Projection model for Computer Network Security Evaluation with interval-valued intuitionistic fuzzy information

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Abstract. Computer technology is rapid development change with each passing day, powerful computer and Intranet/Internet worldwide popularity. Information and network is the world's current economic and social development of the trend of the development and utilization of information resources deeply and people from all walks of life, information network has been evolving rapidly; The whole society wide application of information technology, the computer network domain widely used pays close attention to for people place. But at the same time, network security technology in people's real life in a wide range of applications. The aim of this paper is to investigate the multiple attribute decision making problems for Computer Network Security Evaluation with interval-valued intuitionistic fuzzy information, in which the information about attribute weights is completely known, and the attribute values take the form of interval-valued intuitionistic fuzzy numbers. A project model is proposed. Then, based on the traditional project model, calculation steps for solving interval-valued intuitionistic fuzzy multiple attribute decision-making problems with known weight information are given. The project values between every alternative and positive ideal solution are calculated. Then, the project values are utilized defined to determine the ranking order of all alternatives. Finally, an illustrative example for computer network security evaluation is given to verify the developed approach and to demonstrate its practicality and effectiveness.

Keywords: Multiple Attribute Decision Making; Interval-valued Intuitionistic Fuzzy Numbers; Project Method; Computer Network Security Evaluation.

1. Introduction

The proliferation of today's networks mainly is due to the system integration of the fields of communications, network, automation, and control. The computer network has grown from a simple time-sharing system-a number of terminals connected to a central computer-to a large, complex environment that provides infrastructures to many critical and economically valuable components of economies. The military started out with the idea of securing each individual computer and later expanded the concept to securing a network of computers and devices. However, it is not the only organization that requires and has implemented some form of network security. Network security has evolved over the years and also in other departments of government and government networks. Computer technology is rapid development change with each passing day, powerful computer and Intranet/Internet worldwide popularity. Information and network is the world's current economic and social development of the trend of the development and utilization of information resources deeply and people from all walks of life, information network has been evolving rapidly; The whole society wide application of information technology, the computer network domain widely used pays close attention to for people place. But at the same time, network security technology in people's real life in a wide range of applications.

Atanassov [1-2] introduced the concept of intuitionistic fuzzy set (IFS), which is a generalization of the concept of fuzzy set [3]. The intuitionistic fuzzy set has received more and more attention since its appearance[1-15]. Gau and Buehrer [4] introduced the concept of vague set. But Bustince and Burillo [5] showed that vague sets are intuitionistic fuzzy sets. Xu[6-7] developed some information aggregation operators. Later, Atanassov and Gargov [8-9] further introduced the interval-valued intuitionistic fuzzy set (IVIFS), which is a generalization of the IFS. The fundamental characteristic of the IVIFS is that the values of its membership function and nonmembership function are intervals rather than exact numbers. The aim of this paper is to extend the concept of project model to develop a methodology for solving MADM problems for computer network security evaluation with interval-valued intuitionistic fuzzy information, in which the information about attribute weights is completely known, and the attribute values take the form of interval-valued intuitionistic fuzzy numbers. The rest of the paper is organized as follows: next section briefly introduce some basic concepts related to interval-valued intuitionistic fuzzy sets. In Section 3, we introduce the project model for MADM problems with interval-valued intuitionistic fuzzy information, In Section 4 we illustrate our proposed algorithmic method with an example for computer network security evaluation. The final section concludes.

2. Preliminaries

In the following, we introduce some basic concepts related to interval-valued intuitionistic fuzzy sets.

Definition 1. Let X be a universe of discourse, then a fuzzy set is defined as:

$$A=\left\{\left\langle x,\mu_A(x)\right\rangle \middle| x\in X\right\} \tag{1}$$

Which is characterized by a membership function $\mu_A : X \rightarrow [0,1]$, where $\mu_A(x)$ denotes the degree of membership of the element x to the set A [3]. Atanassov extended the fuzzy set to the IFS, shown as follows:

Definition 2. An IFS A in X is given by

$$A=\left\{\left\langle x,\mu_A(x),\nu_A(x)\right\rangle \middle| x\in X\right\} \tag{2}$$

Where $\mu_A : X \rightarrow [0,1]$ and $\nu_A : X \rightarrow [0,1]$, with the condition

$$0\le \mu_A(x)+\nu_A(x)\le 1,\ \forall\, x\in X$$

The numbers $\mu_A(x)$ and $\nu_A(x)$ represent, respectively, the membership degree and non-membership degree of the element x to the set A [1,2].

Definition 3. For each IFS A in X, if

$$\pi_A(x)=1-\mu_A(x)-\nu_A(x),\ \forall\, x\in X. \tag{3}$$

Then $\pi_A(x)$ is called the degree of indeterminacy of x to A [1,2].

