ASSESSMENT OF VRS-GPS FOR PRACTICAL APPLICATION TO LOCAL CONTROL SURVEYING

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ABSTRACT:

With the geodetic datum switching over to JGD2000 (Japan Geodetic Datum 2000) and the opening of GPS data in real time observed by GEONET (GPS Earth Observation NETwork) system, it has been expecting to use the data in surveying of local control points, public survey and so on. It is considered that a new method of RTK-GPS positioning called VRS (Virtual Reference Station) is a prevailing technique for higher precise positioning in real time with higher efficiencies and lower costs by using the minor multiple reference stations of GEONET in a wider area. In order to verify practical applying and the positioning precision of the new RTK-GPS by VRS at the local control points for public survey, field experiments are carried out. As the result of observation, the standard deviation in 3-components of positioning by VRS-GPS is about 2 cm in horizontal and less than 4 cm in vertical. Since the environment for GPS observation in real time is not very good in the residential area of city, there is potentiality for higher positioning precision for VRS-GPS positioning in comparatively better environment. This paper gives a detailed report about the experimental results, the ways for solving some problems and conclusions.

1. INTRODUCTION

Ii is well known that there are some limitations in GPS positioning survey by the traditional way of RTK, both in the cost and the precision. For example, an additional set of GPS receiver is needed for rover's own reference station, but also it is necessary to spend time and energy for setting it. Moreover, the precisions of survey results are under many restrictions such as the distance of baseline between the reference station and the rover, simply the longer a baseline is, the more likely the positioning precision is to fall down due to the effects of the ionosphere and the troposphere.

However, a new method of RTK-GPS positioning called VRS (Virtual Reference Station), as a prevailing technique for higher precise positioning in real time with higher efficiencies and lower costs, can resolve such problems as mentioned above. Because of a wide network covered by multi-reference stations is used to create a VRS near rover, it is possible to do precise positioning surveying everywhere in a wide area just by receiving the correction data from a LBS (Location Business Service), not need to set rover's own reference station one by one in a wide area.

As one of the largest and densest permanent GPS arrays in the world with more than 1200 GPS stations (up to 2003) at an average separation between the stations each other of about 25 km, the GEONET (GPS Earth Observation NETwork) just provides an ideal infrastructure for the new RTK-GPS by VRS. GEONET has been constructed by GSI (Geographical Survey Institute) for monitoring crustal deformation in Japan since 1993. Now, it covered the Japanese islands as not only a foundational monitoring network of crustal deformation, but also the new geodetic control points of Japan.

Since continuous observation is been operating by every station 24 hour per day, in a sense the GPS observation data of GEONET is a huge resource. It has been expecting to take the multiple reference stations of GEONET as the reference network in a wider area and use their data in real time to survey local control points for public survey and so on. GPS data observed by 200 stations of GEONET was provided in real time to the private sector from May 2002. There have been nearly 1000 stations opened with their real time data since October 2003.

In order to verify the validity, practical application of VRS-GPS and its positioning precision in local control surveying, some field experiments were carried out. This paper reports the experimental results and the solutions for solving some problems of the actual field observation. Finally, the conclusions are given.

2. EXPERIMENTAL SURVEYING

The experimental field is located in Toyonaka city of Osaka. The surveying by GPS positioning in real time is carried out at the 3rd and 4th grade local control points total in 32 points that are distributed in a residential area and along three routes (Figure 1). The experimental contents of RTK-GPS positioning by VRS and used hardware & software are shown in Table 1. The methods of experiment and their configurations are presented in Table 2.

At each point, the RTK-GPS positioning by VRS is repeated under different surveying conditions from January 27 to 31, 2003. Table 3 gives the details of different surveying conditions and ways for RTK-GPS positioning. Figure 2 shows two reference networks that VRS is based.

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Experimental date carried out	January 27(Mon.) – 31(Fri.), 2003
Field of experiment	Residential area of Toyonaka City, Osaka (500m^2) (Figure 1)
Public control points used for surveying	32 control points of 3rd and 4th grade in total at 3 routes of I, II, and III (Figure 1)
System of VRS	GPSnet (Trimbls); Operating by LBS provider - JENOBA
Reference stations	Sakai, Inagawa, Ootsu2, Koubechuo, Minoo of GEONET (Figure 2)
Rover's data communication	Mobil phone of J-Phone

