Improving the Accuracy of GNSS Data in the Absolute Point Positioning Based on Linear Relational Model

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Abstract
The aim of this study is to improve GNSS based absolute point positioning accuracy to adequate many applications and reduce the observation time of surveying depending on the Improved Absolute Positioning (IAP) technique. IAP it's a new technique that uses the Linear Relational (LR) model or any other model to improve the accuracy of GNSS data in absolute positioning. Performance evaluation of the IAP technique was based on a compilation of different statistical parameters and goodness-of-fit measures and then outcomes of the LR model in different cases were compared. This study showed a series of significant improvements in the GNSS data in absolute positioning based on the IAP technique. Therefore, it can be applied for improving the accuracy of coordinates from the absolute point positioning in various works and presents suitable accuracy for different engineering applications. In addition, this technique introduces a low-cost technique as a result of reducing the observation time and using a single receiver.

1. Introduction

The Global Navigation Satellite System (GNSS) is used widely in various applications, from low-resolution navigation to high-accuracy positioning (Gülal et al., 2015). GNSS has many features compared to conventional survey techniques (Xu, 2012). According to the measurements made on the GNSS signals, the receiver positioning can be classified into two techniques, single point positioning (SPP) and relative positioning (RP) (Satirapod and Kriengkraiwasin, 2006). When GNSS navigation observations are performed in one particular station, positioning technique is referred to as single point positioning. Instead of the term "single point position", we can use the term "absolute point position" (Hofmann et al., 2001). The relative positioning technique requires tracking the same satellites simultaneously using two receivers, one as a reference station and the other as a Rover station, in order to find Rover coordinates with respect to the reference station (El-Rabbany, 2002). So called differential Global Positioning System (DGPS), this technique is applied to high accuracy positioning measurement. However, the effectiveness of the differential positioning technique generally depends on the distance between the two receivers. Also, the cost of differential positioning technique is still much more expensive than the absolute point positioning. Therefore, from a practical point of view, there should be a measurement technique that contains logistical capacity and flexibility processing the absolute positioning determination as well as providing accurate position solutions from centimeters to the decimeter level (Constantin, 2011).

Lately, many types of research have been tended to develop the absolute positioning technique, because it is a low-cost measurement technique. One of these developments is Precise Point Positioning (PPP). In the PPP approach, observations from a single receiver are used to estimate the receiver location, ambiguity, receiver clock shift and wet tropospheric delay (Zumberge et al., 1997 and Kouba and Héroux, 2001). Several studies have examined attempts to improve PPP accuracy, PPP requires at least 20-minute to achieve 10-centimeter positioning accuracy (Fang et al., 2001 and Gao and Chen, 2004). Satirapod and Homniam (2006), recently developed simple PPP technique provides accuracy lower than one meter, by 15-minute observation period using a dual-frequency GNSS receiver (Satirapod and Homniam, 2006). Static PPP takes 60-minute to reach 5-centimeter horizontal accuracy at a 95% confidence level and 24 hours to achieve 1-centimeter horizontal accuracy at a 95% confidence level (Abou-Galala et al., 2018). PPP needs improvements to reduce the very long initial convergence period (Abou-Galala et al., 2018). It is noted from previous studies that PPP is important

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and used in many applications, but one of its major drawbacks is the need for a long initial convergence period to obtain appropriate accuracy.

Therefore, the main objective of this study is to improve GNSS based absolute point positioning accuracy and allows users to obtain reliable coordinates with accuracies expressed in decimeters derived from rapid data acquisition as a few seconds depending on IAP technique.

2. Materials and Methods

2.1 Study Area and Measurements

The study area is located in Madinaty city, Cairo, Egypt, with an area of about 150 m by 100 m. The observations were carried out on February 02, 2020. Two static GNSS measured points (CP1 and CP2) were used as an occupied and back sight points to tie the Total Station coordinates to the WGS 84 system/UTM zone 36 North as map projection, with EGM-2008 geoid model, and their coordinates were (368127.482, 3327720.167, 280.873) and (368089.773, 3327762.849, 278.498). The total time of the GNSS measurements is approximately 3 hours where each point was occupied by the receiver of about 20 seconds. The area was divided into 165 points with a distance of about 10 m between every two consecutive points. Figure 1 illustrates the study area plan. The coordinates of these 165 points were determined by following instruments:

- A Sokkia CX-105 Total Station was used to measure the coordinates of points.
- To collect coordinates from GNSS data, SOKKIA Grx2 GNSS receiver was adopted.

