International Journal of Hybrid Information Technology
Vol. 9, No.7 (2016), pp. 161-170
http://dx.doi.org/10.14257/ijhit.2016.9.7.16

A Patent Pool Partner Selection Method Based on Time Degrees and Intuitionistic Fuzzy Entropy

Chen Wei, Li Jinqiu, Lin Chaoran and Yang Zaoli

School of Economy and Management Harbin Engineering University, Harbin 150001, China
hanying911@126.com

Abstract

Patent pool partner selection is a typical multi-attribute decision making (MADM) problem, and that based on intuitionistic fuzzy (IF) theory is widely applied in this research field. In this paper, a dynamic MADM method based on time degrees and intuitionistic fuzzy entropy (IFE) is proposed. We determine the attribute weights under different time sequence based on IFE; and establish a non-linear programming model combining the principle of time degrees with grey entropy theory to calculate time weights vector; the dynamic intuitionistic fuzzy weighted geometric-operator(DIFWG) is used to aggregate different periods of weighted intuitionistic fuzzy decision-making matrix; TOPSIS was integrated into dynamic intuitionistic fuzzy multiple attribute decision making (DIF-MADM), by calculating the relative closeness of alternatives with ideal solution, we obtain the optimum alternative; finally, an example is given to illustrate the applicability and rationality of the proposed approach.

Keywords*: patent pool partner selection; time degrees; DIFWG; intuitionistic fuzzy entropy; multi-attribute decision-making*

1. Introduction

Patent pool is a joint organization that helps patentee alliance management agency authorized to license its intellectual property by marketing and packaging [1]. 150 years ago, the American sewing machine manufacturing set up the first patent pool in the world [2]. In recent decades, the patent pool has been successfully used, especially in high-tech fields, a patent pool is considered to be competitive weapon of intellectual property, its important role are increasingly significant [3]. Choose a good patent pool research and development partner not only can promote the formation and development of patent pool, but also guarantee the stable operation of the entire patent pool. But patent pool research and development partner selection is a decision process that involves many factors, decision-making information is uncertain and ambiguous, it is a multiple attribute decision making problem on fuzzy multiple attributes.

Currently, most scholars have adopted the intuitionistic fuzzy theory and methods to solve such multi-attribute decision making problems: Xu (2006,2007) et al. [4-5] proposed the intuitionistic fuzzy arithmetic average operator (IFAA), weighted arithmetic average operator (IFWAA), intuitionistic fuzzy weighted geometric operator (IFWG), ordered weighted geometric Operators (IFOWG) and mixed geometry operator (IFHG); Tan (2010) [6] and Wan Shuping (2014) [7] are proposed fuzzy multiple attribute decision making based on intuitionistic fuzzy ordered weighted averaging operator (IFOWA) and Choquet integral operator intuition; He Yingdong (2013,2013) [8-9] Improved the algorithms of intuitionistic fuzzy numbers and proposed a multi-attribute decision making method based on cross-influence of intuitionistic fuzzy weighted average operator. Yager and Xu (2010) [10] proposed power geometric average operator, Xu (2011) [11] extended it to the intuition fuzzy theory and proposed intuitionistic fuzzy

ISSN: 1738-9968 IJHIT

power geometric average operator; Gao Yan et al. (2012) [12] proposed a triangular fuzzy number intuitionistic fuzzy association ordered weighted averaging operator (R-TIOWA), associated with a weighted geometric average operator (R-TIWGA) and the associated ordered weighted geometric averaging operator (R -TIOWGA), it expand research to attribute value triangular fuzzy number intuitionistic fuzzy multiple attribute group decision making method. Li Peng (2011,2013) [13-14], Yue (2014) [15], and Iancu (2014) [16] combined the ideology of grey relational model, D-S evidence theory, prospect theory, TOPSIS method with intuition fuzzy set theory respectively, and use parameterize t-norms into intuitionistic fuzzy set theory, to solve intuitionistic fuzzy multiple attribute decision making problem. However, these effects on intuitionistic fuzzy multiple attribute decision making only consider a single period based on static information, ignoring the timing characteristics of the decision-making results. Although there are scholars such as Su (2011) [17], Park (2013) [18] who introduced the time weight vector, established intuition fuzzy decision model based on dynamic time series, but its time weight is rely on subjective evaluation, influenced the objectivity and rationality of decision-making. In addition, Xu (2008) [19] and Mao Jun-jun (2014) [20] were proposed weight-solving method based on BUM function, normal distribution, exponential distribution and T-mean-age-models, and they also proposed time weighting method based on exponential decay model. These methods are based on the basic idea of probability theory to determine the weight of timing, even though it can fully mining objective information in decision-making, but does not consider the subjective preferences of decision makers, resulting in instability of the decision result, and impact the scientific of decision-making.

