Application of Grey Relational Analysis in Computer Communication Network Security Evaluation

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Abstract

With the rapid development of computer and communication technology, the computer network throughout people whole live, concern government, factory, school, communication, bank, military and the other world, as the people daily life, as big is as slightly stable as the national security. It can't be avoid problem how to design a network topology structure of high capacity, low cost, easy expansion to every network managers. The key of computer communication network topology structure is the planning design of back-bone network topology structure, during the back-bone network designing the key guideline is all-terminal network reliable capacity. It is the best technology guideline to embody back-bone network reliable capacity. The problem of evaluating the computer communication network security based on grey relational analysis is the multiple attribute decision making (MADM) problems. In this paper, we investigate the multiple attribute decision making (MADM) problems for evaluating the computer communication network security. Then, we extended the grey relational analysis (GRA) model to evaluate the computer communication network security. According to the traditional ideas of GRA, the optimal alternative(s) is determined by calculating the relational degree of every alternative and positive ideal solution (PIS) and negative ideal solution (NIS). It is based on the concept that the optimal alternative should have the largest relational degree from the positive ideal solution and on the other side the smallest relational degree from the negative ideal solution. Finally, an illustrative example demonstrates the practicality and effectiveness of the proposed method.

Keywords: Multiple Attribute Decision Making (MADM), Computer Communication Network, Grey Relational Analysis (GRA), Relational Degree

1. Introduction

So far, there was not a normal and integrated risk assessment system for computer network information security, and also, the opinion of sorting risk assessment didn’t come to an agreement. Since absence of risk assessment standard, different risk assessment department got the different result in evaluating the same system. At the same time, with speeding up organization information process and enhancing the foundation and integer of network information system, information security problem became more and more important. Current information security needed to strengthen the risk assessment quickly. The existed research areas included security construction and development for computer network system, rule and method of network information security risk assessment. With analyzing the current situation of computer information system, the key points and problems of risk assessment could be found to provide the reference and basis for network security organization. Because many information system security risk assessment theories were hard to be operated, regularity union risk assessment was designed and implemented to improve the maneuverability, achieved qualitative and measurable risk analysis, at the same time, analyzed and discussed development aspect of network information security risk assessment. With the development of the Information Technology, computer networks have been widely used in many fields. But people are anxious for the security of the computer networks more and more. Recent years, more than 60% user networks have been broken. The computer networks have the great risk. The desire of the networks for different type of users is different. The network engineers usually construct a computer network according to their experience and the requests of the user. Qualitative analysis of the security for a network is often used. With the rapid development of information technology, the internet has already become the vital vehicle for information dissemination globally. However, since after the advent of the internet, resource sharing and information security have turn into one pair of irreconcilable contradictions. The more and the wider internet information is shared, the more and the deeper
information security problems are increasingly exposed. Therefore, traditional passive protection is not adaptable to the current security situation, and the theory of proactive network security assessment has been created accordingly. The favorable network security assessment can assist the management staff to comprehensively and precisely control the level of security, this makes a great importance to safeguard the internet to run smoothly[1-10].

The problem of evaluating the computer communication network security based on grey relational analysis are the multiple attribute decision making (MADM) problems. The aim of this paper is to investigate the MADM problems for evaluating the computer communication network security based on grey relational analysis. Then, we extended the grey relational analysis (GRA) model to evaluate the computer communication network security. According to the traditional ideas of GRA, the optimal alternative(s) is determined by calculating the relational degree of every alternative and positive ideal solution (PIS) and negative ideal solution (NIS). It is based on the concept that the optimal alternative should have the largest relational degree from the positive ideal solution and on the other side the smallest relational degree from the negative ideal solution. In order to do so, the rest of the paper is organized as follows: next section briefly introduce some basic concepts related to the grey relational analysis (GRA) model. In Section 3, we extended the grey relational analysis (GRA) model to evaluate the computer communication network security. According to the traditional ideas of GRA, the optimal alternative(s) is determined by calculating the relational degree of every alternative and positive ideal solution (PIS) and negative ideal solution (NIS). It is based on the concept that the optimal alternative should have the largest relational degree from the positive ideal solution and on the other side the smallest relational degree from the negative ideal solution. In Section 4 we illustrate our proposed algorithmic method with an example. The final section concludes.

