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INVESTIGATION OF ACCURATE METHOD IN 3-D POSITION USING CORS-NET IN ISTANBUL

Investigação de método acurado no posicionamento 3D baseado em CORS-NET em Istambul

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ABSTRACT

In this study, for Istanbul, there are two Cors Networks (Cors-TR, Iski Cors) providing Virtual Reference Station (VRS), and Flachen Korrektur Parameter (FKP), corrections to rover receiver for determining 3-D positions in real time by Global Positioning System (GPS). To determine which method (or technique) provides accurate method for position fixing, a test network consisting of 49 stations was set up in Yildiz Technical University Davudpasa Campus. The coordinates of the stations in the test network were determined by conventional geodetic, classical RTK, VRS and FKP methods serviced by both Cors-TR and Iski Cors. The results were compared to the coordinates by the conventional method by using total station. The results showed a complex structure as the accuracy differs from one component to another such as in horizontal coordinates, Y components by CorsTR_VRS and Cors_TR_ FKP showed 'best' results while the same technique provided X components consistent accuracy with the Y component but less accurate than by real time kinematic (RTK). In vertical components, of all the techniques used for the h components, CorsTR_VRS showed 'best' accuracy with three outliers.

Keywords: CORS-TR; Iski CORS; RTK; CORS-NETWORK; Virtual Reference Station (VRS); Flachen Korrektur Parameter (FKP).

RESUMO

Nessa pesquisa foram utilizados dados de duas redes de estações de referência de Istambul (Cors-TR, Iski Cors) que disponibilizam correções provindas do conceito de VRS (*Virtual Reference Station*) e FKP (*Flachen Korrektur Parameter*). A partir dessas correções o usuário determina posições 3D em tempo real usando GPS. Para determinar qual método (ou técnica) obtém posicionamento mais acurado, uma rede teste com 49 estações foi selecionada no campus da Yildiz Technical University Davudpasa. As coordenadas das estações nessa rede teste foram obtidas pelo método clássico RTK e pelos métodos VRS e FKP das redes Cors-TR e Iski Cors. Os resultados foram comparados com as coordenadas obtidas com o método convencional de estação total. Os resultados mostraram uma complexa estrutura, pois a acurácia difere de uma componente para outra. Por exemplo, nas coordenadas horizontais, a componente Y da CorsTR_VRS e Cors_TR_ FKP mostrou os 'melhores' resultados. Mas, para a componente X os resultados mais acurados foram obtidos no RTK. Na componente vertical, entre todas as técnicas usadas para determinar a componente h, o método CorsTR_VRS apresentou as 'melhores' acurácias com três erros grosseiros.

Palavras-chave: CORS-TR; Iski CORS; RTK; CORS-NETWORK; Virtual Reference Station (VRS); Flachen Korrektur Parameter (FKP).

1. INTRODUCTION

Global Positioning System (GPS) can provide position fixing in cm level when used in differential mode (Seeber, 2003). This requires at least two receivers, sophisticated software and precise ephemerides, etc. This demands time and does not provide real time positioning. Alternatively, to provide cm level accuracy in position fixing using GPS, countries establish country-wide-cors (Continuously Operating Reference Stations) network (Sunantyo, 2009). It provides a stable and precise positioning in real time. Turkey has established its own network called CORS-TR (TUSAGA-active)(Eren et al., 2009). Along with this even there exists a private CORS system to serve only in a confined area such as Istanbul Municipality Cors Network called Iski-Cors (www.iski.gov.tr). In general, cors network consists of a number of continuously operating stations whose positions are accurately known. Therefore, correction parameters due to ionosphere, troposphere, time, etc. can be calculated and sent to a user that requests corrections (Öcalan & Tunalıoğlu, 2010). Then the user uses these corrections to its observations to estimate its position in cm level. A number of methods or techniques for calculating correction parameters exists namely; virtual reference station (VRS) (Wanninger, 2003), linear area corrections (Flachen Korrektur Parameter =FKP) (Wübbena & Bagge, 1998) and Master Auxiliary Concept (MAC) Methods (Brown et al., 2005). They have advantageous and disadvantageous over one another. However, which method provides accurate service is still continuing debate and draws scientist attention. Few studies done to investigate the accurate methods include Eren et al. (2009) and

Butun Baybura (2010); so more studies need carrying out on the subject to make a clear understanding.

