American Journal of Remote Sensing
2024, Vol. 12, No. 1, pp. 18-23
https://doi.org/10.11648/j.ajrs.20241201.13

Research Article

Assessing the Results of Satellite Positioning for Geodetic Network Points with Different Observation Sessions

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Abstract

Nowadays, static satellite observations are widely used in many fields. To obtain high measurement accuracy, the static satellite observations of the geodetic network have been carried out using one and two base stations. This study is important due to the lack of information on whether using several base stations impacts measurement accuracy. In addition, the dependence of the measurement accuracy of different lengths of the geodetic network lines on the observation time is investigated. Direct measurements have been carried out on the territory of Egypt, where the development of a geodetic network of the National Agricultural Cadastral Network (NACN) is a burning issue. The observations were conducted using Trimble R10 dual-frequency receivers based on specific schemes. In the case of using one base station, all the lines that connect the nearest points to the station were calculated. In the case where two stations were being used, the observations were carried out simultaneously on three points, including the base points. The third point is the closest point to the baseline. The other three points were determined as follows: two points had been taken from the previous triangle; and the one that was the nearest one to the line formed by the first two points, etc. The analysis of the results shows that if only one station is used, it takes at least 3–4 hours to make measurements that are precise up to a centimeter. The use of two base stations can reduce measurement time by two hours. Additionally, these studies can help select satellite positioning technology based on the equipment available.

Keywords

Base Station, Line Determination, Observing Session Duration, RMS Measurement Error, Static Observations

1. Introduction

Now we can determine the position with high accuracy by making use of GNSS systems. The point coordinates are determined by means of observations and calculations carried out from an unknown position point to a known position point. GPS satellites are used as a point with a known position [1]. GNSS provides real-time three-dimensional coordinates, time, and speed in any weather and any location where the receiver has a clear view of the sky [2].

Accurate position determination is now possible with sub-decimeter accuracy thanks to advancements in data processing and analysis [3]. With a longer observation time, the position can be determined statically with a high degree of accuracy [4]. At the same time, its practical and efficient use is associated with the solution of such issues as the influence of

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Received: 27 March 2024; **Accepted:** 16 April 2024; **Published:** 30 May 2024

line lengths and the number of base stations on the accuracy of satellite determinations. It is especially important to address these issues in the design of geodetic networks.

The main objective of this study is to determine the time required for conducting static observations in order to obtain a given accuracy, which is assumed to be 1.5 cm. Static GNSS surveying, used in the current research, is a relative positioning technique that depends on the carrier-phase measurements [5]. In geodetic control surveys, this method is used to provide high precision over long baselines [6]. Two or more stationary receivers track the same satellites. One receiver - the base receiver - is set up over a point with precisely known coordinates, such as a survey monument. The other receiver, the remote receiver, is set up over a point whose coordinates are unknown. The base receiver can support any number of remote receivers, as long as a minimum of four common satellites is visible at both the base and the remote sites [5].

Several studies have evaluated GPS accuracy, such as by [7-17]. These studies focused on GPS accuracy and developed prediction formulas based on factors such as baseline length, observing session duration, and network geometry. The software used in these studies also played a role. One of the first accuracy formulations, among the RP studies, was implemented by a National Geodetic Survey (NGS) team using the CORS stations of the country [13]. Since the stations were separated in 25-300 km baseline lengths, the team tested relative positioning accuracy depending on baseline lengths as well as observing session durations. Hence the accuracy of relative positioning was entirely dependent on observing session durations. Firuzabadi, D. *et al.* [17] conducted a study to test the impact of network geometry, specifically the distribution and number of network points, and the duration of the observing session on positioning accuracy. Their findings indicate that to achieve the current IGS accuracy, at least 6 hours of GPS data and a minimum of 4 well-distributed reference stations are required.