2. Grey relational analysis

Grey relational analysis (GRA) method [11-12] was originally developed by Deng and has been successfully applied in solving a variety of MADM problems [13-21]. The main procedure of GRA is firstly translating the performance of all alternatives into a comparability sequence. This step is called grey relational generating. According to these sequences, an ideal target sequence is defined. Then, the grey relational coefficient between all comparability sequences and ideal target sequence is calculated. Finally, base on these grey relational coefficients, the grey relational degree between ideal target sequence and every comparability sequences is calculated. If a comparability sequence translated from an alternative has the highest grey relational degree between the ideal target sequence and itself, that alternative will be the best choice. The procedures of grey relational analysis are shown in Fig. 1 [11-12].

With the continuous development of computer technology and the wide spread of network application, network security is becoming an important issue which technicians face and many studies relating to the network security technology are becoming mature. Network security situational awareness is a technology which can realize the network security inspection and monitoring. Besides, it is a hot topic on the information security research. It is very significant to carry out this research, for it can improve the emergency response ability of net system, mitigate the harm caused by cyber attacks, discover the malicious invasion behavior and improve the system’s counter-attack ability. In this section, we consider a multiple attribute decision making problems to evaluate the computer communication network security based on grey relational analysis. Let \( A = \{ A_1, A_2, \cdots, A_m \} \) be a discrete set of alternatives, and \( G = \{ G_1, G_2, \cdots, G_n \} \) be the set of attributes, \( \omega = (\omega_1, \omega_2, \cdots, \omega_n) \) is the weighting vector of the attributes \( G_j (j = 1, 2, \cdots, n) \), where \( \omega_j \in [0,1], \sum_{j=1}^{n} \omega_j = 1 \). Suppose that \( A = (a_{ij})_{m \times n} \) is the decision matrix, where \( a_{ij} \) is a preference value, given by the decision maker for the alternative \( A_i \in A \) with respect to the attribute \( G_j \in G \).

In the following, we will extend the grey relational analysis (GRA) model to evaluate the computer communication network security.

**Step 1.** Calculate the normalized decision matrix. The normalized value \( b_{ij} \) is calculated as

If attribute \( G_j \) is a benefit criterion:

\[
    b_{ij} = \frac{a_{ij} - \min_{i} a_{ij}}{\max_{i} a_{ij} - \min_{i} a_{ij}}, \quad i = 1, 2, \cdots, m, \quad j = 1, 2, \cdots, n.
\]

(1)

If attribute \( G_j \) is a cost criterion:

\[
    b_{ij} = \frac{\max_{i} a_{ij} - a_{ij}}{\max_{i} a_{ij} - \min_{i} a_{ij}}, \quad i = 1, 2, \cdots, m, \quad j = 1, 2, \cdots, n.
\]

(2)

**Step 2.** Determine the positive ideal solution and negative ideal solution

\[
    B^+ = \{ b_{1}^+, \cdots, b_{n}^+ \} = \left\{ \max_{i} b_{ij} \right\}
\]

(3)

\[
    B^- = \{ b_{1}^-, \cdots, b_{n}^- \} = \left\{ \min_{i} b_{ij} \right\}
\]

(4)

**Step 3.** Calculate the grey relational coefficient of each alternative from PIS and NIS using the following equation, respectively:

The grey relational coefficient of each alternative from PIS is given as

\[
    \rho_{ij} = \frac{\min \{ b_{ij}^+, b_{ij}^- \} + \alpha \cdot \max \{ b_{ij}^+, b_{ij}^- \}}{\max \{ b_{ij}^+, b_{ij}^- \} - \min \{ b_{ij}^+, b_{ij}^- \}}, \quad i = 1, 2, \cdots, m, \quad j = 1, 2, \cdots, n.
\]

where \( \alpha \) is a constant, typically \( \alpha = \frac{1}{2} \).
Similarly, the grey relational coefficient of each alternative from NIS is given as

$$\xi_{ij}^- = \frac{\min_{\text{dom} \in \text{IS}} |b_j^* - b_j| - \rho \max_{\text{dom} \in \text{IS}} |b_j^* - b_j|}{|b_j^* - b_j| + \rho \max_{\text{dom} \in \text{IS}} |b_j^* - b_j|}, \quad i = 1, 2, \cdots, m, j = 1, 2, \cdots, n. \tag{6}$$

where the identification coefficient $\rho = 0.5$.