Table 1. Summary of the experiment, used hardware and software

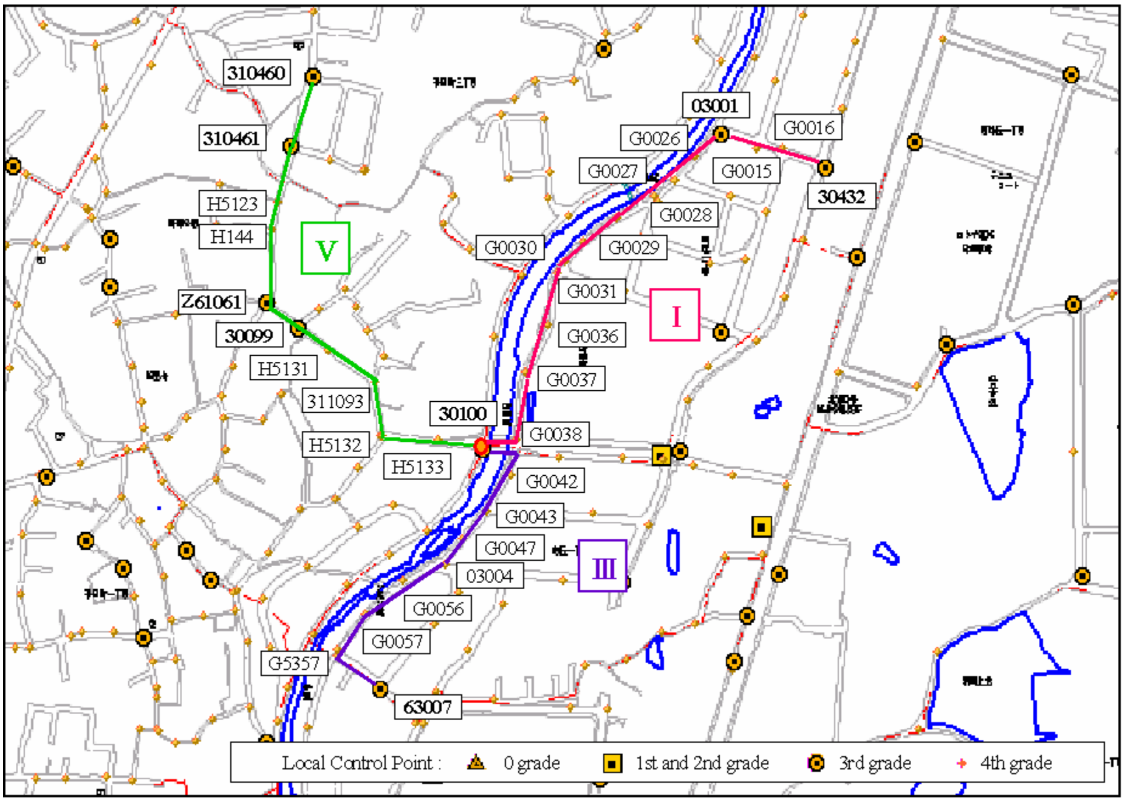

Figure 1. Distribution map of local control points for public surveying
(A total of 32 local control points of 3rd and 4th grade spread over a residential area in Toyonaka city)

Surveying of the control points	A repeated positioning at each point of 3 routes under different surveying ways
Elevation of GPS satellites	10 degree both in VRS system and the rover
The limits of 20 epochs per set	PDOP: less than 4; The deviation in XY is less than +-20 mm and +-30 mm in H

