Testing CORS System for Cadastral Surveying

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SUMMARY

CORS surveys with GNSS have been used for a variety of different surveying applications. Surveyors, GIS users, engineers, scientists, and the public at large that collect GNSS data can use CORS data to improve the precision of their positions. CORS enhanced post-processed coordinates approach a few centimeters relative to the Reference System, both horizontally and vertically. A network of Continuously Operating Reference Stations (CORS) that provide Global Navigation Satellite System (GNSS) data consisting of carrier phase and code range measurements in support of three dimensional positioning, meteorology, space weather, and geophysical applications. Its use for cadastral work is becoming commonplace. A case study was conducted to investigate the use of the CORS technique for boundary surveys. For this purpose, measurements were performed in the city of İstanbul, Turkey. Fourteen points were selected in both normal and difficult measurement conditions in the project area. The analyses were made in three steps. In the first step, the CORS results obtained on different periods were compared with each other; in the second, the total station observations have been realized on site to assign as fixed coordinates in evaluations; in the last step, the CORS measurement results were compared with those of the total station. The results showed differences of up to centimeters between the coordinates derived from the two survey methods in the obstructed areas. We conclude that the CORS technique competes well with the traditional survey methods in terms of accuracy except in obstructed areas.

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1. INTRODUCTION

Cadastral survey is the discipline of land surveying that deals with either geometrical definition of the boundary property or legal assignment and/or registration of landowner, and which manages and arranges this relationship based on laws. There have been various techniques used for cadastral surveying such as digital cadaster using total stations and Global Positioning Systems (GPS) instruments, digital aerial photogrammetry, and cadastral mapping using high-resolution satellite images [1]. Cadastral maps produced by cadastral surveys are fundamental requirement to enhance a sustainable and justified determination and arrangement on land properties regarding owner rights.

With continual research and development into GPS/GNSS systems, the techniques and systems have become more reliable, cheaper and more productive, which brings the GNSS more attractive for variety of surveying solutions [2]. GPS/GNSS based survey for point positioning has become a fundamental survey technique for all kind of engineering and related survey issues. Furthermore, the advantages of the technique and the recent developments regarding positioning have been issued to different disciple studies as well. The usage areas of GPS/GNSS system have been widened due to technological developments and methodological enhancements that have been met in recent years. Among the various types of surveys, particularly cadastral survey, GPS/GNSS based surveying method has found significant importance in terms of accurate positioning, easy to apply, less labor on site.

CORS surveys with GNSS have been used for a variety of different surveying applications. Surveyors, GIS users, engineers, scientists, and the public at large that collect GNSS data can use CORS data to improve the precision of their positions. A case study was conducted to investigate the use of the CORS technique for boundary surveys. For this purpose, measurements were performed in the city of İstanbul, Turkey. A group of data points (14 points) was selected in both normal and difficult measurement conditions in the project area. In the first step, the CORS results obtained on different times were compared to each other; in latter, the total station measurement have been done assigned to be fixed; in the third, the CORS measurement results were compared with those of the total station. The results showed differences of up to centimeters between the coordinates derived from the two survey methods in the obstructed areas.

2. RTK GNSS IN CADASTRAL SURVEYING

RTK GPS is the dynamic GPS positioning technique using short observation time; this system provides precise results in real time. To achieve higher positioning accuracies (decimeter or centimeter level) in real time, the double differencing technique should be implemented using carrier phase data [3]. kinematic carrier phase based positioning can be carried out in real

time if an appropriate communications link is provided over which the carrier phase data collected at a static base receiver can be made available to the rover receiver’s onboard computer to generate the double-differences, resolve the ambiguities and perform the position calculations [4], which is referred as “Real Time Kinematic” (RTK) GNSS positioning. The survey principle of RTK GNSS depends on using and processing carrier phase observations for providing point positions in cm level positioning precision.
The Network RTK (NRTK), which is an active system, had been developed in order to determine high precise position data in short time intervals to the surveyors, GIS/LIS (Geographic Information Systems/Land Information Systems) professionals, engineers, scientist and other users since 1990s [5]. Regarding the nature of the methodology, post-processing of the data to obtain a position solution in RTK survey facility is not required, which presents to the users allowing real-time surveying results in the field. This method allows the surveyor to make corner moves (stake out) similar to total station/data collector methods.
As it is well known, staking out, positioning detail points and application works usually require much time and effort when traditional (terrestrial) equipment and procedures are used. With this relatively new method of positioning, however, these tasks can readily be carried out in much less time and with accuracy equal to (or even better than) that provided by the terrestrial methods [6].

