Cors Networks And Investigation Of Point Positioning Accuracy Of Konya Permanent GNSS Network (Kosaga)

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Key words: GNSS, Cors-Tr, Kosaga

SUMMARY

Mankind has always wondered where it is on the earth. To answer this question, they come to the point of Global Navigation Satellite Systems (GNSS) from the primitive methods in the early ages thanks to the technological developments in the present.

In satellite positioning, static relative positioning, differential GNSS (DGNSS), conventional RTK (Real Time Kinematic) and Network RTK (Cors) methods are used.Satellite Positioning Systems brings a new understanding to location determination and are used effectively in navigation of land, sea and air vehicles, geodetic and geodynamic measurements, cadastral measurements, deformation measurements, vehicle tracking systems, tourism, agriculture, forestry, sports, security, hydrographic studies and GIS applications.

Many countries have established GNSS based Continuously Operating Reference Stations (Cors) to provide centimeter level accuracy to the end users and they can be used locally or regionally. In this context, TUSAGA-aktif (Cors-TR) (TNPGN- Turkish National Permanent GPS Network) and Kosaga which is covering Konya province (including the surrounding districts), permanent GNSS stations are established and operating.

In this study, a test network consisting of 10 trig stations and 20 traverse points was established with a total of 30 points in Selcuk University Alaeddin Keykubat Campus Area in order to investigate the point positioning accuracy of Konya Cors Network (Kosaga) and Cors-TR stations are measured by Static Method and traverse points are measured by Rapid-Static and RTK GPS. The results of the evaluations are compared with the point position accuracies obtained with Cors-TR and Kosaga systems.

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1. INTRODUCTION

From the beginning of successfully placing GNSS satellite in orbit until today, initially by using GNSS technique and later via real-time determination of position technique, accuracy level has been refined from several hundred meters to several centimetres. In this technology, studies have been in a rapid progress, and as a result new satellite systems have been used: GPS (USA), GLONASS (Russia), Beidou/COMPAS (China), Galileo (EU), QZSS (Japan), IRNSS/Gagan (India) (McDonald 2002, Kahveci and Yildiz 2017; Kirk 2007; Kahveci et al. 2011). On the other hand, within this period, in pursuit of high accuracy and reliability, it has been developed several GNSS methods; one of which is Differential GNSS(DGNSS) technique. In DGNSS technique, the coordinates of a rover receiver dependent to a known reference point obtained via pseudorange observation are used, and it has a point positioning accuracy at meter-level. For more accurate positioning, phase observation has been used.

The most important problems in the phase observation are carrier-phase ambiguity and cycle slip. The solution to these problems, at the beginning, was carrying out the GNSS (Global Navigation Satellite Systems) observation as static phase observation and evaluating the data collected for hours in the field, by software post-processing in the office. However, today; by means of improvement in both technology and calculation, modelling methods; and in addition, by using the Real-Time Kinematic (RTK) applications and RTK networks (Net-RTK or CORS) it is possible to determine real-time point positioning with a high accuracy (several cms), without post calculation in the office.(Gumus, et al. 2012; Kahveci, et al. 2011).

In this study, point-positioning accuracy levels of coordinates obtained from permanent GNSS Network in Konya (Kosaga), were compared.

2. GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

Global Navigation Satellite Systems (GNSS) are radio navigation systems using satellite signals; which make a possible determination of time and continuous location, velocity, route instantly and economically; anywhere on earth, at any time and under every weather conditions in a global coordinate system with high accuracy. Global Navigation Satellite Systems (GNSS) can be sum up as GPS (USA), GLONASS (Russia), Beidou/COMPAS (China), Galileo (EU), QZSS (Japan), IRNSS/Gagan (India) and SBAS. GNSS are able to determine point positions absolutely and relatively. GNSS use static and kinematic methods according to the type of point and preferred accuracy (Kahveci and Yildiz, 2017).

