H K . N C C P
International Journal of Intelligent Information and Management Science
ISSN: 2307-0692 Volume 4, Issue 3, June 2015

Plane point Precision Comparing between GPS and Common Control Survey

Shuaili WANG
[1]School of Geosciences and Info-physics ,Central South University, Changsha, Hunan, 410083, CHINA
[2]Modern education technology center, Hunan City University , Yiyang, Hunan, 413000, CHINA

Abstract: It can conclude that GPS static relative positioning precision can achieve appropriate control plane Network required accuracy ,through a comparative analysis of plane point precision in a small area between GPS and Common Control Survey.

Keywords: GPS; Static Relative Positioning; Plane Position; Precision Comparison

1. Introduction

The global positioning system's positioning technology is widely applied in surveying and mapping, astronomy, navigation and communications. It has brought fundamental resolution in

Surveying Science. The basic theory of GPS satellite positioning and its further development and application have gradually become one of the contents and tasks of Surveying Science. Compared with the traditional control survey, GPS, especially Plane Control Survey, has developed resolutely.

Complex topography, wide surveying scope and other reasons make Conventional survey methods difficult. With the development of high-precision GPS positioning technology, high-precision Control network technology based on GPS will gradually replace Conventional Control network. Especially in the large and medium project items, the precision of GPS Control network has become highly accurate after years of research and practice. Due to its numerous advantages, many small project control networks are set up on the basis of GPS recently. The advantages of GPS technology are as follows: (1)the location of GPS is accurate, especially in the Plane control position;(2)GPS has high speed, low cost and small labor intensity;(3)GPS survey, which has no requirement of visibility and can overcome the effects of environment, is beneficial for optimization of surveying nets.In order to improve the efficiency of GPS survey, the analysis and research of Baseline Precision and GPS network adjustment Precision of GPS survey in small areas are necessary. This will be helpful and valuable for the application of GPS in various Control Networks, the improvement of survey efficiency and reduction of Fieldwork.

Through a comparative analysis of plane point precision in a small area between GPS and Common Control Survey, the paper, based on the theory of GPS Static positioning. tests whether GPS in the control survey can achieve the accuracy of common survey. In consideration of the requirement of the common survey in practice and comparative analysis of the accuracy between GPS and Precision total stations in a small area, the paper applies four Triangulation Control network respectively, that is, 100m, 300m, 500m, 1000m. in addition, the four control networks all use Independent Coordinate System. So the comparison of the Plane precision in the paper is mainly the comparison of Baseline length. Finally, some practical and useful conclusions will be achieved.

2. Case Analysis of GPS and Conventional Survey Plane Position Accuracy

2.1. Experiment

The data are collected from the new campus of Hunan city university in Yiang, Hunan province, which is located in Latitude 28 ° and Longitude 112 °. Four Control networks with different Baseline length100m, 300m, 500m, 1000m are applied. Referring to GPS Survey Norms GB/T 18314-2001and Project Survey Norms GB50026-2007 and considering the terrain of the texted area, we can find that the use of Triangle Closed traverse can reduce the area and help to choose the points. Though the side length of control network is kept roughly equal, every two control points can keep visible. Each control point has a broad field of vision, the height angle of the obstacles in the vision should not exceed 15° , and high-power Radio emission source should be kept far away. Also, things reflecting strong Satellite signals should be displaced. Because the Joint measurement of the Known coordinates has not been applied in the test, the control network all use the Independent Coordinate System of Beijing -54 Ellipsoid, which is named Yiyang-54 and belongs to Level E GPS network.

In the table, the distance accuracy index a, b are used to estimate the distance standard error of the adjacent points.(mean error):

$$s = \sqrt{a^2 + (b \cdot d)^2} \quad (1)$$

Table 1. Laid Requirements of GPS network

Item \ Level	A	B	C	D	E
Edges of the Closed loop or Annexed leveling line	≤5	≤6	≤6	≤8	≤10
The average distance (km)	300	70	10~15	5~10	0.2~5

Table 2. The main technical requirements of urban GPS network

Level	Average distance (km)	Distance accuracy specification		The weak side relative error
		a(mm)	b(mm)	
2	8	≤10	≤2	1/120000
3	5	≤10	≤5	1/80000
4	2	≤10	≤10	1/45000
1	1	≤10	≤10	1/20000
2	<1	≤15	≤20	1/10000

