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Adjusting of Absolute Point Positioning Accuracy

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Abstract—*In this paper, some trials were done to increase the positioning accuracy using one unit of GPS receiver. Firstly, the positioning accuracy improved from 40 to 20 m when errors correction models have been used, except ionospheric model. Secondly, the ionospheric error was studied relative to the other GPS errors, and it was founded a good relation (Empirical equation) between the ionospheric error and the earth rotation with correlation coefficient 99.4%. The usage of this relation improved the accuracy to 10m; which means that this relation is not accurate enough to predict the ionospheric error. Thirdly, a new positioning method , called (interpolation relative positioning), has been done by observing a fixed point in the observation area and moving in a short time , 5 minutes , to the unknown point. The resulting accuracy from this is improved to 50cm. Finally, a modification has been done on the previous method which returns to the fixed point to observe it again in a short time. This method called as (Extrapolation Relative Positioning), because the dependent mathematical technique is extrapolation technique. This method improved the accuracy to 20cm at short time equals 8 minutes.*

Keywords: *GPS, Absolute Positioning, Interpolation and Extrapolation Relative Positioning,*

1. INTRODUCTION

There are several sources of error that degrade the GPS position from few meters to tens of meters [1]. These error sources are orbital errors: ionospheric and tropospheric delays, satellite and receiver clock errors, multipath, biases, and cycle slip [2].

GPS positioning can be classified into two positioning techniques: absolute and differential positioning (Fig. 1). The Absolute Point Positioning (APP) uses one unit receiver to determine the coordinate positioning, but due to the affected errors, this mode has a bad accuracy, if there is any correction method for it [3]. In the differential GPS Positioning (DGPS), two or more receivers are used to measure the same satellites at the same time, where one receiver occupies and observes the known point and the other receiver occupies and observes the unknown point. The coordinates of the unknown points are determined relative to the coordinates of the base station; therefore most of the errors can be eliminated or reduced through the differences. The accuracy in this method can reach to centimeters from baselines less than 20 km [4].

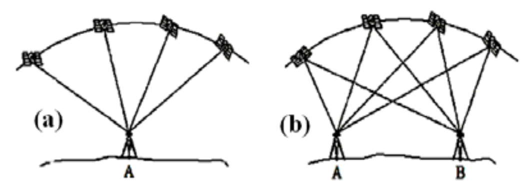

Fig. 1: GPS positioning techniques (a- APP technique and b- DGPS technique)

Absolute Point Positioning (APP) is much economic and easier than DGPS, because it uses one unit receiver. It has two levels from positioning Service according to accuracy; Standard Point Positioning (SPP) and Precise Point Positioning (PPP) [5 and 6]. The **first** technique, SPS, uses the broadcast ephemeris data in estimating the receiver position [4, 7 and 8], where its accuracy about 40m [9, and 10]. The **second** technique, PPP, was proposed for the first time in 1995 by Heroux and Kouba. It performs position determination by processing un-differentiated dual frequency code and carrier-phase measurements from a dual-frequency receiver coupled with precise GPS orbit and clock products. It has been widely demonstrated that it is capable of providing accurate position solutions at sub-decimeter level for kinematic positioning and at sub-centimeter level for static positioning [11, 12 and 13]. These precise products have been supplied by the International GPS Service (IGS) since 2000 [14].