2. Preliminaries

Definition 1 [21]**.** Let a set $X=\{x_1,x_2,...,x_n\}$ be a finite universe of discourse, then define the set $A=\{(x,u_A(x),v_A(x)\mid x\in X)\}$ as an intuitionistic fuzzy set. Where, $u_A(x)$ and $v_A(x)$ denote the membership degree and non-membership degree of the element x in X to A, respectively, and $\mu_A(x):X\to[0,1]$, $\upsilon_A(x):X\to[0,1]$,with the condition $0\le\mu_A(x)+\upsilon_A(x)\le 1, x\in X$, $\pi_A=1-\mu_A(x)-\upsilon_A(x)$ is called the degree of indeterminacy of x in X to A. To simplify the computation, we called $\alpha=(\mu_\alpha,\upsilon_\alpha,\pi_\alpha)$ an intuitionistic fuzzy number (IFN), where $\mu_\alpha\in[0,1]$, $\upsilon_\alpha\in[0,1]$, $\mu_\alpha+\upsilon_\alpha\le 1$, $\pi_\alpha=1-\mu_\alpha-\upsilon_\alpha$.

Definition 2 [22]**.** Let $\alpha_1=(\mu_{\alpha_1},\nu_{\alpha_1})$ and $\alpha_2=(\mu_{\alpha_2},\nu_{\alpha_2})$ be two IFNs, λ be a real number, and $\lambda>0$, then

（1） $\alpha_1\oplus\alpha_2=(\mu_{\alpha_1}+\mu_{\alpha_2}-\mu_{\alpha_1}\cdot\mu_{\alpha_2},\nu_{\alpha_1}\cdot\nu_{\alpha_2})$;

（2） $\alpha_1\otimes\alpha_2=(\mu_{\alpha_1}\cdot\mu_{\alpha_2},\nu_{\alpha_1}+\nu_{\alpha_2}-\nu_{\alpha_1}\cdot\nu_{\alpha_2})$;

（3） $\lambda\alpha_1=(1-(1-\mu_{\alpha_1})^\lambda,{\nu_{\alpha_1}}^\lambda)$;

（4） $\alpha_1^\lambda=({\mu_{\alpha_1}}^\lambda,(1-\nu_{\alpha_1})^\lambda)$.

Definition 3 [5]. Let $\alpha_j=(\mu_{A_j}(x),\nu_{A_j}(x)), j=1,2,...,n,$ be an IFN, then we call $IFWA_\omega(\alpha_1,\alpha_2,...,\alpha_n)=\sum_{j=1}^n\omega_j\alpha_j=(1-\prod_{j=1}^n\left(1-\mu_{A_j}(x)\right)^{\omega_j},\prod_{j=1}^n\nu_{A_j}(x)^{\omega_j})$ as an intuitionistic fuzzy weighted averaging (IFWA) operator. Where, $IFWA:Q^n\to Q$, $\omega=(\omega_1,\ \omega_2,\ ...,\ \omega_n)^T$, $\omega_j\ge 0$, $j=1,2,...,n$, $\sum_{j=1}^n\omega_j=1$.

Definition 4 [19] Let t be a time variable, then we call $\alpha(t)=\left(\mu_{\alpha(t)}(x),\ \nu_{\alpha(t)}(x)\right)$ an IFN, where $\mu_{\alpha(t)}(x)\in[0,1]$, $\nu_{\alpha(t)}(x)\in[0,1]$, $\mu_{\alpha(t)}(x)+\nu_{\alpha(t)}(x)\le 1$,if $t=t_1,\ t_2,\ \ldots,t_n$, then $\alpha(t_1),\alpha(t_2),\ldots,\alpha(t_p)$ denotes an IFS of p different periods.