3. TEST SURVEY

3.1 Test Environment

The study is concerned with establishing the existing guides’ information for the use of RTK GNSS for cadastral surveying in Turkey, to define and identify its use in professional practice. Thus, the testing area is selected due to physically changed site conditions that are relevant to control points, which are located in open area and very close to high buildings. Moreover, the aim of the testing is to achieve desired accuracy for the use of RTK GNSS for cadastral surveys and determine whether RTK may in fact achieve terrestrial survey (provided by total station observations) standard similar observation accuracy.

(a) (b)

Figure 1. (a) Aerial photography (Yandex, 2015) (b) Sketch of Area of Interest

On this manner, an experimental area for this study has been selected on Pendik of İstanbul, Turkey, located on the eastside of İstanbul. Fig. 1 shows the aerial photography and sketch of the area that show the physical site conditions combined with testing ground points. 14 points have been examined regarding the study on the boundary of the parcels and also taking attention of point selection being near the buildings to determine the effects which may cause noises on the residential areas (see Fig. 2).

Figure 2. Testing pictures of control points

3.2 Survey Methodology

The boundary coordinates of the parcel has been surveyed by both terrestrial survey using total station and GPS/GNSS method, and the validation of GPS/GNSS system has been analyzed by comparing the results that were obtained on horizontal coordinates. Test study has been realized in two different survey time to ensure the repeatability, which may also provide data to examine precision effects of satellite access.
In the testing area for boundary surveying, there were four traverse ground points and three of them were used in the testing facility. Initially, the stake out of the boundary points were performed based on terrestrial survey methodology using total station and then, the coordinates of boundary determined have been taken as permanent location information. The lateral stage of testing is performed by RTK GNSS survey methodology. To ensure network approach, ISKI UKBS CORS network have been preferred. FKP mode have been considered to receive corrections of coordinate differences. Two period surveys have been handled to get repeated data for RTK surveys.

3.3 Test Results

To evaluate the performance of RTK surveys in cadastral applications, the total station (TS) survey obtained have been assigned as fixed solutions and two period RTK GNSS survey results have been compared with TS results for coordinate components. Table 1 shows the total station survey results indicated as original coordinates during the calculation process and two period RTK survey results.

Table 1. Coordinate chart for TS and RTK surveys

Point No.	Total Station (TS)		ISKI-UKBS-Period: 1			ISKI-UKBS-Period: 2		
	Y	X	Y (m)	X(m)	H(m)	Y (m)	X(m)	H(m)
1	439190.63	4528808.80	439190.625	4528808.805	118.566	439190.637	4528808.840	118.575
2	439208.82	4528812.81	439208.821	4528812.829	117.351	439208.821	4528812.821	117.362
3	439232.02	4528817.92	439232.032	4528817.931	116.377	439232.010	4528817.927	116.375
4	439234.99	4528818.58	439235.005	4528818.558	116.201	439234.998	4528818.566	116.183
5	439237.96	4528819.22	439237.970	4528819.236	116.017	439237.954	4528819.235	116.012
6	439253.63	4528822.61	439253.630	4528822.592	114.930	439253.629	4528822.579	114.915
7	439272.05	4528826.56	439272.047	4528826.555	113.612	439272.048	4528826.547	113.609
8	439274.63	4528825.08	439274.645	4528825.075	113.494	439274.645	4528825.076	113.490
19	439189.31	4528806.47	439189.302	4528806.470	118.744	439189.296	4528806.462	118.749
25	439239.66	4528798.96	439239.674	4528798.962	116.917	439239.687	4528798.990	116.923
26	439244.90	4528793.98	439244.891	4528793.975	116.846	439244.876	4528793.960	116.820
690	439181.41	4528814.64	439181.403	4528814.679	118.927	439181.396	4528814.676	118.910
691	439232.41	4528823.06	439232.301	4528823.054	116.173	439232.305	4528823.049	116.207
692	439278.05	4528829.43	439277.977	4528829.496	113.056	439277.998	4528829.491	113.079