Over the past fifteen years, a number of researchers and engineers had developed the Single Point Positioning technique and its applications. Alkan. R. M. [2002] was studied the variation on navigation coordinates without Selective Availability (SA) and the advantages of removing SA to single point positioning accuracy , where an accuracy in some position , from 15 to 25 meters , was achieved [9]. El-Rabbany [2002] was presented a number of GPS point positioning approaches: firstly, by using the ionosphere-free code with broadcast ephemeris as the accuracy was about 10-15m; secondly, by using the ionosphere-free code with precise ephemeris and clocks as the accuracy was about 5-10m; finally, by using the IGS network with final precise ephemeris and clocks as the accuracy was little than 1m [3]. Mosavi, M. R., et. al., [2013] were estimated the receiver position using

Kalman Filter (KF) with pseudo-range data , carrier phase data and the combination of these with presenting the advantages and disadvantages of them. The accuracy achieved was 23.20m at KF code observable, 20.83m at KF phase observable and 12.52m at phase code observables [15]. Chen, H. W., et al., [2013] were used a new GPS positioning algorithm to improve the single point positioning at short observation time , by combining the doppler and the code-phase measurements. The results referred to the accuracy which equals 24 m for an observation time about 1 minute, and the accuracy ranging from 10 to 20 m for an observation time equal 10 minute [10].

2. OBSERVATION DATA AND ITS PROCESSING

2.1- Observation Data

The observation data which processed in this research was taken from master thesis work for a demonstrator in Mining and Metallurgy Department in Assiut University. The collected data was for 20 points at open area (El -Wady El-Assiuty) (Fig. 2) observed by GPS receiver (ASHTECH A-12), where the real coordinates of these 20 points were determined by Differential GPS Positioning method (DGPS), as it is the most accurate positioning method . The observation conditions of the collected data were mask angle=12^o, where it is the optimum value of elevation mask angle [16], epoch interval= 1 sec, where it is the good interval [17] and occupation period=20 min, but in applying the following studied trials, this period had varies in times.

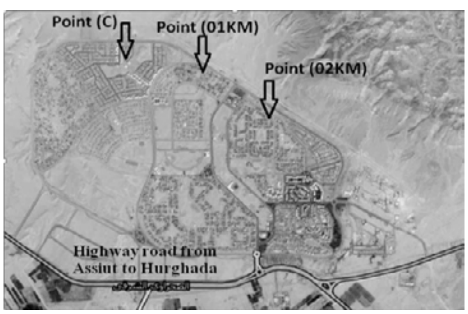

Fig. 2: The studied area

The studied area ; shown in (Fig. 2), has one known fixed point (C); its coordinates are shown in (Table1). The resultant coordinates from the following trials will be compared with the coordinates from DGPS method.

Table 1: The coordinates of fixed point (C).

Co-ordinate frame	Fixed point (C)		
ECEF frame X,Y , and Z	4847990.24	2944869.45	2906897.9
Geodetic frame Lat, long and h_{elip}	27.2902965 ° N	31.2762236° E	128.346
Old Egypt 1906 E,N and h_{orth}	642190.684	509720.116	118.699

2.2 Data Processing

Basically, there are two kinds of measurements which can be used for positioning: code (also called pseudorange, or code pseudorange) and carrier phase. Both measurements are a subject to ionospheric refraction errors, tropospheric refraction errors, the receiver clock error, the satellite clock error, multipath errors (caused by reflections), and random measurement noise [18]. Using the carrier phase measurement for position estimation is more accurate than using the code measurement [19]; because the code measurement has high bias, but it can easily be used for positioning. The main problem at phase measurement is that it includes some whole cycles (integer ambiguity) plus a fraction of carrier phase , this integer ambiguity may change through time however this change has unknown value [15].

2.2.1 Absolute Positioning Using Errors Adjustment.

Firstly; to enhance the APP positioning accuracy, as the first step is the calculation of standalone positioning using code measurement and its equation (Equ. 1) [20, 21], after correcting the most errors affecting on the GPS observations, except ionospheric error, using errors adjusting models from the previous researches.

$$\boldsymbol{P}_{\mathbf{L_i}}(\boldsymbol{t}) = \rho(t) + c[\,\delta t_r(t) - \delta t_s\,(t)] + T(t) + I(t) + ER_t(t) + Mpath \qquad \textbf{Equ.1}$$

Where P: is the measured pseudorange (m); ρ: is the true geometric range (m); c: is the speed of light (m/s); δtr: is the receiver clock error (s); δts: is the satellite clock error (s); T: is the tropospheric delay (m); I: is the tropospheric delay (m); ERt: is the earth rotation error (m); and Mpath: is the multipath error (m). But, in this research, the observing must be done in an open area, so ‘Mpath‘ error is approximately zero.

