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* **Corresponding author**.

arorap151@gmail.com

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Selecting the Best Project using Generalized Parametric Fuzzy Entropy Measure on Intuitionistic Fuzzy Sets

Priya Arora[1]*, V P Tomar[2]

1 Research Scholar, Department of Mathematics, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, 131039, India
2 Associate Professor, Department of Mathematics, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, 131039, Haryana, India

Abstract

Objectives: To develop a new parametric measure of entropy for Intuitionistic Fuzzy Sets and to study its application in selecting the best project for a company. Methods: We have used five-point Likert scale to determine the feedback of different projects and devised a method based on parametric intuitionistic fuzzy entropy to select the best project for the company. Findings: In this study, a parametric measure of entropy is being proposed for intuitionistic fuzzy sets. It is a generalized version of entropy for intuitionistic fuzzy sets. Properties of the proposed entropy have also been discussed. The proposed entropy is compared with other existing measures of entropy for intuitionistic fuzzy sets using a numerical example. Finally, the application of proposed entropy in selecting the best project is studied. Novelty: The proposed entropy is stable with the structured linguistic variables which most of the entropies are not. We have used a standard method based on parametric intuitionistic fuzzy entropy measure to determine the weights of each criterion which makes it more generalized and flexible. Instead of depending just on their own knowledge, decision-makers may use the suggested model to better comprehend the relative importance of each criteria for the selection of best project.

Keywords: Fuzzy set; Intuitionistic fuzzy set; Fuzzy entropy; Intuitionistic fuzzy entropy; Linguistic variable

1 Introduction

As a result of pandemics and geopolitical issues, the level of global business uncertainty has spiked in the past few years. These new conditions aim to employ various models in business that can deal with uncertainty, which is also pertinent to project management concerns. Typically, decision-maker evaluations, including preference information, are expressed in linguistic terms. The values of a Linguistic variable are language elements that include words and phrases. Atanassov introduced the intuitionistic fuzzy sets theory, which permits vagueness to be represented quantitatively. When confronted with this decision environment, specialists cannot always express their opinions using precise values. Intuitionistic fuzzy sets (IFS) are valuable tools for handling uncertainty information because experts can articulate their opinions flexibly according to the degree of membership, degree of non membership, and degree of indeterminacy. In disciplines of decision science, FS and IFS concept has been widely utilized in a variety of decision-making scenarios, including supplier selection, personnel selection, project selection equipment selection etc. While Decision Makers' (DM's) knowledge and experience are certainly valuable in many real-world scenarios, obtaining subjective weights may be challenging. One of the most often used strategies for resolving the Multi Attribute Decision Making (MADM) issue is the entropy technique. In recent years, various measures of intuitionistic fuzzy entropy have been developed[1–6].

Numerous techniques such as TOPSIS, MULTIMOORA, TODIM, and VIKOR have been adopted for decision-making problem.[7–9]. Expertise alone cannot always serve as a sufficient criterion. To address this problem, Rahimi et al.[10] developed a novel approach to give a standard assessment for choosing the best supplier using intuitionistic fuzzy entropy. Ma et al.[11], Shamsuzzoha et al.[12], Chen and Hung[13] and some other authors have suggested approaches for project selection which relies heavily on expert opinions. To address this research gap, this study proposes a method for Project Selection based on Rahimi's[10] method and uses a common procedure for determining the weight, and the influence of knowledge on the decision-making has been diminished. The method is more generalized and flexible than Rahimi's[10] Method due to the parameter factor. The proposed approach relies on a novel introduced parametric intuitionistic fuzzy entropy measure that incorporates the decision maker's subjective stance during the decision-making procedure by means of parameter selection.

Managers in any organisation will only take on projects that they believe have a good chance of succeeding. Successful project selection is crucial for every business; hence this topic has received extensive attention. Finding the complicated tasks that need extra care and attention is essential for working on a successful project. A large amount of research has been devoted to the study of project selection because of its importance to managers. Hamdan et al.[14] surveyed contractors to learn what causes electrical installation projects to run behind schedule, and Han et al.[15] applied MCDM method to project selection.

Multi-criterion project portfolio selection with an emphasis on environmental impact was the subject of research by Ma et al.[11]. Researchers have looked at the topic of risk and uncertainty in multi-criteria project selection (Pramanik et al.[16], Dandage et al.[17]).