3.3.1 Horizontal Accuracy

As assigned permanent coordinates of cadastral points provided by TS observations, the coordinate differences have been taken between TS and RTK 1st period survey and between TS and RTK 2nd period surveys. Accordingly, RTK 1st and 2nd period survey results have been reviewed on this concept. As can be seen from Table 2, the points of 25 and 26, which are located between the buildings, enhance acceptable coordinate differences. The closest point to the obstruct in the test area is 26; agree the accuracy with the maximum absolute differences 0.024 m in Y direction and 0.020 m in X direction.

Table 2. Combination of Coordinate Differences between TS-RTK 1&2 periods

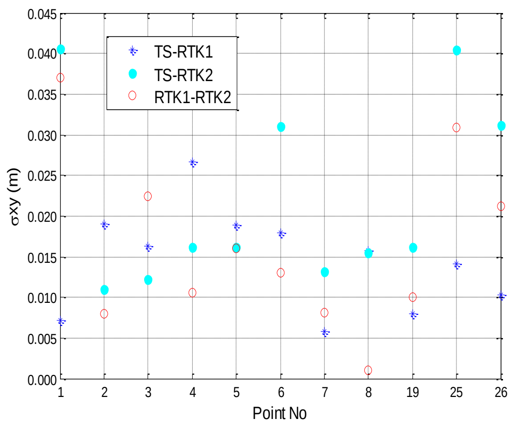
Point No.	Error (TS-RTK-1)		Error (TS-RTK-2)		Error (RTK-(1-2))	
	□Y (m)	□X (m)	□Y (m)	□X (m)	□Y (m)	□X (m)
1	0.005	-0.005	-0.007	-0.040	-0.012	-0.035
2	-0.001	-0.019	-0.001	-0.011	0.000	0.008
3	-0.012	-0.011	0.010	-0.007	0.022	0.004
4	-0.015	0.022	-0.008	0.014	0.007	-0.008
5	-0.010	-0.016	0.006	-0.015	0.016	0.001
6	0.000	0.018	0.001	0.031	0.001	0.013
7	0.003	0.005	0.002	0.013	-0.001	0.008
8	-0.015	0.005	-0.015	0.004	0.000	-0.001
19	0.008	0.000	0.014	0.008	0.006	0.008
25	**-0.014**	**-0.002**	**-0.027**	**-0.030**	**-0.013**	**-0.028**
26	**0.009**	**0.005**	**0.024**	**0.020**	**0.015**	**0.015**
690	0.007	-0.039	0.014	-0.036	0.007	0.003
691	0.109	0.006	0.105	0.011	-0.004	0.005
692	0.073	-0.066	0.052	-0.061	-0.021	0.005

To ensure the reliability of the RTK GNSS surveys in cadastral applications, the standard deviations (□□ of the coordinate differences have been calculated for three calculation phases regarding namely as TS and RTK 1st period, TS and RTK 2nd period and, RTK 1st and 2nd periods (see Table 3). The calculations for RTK 1st and 2nd are given to represent the internal accuracy of the RTK survey methodology. During the testing application, the maximum and minimum standard deviations for three phases is reached as 4 cm and <1 cm, respectively.

Table 3. (a) Standard deviations of coordinate differences, (b) Graphical representation of $□_{XY}$

Point No.	TS- RTK-1 □XY (m)	TS- RTK-2 □XY (m)	RTK-(1-2) □XY (m)
1	0.0071	**0.0406**	0.0370
2	0.0190	0.0110	0.0080
3	0.0163	0.0122	0.0224
4	0.0266	0.0161	0.0106
5	0.0189	0.0162	0.0160
6	0.0180	0.0310	0.0130
7	0.0058	0.0132	0.0081
8	0.0158	0.0155	**0.0010**
19	0.0080	0.0161	0.0100
25	0.0141	0.0404	0.0309
26	0.0103	0.0312	0.0212

(a)



(b)

Moreover, mean RTK survey results and total station values have been compared in Table 4 with derived misclose vectors of the points. The maximum value of misclose vector has been shown up for point 25 and 26, with the values of 0.086 and 0.057, respectively, where they are located between the buildings indicated as obstructed area. The misclose distances obtained from total station survey and mean RTK observations (see Fig.3) have been ranged from 9 mm (with no obstruction) to 86 mm (under obstruction area).

