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Evaluation of scientific publications with hesitant fuzzy uncertain linguistic and semantic information

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Abstract. Scientific and technological papers play a fundamental role in the scientific and technological innovation of countries. The quality control of scientific and technological articles is vital to the journals and management of personnel. This paper investigates multiple attribute decision-making problems with the application of hesitant fuzzy uncertain linguistic information. Motivated by the ideal traditional I-COA operator, an induced hesitant fuzzy uncertain linguistic correlated averaging (IHFULCA) operator is developed. The IHFULCA operator was used to develop approaches to solve hesitant fuzzy uncertain linguistic multiple attribute decision-making problems. Finally, a practical example for evaluating the academic value of scientific and technological papers is provided to verify the developed approach and demonstrate its practicality and effectiveness.

Keywords: Multiple attribute decision-making, hesitant fuzzy uncertain linguistic values, scientific publications

1. Introduction

Enhancing innovative ability is a core national development strategy necessary to the construction of an innovative country, and is the key to improving overall national strength [29, 30]. The process of improving independent innovation must be accompanied by the realization of scientific and technological achievements. Transfer capacity of technological innovation and technology is an area of core competitiveness between countries [21, 22]. While technical papers remain an important means by which innovation and technology researchers disseminate their ideas, they are also a way for scientific and technological achievements to be transformed into productivity [1]. Cost and time effectiveness are issues common to much of this work [2, 18, 32].

The emergence and popularization of network technology has enabled the wider dissemination of scientific papers. Information technology is now widely used to construct online platforms on which papers can appear [22, 31]. The Internet has created an information superhighway that breaks through the traditional modes of information transmission, and makes academic resources available to a wider global audience in a more permanent way [23]. Researchers can access the latest research and conduct academic exchanges quickly and efficiently [17]. China was late to the movement with its Open Access policy and publication of scientific papers [13, 16]. To date, China has not yet

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perfected the publication of scientific papers using the academic evaluation influence system [10, 12]. This makes it difficult to perform objective and comprehensive assessments of the academic influence of published scientific papers [11]. Online papers published in many networks are not readily recognized, resulting in the loss of a large number of high-quality, highly impactful research results, which in turn affects the publication of scientific papers and their further development and expansion in relevant fields [9].

In recent years, the field of information science has focused on exploring and establishing an impact evaluation index and evaluation system for published scientific papers [26, 33]. This paper evaluates the impact evaluation of academic papers published on the Internet and to establish standardized scientific evaluation criteria [8, 19, 20]. This study aims to construct impact assessment indices for scientific papers, which can provide a reference for the evaluation of academic resources, and ultimately ensure that scientific papers published in our country can induce real social change [14, 55]. Simultaneously, this project is important to the realization of the effective configuration of scientific resources, enhancing efficient utilization of scientific resources and accelerating the transfer of research findings into productivity [3, 4, 27]. The problem of evaluating the academic value of scientific and technological papers with hesitant fuzzy uncertain linguistic information is the complexity of multiple attribute decision-making problems [6, 25, 28].

The peer review, influential factor and citation evaluation systems that are common worldwide are all specific to the journal in which the thesis is published and the citation, which presents shortcomings and limitations: there is a lack of evaluation of the thesis itself, which is influenced by the subject difference [5, 7]. Therefore, it is urgent to establish a comprehensive and systematic thesis evaluation system, so as to overcome the limitations of the existing evaluation system and take into account the demand of many kinds of theses such as open access. For this reason, this paper investigates multiple attribute decision-making problems with hesitant fuzzy uncertain linguistic information.

The research motivations of this paper can be summarized as follows. Motivated by the ideal traditional I-COA operator, an induced hesitant fuzzy uncertain linguistic correlated averaging (IHFULCA) operator is developed. The IHFULCA operator is used to develop an approach to solve hesitant fuzzy uncertain linguistic multiple attribute decision-making problems.

2. Proposed approach

Scientific and technological theses reflect the research level and achievements of the researchers, and the evaluation of the theses of scientific research personnel can potentially reflect their academic level. At present, the academic theses evaluation is an important means for scientific research institutes, higher education and government departments to conduct performance assessments, title evaluation and determine scientific award to the scientific research personnel. This work is of significance, but there is also great controversy, which is primarily reflected in the evaluation method of academic theses. This paper investigates multiple attribute decision-making problems with hesitant fuzzy uncertain linguistic information.