This paper aims at determining accurate method among CorsTR_VRS, CorsTR_FKP, IskiCors_VRS, IskiCors_FKP and classical RTK compared to the coordinates obtained by conventional geodetic position fixing method using total stations. A test network was established in Yildiz Technical University Davutpaşa Campus. The network consists of 49 stations whose positions were fixed by the methods mentioned above and the results were presented.

2. MATERIALS AND METHODS

To find out accurate method of determining point coordinates by GPS, there are two cors networks involved in this study namely; Cors-TR covered country-wide Turkey and Iski-Cors consists of only 8 stations serving only in Istanbul city, Turkey. A brief description of the networks and the method used to calculate corrections virtual reference station (VRS) and Flachen Korrektur Parameter (FKP) are described. Then acquired data was introduced.

2.1 Continuous Operating Reference Stations Networks (Cors-NET)

Differential Global Positioning System (DGPS) based on pseudo-range observations provides real time positioning in meter level provided that there is/are satellite broadcasting correction parameters a roving receiver whose coordinates are in question (Lapucha & Maynard, 1992). However, for applications demanding high precision, phase observations are essential. In this case, integer ambiguity of the number of wavelength makes it more complicated. Current advances in GPS technology enabled us to determine real time positions using phase observations. This is called Real Time Kinematic (RTK) method. However, the distance between reference station and roving station affects the accuracy of position fixing.

To overcome this distance dependence problem, WAAS, WADGPS, etc. have been developed based on a number of control stations located in large areas but they also provide accuracy in decimeter level due to code observations (Alves et al., 2011). Alternatively, countries established country-wide continuous operating stations network (Cors-Net) (Kahveci, 2009). To make Cors-Net clearly understood, first classical RTK will be given here.

2.2 Classical Real Time Kinematic (RTK)

This technique requires a station whose coordinates are precisely known and a roving receiver whose coordinates are in question. RTK is based on phase measurements and communication to roving station. Either raw observations or calculated corrections obtained at the reference station are sent to the roving receiver. The corrections, which are calculated at either the reference station or roving receiver, including position, atmosphere, pseudorange, etc. are possible due to known reference station coordinates. The atmospheric corrections are valid only within the limited area (~15-20 km) from the reference station location. Therefore,

this technique is distance dependent. Because the corrections are calculated based on only one reference station, there is no control mechanism on it.

2.3 The Cors-Networks

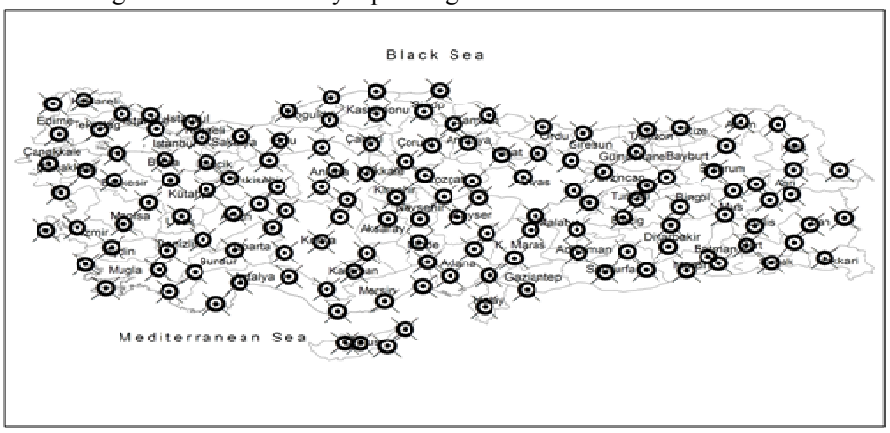
This technique is based on correction calculation at a computation center using observations from continuously operating reference stations and they are sent to the user that demands correction via a suitable means. If the reference stations are located on country-wide with a certain distance apart to each other, then it is possible to determine roving receiver position in cm level. There are a number of Cors-Networks established around the world including Germany, UK, USA, Turkey, etc. Here Turkey's Cors-network called Cors-TR (TUSAGA-Active) will be introduced.