Definition 5 [19]**.** Let $\alpha_{t_k}=\left(\mu_{t_k},\ \nu_{t_k}\right)\left(k=1,2,\ \ldots,p\right)$ be an IFN at period t_k, and $\eta(t_k)=(\eta(t_1),\ \eta(t_2),\ \ldots,\eta(t_p))^T$ be the weight vector of the periods t_k, then we call $DIFWG_{\eta(\mathrm{t})}(\alpha_{t_1},\alpha_{t_2},...,\alpha_{t_p})=\prod_{k=1}^{p}\alpha_{t_k}^{\eta(\mathrm{t}_k)}=(\prod_{k=1}^{p}\mu_{t_k}^{\eta(\mathrm{t}_k)},1-\prod_{k=1}^{p}(1-\nu_{t_k})^{\eta(\mathrm{t}_k)})$ as a dynamic intuitionistic fuzzy weighted averaging (DIFWA) operator. Where, $\eta(t_k)\in[0,1],\sum_{k=1}^{p}\eta(t_k)=1\ \left(k=1,2,\ \ldots,p\right)$.

3. Presented Algorithm

3.1. Framework of the Proposed Model

In this section, we research on DIF-MADM problem where all attribute values are expressed in intuitionistic fuzzy numbers, which are collected at different periods, and we consider the difference of decision information and the preference to attribute of decision makers at different periods, using the intuitionistic fuzzy entropy (IFE) to determine the attribute weights in different time series. The specific steps of the algorithm are as follows:

Let $S=\{S_1,S_2,...,S_m\}$ be a discrete set of m feasible alternatives, and let $G=\{G_1,G_2,...,G_n\}$ be a finite set of n attributes, There are p periods $t_k(k=1,2,...,p)$, whose weight vector is $\eta(t)=(\eta(t_1),\eta(t_2),...,\eta(t_p))^T$, where $\eta(t_k)$ denotes the weight of period $t_k,\eta(t_k)\ge 0,\sum_{k=1}^{p}\eta(t_k)=1,k=1,2,...,p$. And the temporal weights represent the importance of different periods in the decision-making process. Suppose that $X\left(t_k\right)=\left(x_{ij}(t_k)\right)_{m\times n}$ an intuitionistic fuzzy decision matrix of the period t_k , where $x_{ij}(t_k)=(\mu_{ij}(t_k),\nu_{ij}(t_k))$ is an attribute value, denoted by an IFN, $\mu_{ij}(t_k)$ indicates the degree that the alternative i should satisfy the attribute j at period t_k, $\nu_{ij}(t_k)$ indicates the degree that the alternative i should not satisfy the attribute j at period t_k, $\pi_{ij}(t_k)$ indicates the degree of indeterminacy of the alternative i to the attribute j, such that $\pi_{ij}(t_k)=1-\mu_{ij}(t_k)-\nu_{ij}(t_k)$.

Compute the intuitionistic fuzzy entropy $E_j(t_k)$ of the attribute j at period t_k:

$$E_j(t_k)=\frac{1}{m}\sum_{i=1}^{m}\left\{1-\sqrt{\left(1-\pi_{ij}(t_k)\right)^2-\mu_{ij}(t_k)\nu_{ij}(t_k)}\right\} \tag{1}$$

Let $\omega_j(t_k)$ be the weight of the attribute j at period t_k, and the optimization model (M-1) of attribute weights at period t_k is established as follows:

$$(M-1)\begin{cases} \min \sum_{j=1}^{n} \left(\omega_j(t_k)\right)^2 E_j(t_k) \\ s.t \sum_{j=1}^{n} \omega_j(t_k) = 1 \end{cases}$$

To solve the above model, we construct the Lagrange function of the constrained optimization model (M-1), as follows:

$$L(\omega_j(t_k),\lambda) = \sum_{j=1}^{n} \left(\omega_j(t_k)\right)^2 E_j(t_k) + 2\lambda\left(\sum_{j=1}^{n} \omega_j(t_k) - 1\right)$$

Where λ is a real number, denoting the Lagrange multiplier variable. Then the partial derivatives of L are computed as:

$$\begin{cases} \dfrac{\partial L(\omega_j(t_k),\lambda)}{\partial \omega_j(t_k)} = 2\omega_j(t_k)E_j(t_k) + 2\lambda = 0 \\ \dfrac{\partial L(\omega_j(t_k),\lambda)}{\partial \lambda} = 2(\sum_{j=1}^{n} \omega_j(t_k) - 1) = 0 \end{cases}$$

Calculate the above formula, and we can have the weight of attribute j at period t_k :

$$\omega_j(t_k) = \frac{\left(E_j(t_k)\right)^{-1}}{\sum_{j=1}^{n}\left(E_j(t_k)\right)^{-1}} \tag{2}$$

For DIF-MADM problems, the more closer one time point to the current period is, which can reflect the characteristics of decision attributes, the more effective the decision evaluation results are. Since the decision system has some uncertainty, we should determine the time weights minimizing the uncertainty of the time series and maximizing the ability of information acquisition. Therefore, we construct a non-linear programming model to solve the temporal weights vector combining the time degrees with gray entropy.

