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Araştırma Makalesi / Research Article

Decision-Making Method That Prioritizes User Ranking by Using Intuitionistic Fuzzy Soft Set

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Abstract

Decision-making holds significant importance in real life applications. To manage uncertainties in practical applications, soft sets, fuzzy sets and fuzzy soft sets are commonly used nowadays. Also, the effectiveness of intuitionistic fuzzy soft sets has been highlighted in numerous studies. In daily life, considering users priorities in decisions always affects the decision, for this reason, user priority ranking is important in a decision-making algorithm. This study aims to address decision-making problems by using fuzzy soft set (FSS) and intuitionistic fuzzy soft set (IFSS) frameworks. A key distinction of this work is its consideration of user priority rankings, which are integrated into the decision-making algorithms. This paper introduces two algorithms for decision-making: first one based on fuzzy soft sets and the second one based on intuitionistic fuzzy soft sets. Both approaches enable a user to select an object from a group of multi-attribute objects by considering priority ranking of the user for the attributes, thereby identifying the most suitable choice.

Keywords: Fuzzy set, Fuzzy soft set, Intuitionistic fuzzy soft set, Decision making.

Sezgisel Bulanık Esnek Küme Kullanarak Kullanıcı Sıralamasını Önceliklendiren Karar Verme Yöntemi

Öz

Karar verme, gerçek yaşam uygulamalarında önemli bir yere sahiptir. Pratik uygulamalarda belirsizlikleri yönetmek için günümüzde esnek kümeler, bulanık kümeler ve bulanık esnek kümeler yaygın olarak kullanılmaktadır. Ayrıca sezgisel bulanık esnek kümelerin etkinliği çok sayıda çalışmada vurgulanmıştır. Günlük yaşamda, kararlarda kullanıcıların önceliklerini dikkate almak her zaman kararı etkiler, bu nedenle bir karar verme algoritmasında kullanıcı öncelik sıralaması önemli bir yere sahiptir. Bu çalışma, bulanık esnek küme (FSS) ve sezgisel bulanık esnek küme (IFSS) çerçevelerini kullanarak karar verme problemlerini ele almayı amaçlamaktadır. Bu çalışmanın temel farkı, karar verme algoritmalarına entegre edilen kullanıcı öncelik sıralamalarını dikkate almasıdır. Bu makale karar verme için iki algoritma tanıtmaktadır: birincisi bulanık esnek kümelere dayalı ve ikincisi sezgisel bulanık esnek kümelere dayalıdır. Her iki yaklaşım da kullanıcının nitelikler için öncelik sıralamasını dikkate alarak çok nitelikli nesnelerden oluşan bir gruptan bir nesne seçmesini ve böylece en uygun seçeneği belirlemesini sağlar.

Anahtar Kelimeler: Bulanık küme, Bulanık esnek küme, Sezgisel bulanık esnek küme, Karar verme.

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1. Introduction

Decision-making plays an essential role in various real-world applications, including medical diagnoses, industrial management and more. Nonetheless, the natural uncertainty and vagueness involved in such cases frequently makes decision making a challenging task. With the aim of resolving these challenges, various mathematical tools have been developed over time, including fuzzy set theory introduced by Zadeh in 1965 (Zadeh, 1965) and later extended to soft set theory by Molodtsov in 1999 (Molodtsov, 1999). These fundamental theories have contributed extensively to the area, presenting approaches to manage uncertain data effectively. Maji et al. (2001) built upon the foundations of fuzzy set and soft set theories by combining them presenting the notion of fuzzy soft set theory, which enhancing decision-making in uncertain situations. Subsequent advancements came with Atanassov's intuitionistic fuzzy sets (Atanassov, 1986), which expanded a new dimension to fuzzy sets by integrating degrees of membership and non-membership, offering a more comprehensive approach to modelling uncertainty. Through the combination of intuitionistic fuzzy set and soft set theories, Yong-jie et al. (2010) established the concept of intuitionistic fuzzy soft set (IFSS).

Recent studies have highlighted the potential of IFSS in various applications. Building upon this Jiang et al. (2011) extended the adjustable approach for decision-making based on fuzzy soft sets and developed an adjustable method for decision making using IFSSs through the level soft sets of IFSSs. Similarly, a decision-making approach utilizing entropy weights based on IFSSs was presented by Yang and Qian (2013). Additionally, Das and Kar (2014) proposed a group decision-making method in medical science, utilizing operations grounded in IFSSs. Also an innovative multi-criteria ranking method grounded in IFSSs is generalized by Zhao et al. (2017). Moreover, a group decision-making (GDM) framework for medical diagnosis was developed in (Hu et al. 2019), utilizing a new similarity measure of IFSSs to assign expert weights. Continuing this progression, Adithya, et al. (2024) proposed the concept of circular IFSS theory, which integrates circular intuitionistic fuzzy sets with soft set theory and applied a decision-making problem. More recently, Saqlain and Saeed (2024) brought forward similarity metrics for multi-polar interval-valued intuitionistic fuzzy soft sets (mPIVIFSS). Additionally, some recent decision-making studies employing IFSSs for medical diagnosis models are illustrated in (Masmali et al., 2024) and (Chen and Liu, 2024). A decision-making algortihm using energy of interval-valued hesitant fuzzy soft sets was introduced in (Stojanovic et al., 2025). Two adaptive machine learning approaches utilizing soft decision-making via intuitionistic fuzzy parametrized intuitionistic fuzzy soft matrices were given in (Memiş et al., 2025). Moreover, the circular intuitionistic fuzzy EDAS approach was introduced to manage decision-making challenges within automotive industry in (Imran and Ullah, 2025).

Certainly, the studies conducted using soft set and fuzzy soft set theories are not limited to those mentioned above. For instance, an adjustable approach for fuzzy soft set-based decision-making was proposed and the application of weighted fuzzy soft sets was explored in (Feng et al., 2010). Furthermore the studies in (Polat et al., 2019), (Yaylalı Umul et al., 2021) and (Yaylalı Umul, 2025) developed decision making methods using graphs and intervals on soft sets respectively. Additionally, (α, β)-cuts and its properties in bipolar fuzzy soft set was introduced in (Dalkılıç, 2021). A decision-making algorithm based on bipolar soft rough classes was introduced in (Dalkılıç and Demirtaş, 2022). The topological structure of virtual fuzzy parametrized fuzzy soft sets were examined in (Dalkılıç, 2022). Also some hybrid set types were introduced, which were consisting of combination of fuzzy sets and soft sets and a decision making algorithm was given in (Dalkılıç and Demirtaş, 2023). More recently, Demirtaş et al. (Demirtaş et al., 2024) have introduced various algorithms based on the soft set theory to address decision-making problems involving different types of uncertainties. Dalkılıç and Cangul (2024) were examined decision-making processes that require determining the interactions between objects in two distinct universe set and they presented two decision-making algorithms based on binary soft set. Moreover, a decision-making algorithm based on bipolar fuzzy soft set, with the application on medical diagnosis, was given in (Demirtaş and Dalkılıç, 2024).

In the line with the above mentioned, in this study, two different decision making methods are presented using the concepts of fuzzy soft set and intuitionistic fuzzy soft set. What makes both of these methods different from the previous methods is that, they present the most suitable decision object to the user by considering the ranking of user. In daily life, considering our priorities in our decisions always affects our decisions, for this reason, user priority ranking is important in a decision making algorithm. Thus, by presenting these decision-making algorithms, it is aimed to fill this gap in the literature.