2.4 Cors-TR

There are 147 continuously operating reference stations located on country-wide (Figure 1) and three control centers (computation centers); two of them located inAnkara and one in Istanbul. The reference station coordinates are in ITRF96 datum. Observations made at the reference stations are sent to control centers. Control center calculates corrections using three different techniques namely, VRS, FKP and MAC. A user (rover receiver) sends its approximate coordinates for requesting corrections via GSM. Depending on the technique user requested, corrections are sent to it. These corrections are calculated using Trimble Net R5 by Land Registry and Cadastre General Directorate.

Then the user receiver is capable to apply these corrections to its observation to calculate its position in cm level.

Figure 1 - Continuously Operating Reference Stations in Cors-TR.

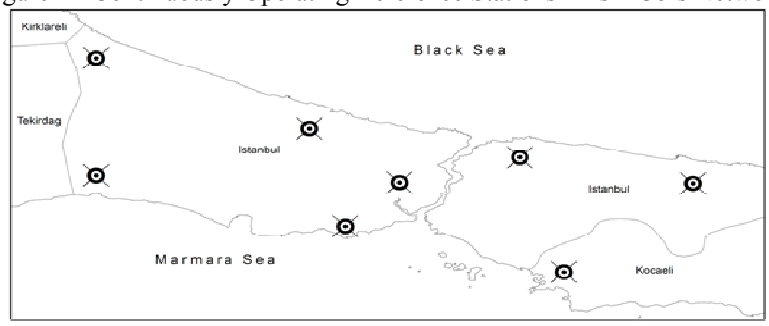


2.5 Iski-Cors

In Istanbul, there is another cors network established by Istanbul Municipality called Iski Cors (IskiCors) (www.iski.gov.tr). This network consists of only eight stations distributed in Istanbul city boundary (Figure 2). The network can also provide VRS, FKP and MAC corrections. These corrections are calculated by Topcon Geo Plus Plus software. VRS locates a virtual reference station as close as the rover receiver which requests correction calculated with N integer ambiguity fixed by using all the Cors stations data in the network. Then the corrections are sent via the VRS to the user (Wanninger, 2003).

FKP stands for Flachen Korrektur Parameter (flat (linear) correction parameters). It uses the data from all cors stations in the network to calculate corrections and then sent to the requesting of the rover receiver via the nearest cors station to the roving receiver. The main drawback of this technique is that the magnitude of error gets bigger as the nearest cors station to the roving receiver gets farther (Wubbena and Bagge, 1998).

Figure 2 - Continuously Operating Reference Stations in Iski Cors Network.



MAC stands for Master Auxiliary Concept. It is based on correction calculation within the roving receiver using data received from the cors stations around it (Brown et al., 2005).

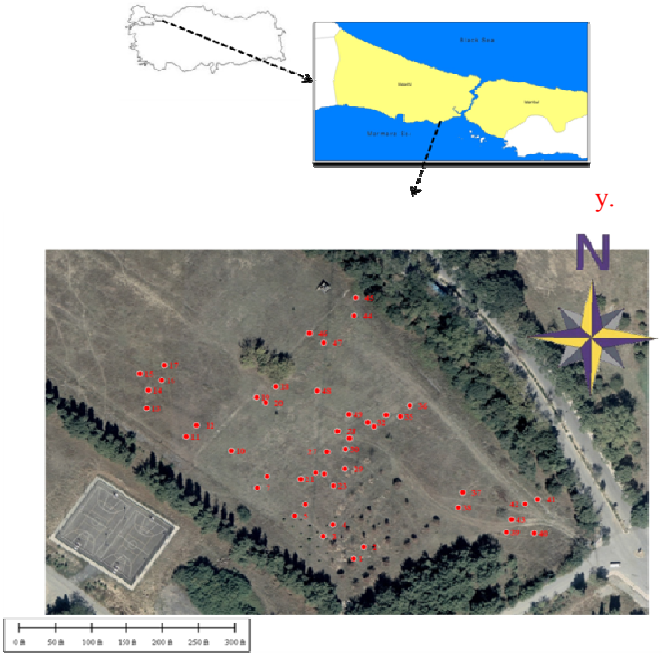
3. DATA DESCRIPTION

To bring about a accurate method of position fixing by GPS using Cors networks in Turkey, there are six methods used to determine the points coordinates in the test network consisting of 49 stations located in Yildiz Technical University Davudpasa Campus (Figure 3).