In the paper, we apply grey entropy in calculating the time weights, which can reflect the information intake level of time weight vector, with characteristics of symmetry, additive and extreme, the entropy value is greater, the amount of information contained is smaller. The expression of gray entropy is shown below:

$$f(\eta(t_k)) = -\sum_{k=1}^{p} \eta(t_k) \ln \eta(t_k), k = 1, 2, ..., p \tag{3}$$

Let θ $(0 \le \theta \le 1)$ be the time degree, which can reflect the preference of decision makers to information at different periods, the more it closes to 1, the more decision preference to the long-term information, and the more it closes to 0, the more decision preference to the recent information. The formula can be expressed as [25]:

$$\theta = \sum_{k=1}^{p} \frac{p-k}{p-1} \eta(t_k) \tag{4}$$

Decision makers generally give the value of time degree according to the experience and preference, considering the difference and uncertainty of the alternatives information in the time sequence, and make the best possible to excavate decision information as the standard of determining the optimal time weights. According to the maximum entropy principle, we construct a non-linear programming model (M-2) as follows:

$$(M-2)\begin{cases} \max\ f(\eta(t_k)) = \max\left(-\sum_{k=1}^{p}\eta(t_k)\ln\eta(t_k)\right) \\ s.t. \qquad \theta = \sum_{k=1}^{p}\frac{p-k}{p-1}\eta(t_k) \\ \sum_{k=1}^{p}\eta(t_k) = 1, \eta(t_k)\in[0,1], k = 1,2,.., p \end{cases}$$

TOPSIS is a type of method to solve the multi-objective decision making problem. The basic idea is that the satisfactory solution should be not only as close as possible to the positive ideal scheme, but also as far as possible to stay away from the negative ideal scheme. We can introduce TOPSIS into the process of intuitionistic fuzzy multiple attribute decision making (IF-MADM), which can obtain a new method of IF-MADM problem [26].

Definition 6 [26]**.** Let A and B be two IFS in a fixed set $X = \{x_1, x_2, ..., x_n\}$, the difference of the IFS can be characterized by Euclidean distance:

$$d(A,B) = \sqrt{\frac{1}{2}\sum_{i=1}^{n}\left[(\mu_A(x_i)-\mu_B(x_i))^2 + (\nu_A(x_i)-\nu_B(x_i))^2 + (\pi_A(x_i)-\pi_B(x_i))^2\right]} \tag{5}$$

In dynamic intuitionistic fuzzy synthetic decision matrix $\tilde{Y} = \left(y_{ij}\right)_{m\times n} = \left((\underline{y}_{ij}, \overline{y}_{ij})\right)_{m\times n}$, intuitionistic fuzzy positive ideal scheme (PIS), denoted by S^+, and intuitionistic fuzzy negative ideal scheme (NIS), denoted by S^-, they can be defined respectively as follows:

$$S^+ = \left((\underline{y}_1^+, \overline{y}_1^+), (\underline{y}_2^+, \overline{y}_2^+), ...(\underline{y}_n^+, \overline{y}_n^+)\right) \tag{6}$$

$$S^- = \left((\underline{y}_1^-, \overline{y}_1^-), (\underline{y}_2^-, \overline{y}_2^-), ...(\underline{y}_n^-, \overline{y}_n^-)\right) \tag{7}$$

where $\underline{y}_j^+ = max_{1\le i\le m}\left\{\underline{y}_{ij}\right\}, \overline{y}_j^+ = min_{1\le i\le m}\left\{\overline{y}_{ij}\right\}, \underline{y}_j^- = min_{1\le i\le m}\left\{\underline{y}_{ij}\right\}, \overline{y}_j^- = max_{1\le i\le m}\left\{\overline{y}_{ij}\right\}$.