Since the first algorithm is written using only fuzzy soft set, second one is designed similarly to the first algorithm and written using intuitionistic fuzzy soft set. In this study, the features of multi-attribute objects are evaluated as parameter sets of fuzzy and intuitionistic fuzzy soft sets, and the priority ranking of user in object attributes is taken into consideration.

In the second section, the foundational definitions underlying the study are provided and in the third section, some new definitions for the algorithms are introduced, the algorithms are explained and examples are included. Also comparisons with several decision-making cases from the literature are included.

2. Materials and Methods

In this section the foundational definitions underlying the study are provided.

Definition 2.1: (Molodtsov, 1999) Let Υ be an initial universe, Ψ be a set of parameters and $\mathrm{X} \subseteq \Psi$. A pair (Γ, X) is called a soft set over Υ where $\Gamma: \mathrm{X} \rightarrow P(\Upsilon)$ is a set-valued function and $P(\Upsilon)$ is a set of all subsets of Υ.

A soft set (Γ, X) is shown as $(\Gamma, \mathrm{X}) = \{(\psi, \Gamma(\psi)): \psi \in \mathrm{X}\}$ in some studies and sometimes $(\psi, \Gamma(\psi))$ is written as $\Gamma(\psi)$ just for making a shorter notation.

Definition 2.2: (Zadeh, 1965) A fuzzy set A in Υ is defined by a characteristic function $\mu_A: \Upsilon \rightarrow [0,1]$ such that

$$A = \{(\gamma, \mu_A(\gamma)): \gamma \in \Upsilon, \mu_A(\gamma) \in [0,1]\}$$

Definition 2.3: (Maji et al., 2004) Let $\wp(\Upsilon)$ denotes the set of all fuzzy sets in Υ and let Ψ be a parameter set. A pair (Γ, Ψ) is called a fuzzy soft set over Υ if $\Gamma: \Psi \rightarrow \wp(\Upsilon)$ such that

$$(\Gamma, \Psi) = \{(\psi, \Gamma(\psi)): \psi \in \Psi, \Gamma(\psi) \in \wp(\Upsilon)\}.$$

Definition 2.4: (Atanassov, 1986) An intuitionistic fuzzy set A on universe Υ is defined as $A = \{(\gamma, \mu_A(\psi), \nu_A(\psi)): \gamma \in \Upsilon, \mu_A(\gamma), \nu_A(\gamma) \in [0,1]\}$ where $\mu_A: \Upsilon \rightarrow [0,1]$ and $\nu_A: \Upsilon \rightarrow [0,1]$ with $0 \leq \mu_A(\gamma) + \nu_A(\gamma) \leq 1$ for all $\gamma \in \Upsilon$. The values $\mu_A(\gamma)$ and $\nu_A(\gamma)$ represents the degree of membership and non-membership values of γ to A respectively.

Definition 2.5: (Xui, 2010) Let Υ be an initial universe Ψ be a set of parameters and IFS(Υ) denoted the intuitionistic fuzzy power set of Υ and $\mathrm{X} \subseteq \Psi$. A pair (Γ, Ψ) is called intuitionistic fuzzy soft set where $\Gamma: \mathrm{X} \rightarrow \mathrm{IFS}(\Upsilon)$.

An intuitionistic fuzzy soft set is a parameterized family of intuitionistic fuzzy subsets of Υ. For all $\psi \in \mathrm{X}$, $\Gamma(\psi)$ is an intuitionistic fuzzy set on Υ such that,

$$\{(\psi, \Gamma(\psi)): \ \Gamma(\psi) = \{(\gamma, \mu_A(\gamma), \nu_A(\gamma)): \gamma \in \Upsilon, \ \mu_A(\gamma), \nu_A(\gamma) \in [0,1]\}\}$$

In this study, we have multi-attribute decision objects and features of these objects are evaluated as a parameter set of FSS and IFSS.

3. Findings and Discussion

In this section, two algorithms for decision making are given, first one is based on fuzzy soft set and second is based on intuitionistic fuzzy soft set. In the both methods one user decides to choose an object where there are multiple objects with multi-attributes and user has a priority ranking in the attributes of the objects. Both methods determine the most suitable decision object among multi-attribute items by taking user priority rankings into account.

Following definitions are going to be used in the both algorithms.

Definition 3.1: Let we have a relation on a parameter set Ψ. Priority ranking value of a parameter $\psi \in \Psi$ is defined by the number of how many times a parameter precedes another parameter in a relation and denoted by p_{ψ}.

Definition 3.2: Let we have a relation on a parameter set Ψ. Non-prioritization value of a parameter $\psi \in \Psi$ is defined by the number of how many times a parameter comes after other parameters in a relation and denoted by np_{ψ}.

Definition 3.3: Let $(\Gamma, \Psi) = \{(\psi, \Gamma(\psi)) : \psi \in \Psi, \Gamma(\psi) \in \wp(\Upsilon)\}$ be a fuzzy soft set and p_{ψ} be a priority ranking value of a parameter ψ. Priority ranking degree of an element $\gamma \in \Upsilon$ with respect to the parameter $\psi \in \Psi$ is defined as $P_{\psi}(\gamma) = p_{\psi}.\mu_A(\gamma)$, where $\mu_A(\gamma)$ is the membership degree of γ.

Definition 3.4: Let $(\Gamma, \Psi) = \{(\psi, \Gamma(\psi)) : \psi \in \Psi, \Gamma(\psi) \in \wp(\Upsilon)\}$ be a fuzzy soft set and np_{ψ} be a non-prioritization value of a parameter ψ. Non-prioritization degree of an element $\gamma \in \Upsilon$ with respect to the parameter $\psi \in \Psi$ is defined as $NP_{\psi}(\gamma) = np_{\psi}.\mu_A(\gamma)$, where $\mu_A(\gamma)$ is the membership degree of γ.

Definition 3.5: Let $(\Gamma, \Psi) = \{(\psi, \Gamma(\psi)) : \psi \in \Psi, \Gamma(\psi) \in \wp(\Upsilon)\}$ be a fuzzy soft set; p_{ψ} and np_{ψ} be a priority ranking and non-prioritization values of a parameter ψ; $P_{\psi}(\gamma)$ and $NP_{\psi}(\gamma)$ be a priority ranking degree and a non-prioritization degree of an element $\gamma \in \Upsilon$ with respect to the parameter $\psi \in \Psi$. Score function for a FSS is a function from Υ to $\mathbb{R}^2$, defined as, for each element $\gamma \in \Upsilon$, $S(\gamma) = (S_1(\gamma), S_2(\gamma))$ where,

$S_1(\gamma) = \sum_{\psi \in \Psi} p_{\psi}.\mu_A(\gamma) = \sum_{\psi \in \Psi} P_{\psi}(\gamma)$ and

$S_2(\gamma) = \sum_{\psi \in \Psi} np_{\psi}.\mu_A(\gamma) = \sum_{\psi \in \Psi} NP_{\psi}(\gamma)$, i.e.,

$$S: \Upsilon \to \mathbb{R}^2,$$

$$S(\gamma) = (S_1(\gamma), S_2(\gamma)) = \left(\sum_{\psi \in \Psi} P_{\psi}(\gamma), \sum_{\psi \in \Psi} NP_{\psi}(\gamma)\right).$$

3.1. Decision Making Method based on fuzzy soft set

In this method, in a fuzzy soft set, the membership degrees of desired objects are determined based on how effectively the objects meet the required properties and the properties of the objects is the set of parameter of FSS. In the first method, the decision is derived based on the membership degrees of FSS and the ordered of properties of the objects.