2.2 Research Methodology

The methodology of enhancing the accuracy of GNSS data in the absolute positioning based on the IAP technique includes data acquisition task, determination of correlation between GNSS data and Total Station for control points, create the LR model, improve the rest of GNSS data by using the LR model. These steps are further elaborated in the following sub-sections. Figure 2 shows the detection flow chart of improving the accuracy of GNSS data using absolute positioning based on the IAP technique.

2.3 Improved Absolute Positioning (IAP) Technique

The IAP it's a new technique that uses the LR model or any other model to improve the accuracy of GNSS data in absolute positioning. In this technique, the LR model was created from of 3-5 control points obtained from Total Station data and GNSS data in absolute positioning.

2.3.1 Linear Relation (LR) model

LR model consists of two-step, in the first step, the mean values (C_X, C_Y, *and* C_h) of the differences between the coordinates of the control points from Total Station data (X_T, Y_T, *and* h_T) and from the GNSS data in absolute positioning (X_G, Y_G, *and* h_G) were determined from equations 1, 2 and 3:

$$C_X = \frac{\Sigma V_X}{n}$$

Equation 1

where $V_X = X_G - X_T$

$$C_Y = \frac{\Sigma V_Y}{n}$$

Equation 3

where $V_Y = Y_G - Y_T$

$$C_h = \frac{\Sigma V_h}{n}$$

Equtation

where $V_h = h_G - h_T$

In the second step, the mean values (C_X, C_Y, *and* C_h) which determined from equations 1, 2 and 3 were used to generate the improved coordinates (X_I, Y_I, *and* h_I) for the rest points by using equations 4, 5 and 6:

$$X_I = X_G - C_X$$

Equation 4

$$Y_I = Y_G - C_Y$$

Eqaution 5

$$h_I = h_G - C_h$$

Equation 6

2.4 Cases of Select Points for Obtained the Relation

The testing was carried out using 165 points and their coordinates were determined from Total Station and GNSS data; These points divided into two groups; the first group (coordinates of some points) used to find the relation between Total Station and GNSS data. Figure 3 shows the numbers and distribution of the 165 points. The second group used to evaluate the results. Four different cases were used to select the first group which used to find the relation between Total Station and GNSS data:

- Case 1, the first 5 points, about 3% of all the data.
- Case 2, the first 10 points, about 6% of all the data.
- Case 3, the first 20 points, about 12% of all the data.
- Case 4, the first 30 points, about 18% of all the data.

Figure 1: Map of the study area

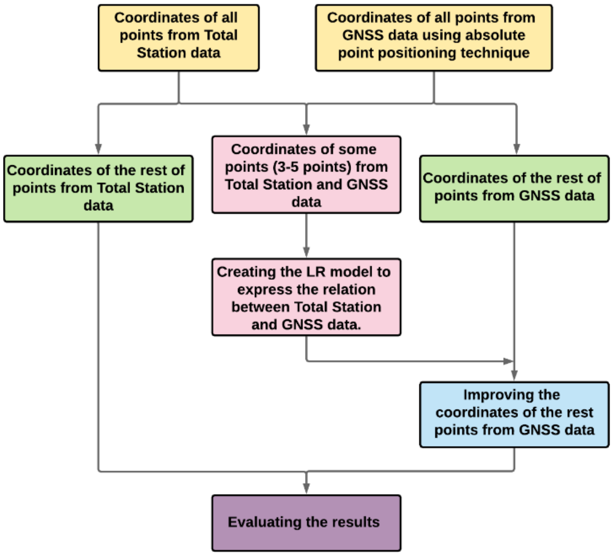

Figure 2: The detection flow chart for improving the accuracy of GNSS data in absolute positioning based on the IAP technique

