Positioning Experiment and Accuracy Analysis Based on Single Base Station CORS System

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Abstract

CORS (Continuously Operating Reference Stations System) has achieved the goal of the large and high-precision positioning. Aiming at the accuracy and stability of the single base station CORS system, This paper discusses the advantages of single base station CORS system, and discusses the method of the precision detection. This experiment simulates the known point detection method to analyze the working principle and accuracy of CORS system. Through the measurement data in the range of the station, A method named statistic analysis is taken to analyze the positioning accuracy including internally coincident precision and externally coincident precision. The accuracy statistics show that a cm-accuracy can be achieved by the single base station CORS, accuracy of 5cm in horizontal, and 8cm in vertical direction. The point measurement of single base station CORS can not only provi des the data satisifyig the precision for scientific research project, but also can be applied to the living application and the engineering progect, which can provide reference for the future practice.

Keywords

Single base CORS, positioning accuracy, accuracy statistic.

1. Introduction

Nowadays, with the rapid development of GPS and the popularization of its applications, the Continuously Operating Reference Stations estabilished by the Network RTK(Real-Time Kinematic) technology has gradually become one of the most hotspots in the field of GPS application development[1]. More and more countries are building or have built CORS systems. Such as the GPS Continuously Operating Reference Stations System (CORS) established in the United States[2]、ANF in Australia[3]、 COGRS established in the United Kingdom、German national satallite positioning and navigation service plan SAPOS[4] and the permanent GPS tracking network built in some smaller countries; as well as the GeoNet[5 and continuous strain monitoring system COSMOS estabilised in Japan and the China mainland tectonic environment monitoring CORS network[6] etc.

CORS system can be regarded as one or several continuously operating stations, which not only intergrates computer technology, internet technology and data communication technology, but also overcomes the shortages of the traditional RTK. With the development of the technology and applications, nowadays, the CORS system can realize the captibility of GPS, GLONASS and BDS[7], and it can provide multiple system and frequency data, greatly improving the stability of the CORSsystem and the accuracy of the diffierential data.

According to the range of the working area and the number of the base stations, CORS system can be divided into two part: single base station CORS system and the network CORS system. The network CORS system can be regarded as a base station network consisted of three or more stations, providing real-time differential positioning data[8]. Single base station is consisted of only one station and working for the users in a small area.

The single base station CORS system can be seen as a RTK, it is equavalent to the superposition of the traditional RTK: one plus one or more than one, and the difference is the station not only is a base station, but also a server, it collect information and send massages through the software and the rovers

exchange the information with station via the internet. During the operation of the single base station CORS system, the base station continuously monitors the GPS signals, at the same time getting the correction information of the measurement area, and transmitting massages to the server. The user receives the positioning information and send it to the server, they obtain the solution information from server through the internet. The working principle of the single base station as shown in Figure1. It is to say that the working principle of the single base station system is similar to the traditional RTK, but the single base station system can ensure the effectiveness and integrality of the signals' transmission[9]. The single base station CORS system has many advantages over the network CORS system, such as it is more compatibility between positioning systems, the system is more easier to upgrade and expand, more cheaper in building and maintain and so on.

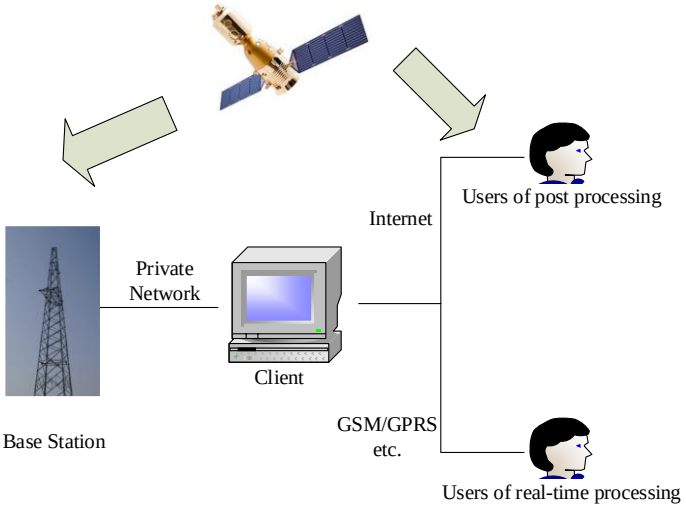

Fig. 1 Working principle of the single base station

2. The Method of CORS system Positioning Accuracy Test

The precision of CORS system directly determines the accuracy of the differential data, so it is an essential work to test the accuarcy of the CORS system. According to the measurement method, the accuracy test can be devided to static accuracy test and the dynamic real-time accuracy test. The detection methods commonly used are the known point detection method, the method of results comparison by post-processing, the geometric trajectory of dynamic rules and the anti-baseline length method[7]. The most direct and fast is the known point detection method, and its results have a certain objectivity, at the same time, it can reflect the true accuracy of the CORS system.

Based on the static known point detection method, within the coverage of the CORS system, we select a certain amount of points which are representative, have accurate coordinate and have differences in environmental factors. And then, measuring and recording data with the receivers setted up at the known points, at last, making a statistical analysis to the localization result[10].