At static GNSS observation, point positions are obtained for desired points (for instance, new trig stations and traverse points) with high accuracy; by the means of known reference points (TUTGA, IGS etc.) and collected raw GNSS data, and using these data to post process in commercial/scientific software. In case of the real-time kinematic navigation system, the position of rover receivers is obtained by transmitted correction from reference stations of known coordinates. If there are an adequate number of satellites (minimum 4 satellites),accuracy will be at cm level; which is referred to as ‘fixed solution’. Otherwise, ambiguity resolution will not be possible and accuracy level will remain at dm level; which is referred to as ‘float solution’. The first form of this method was differential GPS (DGPS). Since at DGPS version it is applied only pseudorange observations, the accuracy is at 1-2 meters level. But, by the time; as a result of progress in technology and calculation, it became possible to use phase observation at a real-time determination of coordinates; which enabled calculation of point coordinates at a high accuracy level. This was named as real-time kinematic GNSS (RTK-GNSS) since it was a different form of DGPS. When using DGPS and RTK methods; the farther it is to the reference station that transmitting correction, the less accurate real-time coordinate is. To avoid this problem, Net-RTK (Cors) method was developed. In this method, calculation and correction conducted at Net-RTK control station are transmitted to rover receivers via GSM/GPRS/satellite or radio modem techniques to determine point position. In contrary, in static GNSS observation, no such problem exists (Kahveci et al. 2011).

Today, in geodetic and cadastral applications instead of static GNSS, it has been used conventional RTK or Net-RTK calculations more and more. To perform Net-RTK applications, CORS network which has national or regional coverage areas, in addition, to continuously operating reference stations are required. To meet these compulsory requirements, different countries built their CORS network: NGS Cors network (ABD), Sopos Cors network (Germany), Geonet Cors network (Japan), Ksa Cors network (Saudi Arabia) ve Cors-Tr network (Turkey), etc. Also in Turkey, municipalities built regional networks in addition to national Cors-Tr. Konya permanent GNSS network (Kosaga) is one of them.

TUSAGA-Aktif (Cors-TR) is a running project covering all Turkey, Istanbul Culture University as the executive institution, General Command of Mapping and General Directorate Acknowledgements of Land Registry and Cadastre as the joint customers. The aim of the projects is to build 147 permanent GPS stations (Figure 1) to implement Real-Time Kinematic (RTK) correction of data. And using obtained data will provide a real-time, positioning at cm-level accuracy and more accurate transformation parameters between different coordinate systems (ITRF-ED50); which will enable, principally, cadastral, cartographic, and geodetic applications, and also assist national security and progress (Inal, et al. 2015).

Figure 1.Cors-Tr Network (URL1)

Konya Permanent GNSS Network (Kosaga), was built by Konya municipality within Konya province, to determine Real-Time Kinematic (RTK) positioning for the cartographic and infrastructural purposes. The network includes stations in Konya, Ilgın, Beysehir, Hotamıs and Oguzeli districts, in total 5 (Figure 2).

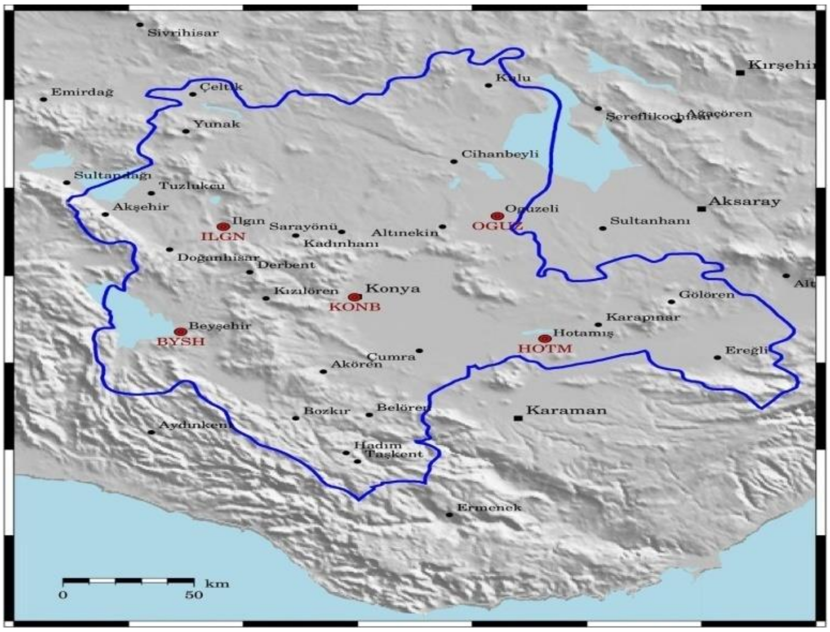

Figure 2. Kosaga Network (Ustun, 2014)

3. APPLICATION

3.1. Test Network

Test network was set up as 10 trig stations and 20 traverse points in Selcuk University, Alâeddin Keykubat campus area (Figure 3).