According to the Eq. (5) we calculate the Euclidean distance of alternatives S_i and intuitionistic fuzzy positive and negative ideal solutions:

$$d(S_i, S^+) = \sqrt{\frac{1}{2}\sum_{j=1}^{n}\left[(\underline{y}_{ij} - \underline{y}_j^+)^2 + (\overline{y}_{ij} - \overline{y}_j^+)^2 + (\overline{\overline{y}}_{ij} - \overline{\overline{y}}_j^+)^2\right]} \tag{8}$$

$$d(S_i, S^-) = \sqrt{\frac{1}{2}\sum_{j=1}^{n}\left[(\underline{y}_{ij} - \underline{y}_j^-)^2 + (\overline{y}_{ij} - \overline{y}_j^-)^2 + (\overline{\overline{y}}_{ij} - \overline{\overline{y}}_j^-)^2\right]} \tag{9}$$

Where $\overline{\overline{y}}_{ij} = 1 - \underline{y}_{ij} - \overline{y}_{ij}, \overline{\overline{y}}_j^+ = 1 - \underline{y}_j^+ - \overline{y}_j^+, \overline{\overline{y}}_j^- = 1 - \underline{y}_j^- - \overline{y}_j^-$.

Calculate the relative closeness coefficient between each alternative and the intuitionistic fuzzy positive ideal scheme:

$$\xi_i = \frac{d(S_i, S^-)}{d(S_i, S^+) + d(S_i, S^-)} (i = 1, 2, ..., m) \tag{10}$$

Rank all the alternatives $S_i \in S(i = 1, 2, ..., m)$ according to the closeness coefficients $\xi_i (i = 1, 2, ..., m; \xi_i \in [0,1])$, the greater the value ξ_i, the better the alternative S_i.

3.2. Procedure of the Proposed Model

According to the preceding text analysis, the computational steps of an algorithm for patent pool partner selection based on IFS and time degrees can be summarized as follows:

Step 1. Calculate the weight of each attribute at different periods $\omega_j(t_k)$ according to the Eq. (2) by using model (M-1);

Step 2. Calculate the time weights $\eta(t_k)$ to obtain time weight vector $\eta(t) = (\eta(t_1), \eta(t_2), ..., \eta(t_p))^T$ by Eq. (3) and Eq. (4), and that utilizing Lingo 11.0 software;

Step 3. Calculate the weighted intuitionistic fuzzy decision matrix $R(t_k) = \left(r_{ij}(t_k)\right)_{m\times n}$ at period t_k based on the intuitionistic fuzzy algorithm., where $r_{ij}(t_k) = (1-(1-\mu_{ij}(t_k))^{\omega_j(t_k)}, (\upsilon_{ij}(t_k))^{\omega_j(t_k)})$;

Step 4. According to Definition 5, utilize the DIFWG operator to aggregate all the periods of intuitionistic fuzzy decision matrices into a complex dynamic intuitionistic fuzzy decision matrix $\tilde{Y} = \left(y_{ij}\right)_{m\times n}$;

Step 5. Utilize Eq. (6) and Eq. (7) to determine the corresponding intuitionistic fuzzy PIS S^+ and the intuitionistic fuzzy NIS S^-;

Step 6. Utilize Eq. (8) and Eq. (9) to calculate the Euclidean distance $d(S_i, S^+)$ and $d(S_i, S^-)$ of each alternative S_i from the intuitionistic fuzzy PIS S^+ and the intuitionistic fuzzy NIS S^-, respectively;

Step 7. Utilize Eq. (10) to calculate the relative closeness coefficient ξ_i of each alternative S_i to the intuitionistic fuzzy PIS S^+. Rank the priorities of alternatives $S_i (i = 1, 2, ..., \mathrm{m})$ according to closeness coefficient $\xi_i (i = 1, 2, ..., \mathrm{m})$ and then select the most desirable one(s).

4. Experimental Analyses

A patent pool is seeking for a R&D partner; taking into account five indicators: cooperation credibility level (G_1); level of resource sharing (G_2); risks resist ability (G_3); the level of quality (G_4); R&D capabilities (G_5), they referred as the attribute set $G = \{G_1, G_2, G_3, G_4, G_5\}$. There are four development partners in the shortlist of alternative, denoted as $S = \{S_1, S_2, S_3, S_4\}$. Experts evaluate all the indicators denoted by IFNs for each alternative in three different time periods $(t_1 < t_2 < t_3)$, to obtain the relevant intuitionistic fuzzy decision matrix. As illustrated in Tables 1 to 3.

