The Effect of Session Duration in Determination of Point Movements with GNSS

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SUMMARY

Nowadays, GNSS (Global Navigation Satellite Systems) techniques are widely used to determine positions of geodetic points. Geodetic networks that have high accuracy can be established with these techniques.

In this study, the effect of session duration was investigated in determination of point movements with GNSS. For this purpose, a micro geodetic network that consists of 7 points was used in Selçuk University Campus area, 6 of these points were reference points and one of which was object point. A mechanism that allows virtual shifting at 1cm intervals on the object point was used. When collecting the GNSS data, the data record interval was taken as 5 seconds and the elevation mask was chosen as 10^{o}. During the measurement, GNSS receiver set up on the mechanism at the object point was shifted to 1 cm intervals and GNSS data were collected for 2 hours on each point while receivers at the reference points were continuously collecting data. Coordinates of the reference points were determined based on CORS-TR (Continuously Operating Reference Stations-Turkey) network and the coordinates of the object point were calculated based on the reference points using 2-h, 30-min and 15-min observations. Leica Geo Office (LGO) v7.0 software was used in calculations. Root mean squares (rms), which were obtained from 2-h, 30-min, and 15-min GNSS measurements carried out successively on the mechanism, were compared with each other. Conclusively, it was seen that there were no significant differences between the 15-min session duration and the 2-h session duration in terms of rms in micro geodetic networks.

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1. INTRODUCTION

Nowadays, satellite-based positioning systems such as Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), GALILEO and BEIDOU, which are known as GNSS are widely used for determination of point positions. The GNSS includes different types of applications and accuracies for positioning. There are generally provided two techniques: absolute or differential (relative) positioning. In the absolute positioning, the position is determined based on the estimated satellite orbits. This technique does not provide the accuracy required for surveying tasks (Hofmann Wellenhof et al., 2008; Dawidowicz and Krzan, 2014). Required accuracy for surveying tasks can be obtained using the differential positioning. More than one GNSS receiver have to collect data simultaneously for differential GNSS (DGNSS). This technique is based on spatial correlation of systematic errors between receivers to estimate or reduce their effects. Many techniques have been developed on the basis of DGNSS for both static and kinematic measurements (Hofmann-Wellenhof et al., 2008; Dawidowicz and Krzan, 2014)

Determination of point movements is an important task in engineering surveys. Just as classical techniques, GNSS techniques can also be used to determine these movements. Static positioning method are commonly used in this kind of precise geodetic applications. Geodetic networks that have high accuracy can be established by using this method. No requirement of visibility between geodetic points in GNSS networks established using the GNSS provides flexibility in the selection of point locations, compared to classical geodetic networks. Compared to the classical techniques, GNSS techniques improve measurement accuracy, productivity and monitoring capacity (Wang et al. 2015).

Session durations could be reduced to several minutes with rapid static positioning technique which is one of the relative positioning methods (Erol et al., 2004). However, with regard to GNSS positioning technique it should be noted that the longer the length of sessions, the better the solution; 12 h of observations will give reasonable accuracies in the horizontal and the vertical with the error in vertical component being about twice that of the horizontal component (Ogundare, 2016).

In this study, the effect of session duration was investigated in determination of point movements in the directions of the coordinate axes. For this purpose, a micro geodetic network that has 7 points was used in Selçuk University Campus area, 6 of these points were reference points and one of which was object point. The points used in the network were constructed in the form of pillars for forced-centering. The mechanism that allows virtual shifting at 1 cm intervals on the object point was developed. During the measurement, the GNSS receiver set up on the mechanism at the object point was shifted to 1 cm intervals and the GNSS observations were carried out for 2 hours on each point while the receivers at the reference points were continuously carrying out observations. The shiftings on the object point were made in the north-south and the east-west directions. The rms, which were obtained from 2-h, 30-min, and 15-min GNSS measurements carried out successively on the mechanism, were compared with each other.

2. STATIC POSITIONING METHOD

While point coordinates can be determined using post-process with the GNSS techniques at the beginning, in recent times these coordinates can be also determined in real time. With post-process, the point coordinates can be determined by different methods such as static positioning, rapid static positioning and pseudokinematic positioning. In applications requiring high accuracy, such as deformation measurements, tectonic plate movements, monitoring of large engineering constructions, the static positioning method is most commonly used because of its high accuracy.

Static positioning method, which gives the coordinates of the unknown points after post-processing, is based on collecting simultaneous data at both the base and rover receivers during a certain period of time. Base vectors between stations can be calculated using more than one receiver with this method. Session durations of 1-2 hours are usually suggested for static positioning for civil engineering applications while for regional and global geophysical studies session durations should be 10 to 24 hours (Hastaoglu and Sanli, 2011; Stewart and Rizos, 2002). Highly accurate results can be achieved with increased session durations. Standard values for the session durations of static observations (particularly for baselines up to some 20 km) are listed in Table 1.