The following is the steps of the algorithm based on fuzzy soft set which considers user priority rankings in the selection of multi-attribute objects.

Algorithm based on fuzzy soft set

Step 1. Write fuzzy soft set (Γ, Ψ).

Step 2. Give the order of the parameters.

Step 3. Find priority ranking value p_ψ for all parameters $\psi \in \Psi$.

Step 4. Find non-prioritization values np_ψ for all $\psi \in \Psi$.

Step 5. Find priority ranking degree of elements of the universal set with respect to the parameters.

Step 6. Find non-prioritization degree of elements of the universal set with respect to the parameters.

Step 7. Evaluate score function $S(\gamma) = (S_1(\gamma), S_2(\gamma))$ for all $\gamma \in \Upsilon$.

Step 8. Choice object is the object is γ_c where $S_1(\gamma_c) = max\{S_1(\gamma): \gamma \in \Upsilon\}$. If there is more than one γ_c then choice object is γ_{co} where

$S_2(\gamma_{co}) = max\{S_2(\gamma_c): \gamma_c \in \{\gamma_c: S_1(\gamma_c) = max\{S_1(\gamma): \gamma \in \Upsilon\}\}$.

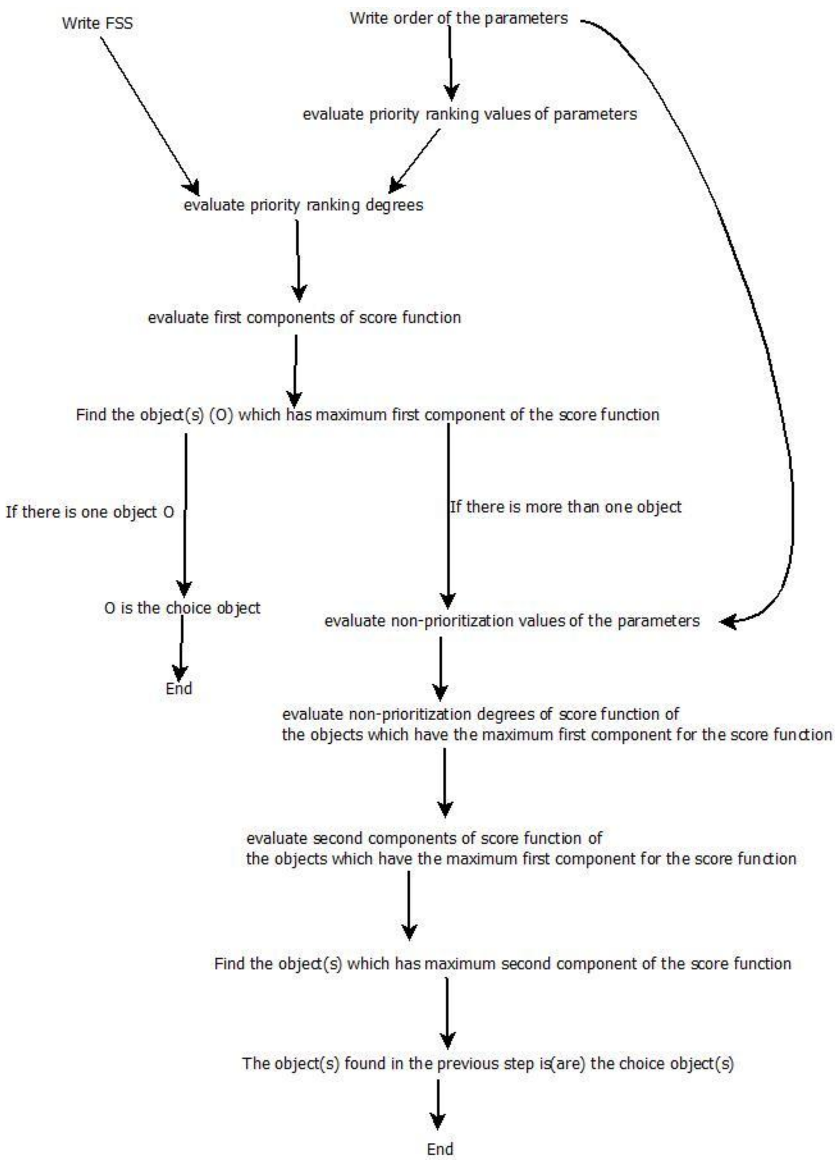

Figure 1. Flowchart of the Algorithm 1 of the decision-making method based on FSS.

Pseudo-code for steps of Algorithm 1 is as follow:

Step 1. Write fuzzy soft set $(\Gamma,\Psi)=\{(\psi,\Gamma(\psi)):\psi\in\Psi,\Gamma(\psi)\in\wp(\Upsilon)\}$.

Input the parameter set : $\Psi=\{\psi_1,\psi_2,\dots,\psi_n\}$.

Input the universal set: $\Upsilon=\{\gamma_1,\gamma_2,\dots\gamma_m\}$.

Step 2. Write the order of the parameters.

Step 3.

For (i=1, i<=n, i++)

$p_{\psi_i}=0$

For (j=1, j<=n, j++)

(If $\psi_i\geq\psi_j$, then $p_{\psi_i}=p_{\psi_i}+1$)

Step 4.

For (i=1, i<=n, i++)

$np_{\psi_i}=0$

For (j=1, j<=n, j++)

(If $\psi_i\leq\psi_j$, then $np_{\psi_i}=np_{\psi_i}+1$)

Step 5.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$P_{\psi_i}(\gamma_j)=p_{\psi_i}.\mu_A(\gamma_j)$

Step 6.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$NP_{\psi_i}(\gamma_j)=np_{\psi_i}.\mu_A(\gamma_j)$

Step 7.

For (j=1, j<=m, j++)

$S_1(\gamma_j)=\sum_{\psi\in\Psi}P_\psi(\gamma_j)$ and $S_2(\gamma_j)=\sum_{\psi\in\Psi}NP_\psi(\gamma_j)$.

Step 8.

$S_1(\gamma_c)=S_1(\gamma_1)$

For (j=1, j<=m, j++)

If $S_1(\gamma_c)\leq S_1(\gamma_j)$, then $S_1(\gamma_c)=S_1(\gamma_j)$.

For (j=1, j<=m, j++)

(count=0

Maxset=∅

If $S_1(\gamma_j)=S_1(\gamma_c)$, count=count+1, add γ_j. to Maxset.)

If count=1, then choice object is γ_c.

If count>1, $S_2(\gamma_{co})$ =first element of Maxset

($count_1$=0

$Maxset_2 = \emptyset$

For (k=1, k<=count, k++)

If $S_2(\gamma_{co}) \leq S_2(\gamma_k)$, then $S_2(\gamma_{co}) = S_2(\gamma_k)$.

$count_1$=$count_1 + 1$

add γ_k to $Maxset_2$)

If $count_1$=1, then choice object is γ_{co}.

If $count_1$>1, choice objects are element of $Maxset_2$.

Example 3.6: Let $\Psi = \{\psi_1: \text{CPU}, \psi_2: \text{Memory}, \psi_3: \text{Harddisk}, \psi_4: \text{GPU}\}$ be a parameter set and $\Upsilon = \{\gamma_1, \gamma_2, \gamma_3, \gamma_4\}$ be an initial universe of computers that taken into consideration. The features of computers given in the following Table 1.

Table 1. Attributes of computer that taken into the consideration.