Definition 1. Given a fixed set X and an uncertain linguistic set $\tilde{S}$, then a hesitant fuzzy uncertain linguistic set (HFULS) of X is in terms of a function that when applied to X, returns a subset of [0, 1]. To be easily understood, the HFULS can be expressed by mathematical symbols as follows:

$$\tilde{A} = \left(\left\langle x, \tilde{s}_{\theta(x)}, h_{\tilde{A}}(x)\right\rangle | x \in X\right)$$

where $h_A(x)$ is a set of values between [0, 1], denoting the possible membership degree of the element $x \in X$ to the uncertain linguistic set $\tilde{s}_{\theta(x)}$.

Definition 2. Let $\tilde{s}_1 = \left[s_{\alpha_1}, s_{\beta_1}\right], \tilde{s}_2 = \left[s_{\alpha_2}, s_{\beta_2}\right]$ be two uncertain linguistic variables, and let $len(\tilde{s}_1) = \beta_1 - \alpha_1$, $len(\tilde{s}_2) = \beta_2 - \alpha_2$. Then, the degree of possibility of $\tilde{s}_1 \geq \tilde{s}_2$ is defined as

$$p(\tilde{s}_1 \geq \tilde{s}_2) = \frac{\max(0, len(\tilde{s}_1) + len(\tilde{s}_2) - \max(\beta_2 - \alpha_1, 0))}{len(\tilde{s}_1) + len(\tilde{s}_2)}$$

Definition 3. Let f be a positive real-valued function of X and m be a fuzzy measure of X. The induced Choquet ordered averaging operator of dimension n is a function $\text{I - COA} : \left(R^+ \times R^+\right) \rightarrow R^+$, which is defined to aggregate the set of a second argument $\langle u_1, f_1\rangle, \langle u_2, f_2\rangle, \ldots, \langle u_n, f_n\rangle$ according to the following expression:

$$\text{I - COA}_m(\langle u_1, f_1\rangle, \langle u_2, f_2\rangle, \ldots, \langle u_n, f_n\rangle) = \sum_{j=1}^{n} f_{\sigma(j)}\left[m\left(A_{\sigma(j)}\right) - m\left(A_{\sigma(j-1)}\right)\right]$$

where $(\sigma(1), \sigma(2), \ldots, \sigma(n))$ is a permutation of $(1, 2, \ldots, n)$, such that $u_{\sigma(i-1)} \geq u_{\sigma(i)}$ for all $j = 2, \ldots, n$, i.e., $\langle u_{\sigma(j)}, f_{\sigma(j)} \rangle$ is the 2-tuple, with $u_{\sigma(j)}$ the jth largest value in the set $(u_1, u_2, \ldots, u_n)$, $A_{\sigma(k)} = \{x_{\sigma(j)} \,|\, j \leq k\}$, for $k \geq 1$, and $A_{\sigma(0)} = \phi$.

The following section develops the IHFULCA operator based on the I-COA operator.

Definition 4. Let $\langle u_j, \tilde{a}_j \rangle = \left\langle u_j, \left(\tilde{s}_{\theta(a_j)}, h(a_j)\right)\right\rangle = \left\langle u_j, \left\langle \left[s_{\theta^L(\tilde{a}_j)}, s_{\theta^R(\tilde{a}_j)}\right], \left(\tilde{s}_{\theta(a_j)}, h(a_j)\right)\right\rangle\right\rangle$ be a collection of 2-tuples of X, and μ be a fuzzy measure of X. Then,

$$\mathrm{IHFULCA}_\mu(\langle u_1, \tilde{a}_1 \rangle, \langle u_2, \tilde{a}_2 \rangle, \ldots, \langle u_n, \tilde{a}_n \rangle) = \bigoplus_{j=1}^{n} \left(\left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) \tilde{a}_{\sigma(j)}\right)$$

where $w = (w_1, w_2, \ldots, w_n)^T$ is a weighting vector such that $w_j > 0$, $\sum_{j=1}^{n} w_j = 1$, $j = 1, 2, \ldots, n$, $\tilde{a}_{\sigma(j)}$ is the $\tilde{a}_j$ value of the IHFULCA pair $\langle u_i, \tilde{a}_i \rangle$ having the jth largest u_i ($u_i \in [0, 1]$), u_i in $\langle u_i, \tilde{a}_i \rangle$ is referred to as the order-inducing variable, and $\tilde{a}_i$ is referred to as the hesitant fuzzy uncertain linguistic arguments.

