The detection method of positioning accuracy in CORS system exists

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Abstract—the positioning accuracy detection of CORS system is an essential link before it is put into market. However, the location accuracy detection method does not take into account the correlation between the comprehensive environment around the detection point and the external coincidence accuracy, so the method is not rigorous and scientific. This paper proposes a method based on nonparametric statistics, which can verify the correlation between the comprehensive environment around the detection point and the external coincidence accuracy from a mathematical point of view, and then it is incorporated into the traditional positioning accuracy detection method, and is verified by a CORS system. The results are satisfactory, which proves that this method is very effective in compensating the integrity of CORS positioning accuracy detection method.

1. Introduction
Continuous operational reference system (CORS) is one of the hot spots in the application of satellite navigation and positioning technology, which constructs and maintains the coordinate framework of the city. However, before the CORS system is put into the market, it is necessary to test the reliability of the positioning accuracy of the CORS system, so as to ensure that users can use it at ease. The purpose of this paper is to evaluate whether the system can meet the accuracy requirements of users in surveying and mapping operation, improve the credibility of positioning accuracy of the system, and lay a solid foundation for the use and promotion of CORS system in the future. [1]

2. Positioning accuracy detection method
2.1. static known point method
The static known point method is used to measure the selected known point, and the coordinate value obtained after processing the observation data is compared with the known value, so as to determine the accuracy. The purpose of this paper is to test the positioning accuracy of the static data of CORS system. Firstly, the receiver frame is used to collect data by multi period observation method on the pre selected points. The observed data are processed and the internal and external coincidence accuracy of CORS system is calculated. The static measurement method can not fully reflect the positioning accuracy of CORS system. The internal and external coincidence accuracy of the system is calculated by processing the observation data in the field to evaluate the positioning quality of the system.
2.2. Dynamic regular geometric trajectory method

From the definition of detection method, we can see that this detection method is to compare the measured data of user receiver with the known figure. This method is not limited by whether the detection points contain known points. [2] The method is simple and easy. Regular geometric figures can be set up in the coverage area of the survey area. The regular figures can be used to describe the measurement track. In this way, some measuring points with uniform spacing can be obtained. The real trajectory is compared with the measured track, and the deviation degree between the point and the actual is calculated to analyze the positioning of CORS system accuracy. Sometimes, when the conditions permit, we usually choose the known points with higher accuracy as the corner points of the figure when laying the graph, so as to improve the detection accuracy. This detection method is different from the static measurement and has some similarities, which is more flexible and suitable for the dynamic test on land. Let's take a triangle as an example.

![Fig. 1 Trajectory of dynamic triangle](image)

If we know the position of A and B, then we can start from the coordinates of A and B, and then we can start to measure the coordinates of A and B according to the coordinates of A and B, and then we can start from the coordinates of A and B, and then we can start from one of the coordinates of A and B. Finally, according to these two indexes, the positioning accuracy of the system is reflected. Due to the existence of error, the measured scattered points (such as point D) will deviate from the actual point position. From this angle, the positioning accuracy of the system can also be reflected. The specific calculation method is as follows:

Suppose \( a()\) \( B() \), then the equation of line \( AB \) can be expressed as follows:

\[
y = \frac{(y_4 - y_2)}{(x_4 - x_2)} x + \frac{(y_4 - y_3)}{(x_4 - x_3)}
\]

Suppose that the D coordinate of the test point is \((x_D, y_D)\), then the offset can be calculated according to the distance formula from the point to the line, as shown in formula (2):

\[
\delta = \frac{|kx_D - y_D + b|}{\sqrt{1+k^2}}
\]

2.3. Different time period method

In an ideal situation, no matter when and where we are, we can receive more than four satellites. However, in the actual engineering practice, under the influence of many external uncertainties, the number of satellites that can be received by the user receiver is different, which leads to different accuracy of users. [3] The detection method of different time period is to divide a day into four satellite Time periods: morning, noon, afternoon and evening. Select a higher level known point, and use the same instrument to measure the known point evenly in four time periods. Each time period is
measured about 100 times. Then the measured data are processed to analyze the positioning accuracy of CORS system.

2.4. different elevation method

According to the previous CORS system positioning accuracy detection experience, the plane accuracy is generally better than the elevation accuracy. When the CORS system calculates the correction number, it is actually related to the elevation of the receiver, so the height detection method is very meaningful for the detection of positioning accuracy of CORS system. Different elevation detection methods are to test the known points of different elevations in the same period of time, such as selecting points at the side of the mountain range with obvious elevation changes at an equal distance of 100m. The accurate coordinates are calculated by static measurement as the true value. Then, the elevation of the point measured by dynamic RTK is compared with the coordinates calculated by static measurement, so as to study the law of positioning accuracy changing with elevation.

