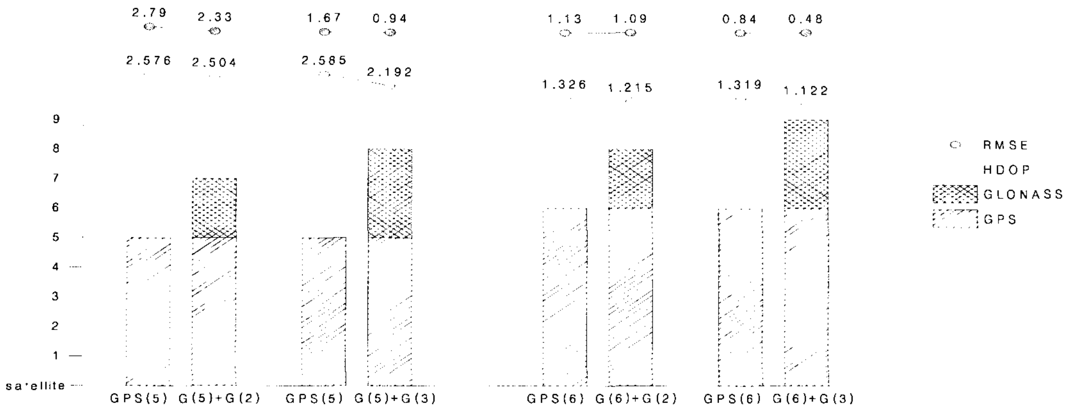

Fig. 8. Result of Real Time GPS/GLONASS combination by Analysis.

4.2.3 Result of Real Time GPS/GLONASS combination by Analysis

Result of RTKGPS/GLONASS combination by Analysis is acquainted and appears in Fiqure 8. The 5 of satellites GPS and when add 2 more GLONASS, resulted in improvement RMSE 16%, HDOP 3%, and when add 3 more GLONASS, resulted in improvement RMSE 44%, HDOP 15%. The 6 of satellites GPS and when add 2 more GLONASS, resulted in improvement RMSE 4%, HDOP 8%, and when add 3 more GLONASS, resulted in improvement RMSE 42%, HDOP 15%.

4.2.4 Analysis for Each Area

1) Analysis of Area I

Area Iwas surveyed with RTK GG, and apartments with H = 75m are on the right side 10m from the first cadastral boundary, and 30m apart from the second boundary. The surveyed values were expressed in linear, and overlaid on the numerical cadastral map. Survey points were displayed in 2m intervals based on numerical cadastral boundaries. Table 5 shows the differentials. The mean error on 10m points was 0.3543m, and that of 30m points was 0.0992m. The results satisfied tolerance(75cm of "Eul 1", the surveying error limit of a parcel of land in Japan.

2) Analysis of Area III The right side of Area III is flatland, and there are 75m-height apartments 9m apart from the left cadastral boundary. The left cadastral boundary was observed using satellite surveying RTKGG. The surveyed values were expressed in linear, and overlaid onto the numerical cadastral map. Survey points were displayed at 2m intervals based on numerical cadastral boundaries. Table 5 shows the differentials. The mean error on 10m points was 0.5180m. The results satisfied tolerance(75cm of "Eul 1", the surveying error limit of a parcel of land in Japan.

3) Analysis of Area IV At the right side of Area IV, there are 75m-height buildings 2m apart from the cadastral boundary. There are only a few visible satellites. When surveying at a 7m distance, visible satellites were available. And, the cadastral boundaries at 12m distance were surveyed and analyzed. The surveyed values were expressed in linear, and overlaid onto the numerical cadastral map. Survey points were displayed at 2m intervals based on numerical cadastral boundaries. Table 5 shows the differentials. The mean error on 7m points was 0. 6538m, and that of 12m points was 0. 2947m. The results satisfied tolerance 75cm of "Eul 1", the surveying error limit of a parcel of land in Japan. Figure 9 shows the mean errors of each detached distance from high buildings.

Table 5. The result of sectional analysis (Unit: m)

No	Area I		Area III	Area IV	
	10m	30m	9m	7m	12m
1	0.3163	0.1213	0.4309	0.6487	0.3006
2	0.3865	0.0859	0.4949	0.6496	0.3120
3	0.3361	0.0843	0.5588	0.6557	0.3094
4	0.3012	0.0742	0.5807	0.6548	0.2435
5	0.3387	0.0921	0.5474	0.6539	0.3142
6	0.3263	0.1144	0.5141	0.6531	0.2808
7	0.3882	0.1310	0.4808	0.6522	0.3030
8	0.3923	0.0771	0.5053	0.6504	0.2915
9	0.3752	0.1018	0.5088	0.6600	0.2911
10	0.3824	0.1100	0.5586	0.6592	0.3011
Average Error	0.3543	0.0992	0.5180	0.6538	0.2947

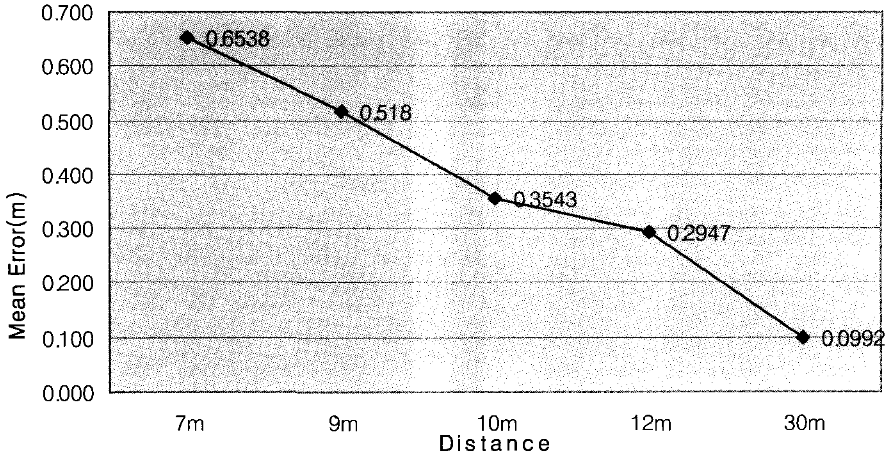

Fig. 9. The average error for each distance.

5. Conclusion

The results of detail surveying on the downtown using Real Time GPS/GLONASS are outlined below.

Firstly, when observing the downtown full of high buildings using RTKGPS, the data acquisition rate was only 24% due to a shortage of visible satellites. However, when RTKGG(GPS/GLONASS) was used, the data acquisition rate was 76%, which was enough to do surveying. Surveying using an assembly of GPS and GLONASS was more efficient in the aspects of securing visible satellites, and improving accuracy.

Secondly, when observing the area divided into 4 sub-areas, detached distances from high buildings influence observing accuracy considerably. Mean errors were 0.6538m, 0.5180m, 0.3543m, 0.2947m and 0.0992m at a distance of 7m, 9m, 10m, 12m and 30m respectively. When surveying at more than a 7m distance, permissible error regulation(tolerance 75cm) was satisfied. Especially, when more than 10m is secured, accuracies were rather high.

Thirdly, as shown in Area II, when high buildings (H = 75m) are located within the interval of 14m, detail surveying using Total Station is desirable, because visible satellites are not affordable. Fourthly, it may be more economic and efficient to numerical cadastral maps if detail surveying is done by assembling RTKGPS and RTKGLONASS in a downtown.

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