Table 3. Technical requirement of Trigonometric leveling

Level	The average length(km)	Angle mean error(″)	The relative error of measuring side	The weak side relative error	Position number			Triangle closure error(″)
					1″ class instrument	2″ class instrument	6″ class instrument	
2	9	1	≤1/250000	≤1/120000	12	---	---	3.5
3	4.5	1.8	≤1/150000	≤1/70000	6	9	---	7
4	2	2.5	≤1/100000	≤1/40000	4	6	---	9
1	1	5	≤1/40000	≤1/20000	---	2	4	15
2	0.5	10	≤1/20000	≤1/10000	---	1	12	30

Table 4. Part of the technical specifications of Traversing

Level	The average length(km)	Ranging mean error(mm)	Ranging relative mean error
3	3	20	1/150000
4	1.5	18	1/80000
1	0.5	15	1/30000
2	0.25	15	1/14000
3	0.1	15	1/7000

In the above formula, a is Fixed error, b is error Scale factor, d is distance. GPS of Level 3 is equal to state C-level net, GPS of level 4 to state D-level net, GPS of level 1 to state E-level net.
Table 1 and Table 2 are part of GPS specifications of survey.

2.2. Data Capture and Data Processing of Total Station

The basis for the technical specification is engineering survey specifications GB50026-20078 and the main instrument is TopconGPT-7500 Long Prism Total Station.

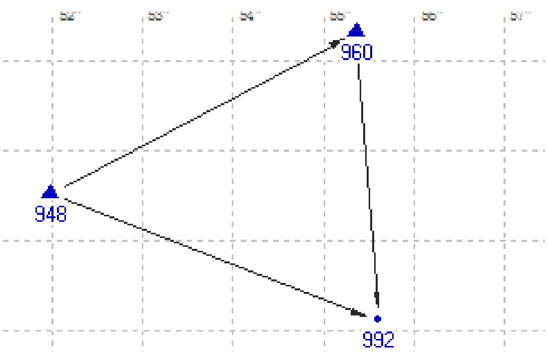

Figure 1. 100m Single triangle

The Angle measurement accuracy is 1″ , and the Ranging Accuracy is 2+2ppm(the fixed error is 2mm +2mm per km)On the observation of all the control points, the data, according to the norms, is dealt with Conditional Adjustment. main The technical basis are as follows:

The data collected by total station and the outcomes after adjustment process is the Single triangle below(100m).

The Single triangle observation data are in Table 5.

Single triangle distance Adjustment is below in Table 6.

100m single triangle directional observation adjustment below in Table 7.

300m single triangle is shown as Figure 2.

300m single triangle survey data below in Table 8.

500m single triangle is shown as Figure 3.

300m single triangle distance adjustment below in Table 9.

300m single triangle directional observation adjustment below in Table 10.

Table 5. Single triangle observation data

Survey station	Sighting point	The average angle (° ′ ″)	Mean distance (m)
948	960	51 19 49	107.681
	992		107.685
992	948	62 49 55	107.685
	960		98.333
960	948	62 49 57	107.680
	992		98.334

Table 6. Single triangle distance Adjustment

Point	Point	Distance (m)	Mean error(cm)	Corrections (cm)	Corrected distance (m)	Relative error of side length
948	960	107.6805	0.14	0.16	107.6821	1/90000
948	992	107.6860	0.14	-0.02	107.6858	1/90000
960	992	98.3350	0.14	-0.15	98.3335	1/82000

Table 7. 100m single triangle directional observation adjustment

Point	Angle corresponding to the site (° ′ ″)	Angle closing error(″)	The correct angle (″)	Mean error(″)
948	54 19 49	19	54 20 02.6	4
992	62 49 55		62 49 53.8	4
960	62 49 57		62 50 03.6	4