3. Strategy based on nonparametric statistical method

The nonparametric statistical method is introduced to verify whether there is a correlation between the comprehensive regional environment around the selected point and the external coincidence accuracy. If there is a relationship, the correlation degree can be calculated to determine how much impact it has on the detection results. If there is a high dependence relationship, regression analysis can also be carried out to determine the expression form of the relationship.

3.1. establishment of nonparametric statistical methods

1) Measurement data type

According to the knowledge of statistical data classification, data can be divided into qualitative data and quantitative data.

2) Contingency table

The two groups of data are classified interactively on attributes. Suppose a has R grades, A1, A2, etc., and B has C grades, B1, B2, etc., then the two groups of data can be arranged as $R \times C$ In the contingency table, R is the row and C is the column.

3) In contingency table $X^2$ test

In the double table data test, it is usually used to check whether the two groups of data are related $X^2$ Testing, especially in qualitative data $X^2$ Testing is the most effective. Specific inspection process:

Firstly, the hypothesis group is established

$H_0$: X is independent of Y (independent)

$H_1$: X and y are not independent

application $X^2$ When making a judgment, we should first get the theoretical number corresponding to the actual number of times, that is, the expected number of times $E_i$, then

$$e_i = \frac{n(F_{\text{a}}(j)(F_{\text{b}}(k)))}{n} = \frac{F_{\text{a}}(j) \times F_{\text{b}}(k)}{n}$$

hypothesis $H_0$ If it is true, then the expected number of times in theory should be equal to the number of conditional times, that is, the difference between the actual number and the expected number of times in theory is 0. However, due to the deviation of measurement results, there is a difference between the actual number and the expected number of times. We can use the size of the difference to
measure the degree of correlation between the two variables $H_0$. The greater the possibility of false, that is, the less possibility that $X$ and $y$ have nothing to do with it. The difference is inversely proportional to the strength of correlation. In order to calculate the magnitude of this difference, we propose $\chi^2$. The statistic $Q$ in the test is expressed as follows:

$$Q = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(f_{ij} - e_{ij})^2}{e_{ij}}$$

The statistic $q$ is approximately subject to the degree of freedom of $df = (r-1)(c-1)$ of $\chi^2$. The significant level can be seen by looking up the table $H_0$, degrees of freedom $df$, find $H_1$. The zero bound of the truth value of $\chi^2$. When the statistic $q$ is greater than or equal to $\chi^2_{1-\alpha}$ or less than $\chi^2_{\alpha}$. You can't refuse $H_0$, indicating that variables are independent of each other; otherwise, it means that $X$ and $y$ are related.

The statistics $Q$ can be used to test the correlation between variables, but it does not reflect the degree of correlation. The correlation coefficient is calculated by $Q$. The following is $\Phi$. The calculation formulas of correlation coefficient method, contingency table correlation coefficient method and Cramer's V correlation coefficient method are given.

The formula of correlation coefficient method is as follows:

$$\varphi = \sqrt{\frac{Q}{n}}$$

The formula of Kramer correlation coefficient method is as follows:

$$V = \sqrt{\frac{Q}{\min[(r-1)(c-1)]}}$$

However, when there are spaces in the binary table, it is called incomplete contingency table. In this case, the statistics we use are the relaxation ratio statistics, and the expression is $-2 \ln \Lambda$. The formula is as follows:

$$-2 \ln \Lambda = -2 \sum_{i=1}^{r} \sum_{j=1}^{c} f_{ij} \left( \ln \frac{e_{ij}}{f_{ij}} \right)$$

4) Correspondence analysis in contingency table

The correspondence analysis of contingency table is to transform the classified column and column data into another form through a series of transformation, and then compare and contrast the two, so as to find the corresponding relationship between the column and column elements. The advantage of this method is that it can reveal the correlation between variables and the states of variables in a clear way. The specific way is to describe the relationship between variables on the two-dimensional graph, which is more conducive to understand the structure of the data. Correspondence analysis is actually an analysis method combining R-type factor analysis and Q-type factor analysis, and it is a kind of multivariate statistical analysis. [4]
3.2. implementation of nonparametric statistical method

3.2.1. establishment of two tables

According to the classification basis in Table 2.1, the external coincidence accuracy error of the detection points is classified. In this paper, the spatial factor detection method mainly discusses the relationship between the environmental factors of administrative regions and external coincidence accuracy, taking Shenyang as an example.