The objective of this paper is to introduce a new parametric measure of entropy for IFS and study its application in selecting the best project for an organisation. In Section 2, we discuss the methodology used in the paper. In section 3, the parametric measure of entropy for IFS is proposed with its proof of validity, properties of proposed entropy are studied, and an illustrative numerical instance is provided to compare the proposed entropy with existing measures of entropy and the application of proposed entropy in selecting the best project is studied.

1.1 Preliminaries

Definition 1: Fuzzy set: Let $X = \{x_1, x_2, x_3, \ldots\ldots\ldots\ldots. x_n\}$ be the universe of discourse, then a fuzzy set A defined on X is

A = $\{< x, \mu_A(x) > \mid x \varepsilon X\}$

where $\mu_A(x)$: X $\to$ [0, 1] is the degree of membership of x in A.[18]

Definition 2: Intuitionistic Fuzzy Set: Intuitionistic Fuzzy set A on X is

A= $\{< x, \mu_A(x), \nu_A(x) > \mid x \varepsilon X\}$

where $\mu_A(x)$: X $\to$ [0,1] is the degree of membership and $\nu_A(x) : X \to$ [0,1] is the degree of non membership where $0 \leq \mu_A(x) + \nu_A(x) \leq 1$.

$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ is called the hesitancy degree or the degree of indeterminacy[19].

Definition 3: A real function e: FS(X)$\to R^+$ is called entropy on FS(X) if e satisfies the following properties:

(e1) e (A) =0 if A is a crisp set.

(e2) e (A) achieves its maximum at $\mu_A = 0.5$

(e3) e (A) $\leq$ e(B) if A is more crisp than B i.e $\mu_A \leq \mu_B$ for $\mu_B \leq 0.5$ and $\mu_A \geq \mu_B$ for $\mu_B \geq 0.5$.

(e4) e (A) $= e(A^c)$ where A^cdenotes the complement of A[20].

Definition 4: A real function E: IFS(X)$\to R^+$ is called entropy on IFS(X) if E satisfies the following properties:

(E1) E(A)=0 if A is a crisp set.

(E2) E(A) achieves its maximum at $\mu_A = \nu_A = \pi_A = \frac{1}{3}$

(E3) E(A) $\leq$ E(B) if A is more crisp than B i.e $\mu_A \leq \mu_B$ and $\nu_A \leq \nu_B$ for max $\{\mu_B, \nu_B\} \leq \frac{1}{3}$and $\mu_A \geq \mu_B$ *and* $\nu_A \geq \nu_B$ for $min\{\mu_B, \nu_B\} \geq \frac{1}{3}$

(E4) E(A) $= E(A^c)$ where A^cdenotes the complement of A[21].

Atanassov[19] also defined some operations on IFS as :

A $\leq$ B iff $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all $x\ \varepsilon$X.

A $\preccurlyeq$ B iff $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \leq \nu_B(x)$ for all x εX.
A= B iff A $\leq$ B and B $\leq$ A
$\bar{A} = \{< x, \nu_A(x), \mu_A(x) > | \, x\varepsilon \text{ X} \}$
Now, we define some of the existing entropies on IFS.
Let A be an IFS in $X = \{x_1, x_2, x_3, \ldots\ldots\ldots\ldots.x_n\}$
Szmidt and Kacprzyk[22] definition of entropy is as follows:
$E_{sk}(A) = \frac{1}{n}\sum_{i=1}^{n} \frac{min(\mu_A(x_i),\, \nu_A(x_i)) + \pi_A(x_i)}{max(\mu_A(x_i),\, \nu_A(x_i)) + \pi_A(x_i)}$
Burilli & Bustince[23] defined the following measure of entropy:
E_{BB} (A) = $\sum_{i=1}^{n} [1 - (\mu_A(x_i) - \nu_A(x_i))]$
Zeng and Li[24] defined entropy on IFS as:
E_{ZL}= 1-(1/n)$\sum_{i=1}^{n} |(\mu_A(x_i) - \nu_A(x_i)|$

2 Methodology

Several writers, including Ma et al.[11], Shamsuzzoha et al.[12], Chen and Hung[13], and others, have proposed methods for project selection that largely rely on expert's judgements. The study suggests a technique for Project Selection that is based on Rahimi's[10] approach and that employs a standardised mechanism for calculating the weight, thereby reducing the need of expertise in making important decisions. The parameter factor makes the approach more generalized and adaptable than Rahimi's[10] approach. The technique is based on newly developed parametric intuitionistic fuzzy entropy that allows the decision maker's subjective outlook to be factored in through the choice of parameters.

