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Quality Control of Kinematic GNSS Networks: a case study of the regional network at Sharqia Governorate in Egypt

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الملخص العربي

الاحتياج للاحداثيات باستخدام نظم الاقمار GNSS اصبح من الامور الضرورية و لان الارصاد المتحركة تكون ذات دقة اقل من الارصاد الثابتة فتم استخدام اكثر من نقطة ثابتة لرفع الدقة و تبين من البحث بان استخدام نقطة واحدة ثابتة قد يعطي دقة بنسبة 33% في حين ان استخدام نقطين ثابتين اعطي احتمال دقة 95% و ذلك بعد عمل اختبارات ضبط الجوده و المقارنة بمنحني التوزيع الطبيعي.

Abstract

Determining the three-dimensional coordinates of points by communication with satellites has always inspired scientists and researchers. Primarily, GNSS were used in a static or semi-static mode if high accuracy is required. However, as a result of the substantial improvement made in the capabilities of the satellites and the signal structure, it was important to investigate methods of improving the accuracy obtained from these systems when used in a high dynamic environment which is of great importance for many applications. The purpose of this research is to the comparative study of the quality of the network by using a different number of base stations, starting from one base to three bases. The F-test is implemented to assess the solution improvement alternative for different cases of the network. According to the F-test, it is better to use two base stations during observation rather than one base station.

Keywords: Kinematic; Network; GNSS; PPK; Quality Control.

1. Introduction

In the last years, the global positioning system (GPS) which is used for getting the position of any point accurately has become the most significant survey instrument (e.g. Abdelfatah et al., 2009). The nominal constellation of 24 GPS satellites orbit in six orbital planes (four satellites per plane) and the inclination angle of the orbital planes is 55° to the equator with an altitude of 20200 km and with 12 sidereal hours as an orbit period (e.g. Hofmann et al., 2007). Nowadays, the nominal number of GPS satellites is 32 operational satellites (e.g. Tabatabaei et al., 2017).

Differential GNSS were established over many years as a technique to improve positioning accuracy. This allows accurate positioning even at centimeter levels using the technique of so-called integer ambiguity resolution. The fundamental concept is to reduce main error sources, ionosphere and delays in the troposphere, orbit errors and satellite clock errors by acquiring satellite data at a well-known location.

The Kinematic Network (KN) technique allows the establishment of positioning systems which serve larger regions or whole countries through the establishment and retention of reference station networks, the collection and preprocessing of its findings and the distribution of monitoring corrections to kinematic network users. The concept behind kinematic network placement is founded on the creation of observed GNSS RINEX (Receiver INdependent EXchange) database stations with a network (two or more base stations). The differential errors between the reference stations within the network are determined on the basis of their known accurate coordinates. The differential errors can then be determined by the least square at any stage in the network (Teunissen et. al, 2017).

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements (Mitra, 2016).

Quality control and improvement involve the set of activities used to ensure that the products and services meet requirements and are improved on a continuous basis as shown in Fig 1. Since variability is often a major source of poor quality, Statistical techniques, including Statistical process control (SPC) and designed experiments, are the major tools of quality control and improvement (Mitra, 2016). Quality improvement is often done on a project by project basis and targets teams led by personnel with specialized knowledge of statistical methods and experience in applying them. Projects should be selected so that they have a significant business impact and are linked with the overall business goals for quality identified during the planning process (Fu, Huang, 2019). The techniques in this paper are integral to successful quality Control improvement. Therefore, F-test was used in the present study.

The objective of any statistical test is to determine the likelihood of a value in a sample, given that the null hypothesis is true. An F-test is a statistical test that compares the variances of two samples so as to test the hypothesis that the samples have been taken from populations with different variances. Its basic purpose is to check for differences among sample variance (Burr, 2018).

In the present study, a comparative study of the quality of the network by using a different number of base stations, one base and two base stations by using three base station as a reference. The F-test is implemented to assess the solution improvements for different cases of the network.