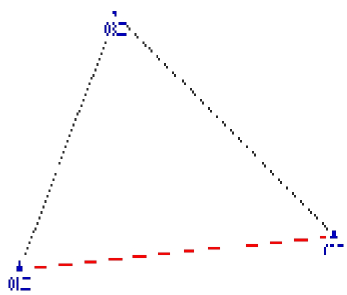

Figure 2. 300m single triangle

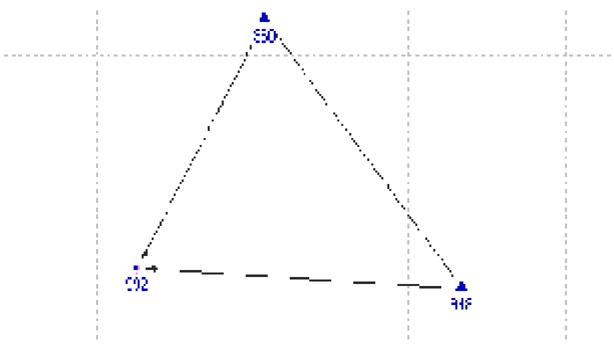

Figure 3. 500m single triangle

Table 8. 300m single triangle survey data

Survey site	Sighting point	Average triangle(° ′ ″)	Average distance(m)
01.Z	02.Z	60 18 28	337.361
	03.Z		247.003
02.Z	01.Z	44 56 22	337.361
	03.Z		303.765
03.Z	01.Z	74 45 03	247.003
	02.Z		337.361

Table 9. 300m single triangle distance Adjustment data

Point	Point	Distance (m)	Mean error(cm)	Corrections (cm)	Corrected distance (m)	Relative error of side length
02.Z	03.Z	303.7650	0.15	-0.08	303.7642	1/200000
01.Z	03.Z	247.0030	0.15	-0.12	247.0018	1/160000
01.Z	02.Z	337.3610	0.15	0.16	337.3626	1/220000

Table 10. 300m single triangle directional observation adjustment data

Point	Angle corresponding to the site (° ′ ″)	Angle closing error(″)	The correct angle (″)	Mean error(″)
01.Z	60 18 28		60 18 30.8	1.7
02.Z	44 56 22	-7.0	44 56 27	1.7
03.Z	74 45 03		74 45 02.2	1.7

Table 11. 500m single triangle survey data

Survey site	Sighting point	Average angle(° ′ ″)	Average distance(m)
948	960	49 41 09	571.53950
	992		567.3465
960	948	64 42 05	571.5405
	992		478.5105
992	948	65 36 44	567.3485
	960		478.5110

Table 12. 500m single triangle distance adjustment data

Point	Point	Distance (m)	Mean error(cm)	Corrections (cm)	Corrected distance (m)	Relative error of side length
960	992	478.5105	0.16	-0.18	478.5087	1/330000
948	992	567.3460	0.16	0.12	567.3472	1/390000
948	960	571.5395	0.16	0.04	571.5399	1/390000

Table 13. 500m single triangle directional observation adjustment data

Point	Angle corresponding to the site (° ′ ″)	Angle closing error(″)	The correct angle(″)	Mean error(″)
992	65 36 44		65 36 43.4	1.2
960	64 42 05	-2.0	64 42 03.3	1.2
948	49 41 09		49 41 13.2	1.2

500m single triangle survey data are in Table 11.
500m single triangle distance adjustment below in Table 12.
500m single triangle directional observation adjustment below in Table 13.
1000m single triangle is as Figure 4.

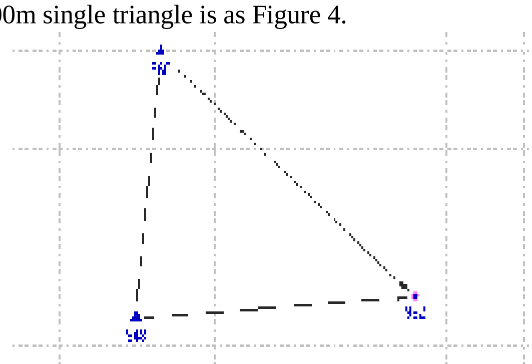

Figure 4. 1000m single triangle

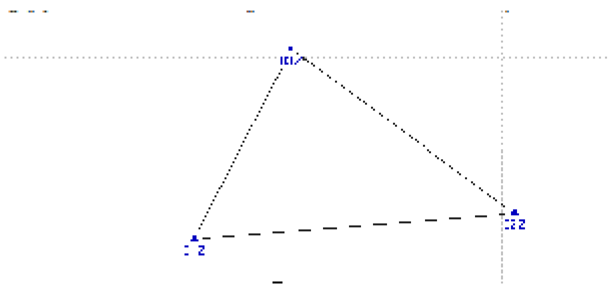

Figure 5. 300m single triangle

1000m single triangle survey below in Table 14.
1000m single triangle distance adjustment below in Table 15.
1000m single triangle directional observation adjustment below in Table 16.

