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Research on scheme evaluation method of automation mechatronic systems

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ABSTRACT

In this paper, we investigate the multiple attribute group decision making (MAGDM) problems for for scheme evaluation method of automation mechatronic systems with intuitionistic fuzzy information. We utilize the intuitionistic fuzzy weighted average (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative and get the overall value of the alternatives, then rank the alternatives and select the most desirable one (s) according to the score function and accuracy function. Finally, an illustrative example is given.

KEYWORDS

Multiple attribute group decision-making (MAGDM); Intuitionistic fuzzy numbers; Intuitionistic fuzzy weighted average (IFWA) operator; Automation mechatronic systems.

INTRODUCTION

Today the development of mechatronics products and systems is mostly based on experience and skill, therefore it is important to study the mechatronics theory deeply and to direct the design by means of unite mechatronics theory for enhancing the mechatronics design. Therefore, the issues of scheme evaluation of automation mechatronic systems have been of great concern in each country and especially in industry requirements. Many authors explicated the information-content based optimality of mechatronic system scheme and applied the basic principles of axiom design (information axiom in particular) to the optimality process of mechatronic system scheme, and analyzed thoroughly the indeterminacies ubiquitous in the deign process. Taking into account the qualitative and quantitative attributes and the time-variable nature of the function and state of mechatronic system, Xu[1] presented a set of concepts, such as information-content based function, design parameter, mechatronic ratio and control efficiency. They also proposed a series of principles for optimal scheme generation of mechatronic system, such as time-domain parameter control principle, maximum information optimality principle, and maximum control efficiency principle, so as to proffer a new design direction to effectively improve the performance of mechatronic systems.

This paper presents a new model, which is based on the intuitionistic fuzzy information processing[2-10], for dealing with the scheme evaluation of automation mechatronic systems. The remainder of this paper is set out as follows. In the next section, we introduce some basic concepts related to intuitionistic fuzzy sets. In Section 3 we introduce the multiple attribute group decision making (MAGDM) problems deal with scheme evaluation problems of automation mechatronic systems, in which the information about attribute weights and expert weight is completely known, and the attribute values take the form of intuitionistic fuzzy numbers. We utilize intuitionistic fuzzy weighted average (TFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one (s). In Section 4, an illustrative example is pointed out. In Section 5 we conclude the paper and give some remarks.

PRELIMINARIES

In the following, we introduce some basic concepts related to IFS.

Definition 1. An IFS A in X is given by

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

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

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

The numbers $\mu_A\left(x\right)$ and $\nu_A\left(x\right)$ represent, respectively, the membership degree and non- membership degree of the element x to the set A [3-4].

Definition 2. Let $\tilde{a}=\left(\mu,\nu\right)$ be an intuitionistic fuzzy number, a score function S of an intuitionistic fuzzy value can be represented as follows[5]:

$$S\left(\tilde{a}\right)=\mu-\nu\ ,\quad S\left(\tilde{a}\right)\in\left[-1,1\right] \tag{2}$$

Definition 3. Let $\tilde{a}=\left(\mu,\nu\right)$ be an intuitionistic fuzzy number, a accuracy function H of an intuitionistic fuzzy value can be represented as follows[6]:

$$H\left(\tilde{a}\right)=\mu+\nu\ ,\quad H\left(\tilde{a}\right)\in\left[0,1\right] \tag{3}$$

to evaluate the degree of accuracy of the intuitionistic fuzzy value $\tilde{a}=\left(\mu,\nu\right)$, 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 intuitionistic fuzzy value $\tilde{a}$.

Based on the score function S and the accuracy function H, Xu[7-8] give an order relation between two intuitionistic fuzzy values, which is defined as follows:

Definition 4. Let $\tilde{a}_1=(\mu_1,\nu_1)$ and $\tilde{a}_2=(\mu_2,\nu_2)$ be two intuitionistic fuzzy values, $s(\tilde{a}_1)=\mu_1-\nu_1$ and $s(\tilde{a}_2)=\mu_2-\nu_2$ be the scores of $\tilde{a}$ and $\tilde{b}$, respectively, and let $H(\tilde{a}_1)=\mu_1+\nu_1$ and $H(\tilde{a}_2)=\mu_2+\nu_2$ be the accuracy degrees of $\tilde{a}$ and $\tilde{b}$, respectively, then if $S(\tilde{a})<S(\tilde{b})$, then $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$; if $S(\tilde{a})=S(\tilde{b})$, then, (1) if $H(\tilde{a})=H(\tilde{b})$, then $\tilde{a}$ and $\tilde{b}$ represent the same information, denoted by $\tilde{a}=\tilde{b}$; (2) if $H(\tilde{a})<H(\tilde{b})$, $\tilde{a}$ is smaller than $\tilde{b}$, denoted by $\tilde{a}<\tilde{b}$.

