THE DESIGN, DATA PROCESSING AND PRECISION ANALYSIS OF THE FIRST GPS CONTROL NETWORK OF ZHENGZHOU UNIVERSITY

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ABSTRACT: This paper discussed the building process of the first GPS surveying control network of Zhengzhou University from 3 parts, that is, the design of the network shape, the field survey of outside stations and the data processing of the GPS measurement in the industry. During the process of field survey, the 3 sets of the Topcon Hiper pro-GPS satellite signal receiver devices are used to carry out the field data collection according to the static relatively positioning theory. The Pinnacle software which the Topcon equipment owns implements the processing and the precision analysis of the survey data. The data processing mainly consists of the effectiveness analysis of the data, the solution of base line, the non-constrained adjustment, the constrained adjustment, etc. The precision analysis consists of the closing error of the nonsynchronous rings, the synchronous rings and the repeat baselines, the analysis of the error ellipsoid, etc. In this paper, with the establishment of the surveying control network the coordinates of the ten control points were transformed from WGS-84 to Xi'an 80. The key difficulty is the establishment of the coordinates of the base, the reasonable sets of various parameters, the accuracy analysis of the closing error of the nonsynchronous rings and the synchronous rings in the constrained adjustment.

Research and analysis shows that during the establishment of the primary GPS surveying control network, the technical design is reasonable, the field observation data is high-quality, the adjustment process is correct and the accuracy of the result is within the national standards. The results of the network adjustment can be used for the late construction and planning of the Zhengzhou University. It also can be used for the professional practice for the next generations.

1. INTRODUCTION

GPS (Global Position System) is built roundly by United States in 1994, which is the new generation of navigation and positioning system and can navigate and positioning three dimensionally in real time comprehensively. Because it can measure automatically in all-weather with high-precision, as the advanced measurement means and new productive force, it has integrated into the fields of national economic construction, national defense construction, social development, etc. GPS (Hong LiBo, 2000) can guide and control military targets precisely in military field, navigate and positioning in transportation industry, build reference frame globally in measurement field, guide in the precision farming and forestry, etc. These are all show the wide development prospects of GPS.

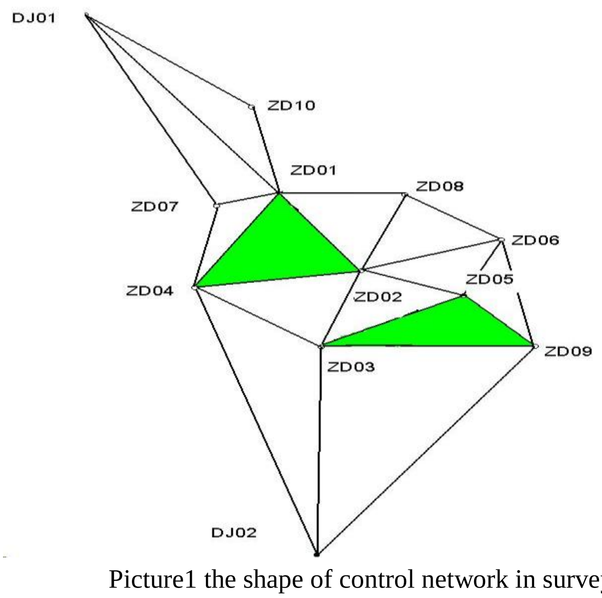
GPS is irreplaceable compared to the conventional measurement technology. It represents the development of the informationalized surveying and mapping (Li TianWen, 2003). So the study of GPS measurement technology has very important strategic value and practical significance. This paper takes the first GPS control network of Zhengzhou University as the example and discusses the building process of this control network in detail, especially the data processing and precision analysis. Discuss in this article can offer the references of the related technical design and data processing for the survey crew.

2. OVERVIEW

This measured position is the new campus of Zhengzhou University which locates in the western suburbs west fourth ring of Zhengzhou city, and the study objects are two national control points and 10 survey points. Use the two national control points in Xi' an 80 coordinates to get the ten survey points in Xi' an 80 coordinates.

The two national control points (Wu LiMin, etc, 2002b) are located near Zhengzhou University. One is near 153 Hospital, and the other is located in highways near the east entrance of Zhengzhou University. The ten survey points are all inner Zhengzhou University.