The methods used to determine the coordinates were conventional geodetic measurements using total station (Nikon DTM 332 with 3+ 2ppm precision), classical RTK, CorsTR-VRS, CorsTR_FKP, IskiCors_VRS, and IskiCors_FKP. In determination of coordinates, Topcon Hyper-Pro receiver was used. For each station ten epochs of measurement performed and the average of ten epochs was recorded

as measured the coordinates. The corrections are sent via GSM, and MAC corrections require large amount of data to be transferred via GSM and hardware must be compatible with MAC corrections. At the time of field work, our GPS receivers had no support for MAC corrections, so we have not considered measuring MAC corrections. Conventional geodetic method provides position fixing with mm level accuracy. The above mentioned total station is used for determining the point coordinates. Each point coordinates determined from one point whose coordinates were checked from an alternative point. The magnitude of distances is very short so the precision remain within few mm (typically 1-2mm). It is a well known fact that the more measurements means the more error, therefore, less measurements for a position fixing was a basic philosophy in determining the position by total station provided that there is no blunders and no systematic errors contained in the measurements. To ensure there is no blunders in the measurements, we have checked coordinates for a particular point from an alternative station whose coordinates precisely known. For possible systematic error we have considered air temperature effects, atmospheric pressure and prism constant. Therefore, this technique assumed free from errors and the coordinates obtained by the other methods were compared to the conventional one.

Figure 3 - Surveyed stations in the Campus of Davutpasa Yildiz Technical Universit



4. DATA ANALYSIS

Accuracy is 'closeness' of quantities to their true values while precision is 'closeness' of quantities to their mean values. The strategy followed in this study is as follows. In a sample of coordinates representing the different positions (49 points) with different methods (five methods namely; classical RTK, CorsTR_FKP, CorsTR_VRS, IskiCors_FKP, and IskiCors_VRS), accuracy is the standard deviation of the coordinates differences from the true values. However, it is important to have data free from outlier. It is a well-known fact that an outlier contained in the data influence the mean of the data set dramatically. Therefore, a robust statistic, median, normality, shape of the data are necessary to comment on the data. A box plot may be drawn to see some of the above information in one place. A box plot is a graphic which can be interpreted in terms of spread, centrality, shape and unusual features.

The value of median is known to be the measure of centrality, and simultaneous examination of inter quartile range and the median value can reveal the shape of data. If there is any data outside the limit of whiskers, which means the data possess unusual features.

5. RESULTS AND DISCUSSION

Point coordinates determined by total station are assumed to be free from errors and 'most' accurate method among the ones used in this study. Therefore, the coordinates obtained by this method were taken as 'true' coordinates. To investigate accurate methods we have used for 3-D positioning by GPS technology, accuracy estimation were performed by taking coordinate differences between true coordinates and the coordinates by classical RTK, CorsTR_FKP, CorsTR_VRS, IskiCors_FKP, and IskiCors_VRS have been taken correspondingly. The results of the differences organized in Y, X and ellipsoidal height h are given in Figures 4, 5, and 6.

It is clear from Figure 4 that Y components (green line) of CorsTR_FKP are 'most' deviated among others, while X component (Figure 5) partially good and bad and h component (Figure 6) is the 'best' of all when one or two points are excluded from the set. Not in the Y and h components but in X component of the points by IskiCors_FKP and IskiCors_VRS have presented systematical shift from the other three methods, which need further consideration (Figure 5).

Figure 4 - Comparison of Differences in Y Components (in meters).

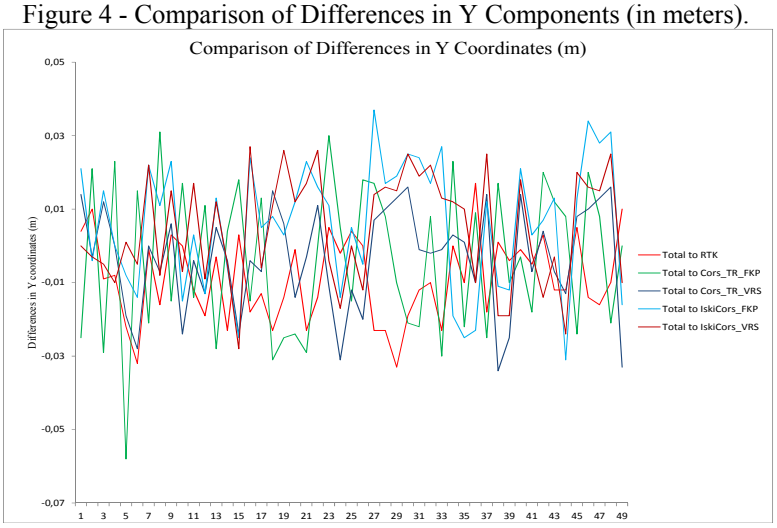


Figure 5 - Comparison of Differences in X Components (in meters).