In GNSS network, stations are generally located where they are needed, but the observation schemas between stations are important [18]. The main goal of this research was to select the best observation schema of GNSS networks according to the number of base stations. Direct measurements have been carried out on the geodetic network, which is laid out on the territory of Egypt from the National Agricultural Cadastral Network (NACN) around river Nile with an area of about 800 km^2 (figure 1).

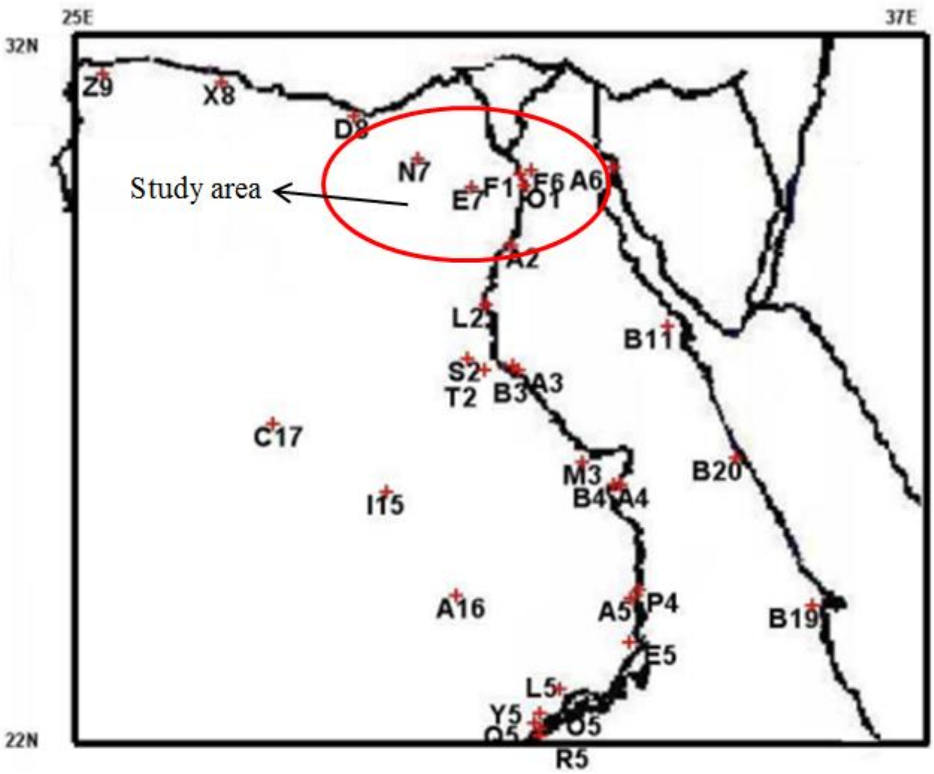

Figure 1. *Data points used in the research.*

2. Methodology

In this study used a part of NACN geodetic network in Egypt as in figure 1. The base lines lengths were measured in two cases using one base station and two base stations for different time observations from 1 to 12 hours. The results of static satellite observations were obtained using two-frequency Trimble R10 receivers with a planned accuracy of (3 mm + 0.5D) mm in static mode [http://www.trimble.com/survey/trimbler10.aspx/], where D is the distance between the receivers in kilometers. Satellite determinations were made using specific methods. If there was only one base station, all the lines that connected the nearest points to the station were calculated. If two stations were used, simultaneous observations were made on three points, including the base points. The third point was the nearest to the baseline (as shown in Figure 3). The other three points were determined as follows: two points were taken from the previous triangle, and the third point was the one closest to the line formed by the first two points.

Observations were carried out over two days in two sessions, six hours each, at four stations: F1, F6, E7 and O1. The purpose of the observations is to determine lines whose lengths ranged from 17 to 72 km (Figure 2). The difference in the lengths of the lines during the observations will make it possible to determine the observation time, which is sufficient to ensure the specified accuracy (1.5 cm). This is very important for planning various observation schemes.