	ψ_1:CPU (Central Processing Unit)	ψ_2: Memory	ψ_3: Harddisk	ψ_4: GPU (graphics processing unit)
γ_1	i5 1235U	32 GB	128 GB SSD	RTX 4050
γ_2	i3 1215U	16 GB	256 GB SSD	RTX 4090
γ_3	i7 13650HX	4 GB	1 TB SSD	RTX 3060
γ_4	i9 14900HX	8 GB	512 GB SSD	RTX 2050

Then according to the Table 1, fuzzy soft set (Γ, Ψ) can be defined as follows

$\Gamma(\psi_1) = \{\frac{\gamma_1}{0,2}, \frac{\gamma_2}{0,1}, \frac{\gamma_3}{0,5}, \frac{\gamma_4}{0,7}\}$,

$\Gamma(\psi_2) = \{\frac{\gamma_1}{0,9}, \frac{\gamma_2}{0,5}, \frac{\gamma_3}{0,1}, \frac{\gamma_4}{0,3}\}$,

$\Gamma(\psi_3) = \{\frac{\gamma_1}{0,1}, \frac{\gamma_2}{0,2}, \frac{\gamma_3}{0,6}, \frac{\gamma_4}{0,4}\}$,

$\Gamma(\psi_4) = \{\frac{\gamma_1}{0,4}, \frac{\gamma_2}{0,8}, \frac{\gamma_3}{0,2}, \frac{\gamma_4}{0,1}\}$.

Let for the user the most important thing in the computer is its Harddisk, additionally, memory and GPU have the same importance for this user but they are important than CPU. After this priority ranking of the user the relation on Ψ is $\{(\psi_1, \psi_1), (\psi_2, \psi_2), (\psi_3, \psi_3), (\psi_4, \psi_4), (\psi_2, \psi_1), (\psi_3, \psi_1), (\psi_4, \psi_1), (\psi_3, \psi_2), (\psi_4, \psi_2), (\psi_2, \psi_4), (\psi_3, \psi_4)\}$.

Priority ranking values of parameters $\psi_1, \psi_2, \psi_3, \psi_4$ are $p_{\psi_1} = 1$, $p_{\psi_2} = 3$, $p_{\psi_3} = 4$, $p_{\psi_4} = 3$. Non-prioritization values of parameters $\psi_1, \psi_2, \psi_3, \psi_4$ are $np_{\psi_1} = 4$, $np_{\psi_2} = 3$, $np_{\psi_3} = 1$, $np_{\psi_4} = 3$.

Priority ranking degrees of elements Υ with respect to the parameter ψ_1 are

$P_{\psi_1}(\gamma_1) = 1.0,2 = 0,2$, $P_{\psi_1}(\gamma_2) = 1.0,1 = 0,1$, $P_{\psi_1}(\gamma_3) = 1.0,5 = 0,5$ and $P_{\psi_1}(\gamma_4) = 1.0,7 = 0,7$.

Priority ranking degrees of elements Υ with respect to the parameter ψ_2 are

$P_{\psi_2}(\gamma_1) = 3.0,9 = 1,8$, $P_{\psi_2}(\gamma_2) = 3.0,5 = 1,5$, $P_{\psi_2}(\gamma_3) = 3.0,1 = 0,3$ and $P_{\psi_2}(\gamma_4) = 3.0,3 = 0,9$.

Priority ranking degrees of elements Υ with respect to the parameter ψ_3 are

$P_{\psi_3}(\gamma_1) = 4.0,1 = 0,4$, $P_{\psi_3}(\gamma_2) = 4.0,2 = 0,8$, $P_{\psi_3}(\gamma_3) = 4.0,6 = 2,4$ and $P_{\psi_3}(\gamma_4) = 4.0,4 = 1,6$.

Priority ranking degrees of elements Υ with respect to the parameter ψ_4 are

$P_{\psi_4}(\gamma_1) = 3.0,4 = 1,2$, $P_{\psi_4}(\gamma_2) = 3.0,8 = 2,4$, $P_{\psi_4}(\gamma_3) = 3.0,2 = 0,6$and $P_{\psi_4}(\gamma_4) = 3.0,1 = 0,3$.

Non-prioritization degree of elements Υ with respect to the parameter ψ_1 are

$NP_{\psi_1}(\gamma_1) = 4.0,2 = 0,8$, $NP_{\psi_1}(\gamma_2) = 4.0,1 = 0,4$, $NP_{\psi_1}(\gamma_3) = 4.0,5 = 2$, $NP_{\psi_1}(\gamma_4) = 4.0,7 = 2,8$.

Non-prioritization degree of elements Υ with respect to the parameter ψ_2 are

$NP_{\psi_2}(\gamma_1) = 3.0,9 = 1,8$, $NP_{\psi_2}(\gamma_2) = 3.0,5 = 1,5$, $NP_{\psi_2}(\gamma_3) = 3.0,1 = 0,3$, $NP_{\psi_2}(\gamma_4) = 3.0,3 = 0,9$.

Non-prioritization degree of elements Υ with respect to the parameter ψ_3 are

$NP_{\psi_3}(\gamma_1) = 1.0,1 = 0,1$, $NP_{\psi_3}(\gamma_2) = 1.0,2 = 0,2$, $NP_{\psi_3}(\gamma_3) = 1.0,6 = 0,6$, $NP_{\psi_3}(\gamma_4) = 1.0,4 = 0,4$.

Non-prioritization degree of elements Υ with respect to the parameter ψ_4 are

$NP_{\psi_4}(\gamma_1) = 3.0,4 = 1,2$, $NP_{\psi_4}(\gamma_2) = 3.0,8 = 2,4$, $NP_{\psi_4}(\gamma_3) = 3.0,2 = 0,6$, $NP_{\psi_4}(\gamma_4) = 3.0,1 = 0,3$.

Now let us evaluate the score function $S(\gamma_i) = (S_1(\gamma_i), S_2(\gamma_i))$ for $i = 1,2,3,4$ where

$S_1(\gamma_1) = 0,2 + 1,8 + 0,4 + 1,2 = 3,6$

$S_2(\gamma_1) = 0,8 + 1,8 + 0,1 + 1,2 = 3,9$

$S_1(\gamma_2) = 0,1 + 1,5 + 0,8 + 2,4 = 4,8$

$S_2(\gamma_2) = 0,4 + 1,5 + 0,2 + 2,4 = 3,5$

$S_1(\gamma_3) = 0,5 + 0,1 + 2,4 + 0,6 = 3,6$

$S_2(\gamma_3) = 2 + 0,1 + 0,6 + 0,6 = 3,3$

$S_1(\gamma_4) = 0,7 + 0,9 + 1,6 + 0,3 = 3,5$

$S_2(\gamma_4) = 2,8 + 0,9 + 0,4 + 0,3 = 4,4$

According to the score function, γ_2 is the choice object. Therefore, for this users' priority rankings' the most suitable choice object is the computer γ_2.

3.2. Decision Making Method based on intuitionistic fuzzy soft set

In this method, in intuitionistic fuzzy soft set, since the membership degrees of desired objects are determined based on how effectively the objects meet the required properties, the non-membership degrees of desired objects are determined based on how effectively the objects do not meet the required properties and the properties of the objects is the set of parameter of IFSS. In the second method, the decision is derived based on the membership and non-membership degrees of IFSS and the order of properties of the objects.

Following definitions are going to be used in the second algorithm.