Table 1. Intuitionistic Fuzzy Decision Matrix $X(t_1)$ at Period t_1

t_1	G_1	G_2	G_3	G_4	G_5
S_1	(0.4,0.5)	(0.5,0.3)	(0.2,0.6)	(0.1,0.7)	(0.4,0.5)
S_2	(0.3,0.6)	(0.3,0.3)	(0.6,0.2)	(0.5,0.4)	(0.2,0.7)
S_3	(0.4,0.5)	(0.2,0.7)	(0.2,0.7)	(0.5,0.3)	(0.3,0.6)
S_4	(0.2,0.7)	(0.3,0.6)	(0.4,0.4)	(0.4,0.5)	(0.4,0.4)

Table 2. Intuitionistic Fuzzy Decision Matrix $X(t_2)$ at Period t_2

t_2	G_1	G_2	G_3	G_4	G_5
S_1	(0.1,0.5)	(0.7,0.2)	(0.6,0.2)	(0.7,0.2)	(0.3,0.6)
S_2	(0.5,0.4)	(0.6,0.1)	(0.4,0.3)	(0.3,0.4)	(0.1,0.7)
S_3	(0.3,0.5)	(0.2,0.7)	(0.3,0.5)	(0.7,0.1)	(0.5,0.4)
S_4	(0.8,0.1)	(0.5,0.4)	(0.4,0.4)	(0.4,0.3)	(0.2,0.7)

Table 3. Intuitionistic Fuzzy Decision Matrix $X(t_3)$ at Period t_3

t_3	G_1	G_2	G_3	G_4	G_5
S_1	(0.3,0.5)	(0.5,0.2)	(0.5,0.3)	(0.5,0.4)	(0.6,0.1)
S_2	(0.3,0.6)	(0.6,0.3)	(0.7,0.2)	(0.8,0.1)	(0.4,0.5)
S_3	(0.1,0.7)	(0.4,0.4)	(0.6,0.3)	(0.2,0.7)	(0.1,0.4)
S_4	(0.2,0.7)	(0.3,0.4)	(0.5,0.1)	(0.5,0.3)	(0.2,0.5)

According to model (M-1) and model (M-2) in steps 1 and 2, using Lingo11.0 software to solve the attribute weights $\omega_j(t_k)$ and temporal weights $\eta(t_k)$ at different time periods. As shown in Table 4.

Table 4. Temporal Weights and Attribute Weights

	$\eta(t_k)$	$\omega_1(t_k)$	$\omega_2(t_k)$	$\omega_3(t_k)$	$\omega_4(t_k)$	$\omega_5(t_k)$
t_1	0.154	0.193	0.187	0.220	0.204	0.196
t_2	0.292	0.197	0.210	0.181	0.203	0.210
t_3	0.554	0.227	0.182	0.195	0.226	0.170

By using $X(t_k)$ and $\omega_j(t_k)$ in Table 4, based on the attribute weights and weighted intuitionistic fuzzy decision matrix in different periods that had calculated in step 3; then according to step 4, using the DIFWG operator to gathered the weighted intuitionistic fuzzy decision matrices at different periods, and obtain dynamic comprehensive intuitionistic fuzzy decision matrix, as shown in Table 5.

Table 5. Dynamic Comprehensive Intuitionistic Fuzzy Decision Matrix

	G_1	G_2	G_3	G_4	G_5
S_1	(0.054,0.863)	(0.143,0.746)	(0.115,0.801)	(0.121,0.819)	(0.110,0.800)
S_2	(0.088,0.880)	(0.140,0.760)	(0.159,0.751)	(0.174,0.725)	(0.051,0.909)
S_3	(0.040,0.903)	(0.065,0.892)	(0.102,0.849)	(0.088,0.856)	(0.039,0.857)
S_4	(0.079,0.881)	(0.079,0.853)	(0.111,0.747)	(0.122,0.788)	(0.046,0.896)

According to steps 5 and 6, ideal positive solution S^+ and negative ideal solution S^- of dynamic comprehensive intuitionistic fuzzy matrix can be obtained.