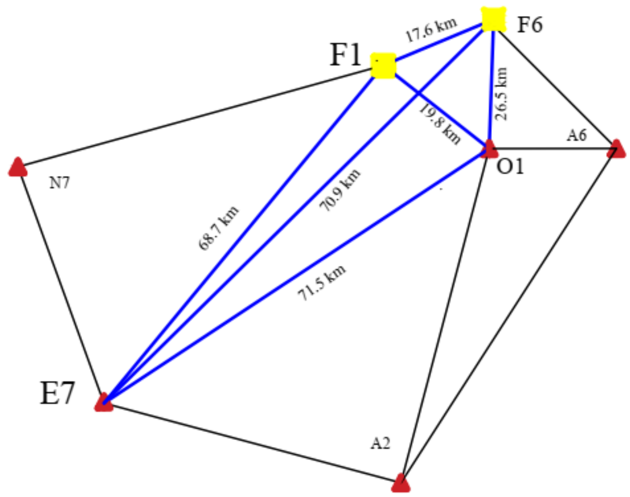

Figure 2. *Used geodetic network.*

Observation sessions were carried out in two intervals of the day, taking into account the visibility of a sufficient number of satellites (at least five) and a good position accuracy reduction parameter (PDOP) [19].

It is known that the more observed satellites and the better their geometry (the smaller the geometric factor DOP), the shorter the required session duration [20]. However, it is necessary to have specific quantitative characteristics. All measurements were processed in the Trimble Business Center software. Observations were performed according to two schemes: 1) satellite determinations using one base station; 2) satellite determinations using two base stations (according to the triangle scheme).

As a result of satellite determinations, the lengths of the lines of the geodetic network were calculated. Observations at the points were carried out for one hour, then the interval increased by one hour, and so on up to 12 hours. The order of performing observations for the two indicated schemes is shown in figure 3.

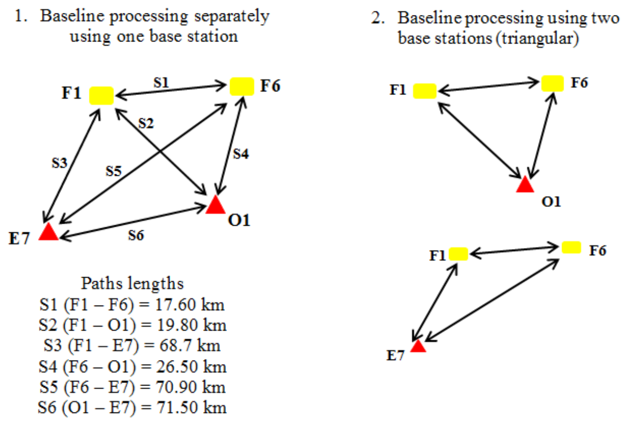

Figure 3. *Different measurement paths.*

The paper began by explaining the fundamental principle of GNSS surveying using the static method and observation schema. The data collection strategy was then discussed within the test area, and the accuracy of four types of GNSS networks was analyzed. Finally, the research results were summarized in the last section.

3. Results and Analysis

The results of the processing of satellite determinations are presented in the table 1, which shows that the observation time and the root mean square errors (RMS) of line measurements in cases of using one or two base stations. Graphs of root-mean-square errors in determining lines for each time interval are shown in figures 4 and 5.

Analysis the results of table 1 and figures 4, 5 show that the RMS errors of GPS observations decreases with each additional hour of observation. With a given line detection accuracy of 15 mm, it took from three to four hours of observations with one base station dependent in base line lengths and two hours with two base stations. Results show that the accuracy of GPS observations increases with the short base line lengths. The RMS for two hours observation increases from 28 mm foe session S1 (length 17.6 km) to 48 mm for session S3 (length 68.7 km) in case of using one base station. In case of using two base stations, the RMS for two hours observations arrives 15 mm for session S3 but for session S1 don't exceed 12 mm. from table and figures, it noticed that for more 6 hours observation intervals the accuracy of GPS observation don't have significant improvements since RMS decreases no more than 2 mm for each additional hour of observation.