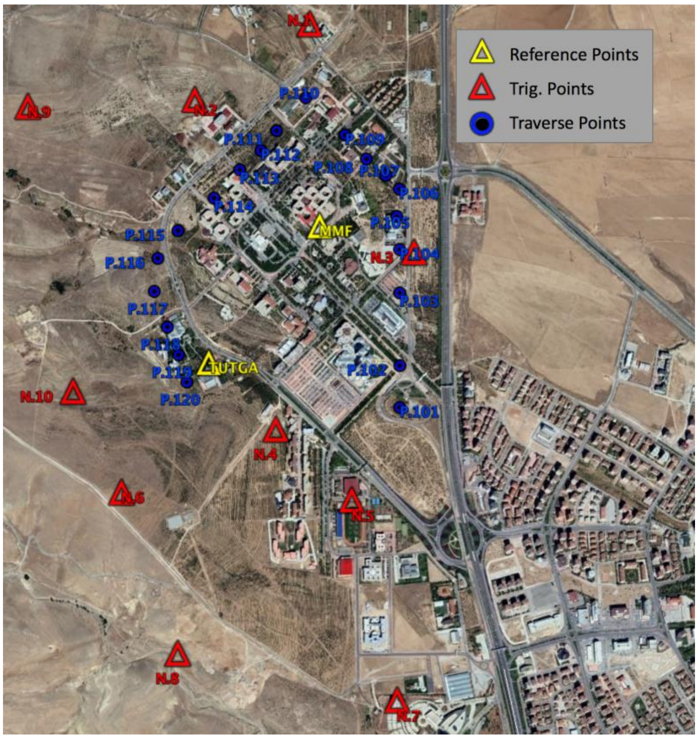

Figure 3. Test Network

3.2. GPS Measurements and Analysis

GPS observations executed at 3 parties. In the first party, SLCK and MMF points in the campus area were taken as reference points, and GNSS observations were carried out at trig stations of the test network as sessions taking 30 minutes, using the static method; and at traverse points, as sessions taking 10 minutes, using the rapid-static method. In the study, 2 TOPCON GR5 and 3 Javad Triımph-1 GPS receivers were used. The point coordinates of test network were calculated in 3 different ways; firstly, SLCK and MMF points in campus area were taken as reference points, secondly, BYS and KNY1 points connected to Cors-Tr were taken as reference points, and thirdly, two points connected to Kosaga (BEYSEHIR and KONB points) were taken as reference points. Analyses were carried out by Leica Geosystems Office Software. Point coordinates of test network were calculated based on 3 degrees wide zones, using the projection of GRS80 ellipsoid and Transversal Mercator (TM) (Table 1). Data for reference stations were obtained from Tusaga-aktif website (**tusaga-aktif**.tkgm.gov.tr) and Kosaga data were obtained from Konya Metropolitan Municipality, Directorate of Construction Affairs and Urban Planning, Department of Cartography.

Table 1. Coordinates of Trig stations

Point No	Static (30^m)			Cors.Tr			Kosaga		
	Y(m)	X(m)	h(m)	Y(m)	X(m)	h(m)	Y(m)	X(m)	h(m)
1	457029.821	4211511.003	1202.039	457029.818	4211511.003	1202.045	457029.817	4211511.000	1202.048
2	456535.544	4211195.870	1217.825	456535.544	4211195.868	1217.816	456535.542	4211195.861	1217.825
3	457464.715	4210537.483	1169.597	457464.716	4210537.487	1169.600	457464.715	4210537.480	1169.607
4	456866.531	4209791.504	1179.609	456866.525	4209791.490	1179.600	456866.525	4209791.484	1179.606
5	457187.775	4209487.444	1167.429	457187.776	4209487.443	1167.429	457187.773	4209487.436	1167.436
6	456205.495	4209530.570	1221.247	456205.493	4209530.566	1221.255	456205.492	4209530.563	1221.262
7	457372.344	4208635.857	1162.630	457372.344	4208635.852	1162.613	457372.344	4208635.849	1162.618
8	456438.212	4208843.761	1195.467	456438.207	4208843.758	1195.462	456438.207	4208843.754	1195.470
9	455823.054	4211173.581	1257.969	455823.050	4211173.582	1257.973	455823.049	4211173.577	1257.980
10	456003.769	4209961.701	1238.706	456003.768	4209961.699	1238.717	456003.767	4209961.694	1238.722