Table 2. Methods of experimental surveying and their configurations

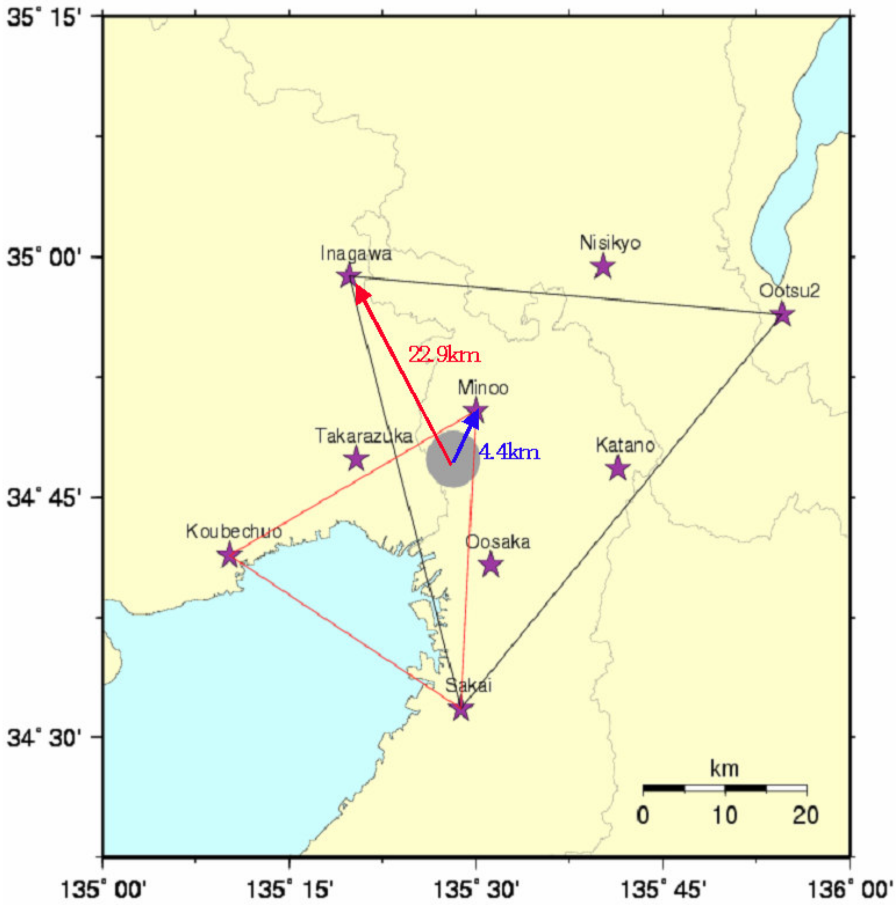

Figure 2. Location map of field and the distribution of GPS continuous observation stations of GEONET used for reference networks in this experiment
(The distance from field to the nearest reference station: 4.4 km in the smaller network and 22.9 km in the larger network)

Surveying by using the different coordinates	Fix the "Geodetic Coordinates 2000" to all reference stations
	Fix the "Recent Analytic Coordinates" to all reference stations
Surveying by using the different REF. networks (refer to Figure 2)	The larger Network (Sakai, Inagawa, Ootsu2) with an average baseline length of 55 km
	The smaller Network (Sakai, Koubechuo, Minoo) with an average baseline length of 34 km
Surveying by using the different RTK systems	The traditional RTK-GPS Correction data: RTCM2.2 / Type 1,3,16,18,19,22
	A new RTK-GPS by VRS Correction data: RTCM2.2 / Type 1,3,16,18,19,59
Surveying by using different GPS receivers	Trimble 5700 (receiver) / Zephyr (antenna) / TSC1 (controller)
	Leica SR530 (receiver) / AT502 (antenna) / TR530 (controller)

Table 3. Details of different surveying ways for RTK-GPS positioning in experiment

VRS Positioning 20 epochs / 1 Set		Trimble 5700				Leica TR530			
		n	NS	EW	UP	n	NS	EW	UP
Larger Ref. Network Geodetic Coord. 2000	the average	**95**	**-19**	**-51**	**146**	**97**	**-25**	**-63**	**146**
	standard deviation		**24.3**	**17.4**	**41.2**		**17.6**	**16.3**	**41.2**
[illegible]	the average	42	-20	-47	147	40	-28	-57	136
	standard deviation		22.1	17.7	38.1		13.9	15.7	40.1
[illegible]	the average	25	-9	-63	132	30	-15	-76	150
	standard deviation		25.1	15.1	37.1		19.3	12.9	40.1
[illegible]	the average	28	-26	-45	156	27	-31	-59	158
	standard deviation		24.9	13.2	46.9		16.7	12.7	41.8
Larger Ref. Network Recent Analytic Coord.	the average	**59**	**-119**	**51**	**41**	**65**	**-115**	**48**	**28**
	standard deviation		**16.1**	**17.0**	**31.0**		**17.7**	**14.5**	**31.6**
[illegible]	the average	26	-114	55	31	37	-115	55	24
	standard deviation		13.5	13.1	24.4		20.6	11.6	29.7
[illegible]	the average	18	-114	40	49	18	-110	34	28
	standard deviation		13.0	16.8	29.3		10.1	12.4	23.4
[illegible]	the average	15	-132	55	46	10	-120	44	40
	standard deviation		17.5	18.7	39.9		16.8	12.4	47.9
Smaller Ref. Network Geodetic Coord. 2000	the average	**58**	**-7**	**-21**	**23**	**54**	**-6**	**-22**	**11**
	standard deviation		**17.5**	**15.2**	**26.9**		**15.3**	**13.0**	**22.7**
[illegible]	the average	24	-10	-19	26	23	-10	-21	9
	standard deviation		22.0	12.3	22.6		17.1	6.4	18.5
[illegible]	the average	18	-3	-31	15	16	2	-35	12
	standard deviation		11.9	13.9	30.2		14.6	9.0	25.3
[illegible]	the average	16	-8	-14	27	15	-7	-11	12
	standard deviation		15.5	15.3	28.8		9.4	12.8	26.9
Smaller Ref. Network Recent Analytic Coord.	the average	**39**	**-114**	**47**	**-12**	**44**	**-121**	**49**	**-38**
	standard deviation		**15.7**	**13.6**	**19.3**		**10.9**	**10.2**	**20.6**
[illegible]	the average	21	-123	55	-22	26	-125	54	-34
	standard deviation		10.9	9.9	14.1		9.5	7.2	23.9
[illegible]	the average	18	-104	38	-1	18	-114	42	-44
	standard deviation		13.9	11.9	18.8		9.7	10.3	13.5
[illegible]	the average								
	standard deviation								
Traditional RTK-GPS Geodetic Coord. 2000	the average	**57**	**2**	**-19**	**18**	**60**	**-16**	**-20**	**-13**
	standard deviation		**19.1**	**14.1**	**30.8**		**16.0**	**14.7**	**22.1**
[illegible]	the average	26	5	-15	7	27	-10	-11	-20
	standard deviation		18.5	11.9	26.4		13.0	11.0	19.6
[illegible]	the average	16	-7	-29	37	16	-11	-37	-19
	standard deviation		11.8	11.7	30.4		12.6	9.1	18.8
[illegible]	the average	15	4	-17	18	17	-31	-18	3
	standard deviation		24.1	15.8	30.4		13.9	8.9	21.6