$$S^+ = ((0.088, 0.863),\quad (0.143, 0.746),\quad (0.159, 0.747),\quad (0.174, 0.725),\quad (0.110, 0.800))$$

$$S^- = ((0.040, 0.903),\quad (0.065, 0.892),\quad (0.102, 0.849),\quad (0.088, 0.856),\quad (0.039, 0.909))$$

As well as the Euclidean distance $d(S_i, S^+)$ between each alternative S_i and intuitionistic fuzzy ideal positive solution S^+, and the Euclidean distance $d(S_i, S^-)$ between each alternative S_i and negative ideal solution S^- are derived, respectively:

$$d(S_1, S^+) = 0.10; d(S_1, S^-) = 0.17; d(S_2, S^+) = 0.10; d(S_2, S^-) = 0.19;$$

$$d(S_3, S^+) = 0.21; d(S_3, S^-) = 0.05; d(S_4, S^+) = 0.15; d(S_4, S^-) = 0.12$$

Furthermore, relative closeness coefficient ξ_i between each alternative and intuitionistic fuzzy positive ideal solution can be determined in accordance with step 7.

$$\xi_i = (\xi_1, \xi_2, \xi_3, \xi_4, \xi_5) = (0.63, 0.66, 0.20, 0.46)$$

According to the closeness coefficient ξ_i, we can determine the ranking orders of alternatives, in this example, the corresponding descending ordering of R&D partners is $S_2 > S_1 > S_4 > S_3$, so S_2 is the best partner in patent pool.

5. Conclusions

In this paper, a dynamic intuitionistic fuzzy compromise decision-making method based on time degrees and intuitionistic fuzzy entropy (IFE) was proposed. On account of time degrees and gray entropy theory, we constructed a non-linear programming model to calculate the temporal weights which synthesized the subjective and objective weighting method, and determined the attribute weights under different time sequence based on intuitionistic fuzzy entropy (IFE). Then we integrated different periods of the intuitionistic fuzzy decision-making matrix by using dynamic intuitionistic fuzzy weighted geometric-operator(DIFWG) based on the algorithm of intuitionistic fuzzy number to obtain dynamic intuitionistic fuzzy comprehensive decision matrix, the method of TOPSIS was applied into the process of the intuitionistic fuzzy multiple attribute decision making, by which the relative closeness of the alternative schemes with fuzzy positive ideal solution is obtained, on the basis, we sorted the alternative schemes. This method combine both of subjective preference and objective samples information, and overcome the randomness of existing attribute weights and temporal weights subjective assignment, in the premise of considering the decision makers' preference of temporal information, the difference of temporal information was excavated, and the objective information of time series samples was fully assimilated. The proposed model was applied to research and development partner selection of patent alliance to verify the feasibility and effectiveness of the method in the actual decision-making process.

Acknowledgments

This research was supported by the National Fund Support Project on Social Science of China (approval no. 14BGL007); National Fund Support Project on Soft Science (no. 2010GXS513173); Heilongjiang Fund Support Project on Social Science of China (no. G201209).

References

[1] S. Brenner, "Optimal formation rules for patent pools", Economic Theory, vol. 40, no. 3, **(2009)**, pp. 373-388.
[2] S. C. Shapiro, "Navigating the patent thicket, cross licenses, patent pools and standard-setting", Innovation Policy and the Economy, no. 1, **(2001)**, pp. 119-150.
[3] S. Ren, W. Gao and J. You, "The performance of patent pool and its influencing factors", Studies in Science of Science, vol. 26, no. 2, **(2009)**, pp. 436-441.
[4] Z. S. Xu and R. R. Yager, "Some geometric aggregation operators based on intuitionistic fuzzy sets", International Journal of General System, vol. 35, no. 4, **(2006)**, pp. 417-433.
[5] Z. S. Xu, "Intuitionistic fuzzy aggregation operators", IEEE Transactions on Fuzzy Systems, vol. 15, no. 6, **(2007)**, pp. 1179-1187.
[6] C. Tan and X. Chen, "Intuitionistic fuzzy Choquet integral operator for multi-criteria decision making", Expert Systems with Applications, vol. 37, **(2010)**, pp. 149–157.
[7] S. Wan and J. Dong, "Multi-attribute decision making based on triangular intuitionistic fuzzy number choquet integral operator", Chinese journal of management science, vol. 22, no. 3, **(2014)**, pp. 121-129.
[8] Y. He, H. Chen and L. Zhou, "Operations laws for the intuitionistic fuzzy sets and their application based on interaction between membership function and non-membership function", Fuzzy Systems and Mathematics, vol. 27, no. 3, **(2013)**, pp. 100-109.
[9] Y. He, W. Zou, H. Chen and L. Zhou, "The intuitionistic fuzzy weighted geometric aggregation (ifwga)