Table 1. Session durations for static surveys (Hoffman-Wellenhof et al., 2008)

Receiver	Conventional Static	Rapid Static
Single-frequency	30 min + 3 min/km	20 min + 2 min/km
Dual-frequency	20 min + 2 min/km	10 min + 1 min/km

3. APPLICATION

3.1 Study Area

In this study, the effect of session duration was investigated in determination of point movements with GNSS. For this purpose, a micro geodetic network that consists of 7 points was used in Selçuk University Campus area, 6 of these points were reference points and one of which was object point. The distance of the object point to the reference points changes from ~121 m to 1.6 km. The coordinates of the reference points were determined based on CORS-TR network that enables both real-time and post-process positioning, and consists of 146 points covering the whole of Turkey. It has been operating since 2009. In application, the CORS-TR stations used around the study area. The points AKHR, BEYS, CIHA, HALP, KAMN, KAPN, KLUU, KNY1, and YUN1 were used in calculations. The distance to the study area of these points changes from ~17 to 162 km (Figure 1).

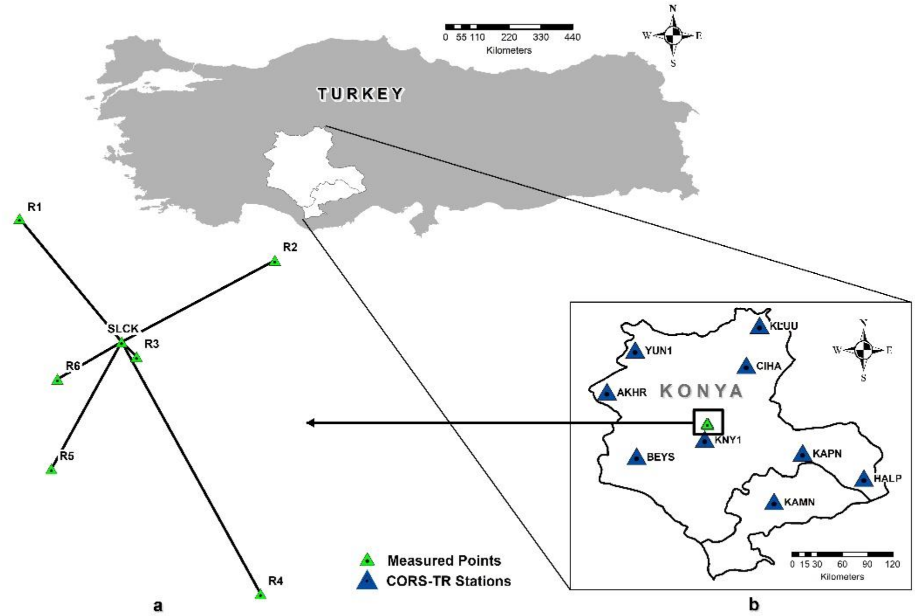

Figure 1. Microgeodetic network (a) and CORS-TR stations (b) used in application

The SLCK-Turkish National Fundamental GPS Network (TUTGA) point was used as the object point in the microgeodetic network established in the study area. The mechanism that allows virtual shiftings at 1 cm intervals in the direction of the coordinate axes was placed on the SLCK-TUTGA point, and measurements at the SLCK-TUTGA point were carried out on this mechanism (Figure 2).

Figure 2. SLCK-TUTGA point

3.2 Introduction of Mechanism

A mechanism was developed to determine virtual position changes at 1 cm intervals (Figure 3). Computer Numerical Control (CNC) lathes were used in the manufacture of the mechanism.

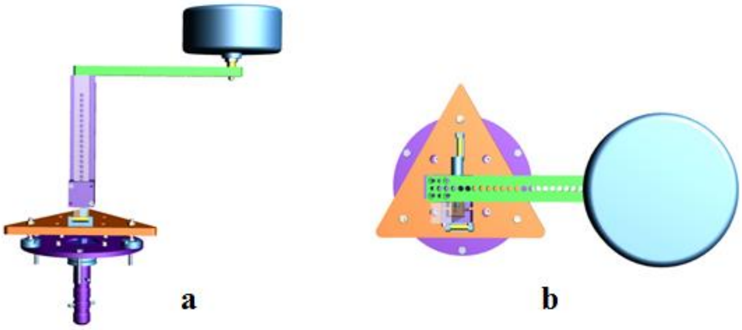

Figure 3. The view of mechanism from side (a) and top (b)

With the help of the mechanism, it is possible to make virtual position changes in the horizontal and the vertical directions with 1 cm intervals. The 1 cm interval points on the mechanism are used to shift the GNSS receiver horizontally (Figure 4a). The GNSS receiver can be set up on each of these points. Whichever direction the mechanism is directed, the position changes occur in that direction. When it is desired to make virtual position changes in the vertical direction, 1 cm interval points shown in the side view of the mechanism are used (Figure 4b).