Table 14. 1000m single triangle survey data

Survey site	sighting point	Average angle(° ′ ″)	Average distance(m)
948	960	79 52 42	840.170
	992		983.566
992	948	44 41 49	983.565
	960		1175.927
960	948	55 25 38	840.171
	992		1175.926

Table 15. 1000m single triangle distance adjustment data

Point	Point	distance (m)	mean error(cm)	Corrections (cm)	Corrected distance (m)	Relative error of side length
948	992	983.5655	0.20	-0.01	983.5654	1/510000
960	992	1175.9265	0.22	0.03	1175.9268	1/560000
948	960	840.1705	0.18	-0.03	840.1702	1/460000

Table 16. 1000m single triangle directional observation adjustment data

Point	Angle corresponding to the site(° ′ ″)	angle closing error (″)	The correct angle(″)	Mean error(″)
992	44 41 49	9	44 41 47.8	2
960	55 25 38		55 25 34.6	2
948	79 52 42		79 52 37.6	2

Data are repeatedly tested in the process of data collection and data processing strictly according to standard data. Based on the qualified data collection and adjustment handling, the data in the above table all meet the requirement.

2.3. Data processing of GPS

In data collection, the main instrument is zhonghaida V8GPS, Nominal accuracy of Static plane is(2.5mm+1x10-6D).As for the data processing of GPS, Central, Meridian is set as112° because of the use of YiYang-54 independent coordinate system in ellipsoid. The coordinate system is transformed from WGS-84to Beijing-54.Take 300m Triangle closed traverse for example :

First, 01.Z is assumed as the known dot and GPS Free network adjustment and Ellipsoid geodetic coordinate system of WGS-84 of 01.Z are chose. Secondly, transform the WGS-84geodetic coordinate system into The plane coordinate of Beijing-54 ellipsoid, and set the plane coordinate as the coordinate of 01.Z, that is, the coordinate of 01.Z in Yiyang-54coordinate system. (though 01.Z's coordinate can be set at random, we set it in this way for convenience in aspects of calculation and comparison) fix the orientation 01.Z→02.Z and transform Adjustment of Conversion again, Azimuth of 01.Z→0.2Z in Beijing-54 ellipsoid can be got. Set the distance 01.Z →0.2Zmeasured by total station as side length and we can get a new plane coordinate of 02.Z in Beijing-54 ellipsoid by coordinate calculate. Fix 02.Z , input the new plane coordinate(the coordinate of 02.Z in Yiyang-54coordinate system) and fix the orientation 01.Z、02.Z and 01.Z-→02.Z, finally carry out Dimensional constrained adjustment, we can get the baseline length and plane coordinate of GPS constrained data that project to Yiyang-54coordinate system. The following are GPS data adjustment results.

100m single triangle constrained adjustment below in Table 17.

300m single triangle constrained adjustment Plane distance adjustment below in Table 18.

500m single triangle constrained adjustment Plane distance adjustment below in Table 19.

1000m single triangle constrained adjustment Plane distance adjustment below in Table 20.

Table 17. 100m single triangle plane distance adjustment

Starting point	Terminal point	Plane distance	Plane distance (m)	Relative error
948	960	107.682		
948	992	107.6903	0.0002	1: 484286
960	992	98.3349	0.0002	1: 442329
948→ 960 is constrained side.				

Table 18. 300m single triangle Plane distance adjustment data

Starting point	Terminal point	Plane distance	Mean error (m)	Relative error

01.Z	02.Z	337.3626		
01.Z	03.Z	247.0003	0.0004	1: 607452
02.Z	03.Z	303.7601	0.0004	1: 747215
01.Z→02.Z is constrained side.				

Table 19. 500m single triangle Plane distance adjustment data

Starting point	Terminal point	Plane distance	Mean error (m)	Relative error
948	960	571.5399		
948	992	567.3426	0.0009	1: 655138
960	992	478.5109	0.0009	1: 552561
948→960 is constrained side.				

Table 20. 1000m single triangle Plane distance adjustment data

Starting point	Terminal point	Plane distance	Mean error (m)	Mean error
948	960	840.1702		
948	992	983.5616	0.0013	1: 745024
960	992	1175.9260	0.0013	1: 890736
948→960 is the constrained side.				