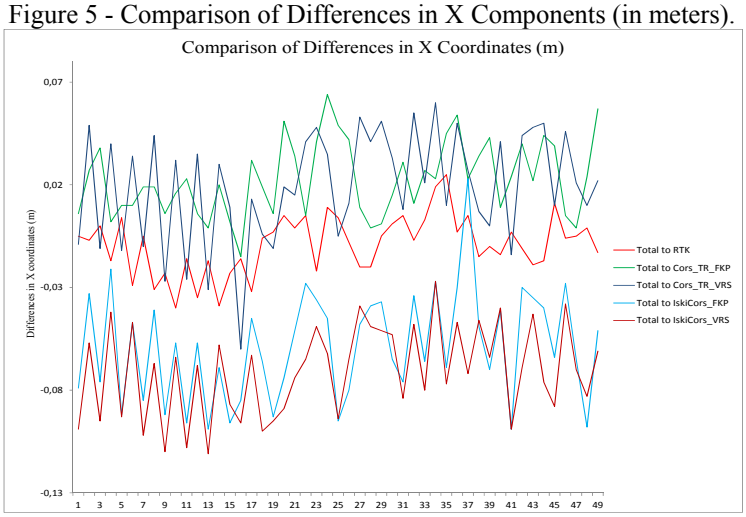
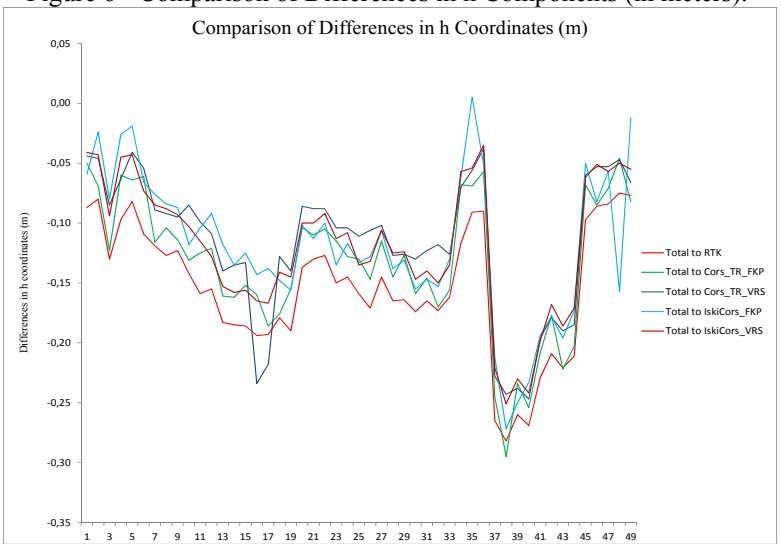


Figure 6 - Comparison of Differences in h Components (in meters).



Below boxplots were created for the component differences to make sure the data are free from outliers. Figure 7 shows boxplots of Y component differences of the stations for the methods to be tested. It is clear from Figure 7 that Y components ranges are in order from 'best' to 'worst' as CorsTR_VRS, RTK, IskiCors_VRS, IskiCors_FKP and CorsTR_FKP. CorsTR_FKP range is the largest of all. An explanation to this might be CorsTR_FKP parameters were calculated from entire network and then were sent to the user via the nearest Cors_TR station, which may not be convenient parameters as compared to IskiCors_FKP, which were calculated from only 8 stations installed in Istanbul where this test data was collected. For this reason, IskiCors_FKP seems better than CorsTR_FKP.

It is expected that the centers of data from the methods tested tent to zero, because they are differences of Y components with respect to true coordinates. From the Figure 7, CorsTR_FKP and VRS are the closest to zero while the rest were approximately equally apart from the zero line. It is interesting that CorsTR_FKP technique produced zero median although its spread is the largest.