Definition 3.7: Let $(\Gamma,\Psi)=\{(\psi,\Gamma(\psi)):\psi\in\Psi,\Gamma(\psi)\in \text{IFS}(\Upsilon)\}$ be an intuitionistic fuzzy soft set and p_ψ be a priority ranking value of a parameter ψ. Nonmember priority ranking degree of an element $\gamma\in\Upsilon$ of the universal set with respect to the parameter ψ is $\tilde{P}_\psi(\gamma)=p_\psi.\nu_A(\gamma)$, where $\nu_A(\gamma)$ is the non-membership degree of γ.

Definition 3.8: Let $(\Gamma,\Psi)=\{(\psi,\Gamma(\psi)):\psi\in\Psi,\Gamma(\psi)\in \text{IFS}(\Upsilon)\}$ be an intuitionistic fuzzy soft set and np_ψ be a non-prioritization value of a parameter ψ. Nonmember non-prioritization degree of an element $\gamma\in\Upsilon$ of the universal set with respect to the parameter ψ is $\widetilde{NP}_\psi(\gamma)=np_\psi.\nu_A(\gamma)$, where $\nu_A(\gamma)$ is the non-membership degree of γ.

Definition 3.9: Let $(\Gamma,\Psi)=\{(\psi,\Gamma(\psi)):\psi\in\Psi,\Gamma(\psi)\in \text{IFS}(\Upsilon)\}$ be an intuitionistic fuzzy soft set; p_ψ and np_ψ be a priority ranking and a non-prioritization value of a parameter ψ; $\tilde{P}_\psi(\gamma)$ and $\widetilde{NP}_\psi(\gamma)$ be a nonmember priority ranking degree and a nonmember non-prioritization degree of an element $\gamma\in\Upsilon$ of the universal set with respect to the parameter ψ. Score function for an IFSS is a function from Υ to $\mathbb{R}^2$, defined as, for each element $\gamma\in\Upsilon$, $S(\gamma)=\left(S_{1_0}(\gamma),S_{2_0}(\gamma)\right)$ where

$S_{1_0}(\gamma)=S_1(\gamma)-\tilde{S}_1(\gamma)$,

$S_1(\gamma)=\sum_{\psi\in\Psi}p_\psi.\mu_A(\gamma)=\sum_{\psi\in\Psi}P_\psi(\gamma)$,

$\tilde{S}_1(\gamma)=\sum_{\psi\in\Psi}p_\psi.\nu_A(\gamma)=\sum_{\psi\in\Psi}\tilde{P}_\psi(\gamma)$

and

$S_{2_0}(\gamma)=S_2(\gamma)-\tilde{S}_2(\gamma)$,

$S_2(\gamma)=\sum_{\psi\in\Psi}np_\psi.\mu_A(\gamma)=\sum_{\psi\in\Psi}NP_\psi(\gamma)$,

$\tilde{S}_2(\gamma)=\sum_{\psi\in\Psi}np_\psi.\nu_A(\gamma)=\sum_{\psi\in\Psi}\widetilde{NP}_\psi(\gamma)$.

i.e.,

$$S:\Upsilon\to\mathbb{R}^2$$
$$S(\gamma)=(S_{1_0}(\gamma),S_{2_0}(\gamma))\ =(\textstyle\sum_{\psi\in\Psi}P_\psi(\gamma)-\sum_{\psi\in\Psi}\tilde{P}_\psi(\gamma)\,,\sum_{\psi\in\Psi}NP_\psi(\gamma)-\sum_{\psi\in\Psi}\widetilde{NP}_\psi(\gamma)).$$

The following is the steps of the algorithm based on intuitionistic fuzzy soft set which considers user priority rankings in the selection of multi-attribute objects.

Algorithm based on intuitionistic fuzzy soft set

Step 1. Write intuitionistic fuzzy soft set (Γ, Ψ).

Step 2. Give the order of the parameters.

Step 3. Find priority ranking value of parameters p_ψ for all $\psi \in \Psi$.

Step 4. Find non-prioritization values of parameters np_ψ for all $\psi \in \Psi$.

Step 5. Find priority ranking degree of elements of the universal set with respect to the parameters.

Step 6. Evaluate nonmember priority ranking degree of elements of the universal set with respect to the parameters.

Step 7. Find non-prioritization degree of elements of the universal set with respect to the parameters.

Step 8. Evaluate nonmember non-prioritization degree of elements of the universal set with respect to the parameters.

Step 9. Evaluate score function $S(\gamma) = \left(S_{1_0}(\gamma), S_{2_0}(\gamma)\right)$ for all $\gamma \in \Upsilon$.

Step 10. Choice object is the object γ_c, where $S_{1_0}(\gamma_c) = max\{S_{1_0}(\gamma): \gamma \in \Upsilon\}$. If there is more than one γ_c, then choice object is γ_{co}, where

$S_{2_0}(\gamma_{co}) = max\{S_{2_0}(\gamma_c): \gamma_c \in \{\gamma_c: S_{1_0}(\gamma_c) = max\{S_{1_0}(\gamma): \gamma \in \Upsilon\}\}$.

