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Research on the Model and Application Progress Based on Grey Relational Analysis Theory

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Abstract: Gray correlation analysis is an important method to measure the development trend of things and the correlation degree of factors. Firstly, the processing process of typical Grey relational data is analyzed. Secondly, by comparing the advantages and disadvantages of Grey relational model, and combining with practical application, two improved analysis models are concluded. Finally, the application status of Grey relational analysis is given, and a set of theoretical system is formed to provide guidance and reference for the improvement and research of subsequent relational degree calculation model.

1. Introduction

Gray correlation analysis has been widely used in daily production and is a mathematical statistical method for multi-factor analysis and index analysis. Compared with regression analysis and principal component analysis, gray correlation analysis has the advantages of poor data and convenient calculation [1]. Based on the traditional correlation degree calculation method, scholars at home and abroad have carried out optimization research on the calculation condition of correlation degree, and put forward relevant calculation model and improved model. In the analysis process, the calculation of correlation degree is the core, and how to quantify the correlation degree among various factors is a key issue in the application.

2. Grey Relational Analysis Theory

Grey correlation analysis is one of the common predictive analysis methods in statistics. It is an important branch of Grey system prediction theory. It is based on the similarity or difference of the development trend between factors, that is, the “Grey correlation degree”. As a method to measure the correlation degree of factors, quantitative analysis is focused on the closeness degree of various factors in human production, life and other fields to determine the influence degree of various factors. Geometric comparison is shown in Figure 1.

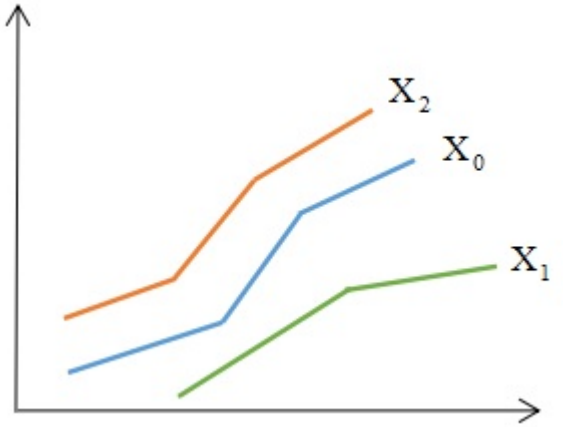

Fig.1 Geometric Comparison of Sequence Correlation Degree

The basic idea: select the comparison sequence and the reference sequence, and judge the degree of correlation by comparing the similarity between them. If the variation trend of the two sequences is similar, the degree of correlation is considered high. On the contrary, the correlation is low [2].

Suppose X_0 is a contrast sequence, X_1 and X_2 is a reference sequence. As can be seen from Figure 1, reference sequences X_2 and contrast sequences X_0 are close in distance and similar in change trend, so the correlation degree ratio of sequences X_2 is higher than X_1.

Advantages :(1) the sample data is not limited; (2) Simple analysis process; (3) High accuracy of prediction results.

Grey relational axiom :(1) normalization; (2) Integrity; (3) Even symmetry; (4) Similarity; (5) Similarity; (6) Comparability; (7) Independence.

3. Grey Relational Analysis Model

Grey correlation analysis mainly describes the consistency of reference sequence and comparison sequence. The consistency of sequences can be characterized by the similarity (numerical value) and the similarity (geometric shape) of curves. In order to better describe the degree of consistency between the two, scholars at home and abroad put forward four typical Grey correlation model.

3.1 Comparison of Basic Models

In addition to the Deng's Grey correlation model, there are also generalized absolute correlation model, slope Grey correlation model and T-type correlation model [3]. The specific characteristics are summarized in Table 1

Table 1 Comparison of Serial Correlation Degree Model

The serial number	serial correlation degree model	advantages	disadvantages
One	Dunn's correlation degree model	describe proximity by distance	does not have order preserving property
Two	Slope correlation model	Can characterize similarity	Cannot characterize data similarity
Three	The T-type correlation model	Can reflect the negative correlation	Insensitive to data translation and slope

		of data	change
Four	Type B-relational grade model	Can reflect the influence of data distance and slope	Low resolution
five	Area relational model	Reflect the similarity and similarity of the curve	Cannot reflect the weight effect
six	Absolute correlation model	Reflect uniqueness, comparable	The algorithm is flawed