The ionospheric error is not corrected for our raw data, because the RINEX files have been downloaded from our receiver not included the important parameters for ionospheric correction (alpha and beta). As the terms 'alpha' are the coefficients of the cubic equation representing the magnitude of the time vertical , and the terms 'beta' are the coefficients of the cubic equation representing the period of the model.

The solution passes through the following steps (Fig. 3):

1. Choosing good observation epoch from observation RINEX file which has PDOP <2, low bias, no cycle slip, and number of satellite≥4 (No. of satellite ≥9 is the best) [22].
2. Determining the approximate position of receiver (X, Y, and Z), by solving three equations at least for geometric distances between three satellites and receiver.
3. Calculating GPS time from the date and time of the observation epoch [23].

4. Calculating the satellites positions and orbital error by using GPS time and Keplerian parameters from navigation RINEX file [21 and 22].
5. Calculating satellite clock error and relativistic error [8 and 23].
6. Calculating the elevation angle and azimuth angle for all satellites.
7. Calculating tropospheric error using Hopfield's model [24].
8. Calculating the earth rotation error [21].
9. Estimating the corrected pseudorange by using the following equation (Equ. 1) [23].
10. Finally, using the least square technique to calculate the 3D coordinates of occupation point and receiver clock error.

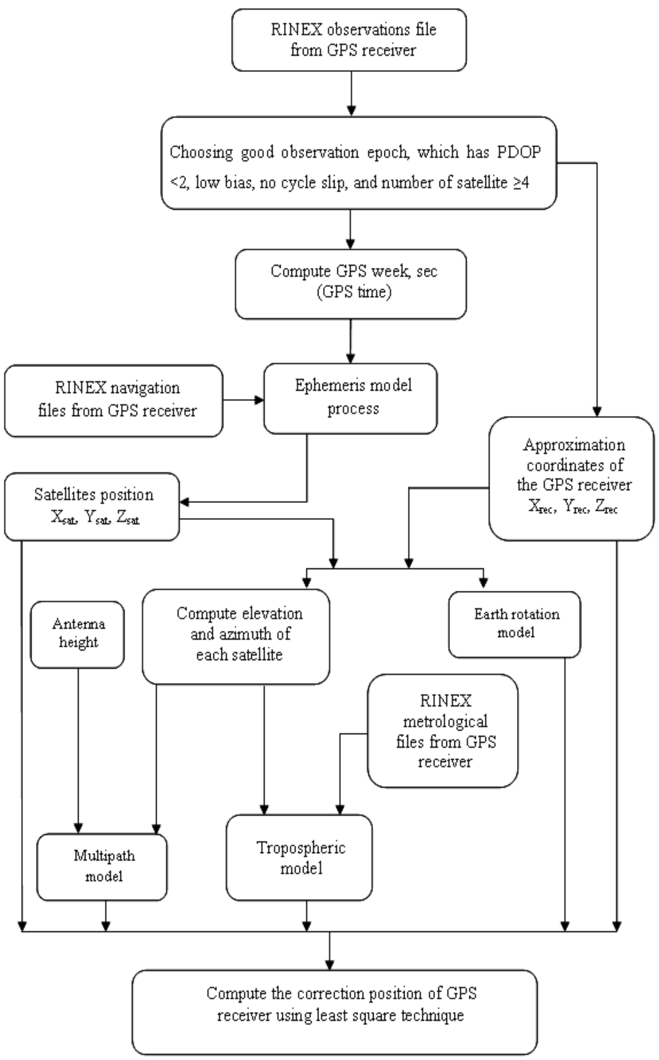

Fig. 3: Flowchart of positioning calculation processing

The results from this trial shown in (Fig. 4) refer to an improvement in accuracy, about 20m. That due to the ionospheric error which has not corrected its major error [25].