1 Representative urban areas (Heping District, Shenhe District, Huanggu District, Tiexi District, Dadong District)
2 Representative suburban areas (Sujiatun, Dongling District, Shenbei New District, Yuhong District)
3 Representing the outer suburbs (Xinmin City, Liaozhong County, Kangping County, Faku County)

Tab. 1 Accuracy of the measurement points outside the table

| Type of measuring point | Error range (mm) |
|-------------------------|------------------|
| A class of points       | 0≤x≤10, 0≤y≤10   |
| Point of the second kind | 10<0<            |
| Three kinds of points   | 20<,20<          |

3.2.2. conduct discriminant statistics according to the regional comprehensive environment where the detection points are located

A double table is established between the statistical accuracy error of the detection points and the administrative region classification.

Tab. 2 Classification of administrative region and the accuracy error

| f ̂ x | 1   | 2   | 3   | Total () |
|------|-----|-----|-----|----------|
| A class (I = 1) 7  | 6   | 4   | 17  |
| Class II (I = 2) 9  | 5   | 5   | 19  |
| Three types (I = 3) 10 | 7   | 6   | 23  |
| Total () 26 | 18  | 15  | 59  |

Tab. 3 Expectation of administrative region and the accuracy error classification

| e ̂ x | 1   | 2   | 3   | Total () |
|------|-----|-----|-----|----------|
| A class (I = 1) 7.4915 | 5.1865 | 4.3220 | 17 |
| Class II (I = 2) 8.3729 | 5.7966 | 4.8305 | 19 |
| Three types (I = 3) 10.1356 | 7.0169 | 5.8475 | 23 |
| Total () 26 | 18 | 15 | 59 |

According to the formula, the statistics Q (r = 3, C = 3) and (r = 3, C = 3) are calculated respectively

r=3;
c=3;
n=59;
f=[9 8 1; 8 7 2; 15 9 1];
fx=[26 18 15];
fy=[17 19 23];
e=zeros(r,c);
for i=1:r
for j=1:c
e(i,j)=fy(i)*fx(j)/n;
End
End
Q=0;
for i=1:3
for j=1:3
Q=Q+[(f(i,j)-e(i,j))*(f(i,j)-e(i,j))]/e(i,j);
End
End
L=0
for i=1:r
for j=1:c
if f(i,j)==0
continue;
End
l=l+[f(i,j)*log(e(i,j)/f(i,j))];
End
End
l=(-2)*l;

4. experiment and analysis
Nonparametric statistical method was used to calculate the statistic $q = 0.352, = 0.351$.

Correlation experiment
Hypothesis $H_0$: regional comprehensive environment is independent of external coincidence accuracy (independent);
$H_1$: the comprehensive environment of the selected point area is related to the external coincidence accuracy (not independent).

The statistic $Q$ approximately obeys the distribution of degree of freedom $DF = (R-1) \times (C-1) = (3 - 1) \times (3 - 1) = 4$. The significance level is 0.05 and the degree of freedom $DF = 4$. It can be seen from Appendix C that $= 0.711, = 9.488$. It is concluded that the value of $Q$ and is not in the range, so $H_1$ is assumed to be true, that is, the regional comprehensive environment is related to the external coincidence accuracy. [5]

The correlation degree experiment was as follows
Through calculation, $= 0.077, C = 0.077, v = 0.055$. According to the law of V correlation coefficient, when $v = 0$, the two variables are independent and uncorrelated; when $v = 1$, the two variables are completely correlated; when $v$ value is between 0-1, the greater the coefficient, the higher the correlation degree of the two variables.

| Significant weak correlation | Moderate correlation | Significant strong correlation |
|-----------------------------|----------------------|-----------------------------|
| $<0.4$                      | 0.4-0.75             | $>0.75$                     |

In this paper, $v = 0.055$, so the two variables are related, but belong to significant weak correlation. It shows that the regional comprehensive environment of the selected detection point will have a weak impact on the positioning accuracy detection of CORS system, but this influence will not bring interference to the detection results.

5. Conclusion
Starting from different detection methods, this paper introduces the principles of various detection methods in detail. Different detection methods verify the reliability of the positioning accuracy of the system from different angles, [6] but ignore the correlation between the comprehensive environment around the detection point and the external coincidence accuracy of the positioning accuracy, so it is
not sure how much impact it has on the detection results. In order to solve this problem, this paper proposes a nonparametric statistical method to calculate, accurately express the correlation degree of the two is significant weak correlation, make up for the shortcomings of traditional detection methods, make the detection method more scientific, more rigorous and more complete, greatly improve the credibility of CORS positioning accuracy, and tests based on Shenyang data, the results are satisfactory.

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