This control network has 11 observation periods. The triangulation networks it builds contain 11 synchronous rings, 2 nonsynchronous rings and 9 repeated baselines. The 11 synchronous rings are ZD03-ZD09-DJ01, ZD03-DJ02-ZD04, DJ01-ZD10-ZD01, DJ01-ZD01-ZD07, ZD07-ZD01-ZD04, ZD01-ZD08-ZD02, ZD02-ZD06-ZD08, ZD05-ZD06-ZD02, ZD05-ZD06-ZD09, ZD02-ZD05-ZD03, and ZD04-ZD02-ZD03. The 2 nonsynchronous rings are ZD01-ZD04-ZD02 and ZD05-ZD03-ZD09 (the blue triangles). The network shape is as the following picture 1 shows:



Picture1 the shape of control network in survey field

The field survey of outside stations uses GPS static and relative positioning to measure the coordinates of the points. The Topcon total station machines used in this measurement are comprised of 2 Topcon Hiper pro-GPS satellite signal receiver devices with double frequency and 1 with single frequency. The nominal accuracy of the machines with double frequency is 3mm+1ppm, while the single frequency is 5mm＋1ppm. The steps of the field survey mainly include choosing survey points, making descriptions of stations, making observation handbook, placing antenna, observing the records, etc.

The data processing uses Pinnacle software to process the data got from Topcon and analyze the precision.