Table 21. GPS mean error in practice and standard error

Side	Mean error(mm)	GPS normal error(mm)	Relative error
107.6903	0. 2	2.6	1: 484286
98.3349	0.2	2.6	1: 442329
247.0003	0.4	2.8	1: 607452
303.7601	0.4	2.8	1: 747215
567.3426	0.9	3	1: 655138
478.5109	0.9	3	1: 552561
983.5616	1.3	3.5	1: 655138
1175.926	1.3	3.5	1: 890736

Table 22. Mutual Difference of GPS and total station side

100m Single Triangle	948→992	960→992	300Single Triangle	01.Z→03.Z	02.Z→03.Z
GPS side(m)	107.6903	98.3349	GPS side(m)	247.0030	303.7601
Total Station side	107.6848	98.3335	Total Station side	247.0018	303.7642
Mutual Difference	+0.0055	+0.0014	Mutual Difference	+0.0022	-0.0041
500m Single Triangle	948→992	960→992	1000mSingle Triangle	948→992	960→992
GPS side(m)	567.3426	478.5109	GPS side(m)	983.5616	1175.9260
Total Station side	567.3472	478.5087	Total Station side	983.5654	1175.9268
Mutual Difference	-0.0046	+0.0022	Mutual Difference	-0.0038	-0.0008

Table 23. GPS error and weakest side' relative error

Control net	Error(mm)	Weakest side'Relative error
100m single triangle	4.01	1/20000
300m single triangle	3.29	1/74000
500m single triangle	3.48	1/123000
1000m single triangle	2.75	1/252195

2.4. Comparative Analysis of GPS Plane point Precision Comparing and Common Control Survey

At first, let's analyze GPS accuracy, and then compare the accuracy of each Triangle closed traverse. According to (2.1) $s = \sqrt{a^2 + (b \cdot d)^2}$, we can get the Table 21.

From Table 21,GPS's actual accuracy can reach its own nominal accuracy(2.5mm+1x10-6D. for objectivity, let's compare GPS with the list of total stations' length Because the two points of each triangle closing traverse are fixed, we will just compare the other two sides. The result can be seen in Table 22.

According to Table 22, the minimum of the mutual difference between GPS side and Total station side is 0.8mmand the maximum is 5.5mm. both sides are quite similar to each other. The data of total station survey is accurate and believable. The same is true of the GPS survey. From the data management of the total station survey, the side accuracy is quite high. We can regard the side after Total Station Adjustment as True value and compute the error of GPS survey.the formula is as follows:

$$d_s = \pm\sqrt{\frac{[\Delta\Delta]}{n}}$$

Based on the true value, we can get the mean error and weakest side' relative error of GPS survey. The result is shown in Table 23.

From Table2.23,GPS survey can meet the requirement of both the triangle net survey of the same level and traversing.

From the above data, it can be concluded that GPS owns high accuracy in the plane point survey, which can reach the accuracy of total station survey. Besides, the farther the distance becomes, GPS accuracy is more closer to the total station accuracy. And, according to the experiment, it is more accurate than the latter. In the small areas, GPS can take the place of total station survey in the Triangle plane control network.

3. Conclusion

(1)First, the paper briefly introduces the basic theory of GPS static relative positioning and gives a comparative analysis of GPS plane survey precision and control survey.

(2)Through the comparative analysis of GPS plane survey precision and control survey, we can conclude that precision of GPS plane survey is equal to that of common survey and it can satisfy the requirement of various levels 'plane control network in small area.

(3)GPS has its unique advantages but also it has some deficiencies:1.it has a high requirement for surrounding environment, or else GPS cannot be used or the data processing becomes impossible; 2. the data processing of GPS hasn't achieved Optimal clearing degree, for example, the conversion between the ellipsoid in data processing is not very tight. Qualified data cannot be gotten without manual intervention..

References

[1] Wangrui-Analysis of GPS Baseline Precision and Variance ComPonent Estimation of GPS Control Newtork[D]. Hohai Unviersiyt, 2005:3-5.

[2] Wangjianjin-Several Problems on Establishment of GPS Plane Control Network[J]. Magazine Office of Electric Power Survey,2005,(4):

[3] Chengang,zengyun,huyoujian,precision analysis of plane control survey in GPS short baseline[J], urban geotechnical investigation,2001,(4)：33.

[4] Xushaoquan,measurement principle of GPS and its application in hydropower projects[M],dam and safty, 2003,1.