We first define a parametric measure of entropy on IFS and then illustrate with a numerical example to show that the behaviour of proposed intuitionistic fuzzy entropy E_α^β is favourable from the perspective of structured linguistic variables. For selection of best project, we follow the following method (Figure 1)

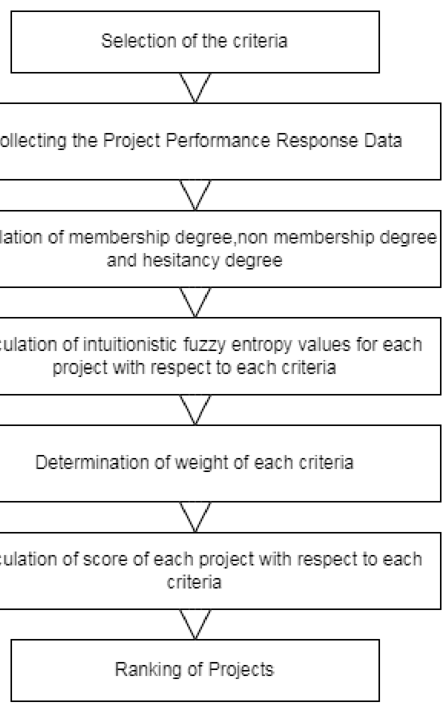

Fig 1. Flowchart of Project Selection Method

Step1: Criteria Selection: Firstly, the criteria are selected against which the performance of each project will be tested.

Step 2: Collecting the Project Performance Data: We use Likert five point scale to record the rating of each project against the criteria chosen in Step 1.

Step 3: Calculation of membership, non membership and hesitancy degree: We use the method given in to calculate Project Performance Data in terms of intuitionistic fuzzy values.

Step 4: Calculation of intuitionistic fuzzy entropy values for each project with respect to each criteria: We calculate the intuitionistic fuzzy entropy values for each project using the proposed intuitionistic fuzzy entropy given in equation (1)

Step 5: Determination of weight of each criteria: We determine the weight of each criteria by multiplying the normalized value of each row with the normalized quantity of corresponding column.

Step 6: Calculation of score of each project with respect to each criteria: We calculate the score of each project with respect to each criteria using equation

Step 7: Ranking of the projects: Calculating the sum of scores of each project, we give rank to the projects.

3 Results and Discussion

3.1 New parametric measure of entropy on IFS

On the basis of fuzzy entropy[25], we define a parametric measure of entropy on IFS.

Let A be an IFS with universe of discourse $X = \{x_1, x_2, x_3, \ldots\ldots\ldots\ldots. x_n\}$. Then

$$E_\alpha^\beta = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)} \sum_{i=1}^{n} \left\{ \left(\left(\frac{\mu_A(x_i) - \upsilon_A(x_i) + 1}{2} \right)^\alpha + \left(\frac{1 - \mu_A(x_i) + \upsilon_A(x_i)}{2} \right)^\alpha \right]^\beta - 1 \right\} \tag{1}$$

$$where\ \alpha > 0, \alpha \neq 1, \beta \neq 0$$

Theorem 3.1: The above measure of the intuitionistic fuzzy entropy satisfies the following properties:

(P1) E_α^β (A)=0 if A is a crisp set.

(P2) E_α^β (A) achieves its maximum at $\mu_A = \nu_A = \pi_A = \frac{1}{3}$

(P3) E_α^β (A)$\leq E_\alpha^\beta$ (B) if A is more crisp than B i.e $\mu_A \leq \mu_B$ and $\nu_A \leq \nu_B$ for max $\{\mu_B, \nu_B\} \leq \frac{1}{3}$and $\mu_A \geq \mu_B and \nu_A \geq \nu_B$ for $min\{\mu_B, \nu_B\} \geq \frac{1}{3}$

(P4) $E_\alpha^\beta(\mathrm{A}) = E_\alpha^\beta\,(A^c)$ where A^c denotes the complement of A

Proof: (P1) Let A be a crisp set.