The accuracy characteristic (RMS) of observations using one or two base stations is shown in figure 6 for base line S1.

Analysis of figure 6 shows that the results don't have a significant difference for using one or two base stations for high observation time. Results show that the base length measurements obtained from more 6 hours no matter which number of base stations used since the differences no exceed 5 mm and this satisfied with [4].

Despite the fact that the specific satellite definitions presented in this article cover a limited range of possible measurements, in practice the use of one or two base stations is very widely used. It is of interest to consider various schemes of satellite measurements: using one, two, and three base stations. At the same time, it is possible to achieve the required measurement accuracy with minimal use of base stations and, of course, equipment. It is observed that the accuracy rates in these studies depend on the measurement time, ranging from 0.1-20 cm in horizontal coordinates and 0.1-54 cm in height. [21]. Namely, users should select observation periods based on intended accuracy.

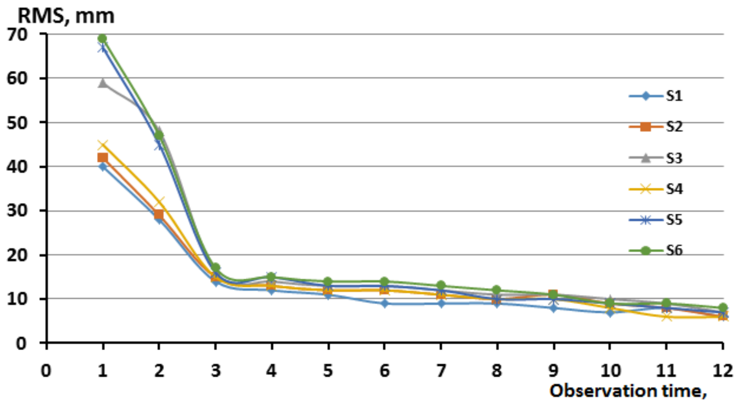

Figure 4. The Root Mean Square errors in determining line lengths for the case of using one base station.

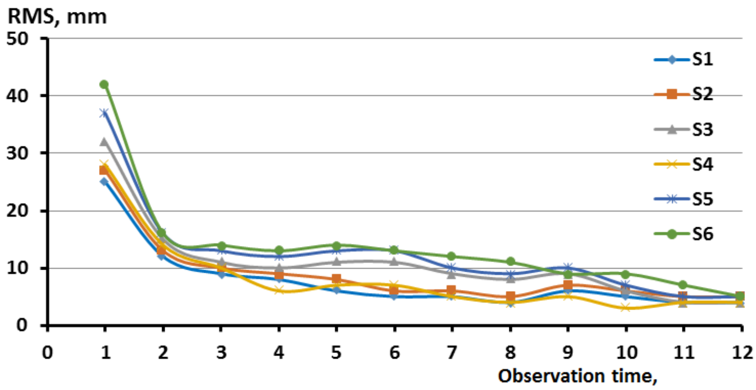

Figure 5. The Root Mean Square errors in determining line lengths for the case of using two base stations.

Table 1. Root Mean Square errors of line lengths measurements for different observation time intervals and for one or two base stations.

Paths line	Line length (km)	Root-Mean-Square error (mm) at observation time, hours											
		1	2	3	4	5	6	7	8	9	10	11	12
Case of Using One base station													
S1	17.60	40.0	28.0	14.0	12.0	11.0	9.0	9.0	9.0	8.0	7.0	8.0	6.0
S2	19.80	42.0	29.0	15.0	13.0	12.0	12.0	11.0	10.0	11.0	9.0	8.0	6.0
S3	68.7	59.0	48.0	16.0	14.0	13.0	13.0	12.0	11.0	11.0	10.0	9.0	7.0
S4	26.50	45.0	32.0	15.0	13.0	12.0	12.0	11.0	10.0	10.0	8.0	6.0	6.0