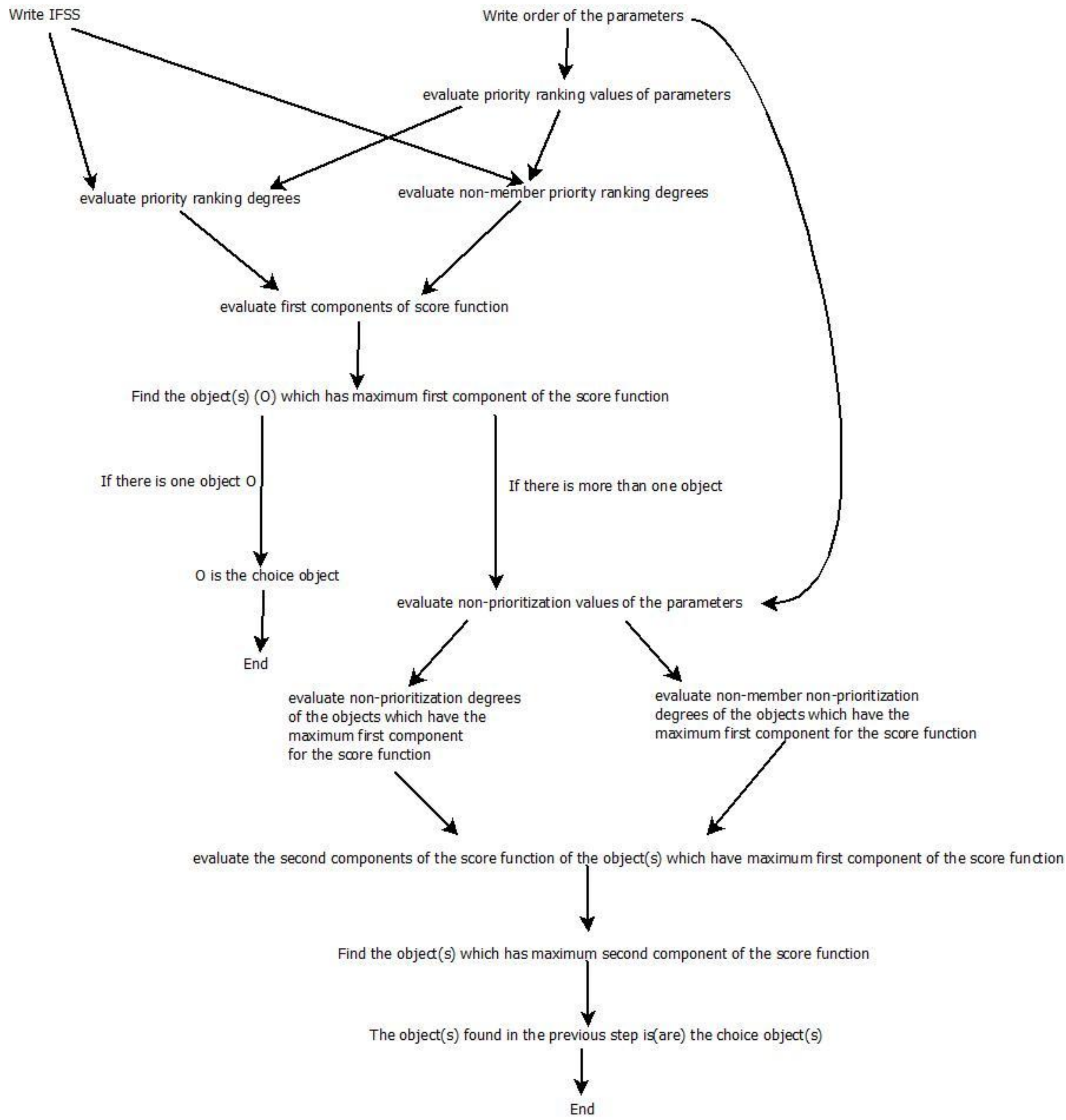

Figure 2. Flowchart of the Algorithm 2 of the decision-making method based on IFSS.

Pseudo-code of steps of Algorithm 2 is as follow:

Step 1. Write intuitionistic fuzzy soft set $(\Gamma, \Psi) = \{(\psi, \Gamma(\psi)) : \psi \in \Psi, \Gamma(\psi) \in \mathrm{IFS}(\Upsilon)\}$.

Input the parameter set: $\Psi = \{\psi_1, \psi_2, \ldots, \psi_n\}$.

Input the universal set: $\Upsilon = \{\gamma_1, \gamma_2, \ldots, \gamma_m\}$.

Step 2. Write the order of the parameters.

Step 3.

For (i=1, i<=n, i++)

$p_{\psi_i} = 0$

(For (j=1, j<=n, j++)

(If $\psi_i \geq \psi_j$, then $p_{\psi_i} = p_{\psi_i} + 1$))

Step 4.

For (i=1, i<=n, i++)

$np_{\psi_i} = 0$

(For (j=1, j<=n, j++)

(If $\psi_i \leq \psi_j$, then $np_{\psi_i} = np_{\psi_i} + 1$))

Step 5.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$P_{\psi_i}(\gamma_j) = p_{\psi_i} . \mu_A(\gamma_j)$

Step 6.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$\tilde{P}_{\psi_i}(\gamma_j) = p_{\psi_i} . \nu_A(\gamma_j)$

Step 7.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$NP_{\psi_i}(\gamma_j) = np_{\psi_i} . \mu_A(\gamma_j)$

Step 8.

For (j=1, j<=m, j++)

For (i=1, i<=n, i++)

$\widetilde{NP}_{\psi_i}(\gamma_j) = np_{\psi_i} . \nu_A(\gamma_j)$

Step 9.

For (j=1, j<=m, j++)

$S_1(\gamma_j) = \sum_{\psi \in \Psi} P_\psi(\gamma_j)$ and $\tilde{S}_1(\gamma_j) = \sum_{\psi \in \Psi} \tilde{P}_\psi(\gamma_j)$

$S_{1_0}(\gamma_j) = S_1(\gamma_j) - \tilde{S}_1(\gamma_j)$,

$S_2(\gamma_j) = \sum_{\psi \in \Psi} NP_\psi(\gamma_j)$ and $\tilde{S}_2(\gamma_j) = \sum_{\psi \in \Psi} \widetilde{NP}_\psi(\gamma_j)$.

$S_{2_0}(\gamma_j) = S_2(\gamma_j) - \tilde{S}_2(\gamma_j)$

Step 10.

($S_{1_0}(\gamma_c) = S_{1_0}(\gamma_1)$

For (j=1, j<=m, j++)

If $S_{1_0}(\gamma_c) \leq S_{1_0}(\gamma_j)$, then $S_{1_0}(\gamma_c) = S_{1_0}(\gamma_j)$.)

For (j=1, j<=m, j++)

(count=0

Maxset=∅

If $S_{1_0}(\gamma_j) = S_{1_0}(\gamma_c)$, count=count+1, add γ_j to Maxset.)

If count=1, then choice object is γ_c.

If count>1,

($S_{2_0}(\gamma_{co})$ =first element of Maxset

$count_1$=0

$Maxset_2 = \emptyset$

For (k=1, k<=count, k++)

(If $S_{2_0}(\gamma_{co}) \leq S_{2_0}(\gamma_k)$, then $S_{2_0}(\gamma_{co}) = S_{2_0}(\gamma_k)$.

$count_1$=$count_1 + 1$

add γ_k to $Maxset_2$)

If $count_1$=1, then choice object is γ_{co}.

If $count_1$>1, choice objects are element of $Maxset_2$.)

Example 3.10: Let us consider the same initial universe and the same parameter set in the Example 3.6, where user has the same priority ranking but now let us use intuitionistic fuzzy soft set to make decision**.** According to the Table 1, IFSS (Γ, Ψ) can be defined as follows.

$\Gamma(\psi_1) = \{\frac{\gamma_1}{0.2,0.6}, \frac{\gamma_2}{0.1,0.9}, \frac{\gamma_3}{0.5,0.3}, \frac{\gamma_4}{0.7,0.1}\}$,

$\Gamma(\psi_2) = \{\frac{\gamma_1}{0.9,0.1}, \frac{\gamma_2}{0.5,0.2}, \frac{\gamma_3}{0.1,0.5}, \frac{\gamma_4}{0.3,0.3}\}$,

$\Gamma(\psi_3) = \{\frac{\gamma_1}{0.1,0.9}, \frac{\gamma_2}{0.2,0.8}, \frac{\gamma_3}{0.6,0.2}, \frac{\gamma_4}{0.4,0.3}\}$,

$\Gamma(\psi_4) = \{\frac{\gamma_1}{0.4,0.3}, \frac{\gamma_2}{0.8,0.2}, \frac{\gamma_3}{0.2,0.4}, \frac{\gamma_4}{0.1,0.5}\}$.

Priority ranking degrees and non-prioritization degrees of elements Υ are same since the memberships values are same. So, let us evaluate non-member priority ranking degrees and nonmember non-prioritization degree of an elements Υ with respect to the parameters.

Nonmember priority ranking degrees of elements Υ with respect to the parameter ψ_1 are $\tilde{P}_{\psi_1}(\gamma_1) = 1.0{,}6 = 0.6$, $\tilde{P}_{\psi_1}(\gamma_2) = 1.0{,}9 = 0{,}9$, $\tilde{P}_{\psi_1}(\gamma_3) = 1.0{,}3 = 0{,}3$ and $\widetilde{P_{\psi_1}}(\gamma_4) = 1.0{,}1 = 0{,}1$.

Nonmember priority ranking degrees of elements Υ with respect to the parameter ψ_2 are $\tilde{P}_{\psi_2}(\gamma_1) = 3.0{,}1 = 0{,}3$, $\tilde{P}_{\psi_2}(\gamma_2) = 3.0{,}2 = 0{,}6$, $\tilde{P}_{\psi_2}(\gamma_3) = 3.0{,}5 = 1{,}5$ and $\tilde{P}_{\psi_2}(\gamma_4) = 3.0{,}3 = 0{,}9$.