**Step 4.** Calculating the degree of grey relational coefficient of each alternative from PIS and NIS using the following equation, respectively:

$$\xi_{ij}^+ = \sum_{j=1}^{n} w_j \xi_{ij}^+, \quad i = 1, 2, \cdots, m. \tag{7}$$

$$\xi_{ij}^- = \sum_{j=1}^{n} w_j \xi_{ij}^-, \quad i = 1, 2, \cdots, m. \tag{8}$$

The basic principle of the GRA method is that the chosen alternative should have the “largest degree of grey relation” from the positive ideal solution and the “smallest degree of grey relation” from the negative ideal solution.

**Step 5.** Calculating the relative relational degree of each alternative from PIS using the following equation,

$$\xi_i = \frac{\xi_{ij}^+}{(\xi_{ij}^- + \xi_{ij}^+)} \cdot \quad i = 1, 2, \cdots, m. \tag{9}$$

**Step 6.** Rank all the alternatives $A_i \quad (i = 1, 2, \cdots, m)$ and select the best one(s) in accordance with $\xi_i \quad (i = 1, 2, \cdots, m)$. If any alternative has the highest $\xi_i$ value, then, it is the most important alternative.

**Step 7.** End.

4. **Numerical example**

The calculator technique develops quickly and makes nowadays the social development have already handed not got away from an information network. Because the calculator network delivers of involve each realm of finance, science education, and military...etc. in the information, include huge economy or national interest among them, so necessary network from each side of everyone attack stones, the network attack stones of the manifestation is also varied, like virus infection, steal the distorting of data, information delete to add an etc.. The problem of evaluating the computer communication network security based on grey relational analysis is the multiple attribute decision making (MADM) problems. In this section, we present an empirical case study of evaluating the computer communication network security based on grey relational analysis. The aim is to evaluate the best enterprise from evaluating the computer communication network security. The five possible computer communication network systems $A_i \quad (i = 1, 2, 3, 4, 5)$ are evaluated. The expert groups must take a decision according to the following six attributes: G1 is the flimsiness of the network; G2 is the
network safety of network information safety; G3 is the familiar network attack the method and counter plan; G4 is the network safety construction; G5 is the network safety technology; G6 is the network safety strategy. The five possible computer communication network systems $A_i (i = 1, 2, 3, 4, 5)$ are to be evaluated by the decision makers under the above six attributes (whose weighting vector $\omega = (0.12, 0.20, 0.15, 0.18, 0.21, 0.14)^T$) using the 0-10 scale, and construct the decision matrix as follows $A = (a_{ij})_{5 \times 6}$:

$$
A = \begin{bmatrix}
7 & 5 & 7 & 8 & 7 & 5 \\
4 & 3 & 9 & 6 & 8 & 4 \\
5 & 9 & 4 & 5 & 5 & 7 \\
9 & 6 & 5 & 4 & 6 & 6 \\
7 & 8 & 8 & 9 & 8 & 3
\end{bmatrix}
$$

To get the most desirable computer communication network systems, the following steps are involved:

**Step 1.** Constructing the normalized decision matrix as $B$ by using formula (1) and (2):

$$
G = \begin{bmatrix}
G_1 & G_2 & G_3 & G_4 & G_5 & G_6 \\
A_1 & 0.60 & 0.33 & 0.60 & 0.80 & 0.67 & 0.50 \\
A_2 & 0.00 & 0.00 & 1.00 & 0.40 & 1.00 & 0.25 \\
A_3 & 0.20 & 1.00 & 0.00 & 0.20 & 0.00 & 1.00 \\
A_4 & 1.00 & 0.50 & 0.20 & 0.00 & 0.33 & 0.75 \\
A_5 & 0.60 & 0.83 & 0.80 & 1.00 & 1.00 & 0.00
\end{bmatrix}
$$

