Research on Measurement Technology of Length and Area Based on COMPASS Positioning

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Abstract—This paper studies the COMPASS Positioning and WI-FI positioning etc. for single point positioning and measurement of distance between two points in the error range. As a reference, GPS measurement data with accurate positioning is shown else. On this basis, calculation rules of the area measurement by which the COMPASS system of irregular region mining point positions into regular polygon approximation is explored, and then the rule method is used to calculate the cumulative area measurement for complex and irregular terrain. It can be shown with irregular area. The experimental data and the measurement results show that the relative error of Bei-dou Positioning length, within distance between 100-200m, is less than 5%, and area measurement error of the regular shape is within 3%.

Keywords—area measurement; GIS; COMPASS positioning; positioning accuracy; error

I. INTRODUCTION

Beidou satellite navigation system of China also known as BDS or COMPASS is the global satellite positioning and navigation system, rendering China the third nation with independent property rights of this system in the world after the United States, Russia. After years of development and improvement, it has gradually developed into a mature system. At present, the global satellite navigation system GPS of the United States occupies the leading position in the use of location monitoring and geodetic mapping. Map of Baidu etc., expanded on the basis of GPS, is relatively mature technologically, and measurement of the length of two points on the earth and the area is more accurate. Nevertheless, the COMPASS, still being potential for substantial development and wider application, is only used in the location of services, deformation monitoring, waters and sea measurements. To break the shackles and manipulation of GPS technology, there is an urgent need to expand the application of the COMPASS system and to make full and effective use of COMPASS signal resources. Based on the COMPASS positioning data, this paper takes the GPS positioning data with high positioning accuracy as the reference and studies the measurement technology of two-point distance and specific surface area.

FIGURE I. THREE BALL INTERSECTION SCHEMATIC DIAGRAM

FIGURE II. PASSIVE POSITIONING SCHEMATIC

FIGURE III. THE ANGLES OF LATITUDE AND LONGITUDE AT SPATIAL COORDINATES
through the ground control center, applies to B and C for two satellites positioning signal, while at the same time sending microwave signal and measuring satellite transmission time back and forth to calculate the distance between the satellite to the client.

As the COMPASS I positioning accuracy is low, China has developed COMPASS II satellite with active positioning and similar passive positioning function of the GPS. Firstly, a reasonable distribution of space satellite system needs to be established, so that most parts of the client can observe more than three satellites, afterwards, continuous observation to the satellites by the receiver is made. When the master station sends a ranging signal, the satellite will return the short message carrying the satellite clock message to the receiver and calculate the pseudo range from the satellite to the receiver. The quaternary system of equations is established involving modified pseudo range and the spatial coordinate of four satellites (Located in a position A, B, C, and D shown in Fig. 2) and the clock difference between satellite and receiver (T), to solve the location of the positioning.

II. GEOMETRIC MEASUREMENT AND EXPERIMENTAL ANALYSIS BASED ON COMPASS LOCATING

A. Space Cartesian Coordinate Transformation for single Point Positioning

Assuming that the latitude and longitude of two points -A and B are \((J_A, \lambda_A)\) and \((J_B, \lambda_B)\) respectively with A marked in Figure 3, and then latitude and longitude of A and B is changed into space Cartesian coordinates \(s_{9,10}\). \(R\) is the radius of the earth\([11]\), as shown in equation (1)

\[
\begin{align*}
X_A &= R \cdot \cos \lambda_A \cdot \cos J_A \\
Y_A &= R \cdot \cos \lambda_A \cdot \sin J_A \\
Z_A &= R \cdot \sin \lambda_A
\end{align*}
\]

Similarly, \(X_B\) and \(Y_B\) and \(Z_B\) of B points are obtained. Then the space distance between two points A and B is as follows:

\[
I_{AB} = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2 + (Z_A - Z_B)^2}
\]

The same point (shown in Figure 4 and 5) of positioning data are obtained by testing the different systems \([13]\), and the GPS and other systems on the same point positioning difference is calculated according to (1), (2). After the location of the positioning point are changed, the two groups of data are obtained as listed in Table 1 through another experiment.

| Absolute error | Compass | WI-FI | GSM |
|----------------|---------|-------|-----|
| The difference distance1(m) | 5.106641 | 45.070693 | 127.756433 |
| The difference distance2(m) | 4.033424 | 55.687001 | 121.160689 |
and accumulated into polygon are according to the equation of coordinates. Finally the area of each triangular area is obtained according to the latitude and longitude conversion of space based on the equation (2), each edge to tall to 2n-3 is calculated regions with more than 3sides is divided into n-2 triangular regions. Then, and latitude of each vertex are measured before the polygonal area is approximated by the regular area [114,15,16], and the area can be obtained from the regular’s. The table 5 is a regular processing of irregular circle area, where the radian of circular evenly is divided, approximating for four, five, hexagon area error.