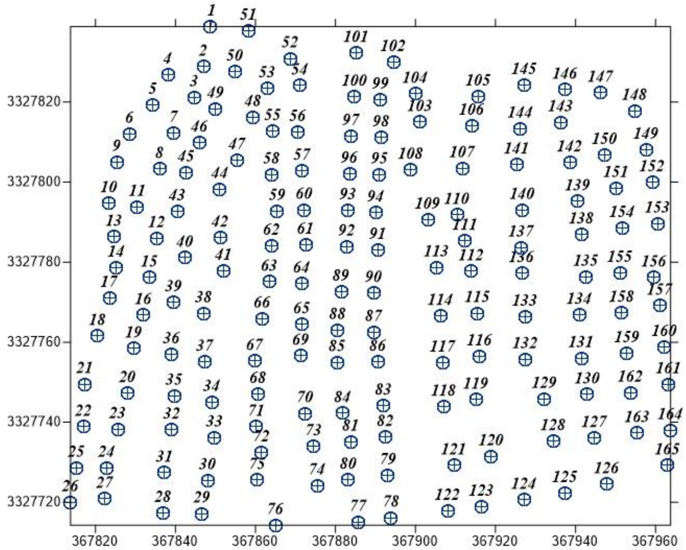

Figure 3: Distribution of the studied points

3. Results and Discussion

Firstly, the coordinates of all the points from Total Station and GNSS data were determined and the differences between them were derived. Secondly, the relation between the Total Station and GNSS data for control points was expressed using the LR model. After that, this relation was used to generate the improved coordinates of the rest of the GNSS data. Finally, to evaluate the results, the improved GNSS coordinates were compared with the Total Station coordinates.

3.1 Accuracy of GNSS Data of All the Points

At this step, the mean value, absolute mean value, and RMSE of the differences between Total Station and GNSS data in absolute point positioning technique of all points were computed and tabulated in Table 1. The results of the table show that the average difference in position between Total Station and GNSS data is about 4.059m. The accuracy of GNSS data in absolute point positioning with an observation duration of 20 seconds is 4.069m which does not match the required accuracy of the geodetic works. Therefore, the important question here, is it possible to improve the accuracy of GNSS data in absolute point positioning technique with a duration of observation of about 20 seconds?.

3.2 Improving the Accuracy of GNSS Data Using the IAP Technique

Firstly, the mean values (C_X, C_Y, *and* C_h) of the differences between Total Station data and GNSS in absolute point positioning technique data by using equations 1, 2, and 3 for control points were determined for the four cases. See Table 2.

After that, the values of C_X, C_Y, and C_h in the four cases were used to generate the improved coordinates of the rest GNSS in absolute point positioning technique data by using equations 4, 5, and 6. To evaluate the accuracy of the results; the descriptive statistics of differences between coordinates of Total Station and improved coordinates of GNSS data were determined and summarized in Tables 3, 4, and 5. The results in the tables showed that, when using the LR model to express the relation between Total Station data and GNSS in absolute positioning data and generate new coordinates from the rest of GNSS data, the mean differences, the absolute mean differences, and RMSE improved in the four cases. There is no significant difference between the improvements in the four cases in the X-direction and the Y-direction.

Table 1: Descriptive statistics of differences between Total Station and GNSS data of all the points

	Mean value of differences (m)	**Absolute mean value** of differences (m)	**RMSE (m)**
X-direction	3.861	3.861	3.864
Y-direction	0.351	0.351	0.386
h-direction	-1.066	1.081	1.216
Position	4.059	4.059	4.069

Table 2: Value of the mean values (C_X, C_Y, and C_h) in the four cases

	case 1	**case 2**	**case 3**	**case 4**
C_X (m)	3.948	3.875	3.841	3.824
C_Y (m)	0.227	0.163	0.164	0.172
C_h (m)	-1.757	-1.435	-1.248	-1.205

Table 3: Descriptive statistics of differences between original/improved coordinates in X-direction

	Mean value of differences (m)		**Absolute mean value of difference (m)**		**RMSE (m)**	
	original GNSS data	improved GNSS data	original GNSS data	improved GNSS data	original GNSS data	improved GNSS data
case 1	3.858	-0.090	3.858	0.162	3.861	0.179
case 2	3.860	-0.015	3.860	0.135	3.863	0.158
case 3	3.864	0.023	3.864	0.132	3.867	0.163
case 4	3.869	0.045	3.869	0.138	3.873	0.172