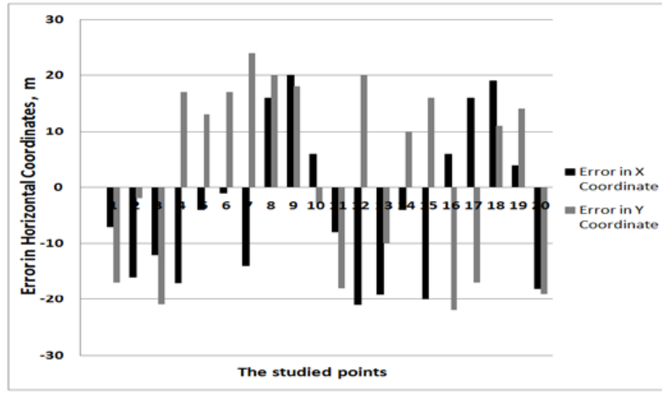

Fig. 4: Errors in X and Y Coordinates resulting from the usage of errors adjusting models.

2.2.2 Empirical Model For Ionospheric Error

This research will consider the residual error as ionospheric error , where the residual error equals the difference between right distance from the receiver to each satellite and the corrected pseudorange from the receiver and each satellite. In the first trial, this ionospheric error (residual error) has been studied to reduce its effect, where all relation between this ionospheric error and the values of others errors affecting on GPS observation have been studied to find the best relationship , which reduce the value of this residual error and improve the positioning accuracy. These relations are shown in (Fig. 5).

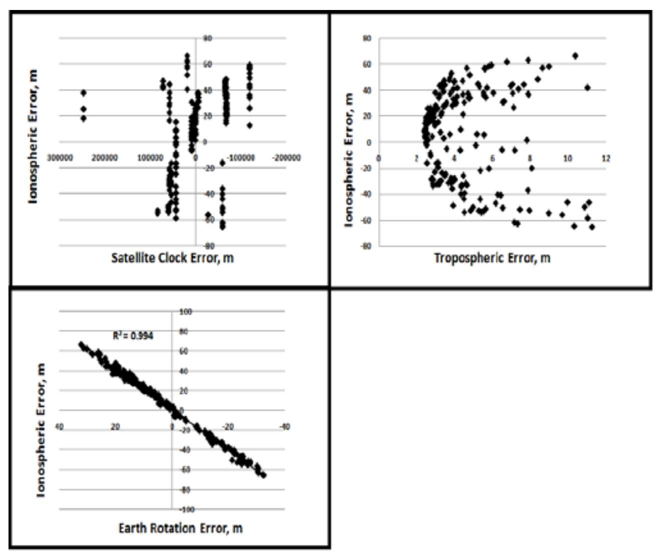

Fig. 5: The relation between some of the affecting errors on GPS observations versus ionospheric error.

It was found that there is a direct proportion between the residual errors in pseudo-ranges and earth rotation errors (ERt) values. The fitting curve for this relation is the linear with high correlation coefficient 99.3% , and the resultant equation was (Equ. 2):

$$\textbf{Ionospheric error} = 0.006 * (ERt)^{\wedge}2 + 9.335 * (ERt) + 3.998 \quad \textbf{Equ.2}$$

$$\textbf{Earth Rot.}(\textbf{ERt}) = \left(\frac{w}{c}\right) * (Xsat * Yrec) - (Ysat * Xrec) \quad \textbf{Equ.3}$$

Where, w: is the earth turn rate (rad / sec)=7.2921151467*10-5 rad / sec.; Xsat and Ysat: are the satellite horizontal coordinates; and Xrec and Yrec are the receiver horizontal coordinates.