In the second party, only traverse points were observed with obtained corrections from Cors.Tr_Vrs system, as two sessions.. Finally, in the third party, only traverse points were used with obtained corrections from Kosaga_Vrs system, as two sessions. The mean coordinates for traverse points are given in Table 2.

Table 2. Coordinates of Traverse points

Point No	Static (10^m)			Cors.Tr			Kosaga		
	Y(m)	X(m)	h(m)	Y(m)	X(m)	h(m)	Y(m)	X(m)	h(m)
P101	457398.859	4209882.611	1163.881	457398.882	4209882.564	1163.918	457398.857	4209882.585	1128.067
P102	457401.377	4210060.268	1164.753	457401.369	4210060.206	1164.806	457401.352	4210060.229	1128.970
P103	457403.143	4210369.386	1167.498	457403.170	4210369.333	1167.538	457403.133	4210369.341	1131.684
P104	457405.707	4210553.394	1169.740	457405.728	4210553.368	1169.825	457405.703	4210553.349	1133.935
P105	457394.611	4210694.939	1171.608	457394.633	4210694.915	1171.651	457394.593	4210694.889	1135.790
P106	457406.860	4210810.168	1172.095	457406.869	4210810.138	1172.110	457406.836	4210810.128	1136.293
P107	457349.164	4210868.681	1173.411	457349.190	4210868.653	1173.427	457349.145	4210868.640	1137.608
P108	457267.198	4210939.203	1175.559	457267.187	4210939.195	1175.594	457267.186	4210939.164	1139.750
P109	457177.356	4211042.081	1177.987	457177.406	4211042.045	1178.028	457177.362	4211042.041	1142.162
P110	457011.576	4211202.568	1187.734	457011.583	4211202.581	1187.845	457011.565	4211202.559	1151.939
P111	456885.352	4211063.165	1191.976	456885.386	4211063.124	1191.988	456885.363	4211063.111	1156.177
P112	456817.634	4210980.732	1194.677	456817.652	4210980.706	1194.689	456817.606	4210980.665	1158.838
P113	456726.573	4210899.293	1198.358	456726.605	4210899.232	1198.412	456726.569	4210899.244	1162.548
P114	456615.133	4210780.340	1196.450	456615.163	4210780.278	1196.485	456615.128	4210780.282	1160.647
P115	456460.867	4210643.774	1193.034	456460.888	4210643.686	1193.075	456460.856	4210643.695	1157.226
P116	456373.801	4210526.345	1193.524	456373.849	4210526.282	1193.553	456373.803	4210526.293	1157.722
P117	456356.770	4210386.075	1197.707	456356.798	4210386.061	1197.678	456356.762	4210386.014	1161.899
P118	456410.303	4210234.360	1202.799	456410.330	4210234.323	1202.781	456410.303	4210234.302	1167.010
P119	456457.960	4210115.592	1202.695	456457.976	4210115.523	1202.763	456457.944	4210115.520	1166.917
P120	456491.756	4209999.153	1198.674	456491.770	4209999.097	1198.727	456491.751	4209999.100	1162.851

The coordinate values obtained from static GNSS observations were taken as real values, the differences between coordinates obtained from Cors.Tr and Kosaga were calculated. Root Mean Square Errors (m_x, m_y, m_h) were calculated as in Table 3 and Table 4.