Moreover, IskiCors_FKP and VRS sound like Y components underwent some amount of shift among others. CorsTR_VRS coordinates showed symmetric distribution, which means the data is normally distributed while CorsTR_FKP slightly left skewed. It is clear from the figure that IskiCors_FKP and VRS data were left skewed while RTK slightly right skewed with no unusual features gap or outlier.

Figure 8 shows boxplots of X component differences of the stations for the methods to be tested. The ranges are in order from 'best' to 'worst' as RTK, CorsTR_FKP, IskiCors_VRS and CorsTR_VRS, and IskiCors_FKP. It is noted that IskiCors_FKP has an outlier (station ID=44). RTK technique provided the most accurate median to the zero line, following it, CorsTR_VRS and FKP comes in the second place, but IskiCors_FKP and VRS showed some shift among the others. For all the techniques used in the test, data sounds normally distributed.

Figure 7 - Box Plot of Y Component Differences (in meters).

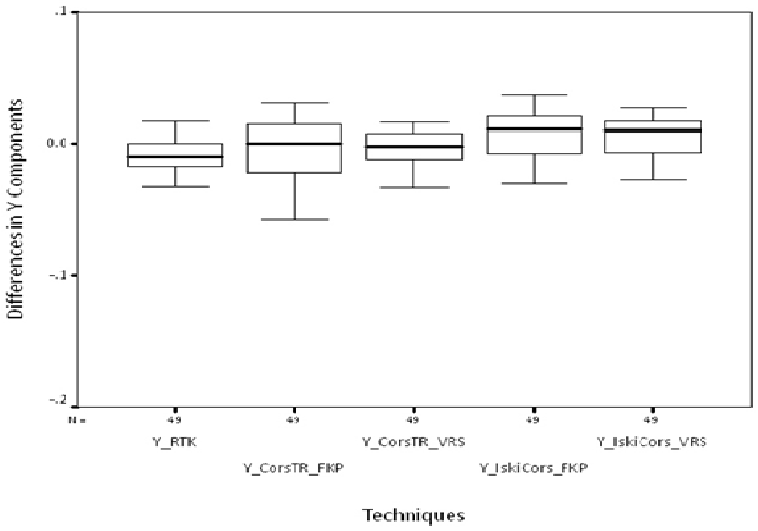


Figure 9 shows the boxplots of h component differences of the stations for the methods to be tested. The ranges are in order from 'best' to 'worst' as RTK, IskiCors_VRS, CorsTR_VRS, CorsTR_FKP and IskiCors_FKP. Of all techniques, median of CorsTR_VRS is 'closest' to the zero line. Following it, IskiCors_FKP and VRS, CorsTR_FKP and finally RTK come in sequences. CorsTR_VRS shows symmetrical distribution while the rest present slightly right skewed distribution. From the figure, it is clear that some outliers appear in the data sets. They are as follows, one point in CorsTR_FKP, three points in CorsTR_VRS and two points in IskiCors_FKP.

Figure 8 - Box Plot of X Component Differences (in meters).

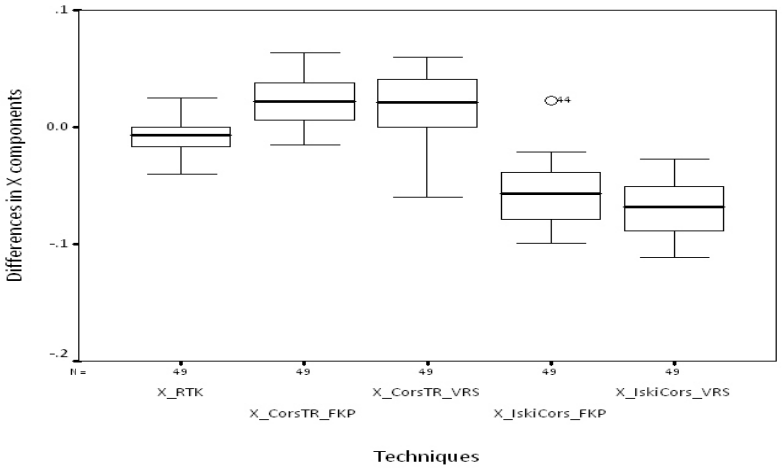
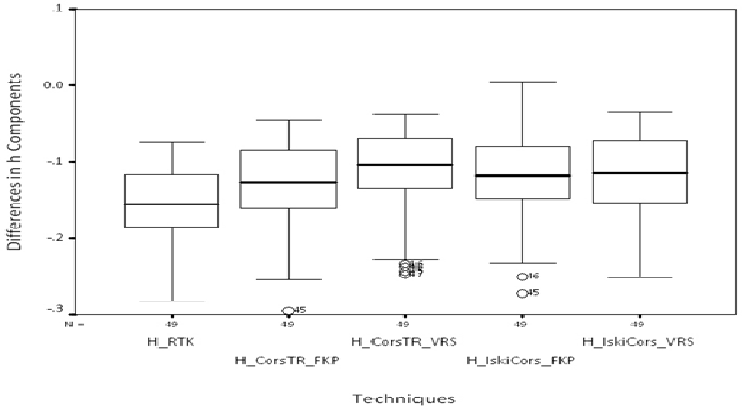