Table 4: Descriptive statistics of differences between original/improved coordinates in Y-direction

	Mean value of differences (m)		**Absolute mean value of difference (m)**		**RMSE (m)**	
	original GNSS data	**improved GNSS data**	**original GNSS data**	**improved GNSS data**	**original GNSS data**	**improved GNSS data**
case 1	0.355	0.128	0.355	0.161	0.390	0.206
case 2	0.364	0.201	0.364	0.205	0.396	0.255
case 3	0.377	0.213	0.377	0.217	0.407	0.262
case 4	0.391	0.219	0.391	0.224	0.419	0.265

Table 5: Descriptive statistics of differences between original/improved coordinates in h-direction

	Mean value of differences (m)		**Absolute mean value of difference (m)**		**RMSE (m)**	
	original GNSS data	**improved GNSS data**	**original GNSS data**	**improved GNSS data**	**original GNSS data**	**improved GNSS data**
case 1	-1.044	0.713	1.060	0.830	1.194	0.918
case 2	-1.042	0.393	1.058	0.614	1.197	0.707
case 3	-1.041	0.207	1.058	0.521	1.205	0.642
case 4	-1.035	0.170	1.035	0.529	1.211	0.652

In the h-direction, it is noted that, the more points used to create the LR model, the greater accuracy is obtained. Additionally, it is not necessary for creating the LR model as much of the control points, but only about 3-5 control points suffice as in case 1. As mentioned by Abdallah and Schwieger (2014) they obtained the RMSE in 3 dimensions of 10 cm from 10 minutes initialization time by using GIPSY-OASIS software, as well as CSRS-PPP online service (Abdallah and Schwieger, 2014). By comparing our study results with these results, here a lower accuracy was obtained, but the observing time was only about 20 seconds. In addition, according to the results obtained by Kim and Park, the horizontal and vertical RMSE along the test route were 0.53 and 0.69 m, respectively, to examine their PPP algorithm for a moving platform (Kim and Park, 2017). Also, by comparing our study results with these results, horizontal accuracy here increased to 0.208m while the vertical resolution was decreased to 0.730m.

3.3 Percentage of Improvement of GNSS Data with the IAP Technique

The percentages of improvement in the accuracy of coordinates of the points from GNSS in absolute positioning data using the LR model have been calculated using equation 7, the results illustrate in Figures 4, 5, and 6:

$$\text{Improvement percentage} = [\ 1 - (I / O)]\ \% \qquad \text{Equation 7}$$

Where: I - Statistics (mean value of differences, absolute mean value of differences and RMSE) of improved coordinates from LR model.

O - Statistics (mean value of differences, absolute mean value of differences and RMSE) of original coordinates from rest of GNSS in absolute positioning data. The results of the previous figures showed that when using the IAP technique to improve the GNSS in absolute positioning data; the mean value of differences in X, Y, and h directions was improved with a percentage of about 99%, 44%, and 75% respectively. The absolute mean value of differences was improved with a percentage of about 97%, 43%, and 48% respectively. While RMSE was improved with a percentage of about 96%, 36%, and 45% respectively. In general, the percentages of improvement in the four cases about 59%, 63%, 66%, and 66% respectively. It is noted that there is no significant difference in the percentage of improvement between the four cases in X-direction and Y-direction, but in h-direction, the results in cases 2, 3 and 4 improved twice as much as in the first case. In addition, when using the IAP technique to improve the GNSS in absolute positioning data; the mean value of differences in position improved from 4.059 m to 0.656 m by a percentage of about 84%. While the RMSE improved from 4.069 m to 0.761 m by a percentage of about 81%.