Then,

$$\mu_A(x_i) = 0,\ \nu_A(x_i) = 1\ or\ \mu_A(x_i) = 1,\ \nu_A(x_i) = 0\ \forall x_i \tag{2}$$

$$\Rightarrow E_\alpha^\beta = 0 \tag{3}$$

$$Let\ t_A(x_i) = \frac{\mu_A(x_i) - \upsilon_A(x_i) + 1}{2} \tag{4}$$

$$\Rightarrow E_\alpha^\beta = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)} \sum_{i=1}^{n} \left[\left(t_i^\alpha + (1-t_i)^\alpha\right)^\beta - 1 \right] \tag{5}$$

$$\therefore E_\alpha^\beta = 0\ iff t_i = 0\ or\ 1 \tag{6}$$

$$i.e\ \frac{\mu_A(x_i) - \upsilon_A(x_i) + 1}{2} = 0\ or\ \frac{\mu_A(x_i) - \upsilon_A(x_i) + 1}{2} = 1\ \forall x_i \tag{7}$$

$$\Rightarrow \mu_A(x_i) - \upsilon_A(x_i) + 1 = 0\ \ or\ \mu_A(x_i) - \upsilon_A(x_i) + 1 = 1 \forall x_i \tag{8}$$

$$\Rightarrow \mu_A(x_i) - \upsilon_A(x_i) = -1\ \ or\ \ \mu_A(x_i) - \upsilon_A(x_i) = 2\ \forall x_i \tag{9}$$

Also, we know that $\mu_A(x_i) + \upsilon_A(x_i) \leq 1 \forall x_i$

$$\therefore \mu_A(x_i) = 0,\ \nu_A(x_i) = 1\ or\ \mu_A(x_i) = 1,\ \nu_A(x_i) = 0\ \forall x_i$$

(P2) Let $\mu_A(x_i) = \nu_A(x_i) \forall x_i$

Then,

$$E_{\alpha}^{\beta} = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)} n\left(\left[\left(\left(\frac{1}{2}\right)^{\alpha} + \left(\frac{1}{2}\right)^{\alpha}\right)^{\beta} - 1\right]\right) \tag{10}$$

$$\Rightarrow E_{\alpha}^{\beta} = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)} n\left[\frac{1}{2^{(\alpha-1)\beta}} - 1\right] \tag{11}$$

$$\therefore E_{\alpha}^{\beta} = 1 \tag{12}$$

Conversely, Let $E_{\alpha}^{\beta} = 1$

Then,

$$\frac{1}{n}\sum h(t_A(x_i)) = 1 \tag{13}$$

Where,

$$h(t_A(x_i)) = \frac{\left(t_i^{\alpha} + (1-t_i)^{\alpha}\right)^{\beta} - 1}{2^{(1-\alpha)\beta} - 1} \forall t_i \tag{14}$$

$$\Rightarrow h(t_A(x_i)) = 1 \forall x_i \tag{15}$$

Differentiating (14) w.r.t t_i and equating to zero

$$\frac{\partial h}{\partial t_i} = \frac{1}{\left(2^{(1-\alpha)\beta}-1\right)}\left[\beta\left(t_i^{\alpha} + (1-t_i)^{\alpha}\right)^{\beta-1}\left(\alpha t_i^{\alpha-1} - \alpha(1-t_i)^{\alpha-1}\right)\right] = 0 \tag{16}$$

$$= \frac{\alpha\beta}{\left(2^{(1-\alpha)\beta}-1\right)}\left[\left(t_i^{\alpha} + (1-t_i)^{\alpha}\right)^{\beta-1}\left(t_i^{\alpha-1} - (1-t_i)^{\alpha-1}\right)\right] = 0 \tag{17}$$

$$t_i = \frac{1}{2} \forall i \tag{18}$$

$$i.e t_A(x_i) = \frac{1}{2} \forall x_i \tag{19}$$

Again Differentiating, we get

$$\frac{\partial^2 h}{\partial t_i^2} = \frac{\alpha\beta}{2^{(1-\alpha)\beta}-1}\left[\alpha(\beta-1)\left(\left(t_i^{\alpha} + (1-t_i)^{\alpha}\right)^{\beta-2}\left(t_i^{\alpha-1} - (1-t_i)^{\alpha-1}\right)^2 + (\alpha-1)\left(t_i^{\alpha} + (1-t_i)^{\alpha}\right)^{\beta-1}\left(t_i^{\alpha-2} + (1-t_i)^{\alpha-2}\right)\right] \tag{20}$$

At $t_i = \frac{1}{2}$

$$\frac{\partial^2 h(t_i)}{\partial t_i^2} = \frac{\alpha\beta}{2^{(1-\alpha)\beta}-1}\left[\left(\frac{1}{2^{\alpha-1}}\right)^{\beta-1}(\alpha-1)\frac{1}{2^{\alpha-3}}\right] \tag{21}$$

and

$$\frac{\partial^2 h(t_i)}{\partial t_i^2} = \frac{\alpha\beta}{2^{(1-\alpha)\beta}-1}\left[(\alpha-1)\frac{1}{2^{(\alpha-1)(\beta-1)+\alpha-3}}\right] < 0 \tag{22}$$