Figure 9 - Box Plot of h Component Differences (in meters).



In Table 1, statistics of the methods used have been summarized. Here standard deviation of Y component of CorsTR_FKP from the true coordinates is the largest (0.021 m) among others. Y components are in order from best to worst; classical RTK, CorsTR_VRS, IskiCors_VRS, IskiCors_FKP and CorsTR_FKP. An explanation to this was mentioned earlier. However, X components for all the methods except classical RTK reflected approximately 1 cm higher standard deviations than that of Y components.

Stations' X components are in order from best to worst classical RTK, CorsTR_FKP, IskiCors_VRS, and IskiCors_FKP and CorsTR_VRS. Here the explanation made earlier for IskiCors_FKP components is not supported, this may be because IskiCors_FKP and IskiCors_VRS showed shift pattern from the rest.

Of all the methods used in this study for the test, standard deviations of h components are half order lower than horizontal components.

The results in Table 1 may be compared to those of Gordini et al. (2006) which represented the evaluations of Cors Network Technologies included two cors network namely VICpos and MELBpos in Australia. They collected samples of 173795 epochs for only one test point from a sparse network, and produced the standard deviations in cm level and one order of higher magnitude for altimetric components. The results in the Table 1 are found to be slightly worse than that of Gordini et al. (2006).

Table1 - Statistics of Components Differences for Methods (in Meters).

Method Name	**Components**	**Min (m)**	**Max (m)**	**Mean (m)**	**Std (m)**
Total to RTK	Y	-0.033	0.017	-0.009	0.011
	X	-0.040	0.025	-0.009	**0.014**
	h	-0.282	-0.075	-0.154	0.054
Total to CorsTR_FKP	Y	-0.058	0.031	-0.004	0.021
	X	-0.015	0.064	0.023	**0.018**
	h	-0.295	-0.046	-0.133	0.058
Total to CorsTR_ VRS	Y	-0.034	0.016	-0.003	0.014
	X	-0.060	0.060	0.019	**0.027**
	h	-0.247	-0.038	-0.117	0.059
Total to IskiCors_FKP	Y	-0.031	0.037	0.006	0.017
	X	-0.099	0.023	-0.059	**0.026**
	h	-0.272	0.005	-0.118	0.060
Total to IskiCors_VRS	Y	-0.028	0.027	0.005	0.015
	X	-0.111	-0.027	-0.071	**0.022**
	h	-0.251	-0.035	-0.119	0.056

The reason for this might be that we have calculated the differences between the assumed true coordinates (obtained by total stations) and those of the method (five different methods) to be compared to as opposed to one method.

6. CONCLUSION

This study involves 49 observations site locations in Istanbul whose coordinates were determined by CorsTR-VRS, CorsTR_FKP, IskiCors_VRS, IskiCors_FKP, classical RTK and conventional geodetic position fixed method with total station. The coordinates components were related to the conventional method and their simple differences were taken to compare one technique to another.

The results showed a complex structure as the accuracy differs from one component to another such as Y components showed 'best' results by CorsTR_VRS and Cors_TR_FKP while the same technique provided X components consistent accuracy with the Y component but less accurate than RTK. Of all the techniques used for the h components, CorsTR_VRS showed 'best' accuracy with three outliers.

Another important conclusion one can draw from the test is that IskiCors_VRS and FKP showed some shift in X and Y component which need further research.

This result is compatible with Eren et al. (2009). Based on the results we obtained, it may be recommended that both CorsTR_VRS and FKP technique may be considered before final coordinate determinations.

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