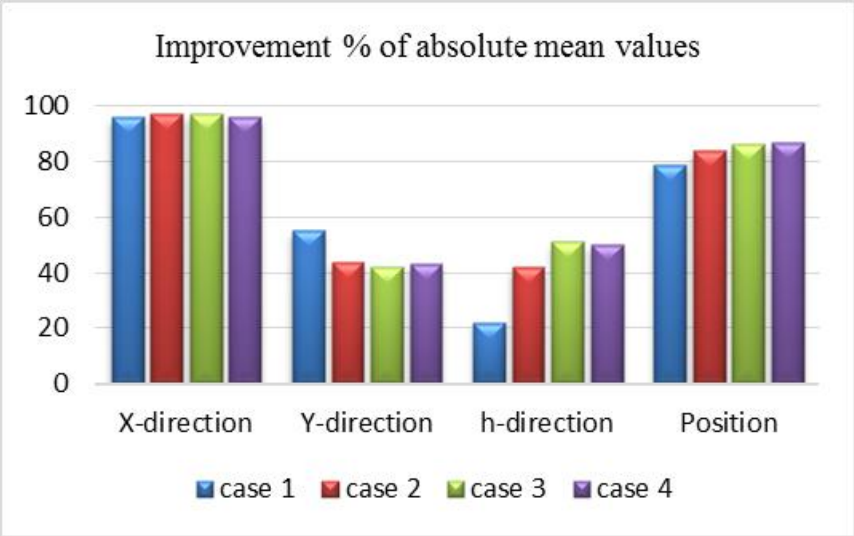

Figure 5: Percentages of improvement in the absolute mean values of GNSS in absolute positioning data using the IAP technique

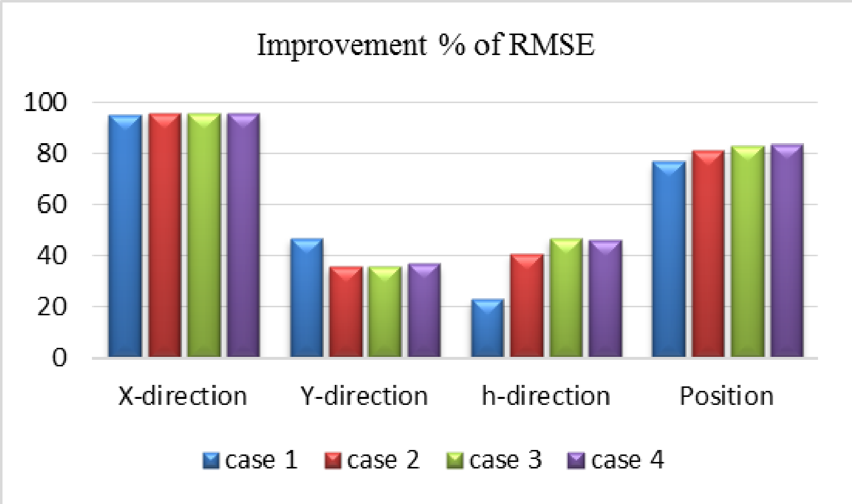

Figure 6: Percentages of improvement in the RMSE of GNSS in absolute positioning data using the IAP technique

4. Conclusions

In recent years, the GNSS has been applied in various aspects of life and it becomes an influencing factor in many engineering applications. The cost of differential positioning technique is still much more expensive than the absolute point positioning. Therefore, many studies have been attempted to improve the accuracy of GNSS in the absolute point positioning technique. The purpose of this paper is to improve the accuracy of GNSS data in absolute positioning and make it convenient for various applications during a rapid survey session of a few seconds. The study idea depends on finding the relation between Total Station and GNSS data in the absolute positioning for some control points (3-5 points) and use this relation to improve the rest of GNSS data. To improve the accuracy of GNSS data in absolute positioning, the IAP technique has been used. IAP is a new technique that uses the LR model or any other model to improve the accuracy of GNSS data in absolute positioning. The LR model was used to express this relation and to achieve the required improvement. The results show that the accuracy of GNSS data improved with the IAP technique in X, Y, and h directions by about 96%, 36%, and 45% respectively. By using the IAP technique, the position of points improved by about 81%. In order to create the LR model It's not necessary using a lot of control points, but enough about 3-5 points. It is well known that the correction factors differ according to the observing times and location, therefore it is preferable to carry out new correction factors in case of using different observing times or other study areas. Further research will be conducted on larger areas, varying environments and conditions to give a better assessment of the application of the IAP technique.

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