Among the above basic models, Dunn's correlation degree model is widely used, and the specific process is as follows:

3.1.1 Determine Comparison Sequence and Reference Sequence

(1)Generally, the factors that can reflect the overall change characteristics of things (also known as research objects) are identified as comparison sequences. Remember to x_0

$$x_0 = [x_0(1), x_0(2), \cdots, x_0(n)]$$

(2)The sequence of factors influencing the object of study is called the reference sequence. Remember to $x_i (i = 1,2,3,\cdots)$

$$x_1 = [x_1(1), x_1(2), \cdots, x_1(n)]$$
$$x_2 = [x_2(1), x_2(2), \cdots, x_2(n)]$$
$$x_k = [x_k(1), x_k(2), \cdots, x_k(n)]$$

3.1.2 Unified Dimension (I.e. Normalized Treatment)

In practical problems, due to the inconsistent units of each influencing factor, there are magnitude differences, which affect the data analysis results. To facilitate data analysis, it is necessary to normalize the data in the reference sequence.

Common data normalization processing methods mean value, initial value and transformation [8]

(1) Initial value method

Divide the first data by the other data in the sequence. It is suitable for data showing a stable and increasing trend.

(2) Mean value method

The average value of the sequence is divided by the other data in the sequence, for data with no up-and-down trend.

(3) Transformation method (also known as interval method)

The difference between each item in the same sequence and the minimum value in the original data of the sequence is divided by the difference between the maximum value and the minimum value in the original data of the sequence to obtain the interval sequence.

Note 1: Generally, the three methods are not mixed. One can be selected according to the characteristics of data changes.

Note 2: If the comparison sequence is negatively correlated with the reference sequence data, it is necessary to invert or invert the data.

The normalized data can be expressed as:

(1)Comparison sequence: $\hat{x}_0 = [\hat{x}_0(1), \hat{x}_0(2), \hat{x}_0(3), \cdots, \hat{x}_0(j), \cdots, \hat{x}_0(n)]$

(2)Reference sequence: $\hat{x}_i = [\hat{x}_i(1), \hat{x}_i(2), \hat{x}_i(3), \cdots, \hat{x}_i(j), \cdots, \hat{x}_i(n)]$, $i = 1,2,3,\cdots,k$

3.1.3 Calculation of Correlation Coefficient

According to the normalized data, the difference of the corresponding points in the reference sequence is calculated

$$\Delta_i(j)=\left|\hat{x}_0(j)-\hat{x}_i(j)\right|,\ j=1,2,3,\cdots,n,\ i=1,2,3,\cdots,k \quad ①$$

According to the above formula, the maximum difference and the minimum difference are calculated

$$\mathrm{M}=\max_i\max_j\Delta_i(j),\ m=\min_i\min_j\Delta_i(j) \quad ②$$

Substitute formula ①and②into formula③to calculate the correlation coefficient

$$\zeta_i(j)=\frac{\mathrm{m}+\rho M}{\Delta_i(j)+\rho M} \quad ③$$

Among, $j=1,2,3,\cdots,n$, $i=1,2,3,\cdots,k$,

ρ is the resolution coefficient, and the value range is between 0 and 1. ρ the smaller the correlation coefficient is, the more obvious the difference is, generally 0.5.

3.1.4 Calculation of Correlation Degree

By substituting formula ③into formula ④,the correlation degree between comparison sequence and reference sequence can be calculated

$$r_i=\frac{1}{n}\sum_{j=1}^{n}\zeta_i(j) \quad ④$$

According to the calculation results, the correlation degree was analyzed in order, and the primary and secondary influencing factors were obtained. The larger the correlation degree value is, the greater the influence degree is; on the contrary, the less the influence degree is. If the correlation degree is equal, the influence degree is equal. This kind of correlation calculation method, also known as Dunn's Grey relational degree model, is to construct the relational degree model through the distance difference between curves.

3.2 Analysis of Correlation Degree Calculation

(1) The operation of absolute value occurs in the calculation of Grey relational degree. Considering only the value of reference sequence and comparison sequence, it is impossible to distinguish the positive and negative values of the operation of absolute value, and there is a certain potential risk in the model operation.