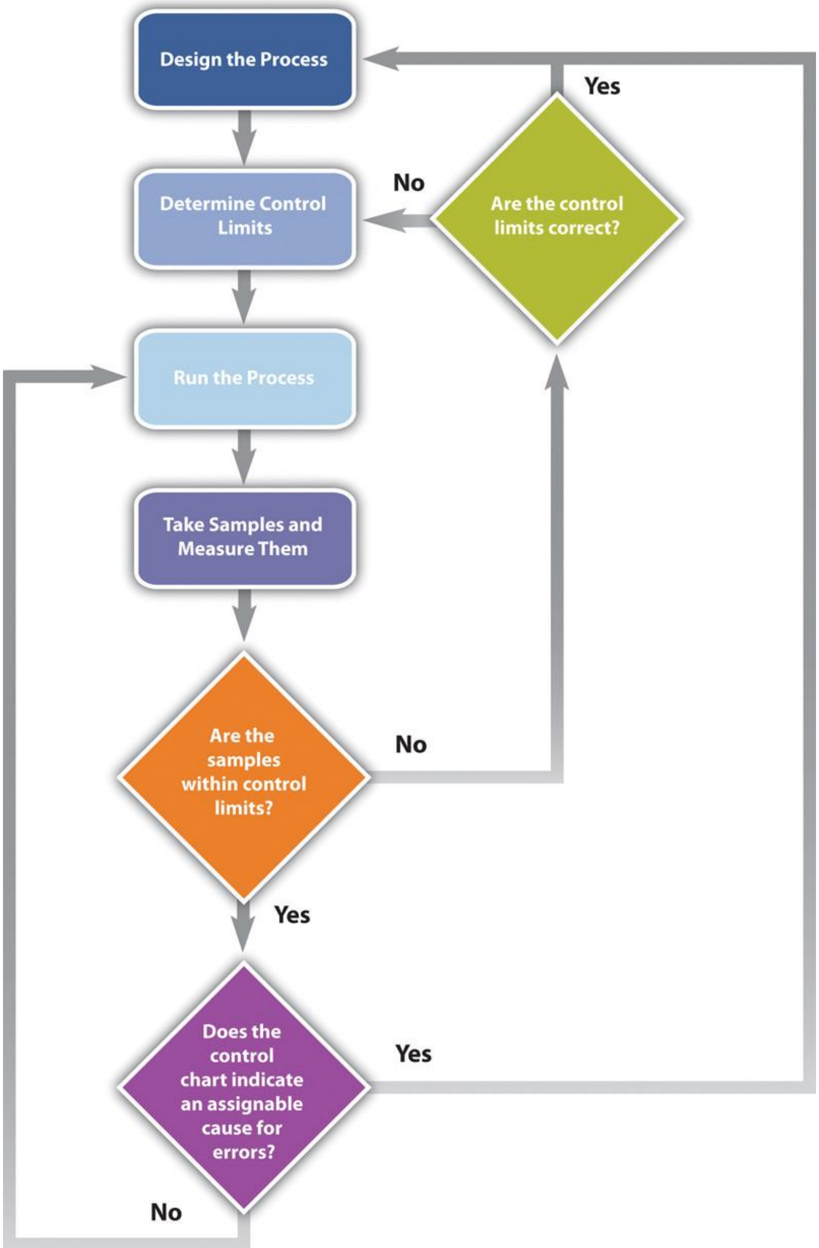

Fig. 1 Process of Quality Control.

2. Study Area

The study area of this research was in Sharqia governorate as shown in Fig. 2. The base stations were distributed around the governorate in Enshas (ENS), Fakous (FKS) and Zagazig (ZAG).

Four GNSS receivers were used. Three receivers were used as base stations and one receiver was used as a rover. The static base stations were in Enshas, Fakous and Zagazig. Two receivers of the type SOKKIA GRX2 were used in Zagazig, Fakous. Another two receivers of type ComNav T300 PLUS were used in Enshas and rover.