The errors in the resultant coordinates from GPS standalone observations, after adjusting the pseudo-range errors and using the previous equation for predicting the Ionospheric error , are about 10 m , as shown in (Fig. 6). Which means that the position accuracy is improving, but it is still low and does not sufficient for any application in engineering surveying.

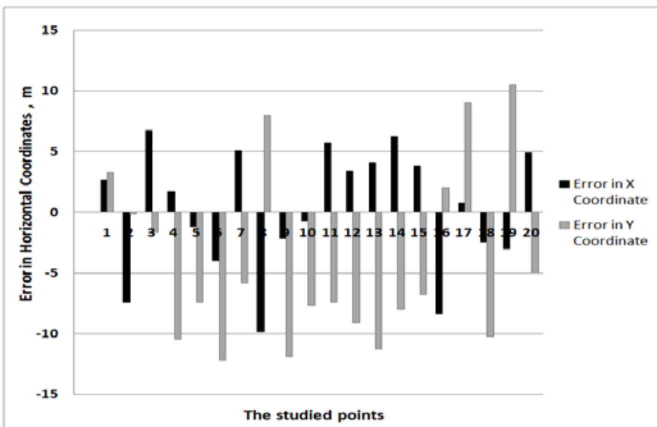

Fig. 6: Errors in X and Y Coordinates resulting from the usage of errors adjusting models and predicting equation for ionospheric error.

2.2.3 New Positioning Method

2.2.3.1 Interpolation Relative Positioning

The idea of this positioning method Inspired from the differential GPS method (DGPS), where the DGPS is considered the best observation method because it vanishes the most affecting errors on GPS observations. In this method , the GPS receiver observes the unknown point after observing the known point (Fig. 7), and correct the errors on the unknown point using the proportionality between the elevation angle of satellites and the values of errors at the known point to estimate the errors at the unknown point. We named this method as **Interpolation Relative Positioning** method

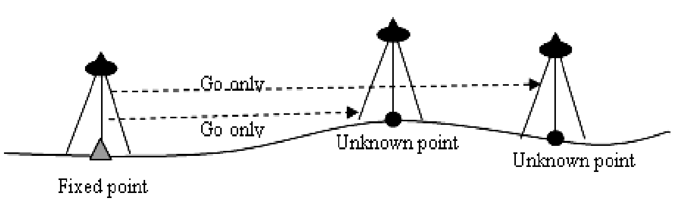

Fig. 7: Interpolation Relative Positioning Method

In this method, the steps of data processing are as following:

1. Occupying the known point for short time.
2. Calculating the pseudo-ranges values between the receiver and each satellite at certain epoch ; from RINEX observation file , after correcting the affecting errors on GPS observation , and determining the elevation angle for each satellite at this epoch.
3. Calculating the value of ionospheric error at the pseudo-range from receiver to each satellite ; from knowing the right ranges between each satellite and the receiver.
4. Occupying the unknown point for short time.
5. Calculating the pseudo-range value between the receiver and each satellite at certain epoch ; from RINEX observation file , after correcting the affecting errors on GPS observation, and determining the elevation angle for each satellite at this epoch.
6. Calculating the value of ionospheric error at the pseudo-range from each satellite and the unknown point using interpolation technique between the elevation angle for each satellite and the ionospheric error, so this method named by Interpolation Relative Positioning.