3. THE DATA PROCESSING AND PRECISION ANALYSIS (Li ZhengHang, 2005a)

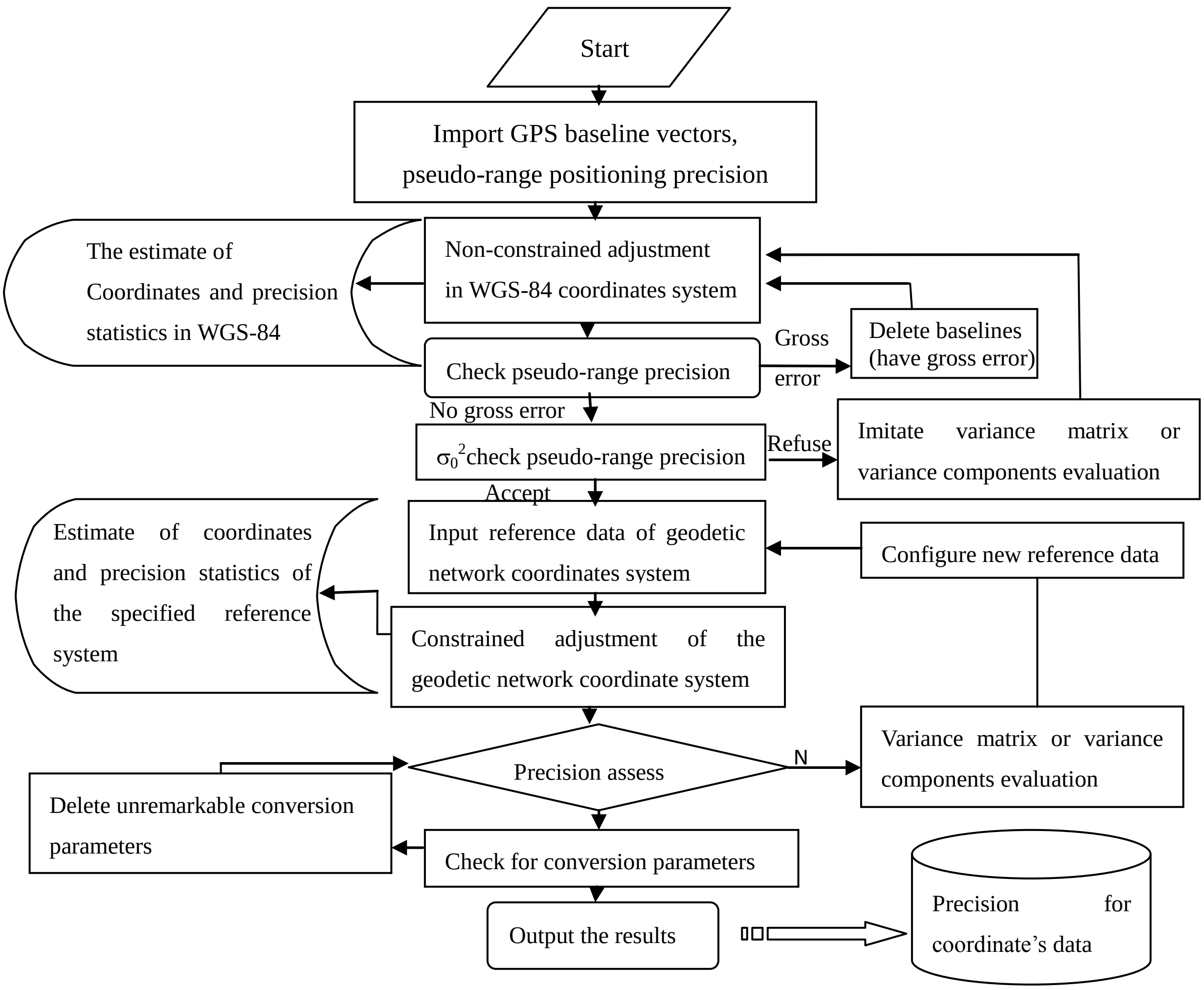


Figure 1 the flow diagram of GPS network adjustment

3.1 Data processing

The steps of data processing are just as Figure 1 above shows. They include filtering the observation periods, baselines settlement and deleting satellites the residual error of which exceed restrictions, non-constrained adjustment, the constrained adjustment, etc.

1) Filter the observation periods: refers to periods' data statistics, ephemeris validation, check for the type and height of antenna.

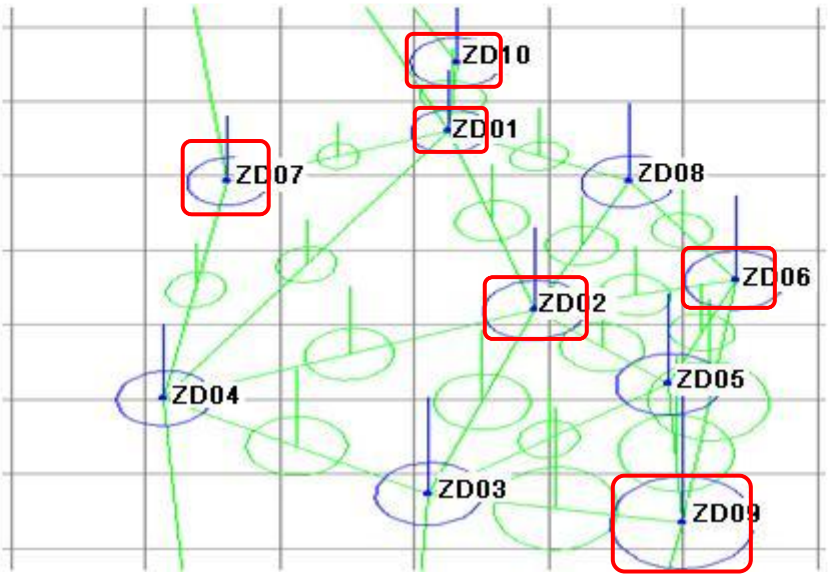
2) Baselines settlement for field observation data (Teunissen P J, 1997): after baselines settlement, the satellites which residual errors in baselines residual plot exceed ±0.25 circuit will be deleted and resettle baselines until no residual errors exceed restrictions. The precision standards are: RMS 3mm+1ppm, Mix fixed ratio 95%.

3) Non-constrained adjustment: it refers to only one position reference in GPS control network. Drag the baselines from baselines settlement window to network adjustment window. Set “automatically reduce weight for gross error”, constraint select “non-constraint adjustment”, system type select “BLH” and system/datum select “WGS-84”.

4) Constrained adjustment: set some fixed coordinate points in local coordinate system or national coordinate system, fixed edges length and fixed directions as references of the network and make them as the constrained conditions of the adjustment. The conversion parameters between GPS network and geodetic network should be considered in the adjustment calculation. First edit the state coordinate system as Xi’ an 80 coordinate system. a=6378140, f=1/298.257. The coordinate system is divided with 3 degrees, the central meridian is 114 which is 38degrees, and the height datum is 85 height datum. Select projection mode: TMERC and import geoid file EGM99; next import state control points. DJ01: X=3857169.465, Y=456260.999, h=101.922; DJ02: X=3848354.908, Y=456575.209, h=147.458; then match the control points, i.e. match Xi’ an 80 system and WGS-84 coordinate system; last execute constrained adjustment. Select geocentric coordinate system, and no rotation is needed.

3.2 GPS precision analysis (State Bureau of Surveying and Mapping (GBT 18314), 2001)

3.2.1 Precision analysis of error ellipsoids



Picture 2 the error ellipsoids of all the survey points and baselines

Different survey points are corresponding to different error ellipsoids. The longer the radius is, the bigger the error is. The radius of error ellipsoid is related to the number of baselines and the environment around the local survey point. From Picture 2, the radius of ZD09 is longer obviously than ZD06. They have the same number of baselines, so the environments around them affect the radius. Through field study, there are many trees around ZD09, and they keep out satellite signals that losses of lock occur. The high-voltage cable around ZD09 disturbs signals and the measurement precision decreases; both of ZD01 and ZD02 have 6 baselines while the radius of ZD01 is shorter than ZD02 obviously. Because ZD01 is located in manmade hill, where there are less obstacles and satellite signals can be received successfully; ZD07 and ZD10 have similar environments but different number of baselines, so they have different error ellipsoids radiuses. Through these phenomena some conclusions can be got: 1)

The settlement errors of survey points and baselines are related to their baseline numbers. The larger the number of baselines is, the smaller the error is. 2) Obstacles block the satellites signals and multipath effects are serious. The corrections of observations are large in common. 3) The cycle slips of some periods are too many to repair perfectly.