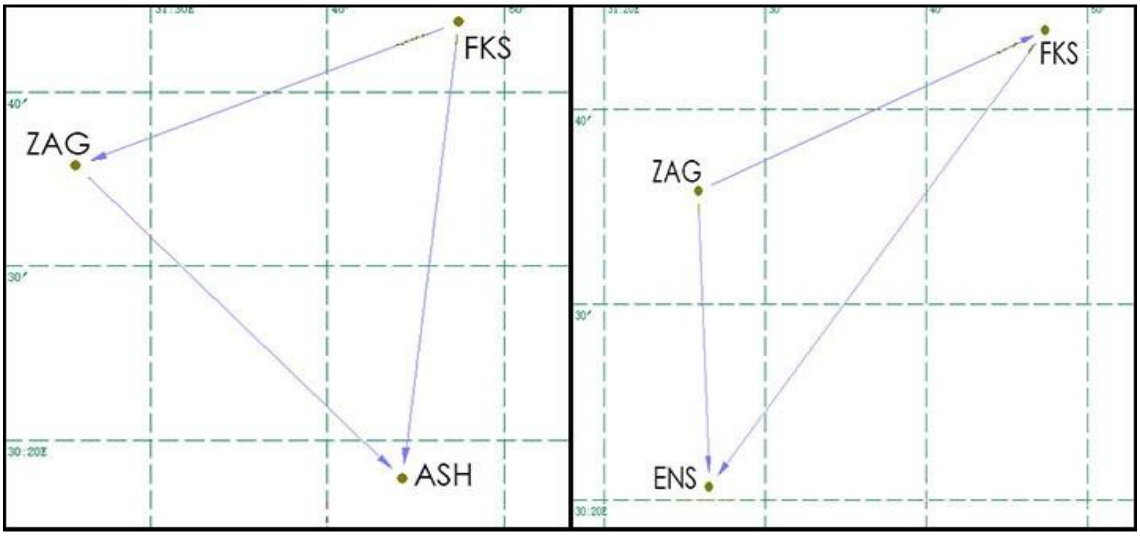

Fig. 2 kinematic Network GNSS surveying.

3. Data Collection

Data were observed at eight different routes (R) in Feb 2019 in Enshas and 10th of Ramadan city as shown in Fig. 3. In 10th of Ramadan city, the rover was fixed on a vehicle and was derived in five routes. At the beginning of each data collection session, the vehicle was idled for five minutes for the receivers to initialize In Enshas, the rover was fixed on carbon robotic stock and walking on foot in three routes as summarized in Table 1. The network was established. The base stations were located in Enshas (ENS), 10th of Ramadan city (ASH), Zagazig (ZAG) and Fakous (FKS) as shown in Table 2. The number of observed epochs were 58746.

The data were solved by using common software "Compass Solution" which has been used as the baseline analysis software and using the mathematical model to analysis kinematic network. The model used the least squares method to analyze the kinematic network for all routes.

Table 1 Number of epochs in each route.

Route no.	Day of observation	Length (km)	No. of epochs	Base stations
R1	**15 Feb 2019**	**15**	**4190**	**ASH, ZAG and FKS**
R2	**17 Feb 2019**	**10**	**1915**	
R3	**20 Feb 2019**	**10**	**4719**	
R4	**22 Feb 2019**	**12**	**4144**	
R5	**23 Feb 2019**	**12**	**4609**	
R6	**16 Feb 2019**	**4**	**9376**	**ENS, ZAG and FKS**
R7	**18 Feb 2019**	**7**	**17643**	
R8	**21 Feb 2019**	**6**	**12150**	