The internal coincidence accuracy is the root-mean-square error of a single observation, which is expressed as the difference between the observed value and the average observed level, reflecting the stability degree of the observation results of the single base station CORS system. The externally coincident precision is similar to the internal coincidence accuracy, which is also the root mean square error of the measured value. However, the externally coincident precision shows the difference between the observed value and the known value, which reflects the accuracy of the single base station CORS system observation result.

This paper uses a method simulated to the static detection method to analyze the accuracy of single base station CORS system. Firstly, we use the average value of the data repeated measured by high precision GPS measuring instrument to take the place of the known data, and compare with the measured values of CORS system to get the coordinate deviation. Secondly, getting the deviation of

the mean value and measurement data of the CORS system. And finally analyzing the internally and externally coincident precision.

3. Case Analysis

3.1 Situation of Test Area and Data Collection

Civil Aviation Flight University of China established a single base station CORS system with StarNav of Chongqing. The system is compatible with GPS/GLONASS/BDS positioning system signals, and it consists of four parts: a continuing operation station, a data communication network system, a data processing center and rovers.

In this experiment, the single base station CORS system of the secong teaching building of Civil Aviation Flight University of China is used to measure the points within the coverage of the CORS system. 20 points are selected within 30km, of which, 7 points are in the coverage of 0-10km; 8 points are in the coverage of 10km-20km and 5 points are in the coverage of 20km-30km. The GPS observation data as shown in Table 1. (All coordinate systems in this paper are the local coordinate system CGS2000)

Table 1. GPS observation data

Numble	X	Y	H
D01	1353***.*13	5305***.*99	4**.*77
D02	1359***.*42	5314***.*11	6**.*11
D03	1354***.*34	5304***.*95	3**.*22
D04	1363***.*00	5304***.*21	5**.*63
D05	1343***.*99	5292***.*42	8**.*68
D06	1358***.*33	5295***.*51	3**.*18
D07	1348***.*64	5307***.*91	5**.*88
D08	1351***.*85	5312***.*35	6**.*53
D09	1355***.*74	5310***.*99	7**.*29
D10	1349***.*27	5295***.*35	4**.*07
D11	1364***.*31	5315***.*89	4**.*62
D12	1370***.*64	5323***.*39	3**.*49
D13	1365***.*93	5286***.*87	4**.*00
D14	1335***.*93	5307***.*23	3**.*74
D15	1350***.*74	5294***.*47	3**.*05
D16	1345***.*80	5319***.*78	3**.*38
D17	1323***.*13	5299***.*99	4**.*30
D18	1314***.*80	5310***.*20	5**.*18
D19	1384***.*80	5308***.*20	4**.*77
D20	1392***.*00	5293***.*49	3**.*03

3.2 Data Processing

3.2.1 Coordinate Conversion

For the single base station CORS system, its corrdinate is WGS-84; but for our experiment, the CGCS2000 coordinate is used to record the locating data, so the coordinate conversion is necessary. The more commonly coordinate conversion models are the seven-parameter model[11] and the four-parameter model[12]. In this paper, we use the seven-parameter model to convert the coordinate system.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + (1+k) R_{\alpha} R_{\beta} R_{\gamma} \begin{bmatrix} X_{84} \\ Y_{84} \\ Z_{84} \end{bmatrix} \quad (1)$$

In the formula (1), ΔX , ΔY , ΔZ are three panning parameters, k is the scale parameter; R_α , R_β , R_γ are three rotation parameters. And the conversion parameters are getted from the coordinate of the known points.

3.2.2 Gross Error Detection

Before the data analysis, the most important thing is to detect the gross error of the data, that is, in the same observation environment, if the measurement error exceeds the limited error, we may think the data has gross error and then remove it. This paper uses the quartile to detect the gross error:

$$S_R = \max_{i=1,2,\ldots,n} \left| \frac{x_i - \frac{1}{2}\left[x_{n_3} + x_n \right]}{x_{n_3} - x_n} \right| \tag{2}$$

$$n_3 = \begin{cases} \frac{1}{4}n, \text{ while } \frac{1}{4}n \text{ is an integer} \\ \left[\frac{1}{4}n \right] + 1, \text{ while } \frac{1}{4}n \text{ is not an integer} \end{cases} \tag{3}$$

$$n_4 = n - n_3 + 1 \tag{4}$$

In the formula (2), (3) and (4), S_R is the statistics of gross error, under a level α , the critical value is S ,when $S_R > S$, removing the data does not meet the requirements.

3.3 Accuracy Analysis

3.3.1 Internally Coincident Precision

In this paper, CORS system is used to repeated measure the data of 20 points, getting the average value of the direction of X, Y, H and then compared with the actual data. Calculate the X, Y, H deviation. In order to get a more visualized distribution, we static the error of the points' coordinates: the measurement deviation can not esceed $\pm$14cm in horizontal direction, and $\pm$30cm in the H direction.