Definition 4. Let X be a universe of discourse, An IVIFS $\tilde{A}$ over X is an object having the form [8-9]:

$$\tilde{A}=\left\{\left\langle x,\tilde{\mu}_A(x),\tilde{\nu}_A(x)\right\rangle \middle| x\in X\right\} \tag{4}$$

Where $\tilde{\mu}_A(x)\subset[0,1]$ and $\tilde{\nu}_A(x)\subset[0,1]$ are interval numbers, and

$$0\le \sup\left(\tilde{\mu}_A(x)\right)+\sup\left(\tilde{\nu}_A(x)\right)\le 1,\ \forall\, x\in X$$

For convenience, let $\tilde{\mu}_A(x)=[a,b], \tilde{\nu}_A(x)=[c,d]$, so $\tilde{A}=([a,b],[c,d])$.

Definition 5. Let $\tilde{a}=([a,b],[c,d])$ be an interval-valued intuitionistic fuzzy number, a score function S of an interval-valued intuitionistic fuzzy value can be represented as follows [10-11]:

$$S(\tilde{a})=\frac{a-c+b-d}{2}, S(\tilde{a})\in[-1,1]. \tag{5}$$

Definition 6. Let $\tilde{a}=([a,b],[c,d])$ be an interval-valued intuitionistic fuzzy number, a accuracy function H of an interval-valued intuitionistic fuzzy value can be represented as follows [10-11]:

$$H\left(\tilde{a}\right)=\frac{a+b+c+d}{2},H\left(\tilde{a}\right)\in\left[0,1\right]. \tag{6}$$

To evaluate the degree of accuracy of the interval-valued intuitionistic fuzzy value $\tilde{a}=\left(\left[a,b\right],\left[c,d\right]\right)$, where $H\left(\tilde{a}\right)\in\left[0,1\right]$. The larger the value of $H\left(\tilde{a}\right)$, the more the degree of accuracy of the interval-valued intuitionistic fuzzy value $\tilde{a}$.

3. Project Model for MADM with interval-valued Intuitionistic Fuzzy Information

Let $A=\left\{A_1,A_2,\cdots,A_m\right\}$ be a discrete set of alternatives, and $G=\left\{G_1,G_2,\cdots,G_n\right\}$ be the set of attributes, $\omega=\left(\omega_1,\omega_2,\cdots,\omega_n\right)$ is the weighting vector of the attribute $G_j\left(j=1,2,\cdots,n\right)$, where $\omega_j\in\left[0,1\right]$, $\sum_{j=1}^{n}\omega_j=1$. Suppose that $\tilde{R}=\left(\tilde{r}_{ij}\right)_{m\times n}=\left(\left[a_{ij},b_{ij}\right],\left[c_{ij},d_{ij}\right]\right)_{m\times n}$ is the interval-valued intuitionistic fuzzy decision matrix, where $\left[a_{ij},b_{ij}\right]$ indicates the degree that the alternative A_i satisfies the attribute G_j given by the decision maker, $\left[c_{ij},d_{ij}\right]$ indicates the degree that the alternative A_i doesn't satisfy the attribute G_j given by the decision maker, $\left[a_{ij},b_{ij}\right]\subset\left[0,1\right]$, $\left[c_{ij},d_{ij}\right]\subset\left[0,1\right]$, $b_{ij}+d_{ij}\le 1$, $i=1,2,\cdots,m$, $j=1,2,\cdots,n$.

In the following, we apply project model to MADM with interval-valued intuitionistic fuzzy information.

Step 1. Determine the positive ideal and negative ideal solution based on intuitionistic fuzzy numbers.

$$\tilde{r}^+=\left[\left(\left[a_1^+,b_1^+\right],\left[c_1^+,d_1^+\right]\right),\left(\left[a_2^+,b_2^+\right],\left[c_2^+,d_2^+\right]\right),\cdots,\left(\left[a_n^+,b_n^+\right],\left[c_n^+,d_n^+\right]\right)\right] \tag{5}$$

where

$$\left(\left[a_j^+,b_j^+\right],\left[c_j^+,d_j^+\right]\right)=\left(\left[\max_i a_{ij},\max_i b_{ij}\right],\left[\min_i c_{ij},\min_i d_{ij}\right]\right),\ j\in 1,2,\cdots,n.$$

Step 2. Calculate the project values of each alternative from PIS using the following equation.

$$\Pr j_{A^+}\left(A_i\right)=\Delta\left(\frac{\sum_{j=1}^{n}\left[w_j^2 h\left(\left[a_{ij},b_{ij}\right],\left[c_{ij},d_{ij}\right]\right)h\left(\left[a_j^+,b_j^+\right],\left[c_j^+,d_j^+\right]\right)\right]}{\sqrt{\sum_{j=1}^{n}\left[w_j h\left(\left[a_j^+,b_j^+\right],\left[c_j^+,d_j^+\right]\right)\right]^2}}\right),$$

$$i=1,2,\cdots,m.. \tag{7}$$

Step 3. Rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and select the best one(s) in accordance with $\Pr j_{A^+}\left(A_i\right)\left(i=1,2,\cdots,m\right)$. If any alternative has the highest $\Pr j_{A^+}\left(A_i\right)$ value, then, it is the most important alternative.