$$m_x = \mp\sqrt{\frac{[dx.dx]}{n}} \qquad m_y = \mp\sqrt{\frac{[dy.dy]}{n}} \qquad m_h = \mp\sqrt{\frac{[dh.dh]}{n}} \qquad (1)$$

$$m_p = \pm\sqrt{m_x{}^2 + m_y{}^2}$$

Table 3. Trig coordinate differences and Root mean square errors (Rms)

	Cors.Tr-Static (30^m)			Kosaga-Static (30^m)		
Point No	**dY(cm)**	**dX(cm)**	**dh(cm)**	**dY(cm)**	**dX(cm)**	**dh(cm)**
1	-0.23	-0.03	0.56	-0.32	-0.34	0.91
2	-0.01	-0.18	-0.88	-0.22	-0.92	-0.01
3	0.09	0.36	0.31	0.01	-0.31	0.96
4	-0.62	-1.37	-0.89	-0.55	-1.93	-0.28
5	0.04	-0.14	0.02	-0.17	-0.79	0.70
6	-0.26	-0.41	0.83	-0.38	-0.75	1.46
7	0.06	-0.53	-1.74	0.04	-0.79	-1.17
8	-0.55	-0.37	-0.53	-0.58	-0.75	0.28
9	-0.50	0.09	0.43	-0.54	-0.43	1.08
10	-0.19	-0.20	1.14	-0.29	-0.65	1.56
Rms	**0.33**	**0.52**	**0.86**	**0.37**	**0.88**	**0.97**

Table 4.Traverse coordinate differences and Root mean square errors (Rms)

Point No	Cors.Tr-Static (10^m)			Kosaga-Static (10^m)		
	dY(cm)	dX(cm)	dh(cm)	dY(cm)	dX(cm)	dh(cm)
P101	-2.31	4.73	-3.75	0.24	2.63	-1.15
P102	0.82	6.15	-5.29	2.52	3.85	-4.19
P103	-2.64	5.32	-3.96	1.01	4.52	-1.01
P104	-2.11	2.57	-8.55	0.44	4.47	-2.05
P105	-2.24	2.40	-4.31	1.81	5.05	-0.71
P106	-0.94	3.03	-1.48	2.41	4.08	-2.28
P107	-2.56	2.80	-1.51	1.94	4.10	-2.11
P108	1.10	0.77	-3.50	1.20	3.92	-1.60
P109	-4.96	3.63	-4.10	-0.56	4.08	0.05
P110	-0.68	-1.31	-11.15	1.17	0.89	-3.05
P111	-3.37	4.08	-1.16	-1.02	5.38	-2.56
P112	-1.80	2.60	-1.24	2.75	6.70	1.41
P113	-3.16	6.05	-5.33	0.39	4.85	-1.43
P114	-3.00	6.24	-3.45	0.50	5.89	-2.15
P115	-2.09	8.82	-4.07	1.11	7.92	-1.67
P116	-4.77	6.31	-2.91	-0.17	5.26	-2.26
P117	-2.84	1.49	2.99	0.81	6.19	-1.61
P118	-2.66	3.69	1.88	0.09	5.79	-3.57
P119	-1.63	6.88	-6.72	1.57	7.23	-4.62
P120	-1.40	5.64	-5.28	0.50	5.34	-0.23
Rms	**2.61**	**4.72**	**4.80**	**1.36**	**5.14**	**2.30**

Coordinate differences (Max, Min, Average) for coordinates obtained from Cors.Tr and Kosaga, root mean square errors and point positioning accuracies are summarized in Table 5 and Table 6.

Table 5. Coordinate differences for trig stations and root mean square errors (Static)

METHODS	Cors.Tr-Static(30^m)			Kosaga-Static(30^m)		
Differences	**dY(cm)**	**dX(cm)**	**dh(cm)**	**dY(cm)**	**dX(cm)**	**dh(cm)**
Max.	0.09	0.36	1.14	0.04	-0.31	1.56
Min.	-0.62	-1.37	-1.74	-0.58	-1.93	-1.17
Averaga	-0.22	-0.28	-0.07	-0.30	-0.76	0.55
Rms	**±0.33**	**±0.52**	**±0.86**	**±0.37**	**±0.88**	**±0.97**
m_p	**±0.62**			**±0.95**		

Table 6. Coordinate differences for traverse points and root mean square errors (Rapid-Static)