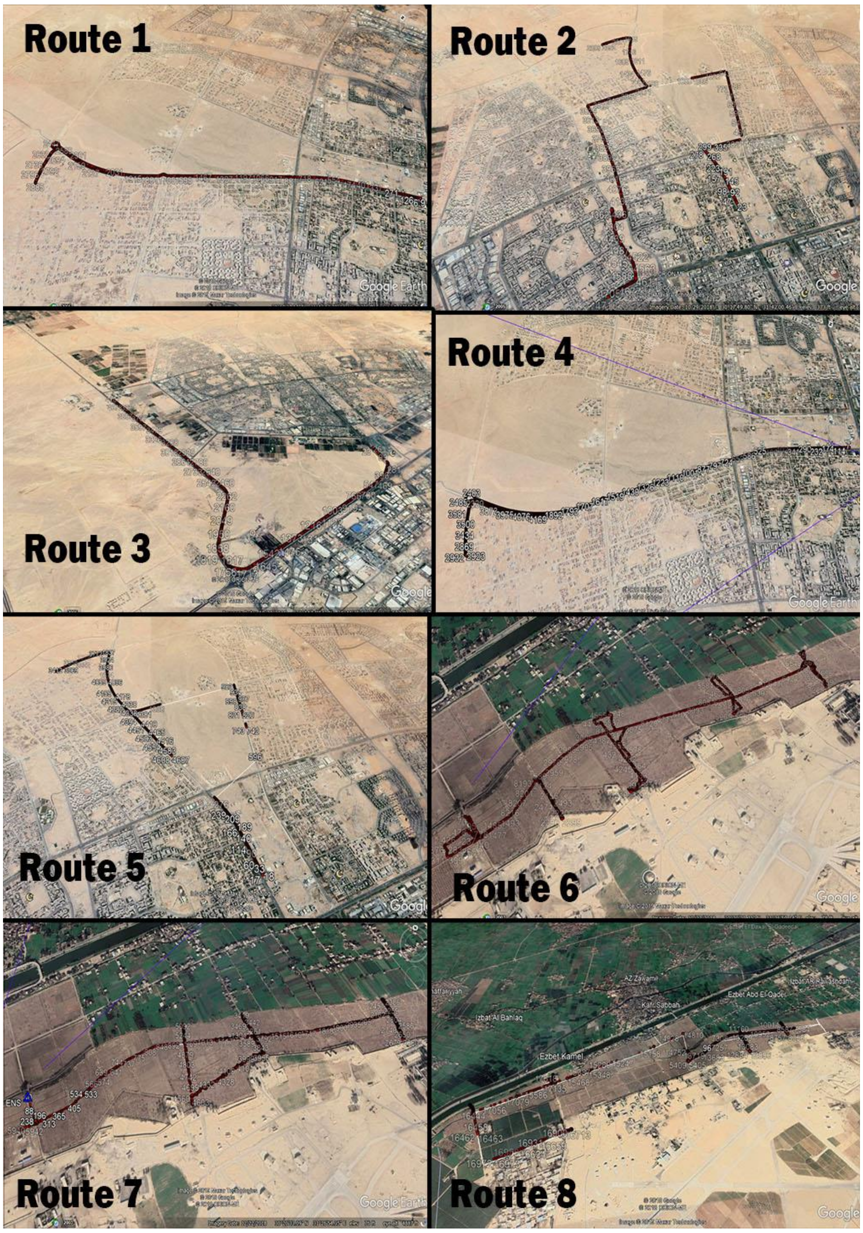

Fig. 3 Routes’ Maps from R1: R8.

Table 2 The accurate values of stations’ coordinates.

Station	Code	Latitude (φ)	Longitude (λ)	Height (h)	Receiver Type
Enshas	ENS	30º20’39.290”	31º26’31.659”	33.65	ComNav T300P
10th of Ramadan	ASH	30º17’46.027”	31º44’14.972”	133.83	ComNav T300P
Zagazig	ZAG	30º35’46.787”	31º25’49.909”	37.32	SOKKIA GRX2
Fakous	FKS	30º43’59.579”	31º47’26.078”	30.30	SOKKIA GRX2

4. GNSS Network Analysis

For the kinematic network, the observations of the three GNSS base stations and rover have been analyzed with the three cases; one base station, two base station and three base station. “Compass Solution” Software Version 1.8.8 is used for analyzing and processing the GNSS network data. The processing flowchart as shown in Fig.3 indicates the implemented steps for the three cases. Route no. 6, the created baselines are ENS-Rover [~1.00 km], ZAG-Rover [~26.00 km] and FKS-Rover [~53.00 km].