**Step 2.** Determining the PIS and the NIS

$$
B^+ = \begin{bmatrix}
1.00 & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00
\end{bmatrix}
$$

**Step 3.** Calculating the grey relational coefficient of each computer communication network system from PIS and NIS

$$
\xi^+ = \left( \xi_{ij}^+ \right)_{5 \times 6} = \begin{bmatrix}
0.5556 & 0.4286 & 0.5556 & 0.7143 & 0.6000 & 0.5000 \\
0.3333 & 0.3333 & 1.0000 & 0.4545 & 1.0000 & 0.4000 \\
0.3846 & 1.0000 & 0.3333 & 0.3846 & 0.3333 & 0.3846 \\
1.0000 & 0.5000 & 0.3846 & 0.3333 & 0.4286 & 0.6667 \\
0.5556 & 0.7500 & 0.7143 & 1.0000 & 1.0000 & 0.3333
\end{bmatrix}
$$
Step 4. Calculating the degree of grey relational coefficient of each computer communication network system from PIS and NIS

\[
\xi^- = (\xi^\tau_{ij})_{5 \times 6} = \begin{bmatrix}
0.4545 & 0.6000 & 0.4545 & 0.3846 & 0.4286 & 0.4826 & 0.5000 \\
1.0000 & 1.0000 & 0.3333 & 0.5556 & 0.3333 & 0.6667 \\
0.7143 & 0.3333 & 1.0000 & 0.7143 & 1.0000 & 0.3333 \\
0.3333 & 0.5000 & 0.7143 & 1.0000 & 0.6000 & 0.4000 \\
0.3333 & 0.3750 & 0.3846 & 0.3333 & 0.3333 & 1.0000
\end{bmatrix}
\]

\[
\xi^+ = \begin{bmatrix}
0.5603 \\
0.6045 \\
0.5754 \\
0.5210 \\
0.7605 \\
0.4720 \\
0.6333 \\
0.6876 \\
0.60901 \\
0.4572
\end{bmatrix}, \xi^- = \begin{bmatrix}
0.5210 \\
0.7605 \\
0.6876 \\
0.60901 \\
0.4572
\end{bmatrix}
\]

Step 5. Calculate the relative relational degree of each computer communication network system from PIS

\[
\xi_1 = 0.5428, \xi_2 = 0.4883, \xi_3 = 0.4556, \xi_4 = 0.4610, \xi_5 = 0.6245
\]

Step 6. According to the relative relational degree, the ranking order of the five computer communication network systems is: \(A_5 > A_4 > A_2 > A_4 > A_3\), and thus the most desirable computer communication network system is \(A_5\).

5. Conclusion

Computer technology is developing very rapidly, powerful computers and Intranet/Internet are becoming popular all over the world. Informationization and networkization become tendency of today’s economic and society’s development of the world. Information technology and computer network have already applied widely. With the rapid development of computer and communication technology, the computer network throughout people whole live, concern government, factory, school, communication, bank, military and the other world, as the people daily life, as big is as slightly stable as the national security. It can’t be avoid problem how to design a network topology structure of high capacity, low cost, easy expansion to every network managers. The key of computer communication network topology structure is the planning design of back-bone network topology structure, during the back-bone network designing the key guideline is all-terminal network reliable capacity. It is the best technology guideline to embody back-bone network reliable capacity. The problem of evaluating the computer communication network security based on grey relational analysis is the multiple attribute decision making (MADM) problems. In this paper, we investigate the multiple attribute decision making (MADM) problems for evaluating the computer communication network security. Then, we extended the grey relational analysis (GRA) model to evaluate the computer communication network security. According to the traditional ideas of GRA, the optimal alternative(s) is determined by calculating the relational degree of every alternative and positive ideal solution (PIS) and negative ideal solution (NIS). It is based on the concept that the optimal alternative should have the largest relational degree from the positive ideal solution and on the other side the smallest relational degree from the negative ideal solution. Finally, an illustrative example demonstrates the practicality and effectiveness of the proposed method.

6. References

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