METHODS	Cors.Tr-Statik(10')			KOSAGA-Statik(10')		
Diffrences	dY(cm)	dX(cm)	dh(cm)	dY(cm)	dX(cm)	dh(cm)
Max. (cm)	1.10	8.80	-1.20	2.70	7.90	0.05
Min. (cm)	-5.00	0.80	-11.10	-1.00	0.90	-4.62
Averaga (cm)	-2.20	4.10	-3.60	0.90	4.90	-1.80
Rms	±2.61	±4.72	±4.8	±1.36	±5.14	±2.30
m_p	±5.39			±5.32		

4.CONCLUSION

Today, real-time point coordinates are determined at cm-level accuracy by GNSS observation. Determination of real-time point position with RTK is carried out; by using data of point position from phase observation obtained from satellites by rover receivers and using corrected data obtained from a reference station by the same rover receivers, simultaneously. Restriction of distance between the reference station and rover receiver (<15-20 kms) and correction of data dependent to a single point are some disadvantages of classic RTA method. Net-RTK was developed during elimination process of those disadvantages. By this development, dependency to single reference station was removed and data from multiple reference stations made it possible to calculate point positioning from longer base distances (<50-100 kms) at high accuracy level. Following the trend in the world, General Directorate of Land Registry and Cadastre of Turkey established Cors-Tr national network and some municipalities established regional permanent GNSS networks, one of which is Konya permanent GNSS (Kosaga) network established by The Metropolitan Municipality of Konya

In this study, to analysepoint-positioning accuracy of Kosaga system, a test network including 10 trig stations and 20 traverse points in Selçuk University, AlaaeddinKeykubat Campus area was set up. After measurements and analysis, accuracies of point positioning were compared.

As it can be seen in Table 5, the most accurate point positioning for trig stations (m_p=±0.62 cm) was obtained from Cors-TR system. Root Mean Square Errors were m_y=±0.62 cm, m_x=±0.52 cm and m_h=±0.86 cm.

Table 6 shows that point positioning accuracies for traverse points obtained from both systems were too close to each other (m_p=±5.39 cm and m_p=±5.32 cm). Root Mean Square Errors for Kosaga were m_y=±1.36 cm, m_x=±5.14 cm and m_h=±2.30 cm.

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REFERENCES

Gumus, K,, Celık, C. T., Erkaya, H., (2012). Investigation of Accurate Method In 3-D Position Using Cors-Net in Istanbul, Bol. Ciênc. Geod., sec. Artigos, Curitiba, v. 18, no 2, p.171-184.

Inal, C., Bulbul, S., Yıldırım, Ö., (2015). The Comparison of Kosaga and Cors-Tr in Real Time Kinematic Positioning, International Refereed Journal of Engineering And Sciences, Autumn Isue: 5, 1-17.

Kahveci, M., Karagöz, H., Selbesoğlu, M.O.,(2011). Comparison of Static and RTK GNSS Observations and Processings, Journal of Geodesy and Geoinformation, Isue: 104, 3-13, Ankara, Turkey (in Turkish).

Kahveci, M., Yıldız, F.,(2017). Position Determining Systems With GPS/GNSS Satellites, Theory and Practice, Nobel Academic Publication, 8.Edition, Ankara, p.222 (in Turkhish)

Kahveci, M., (2009). Kinematic GNSS and RTK CORS Networks, Zerpa Tourism Publication Ltd. Co., Ankara

Kirk, G., (2007). GPS Modernization, GLONASS Augmentation and the Status of GALILEO – Benefits for Heavy and Highway Contactors. Trimble White Paper, USA.

McDonald, K. D., (2002). The Modernization of GPS: Plans, New Capabilities and the Future Relationship to Galileo. Journal of Global Positioning Systems, Vol. 1, No. 1: pp.1-17, USA.

Ustun, A., (2014). Kosaga Project Technical Control Report, Konya (in Turkhish)

Uzel,T. and Eren, K., (2008). Establishing of the National Cors System and Datum Transformation Project, Istanbul.

URL1: https://www.tkgm.gov.tr/sites/default/files/icerik_ekleri/tusagay2_0.jpg (18.02.2018)

BIOGRAPHICAL NOTES

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