With the operation of hesitant fuzzy uncertain linguistic variables, the IHFULCA operator can be transformed into the following form by induction on n:

$$\begin{aligned}
&\mathrm{IHFULCA}_\mu(\langle u_1, \tilde{a}_1 \rangle, \langle u_2, \tilde{a}_2 \rangle, \ldots, \langle u_n, \tilde{a}_n \rangle) \\
&= \bigoplus_{j=1}^{n} \left(\left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) \tilde{a}_{\sigma(j)}\right) \\
&= \left\langle \left[\sum_{j=1}^{n} \left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) s_{\theta^L(\tilde{a}_{\sigma(j)})}, \right.\right. \\
&\qquad \left. \sum_{j=1}^{n} \left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) s_{\theta^R(\tilde{a}_{\sigma(j)})} \right], \\
&\qquad \left(\cup_{\gamma(\tilde{a}_{\sigma(1)}) \in h(\tilde{a}_{\sigma(1)}), \gamma(\tilde{a}_{\sigma(1)}) \in h(\tilde{a}_{\sigma(1)}), \ldots, \gamma(\tilde{a}_{\sigma(1)}) \in h(\tilde{a}_{\sigma(1)})} \right. \\
&\qquad \left.\left. \left\{1 - \prod_{j=1}^{n} \left(1 - \gamma\left(\tilde{a}_{\sigma(j)}\right)\right)^{\left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right)}\right\}\right)\right\rangle
\end{aligned}$$

where $w = (w_1, w_2, \ldots, w_n)^T$ is a weighting vecto, such that $w_j > 0$, $\sum_{j=1}^{n} w_j = 1$, $j = 1, 2, \ldots, n$, $\tilde{a}_{\sigma(j)}$ is the $\tilde{a}_j$ value of the IHFULCA pair $\langle u_i, \tilde{a}_i \rangle$ having the jth largest u_i ($u_i \in [0, 1]$), u_i in $\langle u_i, \tilde{a}_i \rangle$ is referred to as the order-inducing variable and $\tilde{a}_i$ is referred to as the hesitant fuzzy uncertain linguistic arguments.

The IHFULCA operator is applied to multiple attribute decision-making in order to evaluate the academic value of scientific publications with hesitant fuzzy uncertain linguistic and semantic information. Let $A = \{A_1, A_2, \ldots, A_m\}$ be a discrete set of alternatives, and $G = \{G_1, G_2, \ldots, G_n\}$ be the state of nature. If the decision-makers provide several values for the alternative A_i under the state of nature G_j with respect to $\tilde{s}_{\theta_{ij}}$ with anonymity, these values can be considered as a hesitant fuzzy uncertain linguistic element $\langle \tilde{s}_{\theta_{ij}}, h_{ij} \rangle$.

In the following section, the IHFULCA operator is applied to MADM problems in order to evaluate the academic value of scientific and technological papers with hesitant fuzzy uncertain linguistic information.

Step 1. The decision information given in matrix H, and the IHFULCA operator are used as follows:

$$\begin{aligned}
\tilde{h}_i &= \left(\langle \tilde{s}_{\theta_i}, h_i \rangle\right) \\
&= \mathrm{IHFULCA}_w\left(\langle u_{i1}, \tilde{h}_{i1} \rangle, \langle u_2, \tilde{h}_{i2} \rangle, \ldots, \langle u_{in}, \tilde{h}_{in} \rangle\right) \\
&= \bigoplus_{j=1}^{n} \left(\left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) \tilde{h}_{\sigma(ij)}\right) \\
&= \left\langle \left[\sum_{j=1}^{n} \left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) s_{\theta^L_{\sigma(ij)}}, \right.\right. \\
&\qquad \left. \sum_{j=1}^{n} \left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right) s_{\theta^R_{\sigma(ij)}} \right], \\
&\qquad \left(\cup_{\gamma_{\sigma(i1)} \in h_{\sigma(i1)}, \gamma_{\sigma(i2)} \in h_{\sigma(i2)}, \ldots, \gamma_{\sigma(in)} \in h_{\sigma(in)}} \right. \\
&\qquad \left.\left. \left\{1 - \prod_{j=1}^{n} \left(1 - \gamma\left(\tilde{h}_{\sigma(ij)}\right)\right)^{\left(\mu\left(A_{\sigma(j)}\right) - \mu\left(A_{\sigma(j-1)}\right)\right)}\right\}\right)\right\rangle
\end{aligned}$$