operator based on interactions and its application to the multiple attributes decision making", Mathematics in practice and theory, vol. 43, no. 6, **(2013)**, pp. 55-61.
[10] Z. S. Xu and R. R.Yager, "Power-geometric operators and their use in group decision making", .IEEE Transactions on Fuzzy Systems, vol. 18, **(2010)**, pp. 94-105.
[11] Z. S. Xu, "Approaches to multiple attribute group decision making based on intuitionistic fuzzy power aggregation operators", Knowledge-Based Systems, vol. 24, no. 6, **(2011)**, pp. 749 -760.
[12] Y. Gao, D. Zhou, J. Liu and L. Zhang, "Triangular fuzzy number intuitionistic fuzzy aggregation operators and their application base on interaction", Systems Engineering Theory & Practice, vol. 24, no. 9, **(2012)**, pp. 1964-1972.
[13] P. Li and S. Liu, "Interval-valued intuitionistic fuzzy numbers decision-making method based on grey incidence analysis and d-s theory of evidence", Acta Automatica Sinica, vol. 37, no. 8, **(2011)**, pp. 993-998.
[14] P. Li, J. Wu and J. Zhu, "Stochastic multi-criteria decision-making methods based on new intuitionistic fuzzy distance", Systems Engineering Theory & Practice, vol. 33, no. 1, **(2013)**, pp. 1-8.
[15] Z. L. Yue, "TOPSIS-based group decision-making methodology in intuitionistic fuzzy setting", Information Sciences, vol. 277, **(2014)**, pp. 143-157.
[16] C. Iancu, "Intuitionistic fuzzy similarity measures based on Frank t-norms family", Pattern Recognition Letters, vol. 42, **(2014)**, pp. 128-136.
[17] Z. X. Su, M. Y. Chen, G. P. Xia and L. Wang, "An interactive method for dynamic intuitionistic fuzzy multi-attribute group decision making", Expert Systems with Applications, vol. 38, **(2011)**, pp. 15286-15295.
[18] J. H. Park, H. J. Cho and Y C. Kwun, "Extension of the VIKOR method to dynamic intuitionistic fuzzy multiple attribute decision making", Computers and Mathematics with Applications, vol. 65, **(2013)**, pp. 731–744.
[19] Z. Xu and R. Yager, "Dynamic intuitionistic fuzzy multi-attribute decision making", International Journal of Approximate Reasoning, vol. 48, no. 1, **(2008)**, pp. 246-262.
[20] J. Mao, D. Yao and C. Wang, "Group decision-making method based on time-series fuzzy soft sets", Systems Engineering – Theory & Practice, vol. 1, **(2014)**, pp. 182-189.
[21] K. Atanassov, "Intuitionistic fuzzy sets", Fuzzy Sets and Systems, vol. 20, no. 1, **(1986)**, pp. 87-96.
[22] Z.S. Xu, "Intuitionistic fuzzy aggregation operators", IEEE Transactions on Fuzzy Systems, vol. 15, no. 6, **(2007)**, pp. 1179-1187.
[23] Z. Xu and R. Yager, "Dynamic intuitionistic fuzzy multi-attribute decision making", International Journal of Approximate Reasoning, vol. 48, no.1, **(2008)**, pp. 246-262.
[24] X. Zhang and C. Zhu, "Generalized precedence ordering method with ranking preference for time series-based multi-attribute decision-making", Chinese journal of management science, vol.33, no.11, **(2013)**, pp. 2852-2858.
[25] R. R. Yager, "On ordered weighted averaging aggregation operators in multi-criteria decision-making", IEEE Transactions on Systems, Man, and Cybernetics, vol.18, **(1988)**, pp. 183-190.
[26] J. Nan, D. Li and M. Zhang, "TOPSIS method for intuitionistic fuzzy multi-attribute decision making", Operations research and management science, vol.17, no.3, **(2008)**, pp. 34-37.

Authors

Li Jinqiu, she is a PhD in the School of Economy and Management, Harbin Engineering University, China. Her research interests focus on Technology Innovation Management, Intellectual Property Management and Multiple Attribute Decision Making.