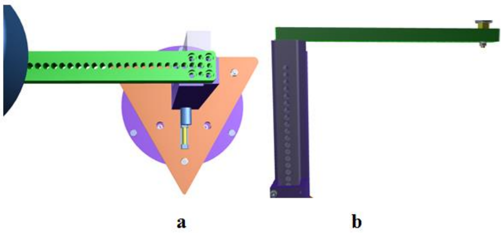

Figure 4. Points used for virtual position changes horizontally (a) and vertically (b)

There are two plate levels perpendicularly positioned to each other on a triangular table on which is placed the mechanism (Figure 5). These levels are set using the screws on the corners of the table, thus it is ensured that the receiver is vertical.

Figure 5. Plate levels on the triangular table

The mechanism can be directed to the desired direction and mounted using four screws on the forced-centering element of the pillar (Figure 6).

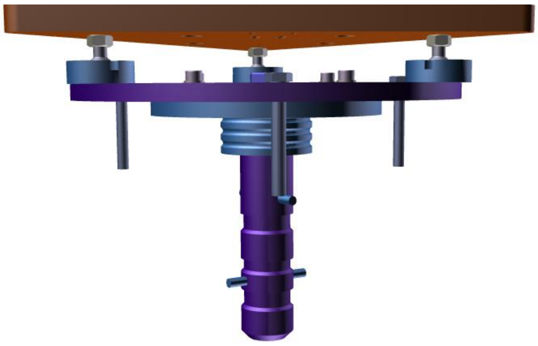

Figure 6. Forced-centering element and triangular table

Once the mechanism is mounted on the pillar and the plate levels are set, system becomes ready for measurements.

3.3 Measurements Carried Out in Study Area and Evaluation

In order to investigate the effect of session duration in determination of point movements with GNSS in the micro-geodetic network designed at the Selçuk University campus area, the mechanism was primarily directed to the north on the SLCK-TUTGA point. During the measurement, the GNSS receiver set up on the mechanism at the object point was shifted to 1 cm intervals and the GNSS observations were carried out for 2 hours on each point while the receivers at the reference points were continuously carrying out observations. Afterwards, in order to investigate the effect of session duration in determination of point movements in the east-west direction, the mechanism was directed to the east and the same measurement plan was applied. The data record interval was taken as 5 seconds. Four Topcon and three Javad GNSS receivers were used for carrying out measurements.

While determining point movements in the north-south and the east-west directions, the coordinates of used reference points calculated based on CORS-TR stations shown in Figure 1, using 10-hour observations. The coordinates at the object point were calculated based on reference points using 2-h, 30-min and 15-min observations.

LGO v7.0 software was used in evaluation of the observations. The rms, which were obtained from 2-h, 30-min, and 15-min GNSS measurements carried out on the mechanism, were compared with each other. In the baseline solutions, IGS (International Geodetic Survey) final orbits were used. GPS / GLONASS observations were evaluated together with the elevation mask of 10^{o}.

Projection coordinates (Transversal Mercator) were used in the comparison of the coordinates obtained from data evaluated. The coordinate differences (dx, dy, dh) between 1 cm interval points on the mechanism;

$$dx = x_{i+1} - x_i \qquad dy = y_{i+1} - y_i \qquad dh = h_{i+1} - h_i \tag{1}$$

errors of these coordinate differences ($\varepsilon_x, \varepsilon_y, \varepsilon_h$);

$$\varepsilon_x = dx - \text{true value} \qquad \varepsilon_y = dy - \text{true value} \qquad \varepsilon_h = dh - \text{true value} \tag{2}$$

were calculated by equations (1)-(2). In equation (2) the true value is 1 cm on shifting axis and 0 cm on the other axes. The coordinate differences and the errors of these differences were obtained from 1 cm interval consecutive points for 2-h, 30-min and 15-min observations. These are given in Tables 2-4, for the north-south and the east-west directions.