$i = 1, 2, \ldots, m.$

Step 2. Calculate the scores $S\left(\tilde{h}_i\right)$ $(i = 1, 2, \ldots, m)$ of the overall hesitant fuzzy uncertain linguistic values $\tilde{h}_i$ $(i = 1, 2, \ldots, m)$.

Step 3. To rank these, the scores $S\left(\tilde{h}_i\right)$ $(i = 1, 2, \ldots, m)$ all of the overall hesitant fuzzy uncertain linguistic preference values $\tilde{h}_i$ $(i = 1, 2, \ldots, m)$ are first compared with all the $S\left(\tilde{h}_j\right)$ $(j = 1, 2, \ldots, m)$.

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

Table 1
Hesitant fuzzy uncertain linguistic decision matrix

	G_1	G_2	G_3	G_4
A_1	$<[s_2, s_3], (0.5,0.6)>$	$<[s_4, s_5], (0.3,0.5)>$	$<[s_2, s_3], (0.7,0.8)>$	$<[s_1, s_2], (0.5)>$
A_2	$<[s_3, s_4], (0.3,0.4)>$	$<[s_2, s_3], (0.6)>$	$<[s_4, s_5], (0.3,0.4)>$	$<[s_2, s_3], (0.4)>$
A_3	$<[s_2, s_3], (0.4, 0.5)>$	$<[s_4, s_5], (0.3,0.6)>$	$<[s_2, s_3], (0.1,0.5)>$	$<[s_4, s_5], (0.4,0.5>$
A_4	$<[s_5, s_6], (0.2,0.3)>$	$<[s_3, s_4], (0.4)>$	$<[s_1, s_2], (0.4,0.7)>$	$<[s_2, s_3], (0.4, 0.7)>$
A_5	$<[s_2, s_3], (0.4,0.5)>$	$<[s_3, s_4], (0.5, 0.6)>$	$<[s_1, s_2], (0.4, 0.6)>$	$<[s_3, s_4], (0.3,0.6)>$

3. Experimental results

At present, the issues of scientific evaluation are most concentrated in the evaluation of institutions, scholars and academic journals, and indicators such as the H index, G index and influential factors are widely used for the above evaluation. However, there is seldom research conducted on the evaluation of a scientific and technological thesis. The evaluation of scientific and technological theses is primarily conducted according to methods of peer review, citation analysis and influential factors regarding the specific journal. Peer review is a relatively common academic thesis evaluation method, but has significant time costs, has the potential for strong interference and is influenced by many subjective elements such as the selection of experts, personal hobbies, social relationships and subject background, introducing strong randomness and subjectivity. When the evaluation of many theses of different subject fields is necessary, it is difficult to obtain appropriate experts. Citation analysis is conducted to evaluate the frequency of the cited thesis. In addition, the influential factor is established on the basis of citation frequency, and will inevitably be influenced by the subject difference; for example, the influential factor of life science is higher than that of journals of mechanics.

With the rapid development of computer and communication technology, library resources in the 21st century have radically changed from paper-based to digital resources. Digital resources, which can be readily shared, updated and developed, have had an important effect on teaching in schools and on scientific research. There are costs associated with an the purchasing of digital resources by an academic library, and these may be higher than the cost of paper-based resources. The purchase of digital resources has become an important part of academic library management. Many academic and scientific research organizations are actively developing evaluations of digital resources. In this section, the IHFULCA operator is applied multiple attribute decision-making in order to evaluate the academic value of scientific and technological papers with hesitant fuzzy uncertain linguistic information. A set of five different types of scientific and technological papers were used, A_i $(i = 1,2,3,4,5)$, which were evaluated according to four attributes: (1) innovation (G_1); (2) scientific value (G_2); (3) application prospects (G_3); and (4) practical significance (G_4). To avoid influencing one another, decision-makers were required to independently and anonymously evaluate the scientific and technological papers A_i $(i = 1,2,3,4,5)$ based on the above mentioned attributes. The decision matrix $H = \left(\tilde{h}_{ij}\right)_{5\times4} = \left(\left\langle \tilde{s}_{\theta_{ij}}, h_{ij}\right\rangle\right)_{5\times4}$ is presented in Table 1.