(2) Dengs correlation degree calculation is also known as relative correlation degree. The results will fluctuate due to the influence of maximum and minimum range values in the calculation process.

(3) The mean processing method is adopted in the calculation of correlation degree, which results in inaccurate and objective results.

3.3 Improved Model

In view of the defects of the above basic models, scholars at home and abroad have proposed an

improved Grey relational degree calculation method, so that the reference sequence curve is infinitely close to the comparison sequence curve and the image change trend is similar.

(1) Combination prediction model

In 2015, XiaoleiNing et al. [4] proposed an improved model of comprehensive difference mode and division mode on the basis of Deng's correlation degree calculation model, and obtained three comprehensive Grey correlation coefficient calculation formulas:

Improved formula 1:

$$r(x_o(k), x_i(k)) = \omega_1 r_1(x_o(k), x_i(k)) + \omega_2 r_2(x_o(k), x_i(k))$$

Improved formula 2:

$$r(x_o(k), x_i(k)) = r_1(x_o(k), x_i(k))^{\omega_1} \times r_2(x_o(k), x_i(k))^{\omega_2}$$

Improved formula3:

$$r(x_o(k), x_i(k)) = \sqrt{r_1(x_o(k), x_i(k)) \times r_2(x_o(k), x_i(k))}$$

Among: $r_1(x_o(k), x_i(k)) = e^{-(\hat{x}_0 - \hat{x}_i)}$, $r_2(x_o(k), x_i(k)) = e^{-\left(\left|1-\frac{x_i}{x_0}\right|\right)}$, $\omega_1 + \omega_2 = 1$

The corresponding correlation degree can be calculated by using the formula④.

In 2019, XiaochengMeng(5) et al considered that the data processing in Deng's Grey correlation coefficient calculation could not meet the requirements of number protection and integrity, and proposed to integrate slope and Grey correlation analysis, and to define the correlation coefficient by comprehensively using the composition ratio and difference of increment of two sequences to further calculate the correlation degree.

(2) Weight optimization model

In 2016,ZHANG An-ping(6), on the premise of Deng's Grey relational model, made a weighted sum of Grey relational coefficients and got an improved Grey relational model.

In 2015, ZhenjieYin et al.(7) analyzed the existing problems of the traditional Grey relational degree algorithm and proposed an improved Grey relational degree algorithm based on weighted average, introducing the weight coefficient to eliminate the error caused by the positive and negative offset of area.

4. Model Application Analysis

(1) Multi-factor analysis

In daily production and life, there are many factors that determine the development trend of things. They influence each other and determine the development trend of things. In the face of complex factors, it is crucial to quickly distinguish the principal contradiction that affects the development of things. Grey correlation analysis is one of the common methods to solve this kind of problems. It is convenient to operate and the process is simple. It only needs to make clear the reference sequence and comparison sequence and calculate the correlation degree according to the steps to carry out Multi-factor analysis.

(2) Index evaluation and analysis

In real production, problems such as comprehensive evaluation are often encountered, and we know that the basis of evaluation is the index. However, as the factors that affect the things to be evaluated are often numerous and complex, it is not reasonable to comprehensively evaluate the things to be evaluated only from a single index. Therefore, it is often necessary to collect the information of multiple indexes reflecting the things to be evaluated to obtain a comprehensive

index, which reflects the situation of the things to be evaluated on the whole.

(3) Comprehensive evaluation

One column of the most valuable sample data is selected from the sample sequence as the reference sequence, and the other sample sequences are taken as the comparison sequence. The two are combined to carry out comparative analysis on the evaluation object, and the optimal impact sequence is obtained.

Conclusions and Suggestions

(1) This paper analyzes the Grey relational degree theory, gives the typical Grey relational analysis and processing process, combines the algorithm and the lack of application of the model, and draws the conclusion of two improved relational degree calculation models.

(2) At present, most of the Grey relational model is improved on the basis of Dunn's correlation method. The similarity and similarity between reference sequence and comparison sequence curves are improved, but the accuracy needs to be improved. The subsequent improved model can be considered to be integrated with other mathematical models.

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