Definition 5. Let $\tilde{a}_j=(\mu_j,\nu_j)(j=1,2,\cdots,n)$ be a collection of intuitionistic fuzzy values, and let IFWA: $Q^n\to Q$, if

$$\mathrm{IFWA}_\omega(\tilde{a}_1,\tilde{a}_2,\cdots,\tilde{a}_n)=\sum_{j=1}^{n}\omega_j\tilde{a}_j=\left(1-\prod_{j=1}^{n}(1-\mu_j)^{\omega_j},\prod_{j=1}^{n}\nu_j^{\omega_j}\right) \tag{4}$$

where $\omega=(\omega_1,\omega_2,\cdots,\omega_n)^T$ be the weight vector of $\tilde{a}_j\,(j=1,2,\cdots,n)$, and $\omega_j>0$, $\sum_{j=1}^{n}\omega_j=1$, then IFWA is called the intuitionistic fuzzy weighted averaging (IFWA) operator[8].

RESEARCH ON SCHEME EVALUATION METHOD OF AUTOMATION MECHATRONIC SYSTEMS WITH INTUITIONISTIC FUZZY INFORMATION

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 attribute $G_j\,(j=1,2,\cdots,n)$, where $\omega_j\in[0,1]$, $\sum_{j=1}^{n}\omega_j=1$. Let $D=\{D_1,D_2,\cdots,D_t\}$ be the set of decision makers, $\nu=(\nu_1,\nu_2,\cdots,\nu_n)$ be the weighting vector of decision makers, with $\nu_k\in[0,1]$, $\sum_{k=1}^{t}\nu_k=1$. Suppose that $\tilde{R}_k=\left(\tilde{r}_{ij}^{(k)}\right)_{m\times n}=\left(\mu_{ij}^{(k)},\nu_{ij}^{(k)}\right)_{m\times n}$ is the intuitionistic fuzzy decision matrix, where $\mu_{ij}^{(k)}$ indicates the degree that the alternative A_i satisfies the attribute G_j given by the decision maker D_k, $\nu_{ij}^{(k)}$ indicates the degree that the alternative A_i doesn't satisfy the attribute G_j given by the decision maker D_k, $\mu_{ij}^{(k)}\subset[0,1]$, $\nu_{ij}^{(k)}\subset[0,1]$, $\mu_{ij}^{(k)}+\nu_{ij}^{(k)}\le 1$, $i=1,2,\cdots,m$, $j=1,2,\cdots,n$, $k=1,2,\cdots,t$.

In the following, we apply the IFWA operator to MAGDM for scheme evaluation method of automation mechatronic systems with intuitionistic fuzzy information.

Step 1. Utilize the decision information given in matrix $\tilde{R}_k$, and the IFWA operator which has associated weighting vector $w=(w_1,w_2,\cdots,w_n)^T$

$$\tilde{r}_{ij}=(\mu_{ij},\nu_{ij})=\mathrm{IFWA}_w\left(\tilde{r}_{ij}^{(1)},\tilde{r}_{ij}^{(2)},\cdots,\tilde{r}_{ij}^{(t)}\right),i=1,2,\cdots,m,\ j=1,2,\cdots,n. \tag{5}$$

to aggregate all the decision matrices $\tilde{R}_k\,(k=1,2,\cdots,t)$ into a collective decision matrix $\tilde{R}=(\tilde{r}_{ij})_{m\times n}$, where $\nu=\{\nu_1,\nu_2,\cdots,\nu_t\}$ be the weighting vector of decision makers.

Step 2. Utilize the decision information given in matrix $\tilde{R}$, and the IFWA operator

$$\tilde{r}_i=(\mu_i,\nu_i)=\mathrm{IFWA}_\omega(\tilde{r}_{i1},\tilde{r}_{i2},\cdots,\tilde{r}_{in}),\ i=1,2,\cdots,m. \tag{6}$$

to derive the collective overall preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$ of the alternative A_i, where $\omega=\left(\omega_1,\omega_2,\cdots,\omega_n\right)^T$ is the weighting vector of the attributes.

Step 3. Calculate the scores $S\left(\tilde{r}_i\right)\left(i=1,2,\cdots,m\right)$ of the collective overall intuitionistic fuzzy preference values $\tilde{r}_i\left(i=1,2,\cdots,m\right)$ to rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and then to select the best one (s) (if there is no difference between two scores $S\left(\tilde{r}_i\right)$ and $S\left(\tilde{r}_j\right)$, then we need to calculate the accuracy degrees $H\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_j\right)$ of the collective overall intuitionistic fuzzy preference values $\tilde{r}_i$ and $\tilde{r}_j$, respectively, and then rank the alternatives A_i and A_j in accordance with the accuracy degrees $H\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_j\right)$.

Step 4. Rank all the alternatives $A_i\left(i=1,2,\cdots,m\right)$ and select the best one (s) in accordance with $S\left(\tilde{r}_i\right)$ and $H\left(\tilde{r}_i\right)\left(i=1,2,\cdots,m\right)$.