Table 4. Summary of positioning results by RTK-GPS and their precisions (unit: mm)

3. RESULTS AND DISCUSSIONS

This experiment aimed at the precision estimation of RTK-GPS positioning by VRS, which depended on the correction data provided by LBS provider. Table 4 gives the statistics of experimental results and their precisions according to the different surveying conditions and methods. The following observations can be made from the results shown in Table 4:

1. In general, well precision has been obtained from experiment. As the result of RTK-GPS positioning by VRS, the standard deviation was about +-2 cm in horizontal components and +- 3 to 4 cm in vertical component. It is considered that there is no remarkable difference between two different types of GPS receiver.

2. The results of RTK-GPS positioning by VRS based on the smaller reference network (the nearest station is Minoo) are consistent with that of the traditional RTK (the reference station is Minoo). Both of their positioning results under the "Geodetic Coordinates 2000" are most closed to the public coordinates of the local control points.

3. There are some systematic errors in positioning results especially at the North-south component irrespective of the reference networks or the types of GPS receiver when the "recent analytic coordinates" are used to the reference stations. A main reason for the general deviation between the "Geodetic Coordinates 2000" and the "recent analytic coordinates" could be caused by crustal deformation during the past several years.

4. Due to the variedness in the velocities of crustal deformation, there are systematic errors in coordinates of local control points between the public results in "Geodetic Coordinates 2000" and the VRS-GPS positioning results based on the reference stations with the coordinates in "Geodetic Coordinates 2000". Still more, the systematic differences vary remarkably with the size of reference network.

It should be mentioned that the RTK-GPS positioning by VRS suffered the effects of multi-path of carrier waves and sky visibility of GPS satellites because more than half of surveying points in the experimental field are located in such cases as near the curve mirrors, street lighters, buildings and so on. There are some similar wrongs of positioning results at some specific points owing to surrounding the worse environment. Therefore, it is considered potential to improve the positioning precision in comparatively better environment for surveying. In fact, it is possible to get the VRS positioning in high precision as that as the results achieved by static observation with the enough number of GPS satellites and stable better PDOP.

However, there are also some problems in the actual field observations. For example, it is necessary to remove the systematic errors caused by crustal deformation and make a consistency processing between the public results in "Geodetic Coordinates 2000" of the existing control points and the VRS-GPS positioning results of new points surveyed. Moreover, it is also necessary to use the others measuring methods, such as the current method by TS (Total Station) for surveying in and around such environment where GPS positioning in real time is impossible at present.

4. CONCLUSION

This paper introduced a new GPS positioning way of RTK-GPS by VRS using in surveying of local control point for public survey. The precision estimation of positioning results surveyed by VRS is also proposed. As the result of filed experiment, the standard deviations of 3-components of real-time positioning by VRS are about +-2 cm in horizontal and less than +-4 cm in vertical and meet the demand for survey precision of local control point. Since the field environment for RTK-GPS observation by VRS is not very good in and around the residential area where the experiment was carried out, the potentiality and possibility for higher positioning precision are expected in better environment.

Since most of the local control points in residential area are located nearby the houses, trees and so on, it is expected that the current method of TS could take the place of RTK-GPS by VRS for surveying at such points. Now, The combined surveying method called "VRS-TS" is being used in our public surveys, and the validity is proved with its effectivities and higher precision.

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