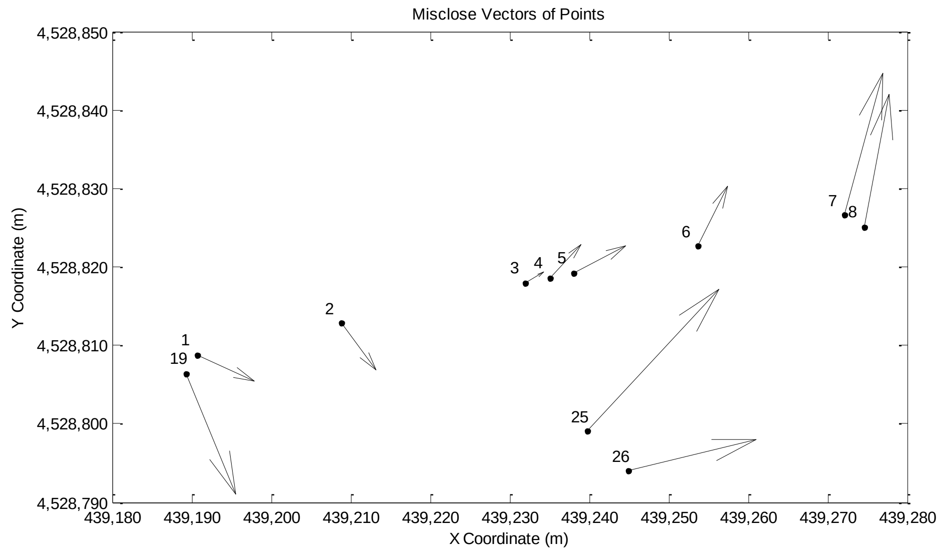


Figure 3. Misclose vectors of points

Table 4. Coordinates derived from Total Station and RTK surveys

	Total Station		Mean RTK Observation		
Point No.	**Y (m)**	**X(m)**	**Y (m)**	**X(m)**	**Misclose Vector (m)**
1	439190.656	4528808.811	439190.631	4528808.823	0.028
2	439208.836	4528812.804	439208.821	4528812.825	0.026
3	439232.029	4528817.934	439232.021	4528817.929	0.009
4	439235.015	4528818.577	439235.002	4528818.562	0.020
5	439237.985	4528819.247	439237.962	4528819.236	0.026
6	439253.643	4528822.613	439253.630	4528822.586	0.031
7	439272.064	4528826.614	439272.048	4528826.551	0.065
8	439274.656	4528825.135	439274.645	4528825.076	0.061
19	439189.321	4528806.412	439189.299	4528806.466	0.058
25	439239.739	4528799.039	439239.681	4528798.976	0.086
26	439244.939	4528793.981	439244.884	4528793.968	0.057

4. CONCLUSION

A case study was conducted to investigate the use of the CORS technique for boundary surveys. For this purpose, measurements were performed in the city of İstanbul, Turkey. Fourteen points were selected in both normal and difficult measurement conditions in the project area. The analyses were made in three steps. In the first step, the CORS results obtained on different periods were compared with each other; in the second, the total station observations have been realized on site to assign as fixed coordinates in evaluations; in the last step, the CORS measurement results were compared with those of the total station. The results showed differences of up to centimeters between the coordinates derived from the two survey methods in the obstructed areas. We conclude that the CORS technique competes well with the traditional survey methods in terms of accuracy, and it can be used in cadastral surveys even in semi residential areas. Moreover, RTK method brings ease of use, efficiency in survey; time and budget save in field works.

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BIOGRAPHICAL NOTES

Nursu Tunalioglu is associated professor of geomatics sciences at Yildiz Technical University, Istanbul Turkey, has held the position since 2015. Her researches have been concentrated on GPS/GNSS system, transportation planning facilities and highway and railway design.

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