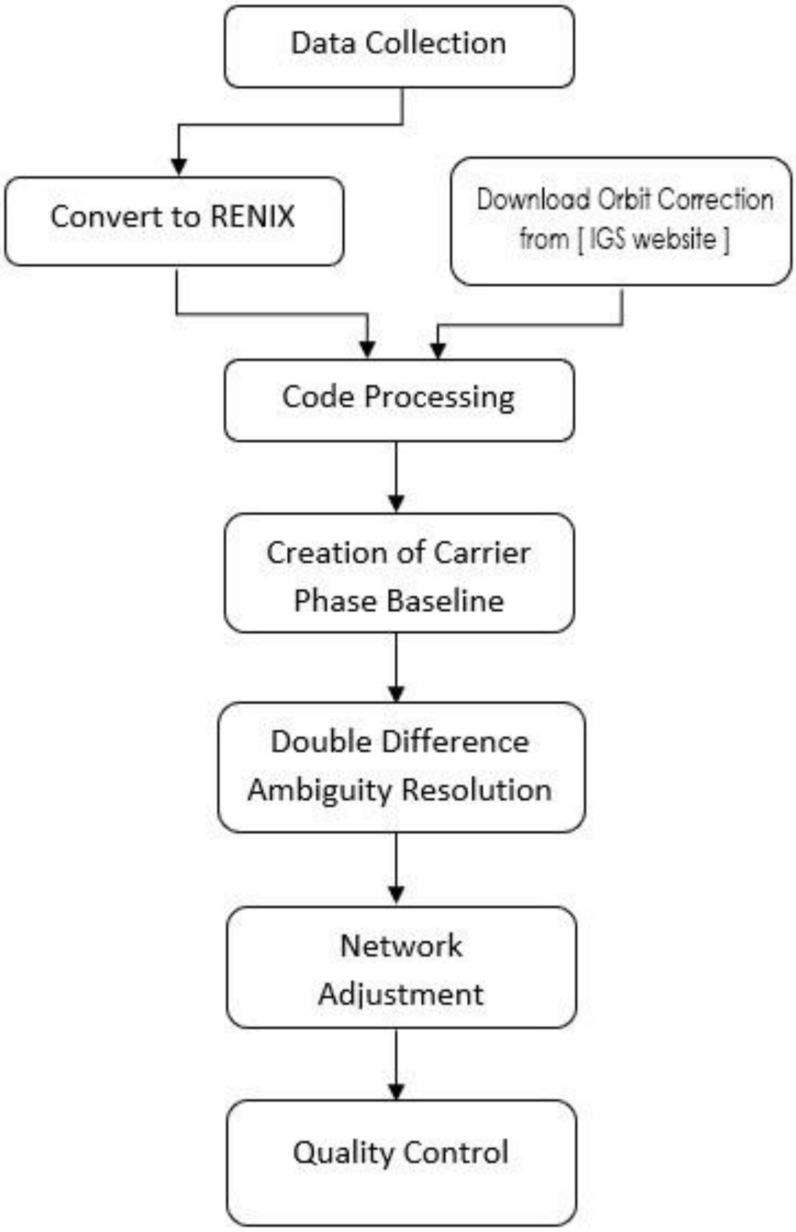

Fig. 3 Steps of Data Analysis and Processing.

5. Results and Discussion

The Compass Solution Software Version 1.8.8 is used for observation data analysis. The next tables show the difference in kinematic network cases and the mean value of errors in them. The results have been evaluated with error value and two sample F-test for all cases.

The F-test has been implemented on the results of the processed data of the year 2019 for all network stations. F-test distribution compares the variances of two samples. The null hypothesis, H_0, and alternative hypothesis, H_a, have been performed for this test.

$$H_0: \frac{S_1^2}{S_2^2} = 1 \tag{1}$$

$$H_a: \frac{S_1^2}{S_2^2} \neq 1 \tag{2}$$

The test statistic is

$$F = \frac{S_1^2}{S_2^2}, \qquad (S_1^2 > S_2^2) \tag{3}$$

The null hypothesis is rejected where:

$$F > F_{\propto/2} \tag{4}$$

Where S_1^2 and S_2^2 are the variances and F is test statistic value (Ghilani, 2017).

Table 3,4 and 5 are showing the value of errors in different cases for longitude, latitude and altitude.

Table 6 is showing the values of F-test for the three parameters; longitude (λ), latitude (Φ) and altitude (h). F-test here is implemented for all different cases. The tabulated F-value at confidence level 95% is 0.45:2.24. The values of F-test smaller than the tabulated value are accepted and greater than the tabulated value are rejected.

Table 3 The mean value (mm) and standard deviation for longitude.