Thus, E_{α}^{β} attains its maximum value at $t_i = \frac{1}{2}$

i.e $\frac{\mu_A(x_i)-\upsilon_A(x_i)+1}{2} = \frac{1}{2}$

$$\mu_A(x_i) = \nu_A(x_i)\ \forall\, x_i$$

(P3) In order to show thatE_α^β satisfies P3, it is sufficient to prove that

$$g(x,y) = \frac{1}{\left(2^{(1-\alpha)\beta}-1\right)}\left[\left(\left(\frac{x-y+1}{2}\right)^\alpha + \left(\frac{1-x+y}{2}\right)^\alpha\right)^\beta - 1\right] \tag{23}$$

where $x,y \in [0,1]$ is increasing w.r.t x and decreasing for y.

Taking partial derivative of $g$with respect to$x$ and y

$$\frac{\partial g}{\partial x} = \frac{\alpha\beta}{2\left(2^{(1-\alpha)\beta}-1\right)}\left[\left(\left(\frac{x-y+1}{2}\right)^\alpha + \left(\frac{1-x+y}{2}\right)^\alpha\right)^{\beta-1}\left(\left(\frac{x-y+1}{2}\right)^{\alpha-1} - \left(\frac{1-x+y}{2}\right)^{\alpha-1}\right)\right] \tag{24}$$

$$\frac{\partial g}{\partial y} = \frac{\alpha\beta}{2\left(2^{(1-\alpha)\beta}-1\right)}\left[\left(\left(\frac{x-y+1}{2}\right)^\alpha + \left(\frac{1-x+y}{2}\right)^\alpha\right)^{\beta-1}\left(-\left(\frac{x-y+1}{2}\right)^{\alpha-1} + \left(\frac{1-x+y}{2}\right)^{\alpha-1}\right)\right] \tag{25}$$

For finding critical point, we put $\frac{\partial g}{\partial x} = 0\ and \frac{\partial g}{\partial y} = 0$, we get

$$x = y$$

From (24) and (25)

$$\frac{\partial g}{\partial x} \geq 0,\ \ whenx \leq y \tag{26}$$

$$\frac{\partial g}{\partial y} \leq 0,\ \ whenx \geq y \tag{27}$$

Thus, from the monotonicity of function$g$, P2 and containment property of IFSs, we get

E_α^β (A)$\leq E_\alpha^\beta$ (B) when A$\leq B$

(P4) Clearly, we can see from the definition of E_α^β (A) that

$$E_\alpha^\beta\ = E_\alpha^\beta(A^c)$$

Theorem 3.2: Let A and B be two IFS on a universe of discourse X $= \{x_1, x_2, \ldots\ldots, x_n\}$, Then $E_\alpha^\beta(\mathrm{A}\cup B) + E_\alpha^\beta(A\cap B) = E_\alpha^\beta(A) + E_\alpha^\beta(B)$

Proof: The universe of discourse can be divided into two parts $X_1$and X_2

X_1={ $x_i \in X$: A$\leq B$}andX_2 ={$x_i \in X$: A$\geq B$}

$$E_\alpha^\beta(A) = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)}\sum_{i=1}^n\left\{\left(\left(\frac{\mu_A(x_i)-\upsilon_A(x_i)+1}{2}\right)^\alpha + \left(\frac{1-\mu_A(x_i)+\upsilon_A(x_i)}{2}\right)^\alpha\right]^\beta - 1\right\} \tag{28}$$

$$E_\alpha^\beta(A\cup B) = \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)}\sum_{i=1}^n\left\{\left(\left(\frac{\mu_{A\cup B}(x_i)-\upsilon_{A\cup B}(x_i)+1}{2}\right)^\alpha + \left(\frac{1-\mu_{A\cup B}(x_i)+\upsilon_{A\cup B}(x_i)}{2}\right)^\alpha\right]^\beta - 1\right\} \tag{29}$$

$$= \frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)}\left[\begin{array}{l}\sum_{x\in X_1}\left\{\left[\left(\frac{\mu_B(x_i)-\nu_A(x_i)+1}{2}\right)^\alpha + \left(\frac{1-\mu_B(x_i)+\nu_A(x_i)}{2}\right)^\alpha\right]^\beta - 1\right\}\Big] \\ +\sum_{x\in X_2}\left\{\left[\left(\frac{\mu_A(x_i)-\nu_B(x_i)+1}{2}\right)^\alpha + \left(\frac{1-\mu_A(x_i)+\nu_B(x_i)}{2}\right)^\alpha\right]^\beta - 1\right\}\Big]\end{array}\right] \tag{30}$$