At the same time, respectively, calculating the internally coincident precision.

$$M = \sqrt{\frac{[\Delta\Delta]}{(n-1)}} \tag{5}$$

Where Δ is the deviation of the positioning data and the mean value, n is the total number of the measurement, M is the internally coincident precision.

The results of the calculation and stattisics are shown in Table 2 and Fig. 3.

Table 2. The internally coincident precision statistics of the single base station CORS system

category	Units and intervals	ΔX	ΔY
Maximum	cm	2.73	2.70
Minimum	cm	0.7	0.51
Mean value	cm	1.38	1.33
The proportion of the distribution of each interval/%	[0,1]	25	25
	(1,2]	55	60
	(2,3]	20	15
	(3,7]	0	0

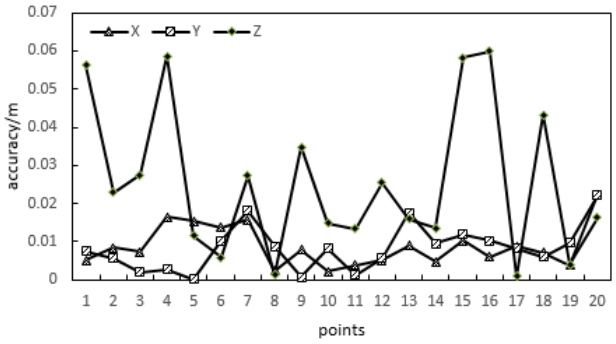

Fig. 3 The internally coincident precision of each point of the single base station CORS system

According to tabel 2 and Fig. 3, the internally coincident precision of X, Y direction in horizontal direction is better than 3cm, and mainly in the range of 1~2cm; in the vertical direction, the accuracy is better than 7cm, and mainly in the range of 3-7cm. this result proves the single base station has a certain stability and it can provide reliable observation data for the follow research and basic engineering measurement.

3.3.2 Relative Externally Coincident Precision

External coincidence accuracy is to analyze the measurement data and the known value of the points(in this paper, using the mean value of the high precision GPS positioning data to take the place of the known data), and the formula is as shown in formula (6):

$$\theta = \sqrt{\frac{\left[\left(\delta_i - \tau_i\right)^2\right]}{N}} \tag{6}$$

In the formula (6), θ is the relative externally coincident precision, δ_i is the measurement data of the point i, τ_i is the known value of the point i, N is the actual observation times.

The maximum value of X direction is 12.2cm, Y direction is no more than 15cm, and the deviation of H direction is below 30cm.

The calculation and statistics of the relative externally coincident precision is shown in Table 3 and Fig. 4.

Table 3: The statistics of externally coincident precision of the single base staion CORS system

category	Units and interval	Δ_X	Δ_Y
Maximum	cm	3.23	3.75
Minimum	cm	0.67	0.84
Mean value	cm	2.18	2.39
The proportion of the distribution of each interval/%	[0,1]	10	5
	(1,2]	30	35
	(2,3]	45	35
	(3,4]	15	25
	(4,8]	0	0

The result in Table 3 and fig.4 show that the maximum relative externally coincident precision in X and Y direction of the single base station CORS system is 3.23cm and 3.75cm;mainly in the range of 1-3cm. And in the H direction is no more than 8cm, mainly in the range of 4-8cm.

The results show that the single base station CORS system can satisfy the accuracy requirements of some engineering and it can provide measurement data to the fllowing research.

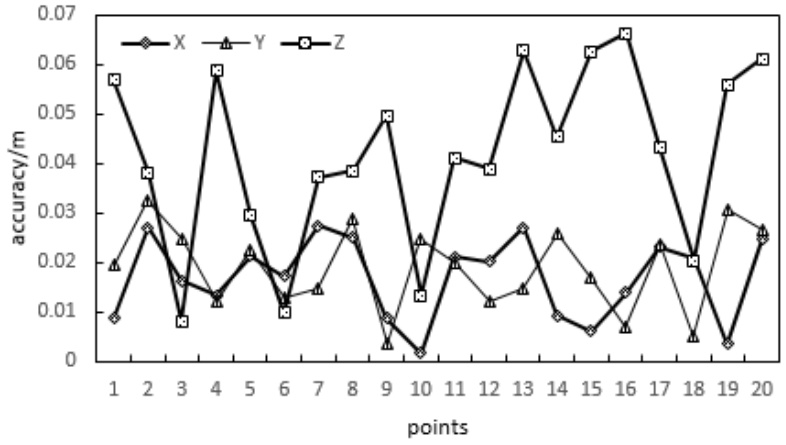

Fig.4 The externally coincident precision of the single base station CORS system

4. Conclusion

In this paper, the advantages of single base station CORS system are discuessed. And the single base station CORS system is more suitable to the engineering and research in some small area.

The process of data collection and accuracy analysis of single base station CORS system is described in detail.The results show that in the coverage area of the single based station CORS system, the internally coincident precision is better than 3cm in horizontal, and 7cm in vertical. And the relative externally coincident precision is no more than 4cm in horizontal and 8cm in vertical. All of the results can show that the single base station CORS system can provide centimeter-level data for the small area engineering, and the data has a certain reliability.

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