Case	Station	Mean (mm)	Standard Deviation
One base station	**FKS**	20.41	8.55
	ZAG	12.43	4.24
	ENS	13.56	5.25
Two base stations	**FKS and ZAG**	13.91	6.91
	FKS and ENS	14.23	9.96
	ENS and ZAG	10.23	3.65
Three base stations	**ENS, ZAG and FKS**	10.43	5.19

Table 4 The mean value (mm) and standard deviation for latitude.

Case	Station	Mean (mm)	Standard Deviation
One base station	FKS	0.70	0.22
	ZAG	0.60	0.45
	ENS	0.58	0.27
Two base stations	FKS and ZAG	0.53	0.20
	FKS and ENS	0.51	0.15
	ENS and ZAG	0.47	0.24
Three base stations	ENS, ZAG and FKS	0.41	0.16

Table 5 The mean value (mm) and standard deviation for altitude.

Case	Station	Mean (mm)	Standard Deviation
One base station	FKS	12.14	5.32
	ZAG	16.98	8.98
	ENS	18.37	8.54
Two base stations	FKS and ZAG	11.61	5.19
	FKS and ENS	12.24	5.16
	ENS and ZAG	13.62	6.12
Three base stations	ENS, ZAG and FKS	9.99	4.47

Table 6 The F-test values for different cases.

Station	λ		Φ		h	
	F test	Status	F test	Status	F test	Status
FKS	2.71	rejected	1.94	accepted	1.41	accepted
ZAG	0.67	accepted	7.63	rejected	4.03	rejected
ENS	1.02	accepted	2.81	rejected	3.64	rejected
FKS and ZAG	1.77	accepted	1.58	accepted	1.34	accepted
FKS and ENS	1.80	accepted	0.92	accepted	1.33	accepted
ENS and ZAG	0.49	accepted	2.23	accepted	1.87	accepted

During the implementation of the F-test, the three base stations case were used as a reference case. In the case of one base station, for longitude (λ), the computed F-test for FKS station is more than the tabulated F-value, so the null hypotheses can be rejected and for ZAG and ENS are between the tabulated F-values, so the null hypotheses can be accepted at confidence level 95%. for latitude (Φ), the computed F-test for FKS station is between than the tabulated F-value, so the null hypotheses can be accepted at confidence level 95% and for ZAG and ENS are more than the tabulated F-values, so the null hypotheses can be rejected. for altitude (h), the computed F-test for FKS station is between than the tabulated F-value, so the null hypotheses can be accepted at confidence level 95% and for ZAG and ENS are more than the tabulated F-values, so the null hypotheses can be rejected. So, there is a risk of using a single base station.

In the case of two base stations, for longitude (λ), the computed F-test for (FKS and ZAG), (FKS and ENS) and (ENS and ZAG) are between the tabulated F-value, so the null hypotheses can be accepted at confidence level 95%. for latitude (Φ), the computed F-test for (FKS and ZAG), (FKS and ENS) and (ENS and ZAG) are between the tabulated F-value, so the null hypotheses can be accepted at confidence level 95%. for altitude (h), the computed F-test for (FKS and ZAG), (FKS and ENS) and (ENS and ZAG) are between the tabulated F-value, so the null hypotheses can be accepted at confidence level 95%. So, there is a risk of using a single base station. Therefore, it is preferable to use two base stations instead of one base station during observation.

6. Conclusions

In this study, a network consists of three base stations and one rover equipped with GNSS receivers were used. Compass Solution software version 1.8.8 was used for processing the observation. Data of eight routes of the year 2019 were used with the same procedure steps. The F-test was performed on the results and used for the comparison between the quality of the network by using a different number of base stations.

Based on the results and analysis of the observed data at different observation mode and days. The following remarks can be concluded:

- The error value for longitude was 15, 13 and 10 mm of one base station, two base stations and three base stations respectively.
- The error value for latitude was 0.6, 0.5 and 0.4 mm of one base station, two base stations and three base stations.
- The error value for altitude was 16, 12 and 10 mm of one base station, two base stations and three base stations respectively. There is an improvement in longitude as the number of base stations increases.
- According to the F-test, it is better to use two base stations during observation rather than one base station.

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