This approach was used to obtain the most desirable scientific and technological papers.

Step 1. Suppose the fuzzy measure of attribute G_j $(j = 1, 2 \ldots, n)$ and attribute sets of G as follows:

$$\mu(G_1) = 0.30, \mu(G_2) = 0.24,$$

$$\mu(G_3) = 0.29, \mu(G_4) = 0.20$$

$$\mu(G_1, G_2) = 0.62, \mu(G_1, G_3) = 0.53,$$

$$\mu(G_1, G_4) = 0.50, \mu(G_2, G_3) = 0.40$$

$$\mu(G_2, G_4) = 0.45, \mu(G_3, G_4) = 0.50,$$

$$\mu(G_1, G_2, G_3) = 0.70, \mu(G_1, G_2, G_4) = 0.80$$

$$\mu(G_1, G_3, G_4) = 0.74, \mu(G_2, G_3, G_4) = 0.68,$$

$$\mu(G_1, G_2, G_3, G_4) = 1.00$$

Step 2. The experts used order-inducing variables to represent the complex attitudinal character involving the opinions of different decision-makers; results are shown in Table 2.

Table 2
Inducing variables

	G_1	G_2	G_3	G_4
A_1	16	14	18	11
A_2	20	22	21	16
A_3	16	15	20	17
A_4	13	19	13	16
A_5	18	20	17	22

Step 3. The decision information given in matrix H and the IHFULCA operator were used to obtain the scores $S\left(\tilde{h}_i\right)$ $(i = 1, 2, 3, 4, 5)$ of the overall hesitant fuzzy uncertain linguistic preference values h_i $(i=1,2,3,4,5)$.

$$S\left(\tilde{h}_1\right) = [s_{1.21}, s_{2.14}], S\left(\tilde{h}_2\right) = [s_{2.56}, s_{3.78}],$$

$$S\left(\tilde{h}_3\right) = [s_{0.74}, s_{1.35}], S\left(\tilde{h}_4\right) = [s_{1.28}, s_{3.78}],$$

$$S\left(\tilde{h}_5\right) = [s_{0.75}, s_{3.59}]$$

Step 4. All five scientific and technological papers A_i $(i=1,2,3,4,5)$ were ranked in accordance with the scores $S\left(\tilde{h}_i\right)$ $(i = 1, 2, 3, 4, 5)$. The ordering of scientific and technological papers was determined as follows: $A_2 \succ A_4 \succ A_5 \succ A_1 \succ A_3$; the best scientific and technological paper was determined to be paper A_2.

The three major retrieval journals, especially the important core journals, require relatively high quality, with regulated draft audit and use procedures. It is equivalent that the journals have been evaluated by peer experts, so they have a relatively high credibility. However, it cannot be denied that three major retrieval journals also present inferior quality. It is suggested that the state should emphasize the important role of the three major retrievals in China, organize experts of various subjects to further screen the three major retrieval journals, and form a high-quality journal group consisting of the three screened major retrieval journals and the domestic important core journals, so as to measure the academic level of the researchers.

4. Conclusions

In this paper, multiple attribute decision-making problems were investigated with hesitant fuzzy uncertain linguistic information. The strengths of this proposed method can be summarized as follows. Driven by the ideal traditional I-COA operator, the IHFULCA operator was developed. The IHFULCA operator was then used to develop an approach to solving hesitant fuzzy uncertain linguistic multiple attribute decision-making problems. A practical example of evaluating the academic value of scientific and technological papers is provided to verify the developed approach and demonstrate its practicality and effectiveness.

The weaknesses of this proposed method can be summarized as follows. The theoretical system of this method is imperfect, and the utilized empirical research is inadequate.

Future research directions can be summarized as follows. First, the basic theories of this proposed method should be improved. Second, more practical examples should be studied to demonstrate the practicality and effectiveness of this method.

Conflict of interests fine tuning

The authors declare that there is no conflict of interests regarding the publication of this article.

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