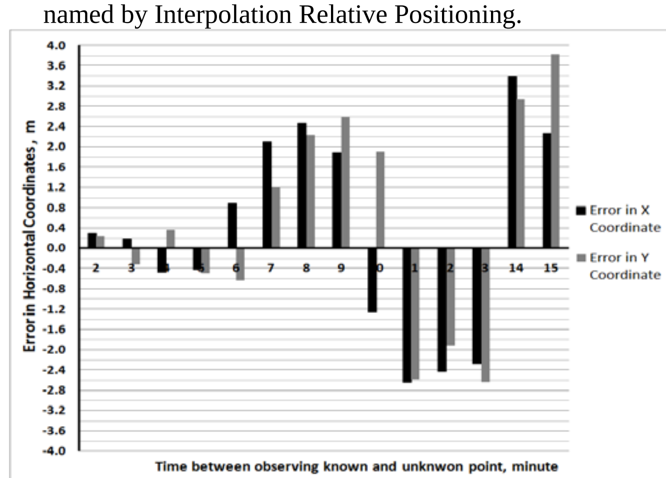

Fig. 8: Errors in X and Y Co-ordinate resulting from usage Interpolation Relative Positioning method.

The results of this method ,shown in (Fig. 8), refer to an improvement in the positioning accuracy about 50 cm , but these results have achieved at short time about 5 min between observing known and unknown point , that due to the rapid variation of ionospheric error with time.

2.2.3.2 Extrapolation Relative Positioning

This method established by modifying the previous method by observing the known point after and before observing the unknown point, by this modification, the dependent mathematical technique will change from interpolation to extrapolation technique . So , this method named as **Extrapolation Relative Positioning** method (Fig. 9).

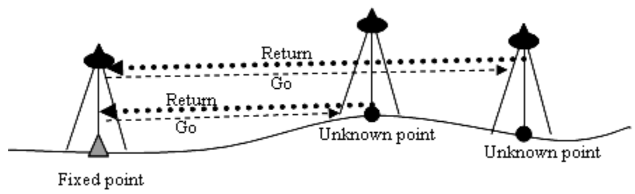

Fig. 9: Extrapolation Relative Positioning Method

In this method , the steps of data processing are as following:

1. Following the steps of the interpolation positioning method from No.1 to No.5.
2. Occupying the known point for short time.
3. Calculating the pseudo-ranges values between the receiver and each satellite at certain epoch ; from RINEX observation file, after correcting the affecting errors on GPS observation, and determining the elevation angle for each satellite at this epoch.
4. Calculating the value of ionospheric error at the pseudo-range from receiver to each satellite, from knowing the right ranges between each satellite and the receiver.
5. Calculating the value of ionospheric error at the pseudo-range from each satellite and the unknown point by using extrapolation technique between the elevation angle for each satellite and the residual error, so this method named by extrapolation Relative Positioning.

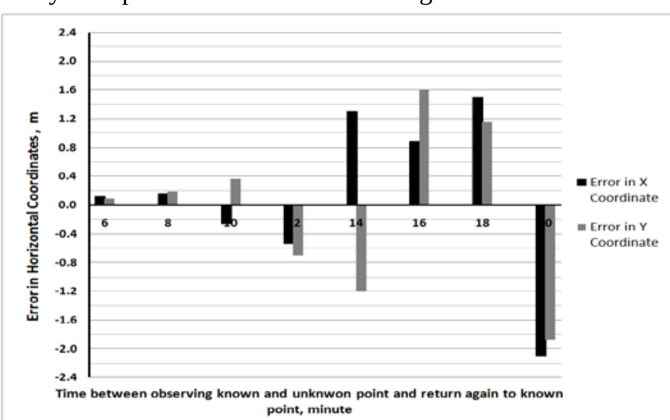

Fig. 10: Errors in X and Y Co-ordinate resulting from the usage of Extrapolation Relative Positioning method.

The results of this method , shown in (Fig. 10), refer to an improvement in the positioning accuracy about 20 cm , but these results have achieved at short time about 8 min between observing known and unknown point and returning again to observe the known point.

3. CONCLUSION

From the results of the studied trials in this research for enhancement absolute point positioning accuracy, it was concluded that; the new methods are achieved good accuracy at short time between known and unknown points. But Extrapolation Relative Positioning method is better than interpolation relative method, where it achieved about 20 cm accuracy for 8 min time interval between known and unknown points.

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