$$E_\alpha^\beta(A\cap B)=\frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)}\sum_{i=1}^{n}\left\{\left(\left(\frac{\mu_{A\cap B}(x_i)-\upsilon_{A\cap B}(x_i)+1}{2}\right)^\alpha+\left(\frac{1-\mu_{A\cap B}(x_i)+\upsilon_{A\cap B}(x_i)}{2}\right)^\alpha\right]^\beta-1\right\} \tag{31}$$

$$=\frac{1}{n\left(2^{(1-\alpha)\beta}-1\right)}\left[\sum_{x\in X_1}\left\{\left[\left(\frac{\mu_A(x_i)-\nu_B(x_i)+1}{2}\right)^\alpha+\left(\frac{1-\mu_A(x_i)+\nu_B(x_i)}{2}\right)^\alpha\right]^\beta-1\right\}\right.$$
$$\left.+\sum\nolimits_{x\in X_2}\left\{\left[\left(\frac{\mu_B(x_i)-\nu_A(x_i)+1}{2}\right)^\alpha+\left(\frac{1-\mu_B(x_i)+\nu_A(x_i)}{2}\right)^\alpha\right]^\beta-1\right\}\right] \tag{32}$$

$$E_\alpha^\beta(A\cup B)+E_\alpha^\beta(A\cap B)=E_\alpha^\beta(A)+E_\alpha^\beta(B) \tag{33}$$

3.2 Numerical Example

Let A = $\{<x_i,\mu_A(x_i),\ \nu_A(x_i)>\}$ be an AIFS in $X=\{x_1,x_2,x_3,\ldots\ldots\ldots\ldots..x_n\}$

De et al.[26] defined the AIFS A^n as follows:

$A^n=\{<x_i,\ (\mu_A(x_i))]^n,1-(1-\nu_A(x_i))]^n>|x_i\ \varepsilon\ X\}$ for any positive real number n.

Consider the AIFS A on $X=\{x_1,x_2,x_3,\ldots\ldots\ldots\ldots..x_n\}$ defined as:

A = {<6, 0.1, 0.8>, <7, 0.3, 0.5>,<8, 0.5, 0.4>,<9, 0.9, 0.>,<10, 1.0, 0.0>}.

De et al.[26] regarded A as "LARGE" on X

$A^{1/2}$ for may be treated as "More or less LARGE"

$A^2$for may be treated as "Very LARGE"

A^3 for may be treated as "Quite very LARGE"

A^4 for may be treated as "Very very LARGE".

Presently we consider these AIFSs to analyze the above entropy measures. From logical consideration, the entropies of these AIFSs are required to follow the following order pattern: E($A^{1/2}$) > E(A) > E(A^2) > E(A^3) > E(A^4)

Table 1. Comparison of proposed entropy at different values of α and β and with other entropy measures

	$A^{1/2}$	A	A^2	A^3	A^4
$E_{0.1}^{0.1}$	0.761	0.766	0.742	0.708	0.674
$E_{0.3}^{0.1}$	0.696	0.704	0.640	0.567	0.507
$E_{0.5}^{0.1}$	0.646	0.655	0.559	0.459	0.397
$E_{1.5}^{0.1}$	0.545	0.528	0.367	0.262	0 .208
$E_{1.7}^{0.1}$	0.536	0.516	0.349	0.247	0.194
$E_{2}^{0.1}$	0.523	0.503	0.332	0.227	0.176
$E_{0.1}^{-0.5}$	0.768	0.771	0.750	0.721	0.694
$E_{0.3}^{-0.5}$	0.707	0.714	0.655	0.584	0.524
$E_{0.5}^{-0.5}$	0.658	0.662	0.574	0.484	0.414
$E_{1.5}^{-0.5}$	0.538	0.518	0.353	0.248	0.196
$E_{1.7}^{-0.5}$	0.524	0.503	0.329	0.224	0.177
$E_{2.0}^{-0.5}$	0.505	0.484	0.300	0.197	0.154
$E_{0.1}^{1}$	0.752	0.756	0.725	0.686	0.661
$E_{0.3}^{1}$	0.683	0.688	0.613	0.536	0.474
$E_{0.5}^{1}$	0.639	0.640	0.539	0.446	0.380
$E_{1.5}^{1}$	0.558	0.542	0.389	0.326	0.227
$E_{1.7}^{1}$	0.553	0.535	0.379	0.275	0.219
E_{2}^{1}	0.549	0.530	0.371	0.266	0.212
E_s	0.404	0.414	0.348	0.299	0.264
E_{sk}	0.319	0.307	0.301	0.212	0.176
E_{bb}	0.462	0.600	0.660	0.672	0.680

According to Table 1, we can observe that Shannon entropies Es and E_{bb} partially satisfy the requirement. At values of α greater than 0.5, the suggested entropy measure agrees with the structured linguistic variables.