Nonmember priority ranking degrees of elements Υ with respect to the parameter ψ_3 are $\tilde{P}_{\psi_3(\gamma_1)} = 4.0{,}9 = 3{,}6$, $P_{\psi_3(\gamma_2)} = 4.0{,}8 = 3{,}2$, $\tilde{P}_{\psi_3(\gamma_3)} = 4.0{,}2 = 0{,}8$ and $\tilde{P}_{\psi_3}(\gamma_4) = 4.0{,}3 = 1{,}2$.

Nonmember priority ranking degrees of elements Υ with respect to the parameter ψ_4 are $\tilde{P}_{\psi_4(\gamma_1)} = 3.0,3 = 0,9$, $\tilde{P}_{\psi_4(\gamma_2)} = 3.0,2 = 0,6$, $\tilde{P}_{\psi_4(\gamma_3)} = 3.0,4 = 1,2$ and $\tilde{P}_{\psi_4}(\gamma_4) = 3.0,5 = 2,5$.

Nonmember non-prioritization degree of elements Υ with respect to the parameter ψ_1 are $\widetilde{NP}_{\psi_1}(\gamma_1) = 4.0,6 = 2,4$, $\widetilde{NP}_{\psi_1}(\gamma_2) = 4.0,9 = 3,6$, $\widetilde{NP}_{\psi_1}(\gamma_3) = 4.0,3 = 1,2$ and $\widetilde{NP}_{\psi_1}(\gamma_4) = 4.0,1 = 0,4$.

Nonmember non-prioritization degree of elements Υ with respect to the parameter ψ_2 are $\widetilde{NP}_{\psi_2}(\gamma_1) = 3.0,1 = 0,3$, $\widetilde{NP}_{\psi_2(\gamma_2)} = 3.0,2 = 0,6$, $\widetilde{NP}_{\psi_2}(\gamma_3) = 3.0,5 = 1,5$ and $\widetilde{NP}_{\psi_2}(\gamma_4) = 3.0,3 = 0,9$.

Nonmember non-prioritization degree of elements Υ with respect to the parameter ψ_3 are $\widetilde{NP}_{\psi_3(\gamma_1)} = 1.0,9 = 0,9$, $\widetilde{NP}_{\psi_3(\gamma_2)} = 1.0,8 = 0,8$, $\widetilde{NP}_{\psi_3}(\gamma_3) = 1.0,2 = 0,2$ and $\widetilde{NP}_{\psi_3}(\gamma_4) = 1.0,3 = 0,3$.

Nonmember non-prioritization degree of elements Υ with respect to the parameter ψ_3 are $\widetilde{NP}_{\psi_4(\gamma_1)} = 3.0,3 = 0,9$, $\widetilde{NP}_{\psi_4(\gamma_2)} = 3.0,2 = 0,6$, $\widetilde{NP}_{\psi_4}(\gamma_3) = 3.0,4 = 1,2$ and $\widetilde{NP}_{\psi_4}(\gamma_4) = 3.0,5 = 1,5$.

Now let us evaluate the score function $S(\gamma_i) = \left(S_{1_0}(\gamma_i), S_{2_0}(\gamma_i)\right)$ for $i = 1,2,3,4$, where

$S_1(\gamma_1) = 0,2 + 1,8 + 0,4 + 1,2 = 3,6$

$S_2(\gamma_1) = 0,8 + 1,8 + 0,1 + 1,2 = 3,9$

$\tilde{S}_1(\gamma_1) = 0,6 + 0,3 + 3,6 + 0,9 = 5,4$

$\tilde{S}_2(\gamma_1) = 2,4 + 0,3 + 0,9 + 0,9 = 4,5$

$S_1(\gamma_2) = 0,1 + 1,5 + 0,8 + 2,4 = 4,8$

$S_2(\gamma_2) = 0,4 + 1,5 + 0,2 + 2,4 = 3,5$

$\tilde{S}_1(\gamma_2) = 0,9 + 0,6 + 3,2 + 0,6 = 5,9$

$\tilde{S}_2(\gamma_2) = 3,6 + 0,6 + 0,8 + 0,6 = 5,6$

$S_1(\gamma_3) = 0,5 + 0,1 + 2,4 + 0,6 = 3,6$

$S_2(\gamma_3) = 2 + 0,1 + 0,6 + 0,6 = 3,3$

$\tilde{S}_1(\gamma_3) = 0,3 + 1,5 + 0,8 + 1,2 = 3,8$

$\tilde{S}_2(\gamma_3) = 1,2 + 1,5 + 0,2 + 1,2 = 5,1$

$S_1(\gamma_4) = 0,7 + 0,9 + 1,6 + 0,3 = 3,5$

$S_2(\gamma_4) = 2,8 + 0,9 + 0,4 + 0,3 = 4,4$

$\tilde{S}_1(\gamma_4) = 0{,}1 + 0{,}9 + 1{,}2 + 1{,}5 = 3{,}7$

$\tilde{S}_2(\gamma_4) = 0{,}4 + 0{,}9 + 0{,}3 + 1{,}5 = 3{,}1$

$S_{1_0}(\gamma_1) = 3{,}6 - 5{,}4 = -1{,}8$ and $S_{2_0}(\gamma_1) = 3{,}9 - 4{,}5 = -0{,}6$.

$S_{1_0}(\gamma_2) = 4{,}8 - 5{,}3 = -0{,}5$ and $S_{2_0}(\gamma_2) = 3{,}5 - 5{,}6 = -2{,}1$.

$S_{1_0}(\gamma_3) = 3{,}6 - 3{,}8 = -0{,}2$ and $S_{2_0}(\gamma_3) = 3{,}3 - 5{,}1 = -1{,}8$.

$S_{1_0}(\gamma_4) = 3{,}5 - 3{,}7 = -0{,}2$ and $S_{2_0}(\gamma_4) = 4{,}4 - 3{,}1 = 1{,}3$.

According to the score function, γ_3 and γ_4 have maximum values for S_{1_0} and since $S_{2_0}(\gamma_4) \geq S_{2_0}(\gamma_3)$, γ_4 is the choice object.

As can be seen from Examples 3.6 and 3.10, different results can be obtained in the same decision-making scenario using FSS and IFSS. While only the membership degrees are used in the method using FSS, the non-membership degrees are also added in the method applied using IFSS, and therefore a more realistic result is obtained for priority ranking of the user.

3.3. Analysis of the proposed method

In this section, some comparative examples are given. In these examples, the results obtained by applying the algorithms introduced in this study were compared with those obtained from some previous studies (Feng et al., 2010) and (Jiang et al., 2011). In Example 3.11, since there is FSS, the first algorithm was applied, yielding same result with previous study (Feng et al., 2010). In Example 3.12, the process started by considering there is FSS and applying the first algorithm. Also, the second algorithm is applied by considering there is IFSS in Example 3.12. The result obtained without ranking is same as the previous study (Jiang et al., 2011), whereas different results is obtained when ranking is applied.

In the examples below, comparisons were made by obtaining results by applying the algorithms given in this study to examples which are taken from two different studies in the literature. One can find details of the FSS in Example 3.11 from the example given in (Feng et al., 2010) and details of the IFSS in Example 3.12 from the Example 1 and Example 4 in (Jiang et al., 2011).