Paths line	Line length (km)	Root-Mean-Square error (mm) at observation time, hours											
		1	2	3	4	5	6	7	8	9	10	11	12
S5	70.90	67.0	45.0	16.0	15.0	13.0	13.0	12.0	10.0	10.0	9.0	8.0	7.0
S6	71.50	69.0	47.0	17.0	15.0	14.0	14.0	13.0	12.0	11.0	9.0	9.0	8.0
Case of Using Two base stations													
S1	17.60	25.0	12.0	9.0	8.0	6.0	5.0	5.0	4.0	6.0	5.0	4.0	4.0
S2	19.80	27.0	13.0	10.0	9.0	8.0	6.0	6.0	5.0	7.0	6.0	5.0	5.0
S3	68.7	32.0	15	11.0	10.0	11.0	11.0	9.0	8.0	9.0	6.0	4.0	4.0
S4	26.50	28.0	14.0	10.0	6.0	7.0	7.0	5.0	4.0	5.0	3.0	4.0	4.0
S5	70.90	37.0	16.0	13.0	12.0	13.0	13.0	10.0	9.0	10.0	7.0	5.0	5.0
S6	71.50	42.0	16.0	14.0	13.0	14.0	13.0	12.0	11.0	9.0	9.0	7.0	5.0

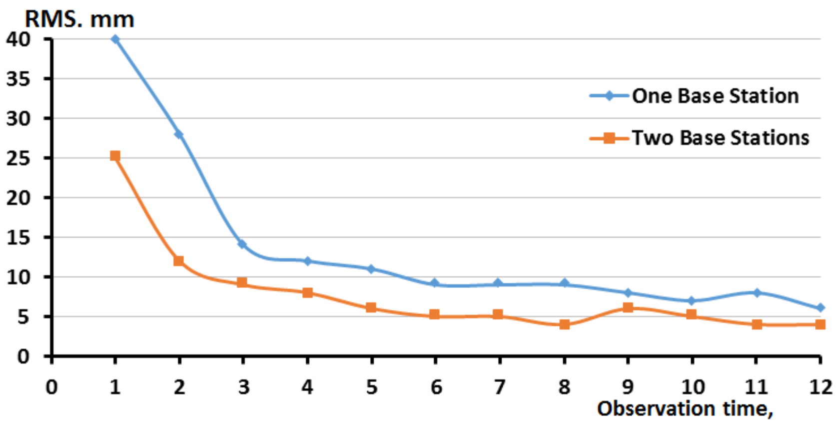

Figure 6. *RMS error variances of observations using one or two base stations.*

4. Conclusion

Research results have shown that the accuracy of GPS observations increases with each additional hour of observation. With a given line detection accuracy of 15 mm, it took from three to four hours of observations with one base station dependent in base line lengths and two hours with two base stations. Such indicators are provided subject to observance of the requirements for making observations and can serve as preliminary data for the organization of satellite observations using one or two base stations.

The next stage of these studies is to consider the observation technology using two base stations and one mobile (rover). There is an opportunity to combine different techniques measurements of the geodetic network, which will make it possible to develop technological schemes for measurements and more flexibly vary the available equipment, which is important both from the practical and scientific side of this issue.

Abbreviations

NACN	National Agricultural Cadastral Network
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
RMS	Root-Mean-Square
NGS	National Geodetic Survey
IGS	International Geodetic Survey
CORS	Continuously Operating Reference Station
DOP	Dilution of Precision

Acknowledgments

The author expresses gratitude to members of the Department of Public Works Engineering, Faculty of Engineering, Tanta University for consultations on certain subjects. In addition, members of the civil engineer department of Higher Future Institute for Engineering and Technology in Mansoura for helping in collecting and analysis of data.

Author Contributions

Sobhy Abdel Monam Younes is the sole author. The author read and approved the final manuscript.

Data Availability Statement

All data generated or analyzed during this study are included in this published article.

Conflicts of Interest

The authors declare no conflicts of interest.

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