3.3 Selection of best project

One of the goals of a high-tech software firm is to boost productivity by choosing an appropriate project. Before making the investment in developing new information systems, businesses should engage in strategic planning to ensure that they fully grasp the strategy and how the project will be used to achieve business goals. The process of choosing an information project is crucial to the success of many businesses. The goal of the selection procedure is to identify the best possible solution from among the available options.

Here, we illustrate the case of company's selection of the difficult project. Often, the complexity of such projects is high, and the organization is having trouble keeping track of them all and allocating resources effectively. Optimal management and distribution of the company's scarce resources towards the most difficult tasks is of the utmost importance. Projects can be prioritised according to their level of complexity to assist the business stay organised and keep deliveries on schedule. After preliminary screening, four projects P1, P2, P3 and P4 are considered for further examination. To determine which project is best, we consider the four criterions for project selection: 1) profitability (C1), 2) organizational goals (C2) 3) competitive response (C3) and 4) availability of competent employees (C4). When traditional quantitative representations are inadequate or insufficient, language phrases or variables are frequently and effectively used to describe the circumstances. In our case, company's managers including project managers give ratings to the projects P1, P2, P3 and P4 in terms of linguistic variables as "very poor", "poor", "fair", "good" "very good". Table 1 shows the rating of decision-making panel to the four projects P1, P2, P3 and P4.

Table 2. Project Performance Data

Projects	C1	C2	C3	C4
P1	G	VG	VG	F
P2	VG	F	G	VG
P3	P	VG	VG	VP
P4	VG	P	P	VG

In Table 2, G, VG, F, P, VP denotes good, very good, fair, poor and very poor respectively. The data in table is in qualitative form. For the quantitative form, we use five-point Likert's scale, i.e. a number among 1, 3, 5, 7 and 9 are assigned to each criteria with regard to each project in case of qualitative questions. (Table 3)

Table 3. Project Performance Data in terms of Five point Likert Scale

Projects	C1	C2	C3	C4
P1	7	9	9	5
P2	9	5	7	9
P3	3	9	9	1
P4	9	3	3	9

To convert, the above data into intuitionistic fuzzy values we use the method given by Deng-Chan[(27)].

Distances from each value to the lowest value were used to determine membership degrees, distances from each value to the highest value were used to determine non-membership degrees, and distances from each value to the average of others were used to get the intuitionistic fuzzy index values. These estimated values are then each divided by the sum of their component parts. The intuitionistic fuzzy degrees, for instance, are computed here for P1:

$\mu_{11} = \frac{(7-3|}{(7-3|+(7-9|+|7-7|}$=0.667, $\nu_{11} = \frac{(7-9|}{(7-3|+(7-9|+|7-7|}$=0.333, $\pi_{11} = \frac{(7-7|}{(7-3|+(7-9|+|7-7|}$=0

Table 4 shows the intuitionistic fuzzy values of each project with respect to each criterion.

Using equation (1), we calculate the intuitionistic fuzzy entropy values (for $\alpha = 2,\ \beta = 1$) for each of the project as shown in Table 5. Greater values for entropy suggest greater degrees of uncertainty. After that, normalized value for each row in Table 5 is calculated by adding 1 to the distance between the total sum value of each row with the greatest total sum value. Due to the contrasting nature of the numbers less than and greater than one, we are adding 1. If we take the vertical group as an example, where the largest value is 2.828, then the first normalised value is expressed as:

$(|2.828-2.828|)+1=1$

Table 4. Project Performance data in terms of intuitionistic fuzzy values

Projects	C1	C2	C3	C4
P1	(0.667,0.333,0.0)	(0.706,0.0,0.294)	(0.75,0.0,0.25)	(0.444,0.444,0.111)
P2	(0.75,0.0,0.25)	(0.267,0.533,0.20)	(0.667,0.333,0.0)	(0.727,0.0,0.273)
P3	(0.0,0.60,0.40)	(0.706,0.0,0.294)	(0.75,0.0,0.25)	(0.0,0.615,0.385)
P4	(0.75,0.0,0.25)	(0.0,0.632,0.368)	(0.0,0.60,0.40)	(0.727,0.0,0.273)

Second Normalized value: $(|2.726 - 2.828|) + 1 = 1.102$
Similarly, we can calculate the normalized values for horizontal group.