TABLE IV. QUADRILATERAL AREA MEASUREMENTS

| NO.1     | NO.2     | NO.3     |
|----------|----------|----------|
| Measured value (m²) | 36242.782355 | 82244.719254 | 30167.985717 |
| Reference value (m²) | 35794.29969 | 80551.82268 | 29864.80418 |
| Absolute error (m²) | 448.48266 | 1692.89658 | 303.18154 |
| Relative error (%) | 0.012529 | 0.021016 | 0.010152 |

C. Area Measurement

1) Triangular area measurement by Compass

Through the experiment, the latitude and longitude of the three vertices are measured, and the length of the three sides a, b and c is obtained by the formula (2). The triangular area S is calculated from the Helen formula (3) to obtain the triangular area of the Compass, WI-FI, as shown in Table 3.

\[
S = \left( \frac{(a + b + c)}{2} \right) \times \left( \sqrt{\left( \frac{(a + b + c)}{2} \right)^2 - a^2} \cdot \left( \frac{(a + b + c)}{2} - b \right) \right)
\]

(3)

TABLE III. COMPASS AND WI-FI POSITONING TRIANGULAR AREA MEASUREMENT AREA ERROR

| Test methods | Measurement area (m²) | Absolute error (m²) | Relative error (%) |
|--------------|-----------------------|---------------------|--------------------|
| Compass      | NO.1 8578.776920      | 113.743890          | 0.013085           |
|              | NO.2 5030.243378      | 60.206897           | 0.011827           |
| GPS(as reference) | NO.1 8692.520810      | 0                   | 0                  |
|              | NO.2 5090.450275      | 0                   | 0                  |
| WI-FI        | NO.3 4960.310000      | 1011.383889         | 0.169363           |
|              | NO.4 7501.530100      | 1529.769832         | 0.169385           |
| GPS(as reference) | NO.3 5971.693889      | 0                   | 0                  |
|              | NO.4 9031.299832      | 0                   | 0                  |

It can be seen from Table 3 that the relative GPS measurement error of the Compass positioning to the triangular area is less than 2%, while the relative error of the survey results of the Compass compared to the WI-FI is relatively smaller with the relative larger error of the WI-FI measurement more than 10%. This is not the best choice for measuring the area.

2) Measurement of Multilateral Area by COMPASS

For the measurement of the polygon regular area, longitude and latitude of each vertex are measured before the polygonal regions with more than 3sides is divided into n-2 triangular regions. Then, based on the equation (2), each edge to tall to 2n-3 is calculated according to the latitude and longitude conversion of space coordinates. Finally the area of each triangular area is obtained and accumulated into polygon are according to the equation (3).

In Table 5, when the circular area is approached by the polygon area, the more vertices are selected, the closer the polygon area is to circle area [5], and the larger number of side length and small triangle area needs to be calculated, which further leads to complex data processing. In the actual measurement, the appropriate number of points needs to be selected according to the error requirements.

The calculation of other irregular area contours is selected appropriate number of points to calculate the distance from a certain point to another point, thus the area of a small triangular area is obtained. By accumulating those small triangle areas, it can be approximated as an irregular area.

III. CONCLUSION

On the basis of discussing the difference between the single position of the Compass and the GPS positioning, the latitude and longitude is transformed into the spatial coordinates to directly measure and calculate the space distance of two points. In the area measurement, the irregular area is approximated to the regular region that is divided into several small triangular regions. The length of each edge depending on the latitude and longitude is firstly calculated, and then the area of the small triangular area is calculated by Helen’s formula to obtain polygon area. The experimental data show that the relative error is all within 5% for the measured distance and the area result. For the irregular area, the more points are selected from the outline, the closer the approximation of regular area is to the irregular area. In length and area measurement, the curve of the arc distance on the surface of the earth is approximated as distance of two points for the space, so the method is more accurate to measure the short distance between two points on the earth. Since the initial data obtained from the measurement are the longitude and latitude of the measured point, the measurements of distance and area of the complex landscape with spatial characteristics are actually the projection values in
the horizontal plane \[17\], so this method is limited to the approximate horizontal plane measurement.

A more accurate measurement of the complex area of the geomorphic area \[18,19\] also requires "elevation" and other influencing factors \[20,21\], which relies on breakthroughs in the precisement of GNSS elevation measurement \[22,23,24\].

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