NUMERICAL EXAMPLE

In this section, we present an empirical case study of scheme evaluation of automation mechatronic systems. The project's aim is to evaluate the best scheme of automation mechatronic systems. The team of experts must take a decision according to the following five attributes: ①G_1 is the time-domain parameter control principle; ②G_2 is the maximum information optimality principle; ③G_3 is the maximum control efficiency principle; ④G_4 is the maximum efficiency management principle; ⑤G_5 is the minimum cost principle. The four possible schemes of automation mechatronic systems $A_i\left(i=1,2,3,4\right)$ are to be evaluated using the intuitionistic fuzzy numbers by the three decision makers (whose weighting vector $\nu=\left(0.35,0.40,0.25\right)^T$) under the above four attributes (whose weighting vector $\omega=\left(0.20,0.10,0.25,0.30,0.15\right)^T$), and construct, respectively, the decision matrices as listed in the following matrices $\tilde{R}_k=\left(\tilde{r}_{ij}^{(k)}\right)_{5\times4}\left(k=1,2,3\right)$ as follows:

$$\tilde{R}_1=\begin{bmatrix}(0.3,0.6) & (0.2,0.7) & (0.6,0.2) & (0.5,0.4) & (0.6,0.3)\\(0.7,0.2) & (0.4,0.5) & (0.4,0.3) & (0.7,0.3) & (0.7,0.2)\\(0.5,0.3) & (0.6,0.3) & (0.7,0.1) & (0.6,0.4) & (0.5,0.4)\\(0.3,0.4) & (0.2,0.6) & (0.5,0.3) & (0.8,0.1) & (0.6,0.3)\end{bmatrix}$$

$$\tilde{R}_2=\begin{bmatrix}(0.1,0.6) & (0.5,0.1) & (0.4,0.3) & (0.5,0.2) & (0.2,0.5)\\(0.3,0.4) & (0.3,0.2) & (0.6,0.2) & (0.6,0.1) & (0.6,0.1)\\(0.5,0.2) & (0.6,0.2) & (0.5,0.3) & (0.4,0.3) & (0.4,0.2)\\(0.1,0.5) & (0.4,0.2) & (0.7,0.1) & (0.5,0.2) & (0.2,0.3)\end{bmatrix}$$

$$\tilde{R}_3=\begin{bmatrix}(0.1,0.8) & (0.5,0.3) & (0.4,0.5) & (0.5,0.4) & (0.2,0.7)\\(0.3,0.6) & (0.3,0.4) & (0.6,0.4) & (0.6,0.3) & (0.6,0.3)\\(0.5,0.4) & (0.6,0.2) & (0.5,0.5) & (0.4,0.5) & (0.4,0.4)\\(0.1,0.7) & (0.4,0.4) & (0.7,0.2) & (0.5,0.4) & (0.2,0.5)\end{bmatrix}$$

Then, we utilize the approach developed to get the most desirable scheme of automation mechatronic systems.

Step 1. Utilize the decision information given in matrix $\tilde{R}_k$, and the IFWA operator which has associated weight vector $w=(0.2,0.45,0.35)^T$, we get a collective decision matrix $\tilde{R}=\left(\tilde{r}_{ij}\right)_{m\times n}$ as follows:

$$\tilde{R}=\begin{bmatrix} (0.153,0.664) & (0.488,0.217) & (0.474,0.331) & (0.533,0.293) & (0.319,0.508) \\ (0.430,0.401) & (0.345,0.306) & (0.604,0.276) & (0.655,0.183) & (0.655,0.169) \\ (0.533,0.276) & (0.635,0.217) & (0.579,0.288) & (0.474,0.380) & (0.450,0.293) \\ (0.153,0.538) & (0.396,0.318) & (0.705,0.159) & (0.612,0.222) & (0.319,0.359) \end{bmatrix}$$

Step 2. Utilize the IFWA operator, we obtain the collective overall preference values $\tilde{r}_i$ of the schemes of automation mechatronic systems $A_i\ (i=1,2,3,4)$.

$$\tilde{r}_1=(0.421,0.375),\tilde{r}_2=(0.579,0.247),\tilde{r}_3=(0.529,0.302),\tilde{r}_4=(0.518,0.271)$$

Step 3. Calculate the scores $S(\tilde{r}_i)\ (i=1,2,3,4)$ of the collective overall intuitionistic fuzzy preference values $\tilde{r}_i\ (i=1,2,3,4)$

$$S(\tilde{r}_1)=0.047,S(\tilde{r}_2)=0.332,S(\tilde{r}_3)=0.226,S(\tilde{r}_4)=0.247$$

Step 4. Rank all the schemes of automation mechatronic systems $A_i\ (i=1,2,3,4)$ in accordance with the scores $S(\tilde{r}_i)\ (i=1,2,3,4)$ of the collective overall intuitionistic fuzzy preference values $\tilde{r}_i\ (i=1,2,3,4)$: $A_2 \succ A_4 \succ A_3 \succ A_1$, and thus the most desirable scheme of automation mechatronic systems is A_2.

CONCLUSION

With respect to the scheme evaluation method of automation mechatronic systems with intuitionistic fuzzy information, in which the information about attribute weights and expert weight is completely known and the attribute values take the form of intuitionistic fuzzy information. We develop an approach to scheme evaluation method of automation mechatronic systems with intuitionistic fuzzy information based on the IFWA operator. Finally, we have presented a practical case study of scheme evaluation method of automation mechatronic systems with intuitionistic fuzzy information to illustrate the proposed approach.

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