Table 5. Intuitionistic Fuzzy Entropy values

Projects	C1	C2	C3	C4	Sum	Normalized value
P1	0.888	0.502	0.438	1	2.828	1
P2	0.438	0.929	0.888	0.471	2.726	1.102
P3	0.64	0.502	0.438	0.622	2.202	1.626
P4	0.438	0.600	0.640	0.471	2.149	1.679
Sum	2.404	2.533	2.404	2.564		
Normalized value	1.16	1.031	1.16	1		

The coefficient of each criterion for each project is now represented by multiplying the normalised values of every row by the normalised values of every column. If we take P2 as an example, we find that C2's coefficient with regard to that P2 is = 1.136 (1.102 × 1.031). Table 6 displays all of the coefficients. Weight of each criteria (Table 6) is obtained by dividing each sum of coefficients by the total sum of the sum of the coefficients i.e. 23.525.

Table 6. Weights of each criteria

Projects	C1	C2	C3	C4
P1	1.16	1.031	1.16	1
P2	1.278	1.136	1.278	1.102
P3	1.886	1.676	1.886	1.626
P4	1.948	1.731	1.948	1.679
Sum	6.272	5.574	6.272	5.407
Weights	0.267	0.237	0.267	0.230

Lastly, the relative relevance of each criterion with regard to each project is calculated by multiplying the score of each intuitionistic fuzzy value with the weight of every criterion. Score value for each IFS value (μ_i, ν_i) is calculated as $\mu_i - \nu_i$. Using P1 as an example, C1 has a score of 0.334 and the weight given to this criterion is 0.280, then the importance value of criteria C1 with respect to P1 is 0.334 ×0.267 is 0.089. Table 6 displays the relative importance of projectsP1, P2, P3, P4 with respect to criteria C1, C2, C3, and C4.

Table 7. Ranking of the projects

Projects	C1	C2	C3	C4	Total	Rank
P1	0.089	0.167	0.200	0	0.456	1
P2	0.200	-0.063	0.089	0.167	0.393	2
P3	-0.160	0.167	0.200	-0.141	0.066	3
P4	0.200	-0.150	-0.160	0.167	0.057	4

According to the data in Table 7, the projects have total rank values of 0.456, 0.393, 0.066 and 0.057 respectively. Hence, the project selection preference can be expressed as:

P1→ P2 →P3→ P4. Hence P1 is the best alternative. Also by Rahimi's method [10] and Yuan's method [6] the best alternative is P1 which shows that the proposed method is reliable and consistent with the existing studies. Unlike, Ma et al. [11], Shamsuzzoha et al. [12], Chen and Hung [13] methods which mainly rely on expert opinion for determination of weight, proposed method calculates the weights by a standard method even when the weights are unknown. With different values of parameter, decision makers can get different values of entropy which makes the method more flexible.

4 Conclusion

In this study, we have proposed a new parametric measure of entropy for IFS. The properties of proposed entropy have also been studied. A numerical model is demonstrated to check the reliability of proposed entropy at various values of α and β. The entropy is steady with the structured linguistic variables if value α is greater than 0.5. In order to demonstrate the usefulness of the proposed entropy measure, we have taken into account the problem of choosing the most suitable project for a software company. The study presents several notable contributions, which are outlined as follows:

1. The utilisation of enhanced intuitionistic fuzzy entropy enables a comprehensive and efficient depiction of fuzzy information in the assessment of innovation capability, encompassing uncertain and unknown factors. This approach enhances the precision and impartiality of evaluation outcomes to a certain degree, and presents a viable solution to the intuitionistic fuzzy multi-attribute problem.
2. When selecting a project, every organization requires a cost-effective selection procedure. Expertise alone cannot always decide. We utilized intuitionistic fuzzy entropy to evaluate projects. Expertise matters when selecting a service, particularly when determining a weight range. Our method reduces the influence of subject matter experts on decision-making by calculating weight differently.
3. The entropy measure presented in this paper incorporates the decision maker's outlook during the decision-making process by means of parameter selection. Proposed entropy is more generalised and provides flexibility in the approach.

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