Step 4. End.

4. Numerical example

The rapid development of computer technology, make the development of modem society can not do without information network. Because of the computer network transmission of information involved in finance, science education, military and other fields, including the huge economic or the interests of the state, so not all the parties from the network attack, the network attack form also is many and varied, such as virus infection, steal data, information manipulation delete add, etc. This article from the network information security, network security vulnerability of the main technical, common network attack methods and countermeasures, network security construction, analyses the current network information security in, and the main problem of common network attack from the technical level is proposed, in the hope that through the network security construction gradually eliminate the network information safety hidden trouble. This section presents a numerical example to evaluate the computer network security with uncertain linguistic information to illustrate the method proposed in this paper. There are five possible computer network systems $A_i\left(i=1,2,3,4,5\right)$ for four attributes $G_j\left(j=1,2,3,4\right)$. The four attributes include the tactics $\left(G_1\right)$, technology and economy $\left(G_2\right)$, logistics $\left(G_3\right)$ and strategy $\left(G_4\right)$, respectively. The five possible computer network systems $A_i\left(i=1,2,\cdots,5\right)$ are to be evaluated by using the interval-valued intuitionistic fuzzy information by the decision maker under the above four attributes, as listed in the following matrix.

$$\tilde{R}=\begin{bmatrix} ([0.4,0.5],[0.3,0.4]) & ([0.4,0.6],[0.2,0.4]) & ([0.1,0.3],[0.5,0.6]) & ([0.3,0.4],[0.3,0.5]) \\ ([0.6,0.7],[0.2,0.3]) & ([0.6,0.7],[0.2,0.3]) & ([0.4,0.7],[0.1,0.2]) & ([0.5,0.6],[0.1,0.3]) \\ ([0.6,0.7],[0.1,0.2]) & ([0.5,0.6],[0.3,0.4]) & ([0.5,0.6],[0.1,0.3]) & ([0.4,0.5],[0.2,0.4]) \\ ([0.3,0.4],[0.2,0.3]) & ([0.6,0.7],[0.1,0.3]) & ([0.3,0.4],[0.1,0.2]) & ([0.3,0.7],[0.1,0.2]) \\ ([0.7,0.8],[0.1,0.2]) & ([0.3,0.5],[0.1,0.3]) & ([0.5,0.6],[0.2,0.3]) & ([0.3,0.4],[0.5,0.6]) \end{bmatrix}$$

And the weighting vector of G_1, G_2, G_3 and G_4 is as follows:

$$w=\left(0.20,0.30,0.10,0.40\right)$$

Then, we utilize the approach developed to get the most desirable computer network systems.

Step 1. Determine the positive ideal and negative ideal solution

$$\tilde{r}^{+}=\left[\left(\left[0.7,0.8\right],\left[0.1,0.2\right]\right),\left(\left[0.6,0.7\right],\left[0.1,0.3\right]\right)\right.$$
$$\left.\left(\left[0.5,0.7\right],\left[0.1,0.2\right]\right),\left(\left[0.5,0.7\right],\left[0.1,0.2\right]\right)\right]$$

Step 2. Calculate the project values of every computer network system and TLPIS

$$\mathrm{Prj}_{A^{+}}\left(A_1\right)=0.2975,\mathrm{Prj}_{A^{+}}\left(A_2\right)=0.3656,\mathrm{Prj}_{A^{+}}\left(A_3\right)=0.3392$$
$$\mathrm{Prj}_{A^{+}}\left(A_4\right)=0.3145,\mathrm{Prj}_{A^{+}}\left(A_5\right)=0.3205$$

Step 3. According to the project values of every alternative and TLPIS, the ranking order of the five alternatives is: $A_2 \succ A_3 \succ A_5 \succ A_4 \succ A_1$, and thus the most desirable computer network system is A_2.

5. Conclusion

In order to effectively use information resources, information sharing and information to adapt to the requirements of rapid expansion, the establishment of internal computer networks and based on computer network management system is entered into the network economy era, is also the basic condition of the establishment of a modern management system technology base, but like unauthorized access, illegal operation, information leak and services such as refuse to issue of network security directly affect the computer network system of the normal application, therefore, network security design become network design is very important part. In this paper, we have investigated the problem of multiple attribute decision-making with completely known information on attribute weights to which the attribute values are given in terms of interval-valued intuitionistic fuzzy numbers, a project model is proposed. Then, based on the traditional concept of project model, calculation steps for solving interval-valued intuitionistic fuzzy multiple attribute decision-making problems with known weight information are given. Finally, an illustrative example for computer network security evaluation is given. In the future, we shall continue working in the application of the interval-valued intuitionistic fuzzy multiple attribute decision-making to other domains.

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