Table 2. The errors in the north-south and the east-west directions for 2-h observations

Points	**The north-south**			**The east-west**		
	ε_x(mm)	**ε_y (mm)**	**ε_h (mm)**	**ε_x(mm)**	**ε_y (mm)**	**ε_h (mm)**
0 - 1	-0.7	0.6	-1.8	0.8	0.1	-3.4
1 - 2	-0.8	0.3	0.7	-0.2	0.4	2.7
2 - 3	1.6	-1.1	-0.8	0.2	0.3	-1.1
3 - 4	1.0	0.1	-1.8	-1.2	-0.3	-2.9
4 - 5	1.8	0.4	-2.3	1.2	-0.4	3.0
5 - 6	-2.6	-0.5	-1.1	2.7	-2.9	-1.3
6 - 7	-1.7	-1.6	2.8	3.6	-0.5	2.0
7 - 8	1.4	0.2	-1.0	0.3	-1.5	1.8
8 - 9	-1.6	-0.3	0.9	0.0	-1.0	-0.1
9 - 10	-0.1	-0.1	2.3	1.0	0.2	0.3

Table 3. The errors in the north-south and the east-west directions for 30-min observations

Points	**The north-south**			**The east-west**		
	ε_x(mm)	**ε_y (mm)**	**ε_h (mm)**	**ε_x(mm)**	**ε_y (mm)**	**ε_h (mm)**
0 - 1	-0.4	0.5	0.8	1.3	-0.9	-4.4

1 - 2	-1.1	0.1	1.0	0.1	0.3	1.7
2 - 3	1.4	-1.7	-0.7	-1.8	0.5	-1.2
3 - 4	1.3	0.5	-4.2	0.2	-0.6	0.0
4 - 5	0.5	0.1	-1.4	1.0	0.1	4.4
5 - 6	-1.3	-0.7	0.2	2.4	-3.0	-0.6
6 - 7	-2.8	-1.7	3.4	3.7	0.2	6.6
7 - 8	2.3	0.6	-1.5	-0.5	-1.6	1.2
8 - 9	-2.3	-1.0	0.5	-0.6	-1.3	-0.4
9 - 10	0.6	-0.7	0.4	1.5	0.8	2.7

Table 4. The errors in the north-south and the east-west directions for 15-min observations

Points	**The north-south**			**The east-west**		
	ε_x(mm)	**ε_y (mm)**	**ε_h (mm)**	**ε_x(mm)**	**ε_y (mm)**	**ε_h (mm)**
0 - 1	-0.9	1.2	4.5	2.0	0.0	-3.7
1 - 2	-0.2	0.6	-4.1	0.3	0.8	3.2
2 - 3	0.9	-2.1	-0.2	-1.4	-1.1	-1.4
3 - 4	0.3	0.2	-2.1	-0.4	0.3	-0.5
4 - 5	2.2	0.4	-0.7	1.4	-0.1	3.9
5 - 6	-2.0	-0.5	-3.3	2.7	-3.1	-0.3
6 - 7	-2.2	-0.4	6.0	3.5	-0.3	6.4
7 - 8	2.5	0.6	-1.4	0.0	-1.9	0.7
8 - 9	-2.7	-1.3	-0.4	-0.2	-1.1	0.2
9 - 10	1.1	-1.4	-0.1	1.3	-0.2	5.1

The rms for the results of the coordinate differences (dx, dy, dh) obtained from 2-h, 30-min. and 15-min observations on the coordinate axes directions, m_x, m_y, m_h:

$$m_x = \pm\sqrt{\frac{[\varepsilon_x^2]}{n}}, \qquad m_y = \pm\sqrt{\frac{[\varepsilon_y^2]}{n}}, \qquad m_h = \pm\sqrt{\frac{[\varepsilon_h^2]}{n}} \tag{3}$$

Where n is the number of the coordinate differences at each axes. The rms are given in Table 5.

Table 5. The rms of the coordinate differences in the north-south and the east-west directions

RMS	**The north-south**			**The east-west**		
	2-h	**30-min**	**15-min**	**2-h**	**30-min**	**15-min**
m_x (mm)	±1.49	±1.60	±1.74	±1.58	±1.68	±1.72
m_y (mm)	±0.76	±0.79	±1.04	±1.12	±1.24	±1.28
m_h (mm)	±1.70	±1.90	±3.02	±2.16	±3.10	±3.30

4. CONCLUSIONS

Just as classical terrestrial techniques, GNSS techniques can also be widely used today in determination of point movements. The use of GNSS techniques is easier, faster and more economical than terrestrial techniques.

With the help of the mechanism designed in this study, the point positions were virtually changed in the direction of the coordinate axes and the determination of these movements was investigated. Coordinates of consecutive points were determined by the static positioning method on the mechanism and the calculated point movements were compared with the true value on the mechanism in terms of 2-h, 30-min and 15-min session durations.

When Table 5 is examined, it is seen that the rms calculated are improved as the session duration increases. However, there is no statistically significant difference between the rms in terms of the session duration. If the distance of the reference points to the object point is short, it can be said that the differences obtained by the 15-min and 2-h observations equal to each other. In this case, it seems that a 15-min session duration is sufficient for such short baselines. As can be seen in Table 5 again, the rms in the vertical direction are generally larger than in the horizontal direction.

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