3.2.2 Precision analysis of the synchronous rings and nonsynchronous rings (Fan DongMing, 2002a**):** The standard deviations of baselines between the two adjacent points in all levels of GPS network and the tolerance can be got from the following formula:

$$\sigma = \sqrt{a^2 + (b \cdot d \cdot 10^{-6})^2}, \qquad T = n * e + a * \Sigma D \tag{1}$$

Where σ (mm) refers to the standard deviation, a (mm) is the fixed error, b is the ratio error coefficient and d (mm) is the distance between the two adjacent points. For D or E level control network, a and b meet the conditions: $a \le 10mm,\ b \le 20$.

In tolerance T formula, Σ D is closing ring length, e is the fixed part and a is the proportionate fraction.

$$W_X \le \frac{\sqrt{3}}{5}\sigma \quad W_Y \le \frac{\sqrt{3}}{5}\sigma \quad W_Z \le \frac{\sqrt{3}}{5}\sigma \tag{2}$$

$$W_X \le 3\sqrt{n}\sigma \quad W_Y \le 3\sqrt{n}\sigma \quad W_Z \le 3\sqrt{n}\sigma \tag{3}$$

In formula (2) (Xiang HuChu, 1994.), the closing errors of the trilateral synchronous rings W_X, W_Y and W_Z meet these conditions.

In formula (3), the closing errors of the trilateral nonsynchronous rings W_X, W_Y and W_Z meet the conditions.

Through Pinnacle software (User manual of Pinnacle, 2000) computes, the constrained adjustment and non-constrained adjustment both meet the restriction conditions. For the control network, V'PV =48.37 which belongs to the interval (21.32, 54.44). The error of weight unit UWE =1.16 and it belongs to the interval (0.77, 1.23). Here, I list the precision analysis about 1 synchronous ring and 2 nonsynchronous rings in the following Table1:

Table 1 the precision analysis about 1 synchronous ring and 2 nonsynchronous rings

Triangular Ring	length(m)	T(m)	W_X (m)	W_Y (m)	W_Z (m)	W_X /T	W_Y /T	W_Z /T	$\frac{\sqrt{3}}{5}\sigma$	$3\sqrt{n}\sigma$
DJ01-ZD01-ZD10	4219	0.1774	0.0008	0.0032	0.0027	0	0.02	0.02	0.0035	---
ZD01-ZD02-ZD04	2776	0.176	0.0049	0.0089	0.0054	0.03	0.05	0.03	---	0.10930
ZD05-ZD03-ZD09	1707	0.1749	0.006	0.0007	0.0028	0.03	0	0.02	---	0.07872

From Table 1, we can get the conclusion that the synchronous rings and the nonsynchronous rings all meet the conditions: For synchronous rings, W_X, W_Y and W_Z are all smaller than $\frac{\sqrt{3}}{5}\sigma$; for nonsynchronous rings, W_X, W_Y and W_Z are all smaller than $3\sqrt{n}\sigma$. Both of errors of synchronous rings and the nonsynchronous rings are within the tolerance T.

4. SUMMARIES

This paper successfully builds the first control network of Zhengzhou University. Use the two national control points in Xi’ an 80 coordinates to get the ten survey points in Xi’ an 80 coordinates.

1) The technical design is reasonable, the field observation data is high-quality, the adjustment process is correct and the accuracy of the result is within the national standards. The results of the network adjustment can be used for the late construction and planning of the Zhengzhou University.

2) The design of the shape of control network is reasonable, and the constrained adjustment and non-constrained adjustment are both within the restrictions.

3) The selections of 10 survey points should avoid trees, electromagnetic facilities, etc. If possible, select survey points in open area. The lengths of baselines should be similar. If the range of the baselines lengths exceed 0.2-5 km, the measure precision will be affected.

4) The error ellipsoids generated by Pinnacle software can analyze the errors qualitatively. The errors are related with the number of its baselines and the environment. The closing errors of the synchronous rings and nonsynchronous rings can analyze adjustment errors quantitatively.

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