Example 3.11: Let us try to apply the presented algorithm in this paper, to an example mentioned at (Feng et al., 2010) for an illustration of a weighted fuzzy soft set based decision making. Let us use weights of parameters to obtain the priority ranking. Since weight of $e_1$is 0.9, weight of $e_2$is 0.6, and weight of $e_3$is 0.6, priority ranking of parameters is $e_1 \geq e_2 = e_3$. Therefore, priority ranking values of parameters e_1, e_2, e_3 are $p_{e_1} = 3$, $p_{e_2} = 2$ and $p_{e_3} = 2$ and non-prioritization values of parameters e_1, e_2, e_3 are $np_{e_1} = 1$, $np_{e_2} = 2$ and $np_{e_3} = 2$ by using the weights of parameters.

Priority ranking degrees of elements of U with respect to the parameter e_1 are $P_{e_1}(h_1) = 3.0,4 = 1,2$, $P_{e_1}(h_2) = 3.0,6 = 1,8$, $P_{e_1}(h_3) = 3.0,5 = 1,5$, $P_{e_1}(h_4) = 3.0,9 = 2,7$ and $P_{e_1}(h_5) = 3.0,3 = 0,9$.

Priority ranking degrees of elements of U with respect to the parameter e_2 are $P_{e_2}(h_1) = 2.1 = 1,2$, $P_{e_2}(h_2) = 2.0,5 = 1$, $P_{e_2}(h_3) = 2.0,5 = 1$, $P_{e_2}(h_4) = 2.0,5 = 1$ and $P_{e_2}(h_5) = 2.0,7 = 1,4$.

Priority ranking degrees of elements of U with respect to the parameter e_3 are $P_{e_3}(h_1) = 2.0,5 = 1$, $P_{e_3}(h_2) = 2.0,6 = 1,2$, $P_{e_3}(h_3) = 2.0,8 = 1,6$, $P_{e_3}(h_4) = 2.0,2 = 1,4$ and $P_{e_3}(h_5) = 2.0,9 = 1,8$.

Non-prioritization degree of elements of U with respect to the parameter e_1 are $NP_{e_1}(h_1) = 1.0,4 = 0,4$, $NP_{e_1}(h_2) = 1.0,6 = 0,6$, $NP_{e_1}(h_3) = 1.0,5 = 0,5$, $NP_{e_1}(h_4) = 1.0,9 = 0,9$ and $NP_{e_1}(h_5) = 1.0,3 = 0,3$.

Non-prioritization degree of elements of U with respect to the parameter e_2 are $NP_{e_2}(h_1) = 2.1 = 1,2$, $NP_{e_2}(h_2) = 2.0,5 = 1$, $NP_{e_2}(h_3) = 2.0,5 = 1$, $NP_{e_2}(h_4) = 2.0,5 = 1$ and $NP_{e_2}(h_5) = 2.0,7 = 1,4$.

Non-prioritization degree of elements of U with respect to the parameter e_3 are $NP_{e_3}(h_1) = 2.0,5 = 1$, $NP_{e_3}(h_2) = 2.0,6 = 1,2$, $NP_{e_3}(h_3) = 2.0,8 = 1,6$, $NP_{e_3}(h_4) = 2.0,2 = 1,4$ and $NP_{e_3}(h_5) = 2.0,9 = 1,8$.

Now let us evaluate the score function $S(h_j) = (S_1(h_j), S_2(h_j))$ for $j = 1, 2, 3, 4, 5$ where

$S_1(h_1) = 1,2 + 2 + 1 = 2,4$ and $S_2(h_1) = 0,4 + 2 + 1 = 3,4$.

$S_1(h_2) = 1,8 + 1 + 1,2 = 4$ and $S_2(h_2) = 0,6 + 1 + 1,2 = 2,8$.

$S_1(h_3) = 1,5 + 1 + 1,6 = 4,1$ and $S_2(h_3) = 0,5 + 1 + 1,6 = 3,1$.

$S_1(h_4) = 2,7 + 1 + 0,4 = 4,1$ and $S_2(h_4) = 0,9 + 1 + 0,4 = 2,3$.

$S_1(h_5) = 0,9 + 1,4 + 1,8 = 4,1$ and $S_2(h_5) = 0,3 + 1,4 + 1,8 = 3,5$.

According to the score function, h_5 is the choice object, also we obtain same choice object with (Feng et al., 2010) for this decision-making problem.

Example 3.12: Let us apply presented algorithms to the example mentioned at (Jiang et al., 2011, (Example 1 and Example 4)). Since no priority ranking was assigned to the parameters in (Jiang et al., 2011), let us solve the same problem by considering that decision maker has a priority ranking on parameters as $\varepsilon_4 = \varepsilon_5 \geq \varepsilon_2 \geq \varepsilon_3 \geq \varepsilon_1$. Therefore, priority ranking values of parameters

$\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, \varepsilon_5$ are $p_{\varepsilon_1} = 1$, $p_{\varepsilon_2} = 3$, $p_{\varepsilon_3} = 2$, $p_{\varepsilon_4} = 5$ and $p_{\varepsilon_5} = 5$ and non-prioritization values of parameters $\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, \varepsilon_5$ are $np_{\varepsilon_1} = 5$, $np_{\varepsilon_2} = 3$, $np_{\varepsilon_3} = 4$, $np_{\varepsilon_4} = 2$ and $np_{\varepsilon_5} = 2$.

Priority ranking degrees of elements U with respect to the parameter ε_1 are $P_{\varepsilon_1}(h_1) = 1.0,9 = 0,9$, $P_{\varepsilon_1}(h_2) = 1.0,7 = 0,7$, $P_{\varepsilon_1}(h_3) = 1.0,8 = 0,8$, $P_{\varepsilon_1}(h_4) = 1.0,5 = 0,5$ and $P_{\varepsilon_1}(h_5) = 1.0,6 = 0,6$, $P_{\varepsilon_1}(h_6) = 1.0,7 = 0,7$.

Priority ranking degrees of elements U with respect to the parameter ε_2 are $P_{\varepsilon_2}(h_1) = 3.0,8 = 2,4$, $P_{\varepsilon_2}(h_2) = 3.0,7 = 2,1$, $P_{\varepsilon_2}(h_3) = 3.0,6 = 1,8$, $P_{\varepsilon_2}(h_4) = 3.0,4 = 1,2$, $P_{\varepsilon_2}(h_5) = 3.0,8 = 2,4$, and $P_{\varepsilon_2}(h_6) = 3.0,5 = 1,5$.

Priority ranking degrees of elements U with respect to the parameter ε_3 are $P_{\varepsilon_3}(h_1) = 2.0,6 = 1,2$, $P_{\varepsilon_3}(h_2) = 2.0,5 = 1$, $P_{\varepsilon_3}(h_3) = 2.0,4 = 0,8$, $P_{\varepsilon_3}(h_4) = 2.0,7 = 1,4$, $P_{\varepsilon_3}(h_5) = 2.0,8 = 1,6$ and $P_{\varepsilon_3}(h_6) = 2.0,6 = 1,2$.

Priority ranking degrees of elements U with respect to the parameter ε_4 are $P_{\varepsilon_4}(h_1) = 5.0,4 = 2$, $P_{\varepsilon_4}(h_2) = 5.0,9 = 4,5$, $P_{\varepsilon_4}(h_3) = 5.0,7 = 3,5$, $P_{\varepsilon_4}(h_4) = 5.0,7 = 3,5$, $P_{\varepsilon_4}(h_5) = 5.0,8 = 4$ and $P_{\varepsilon_4}(h_6) = 5.0,8 = 4$.

Priority ranking degrees of elements U with respect to the parameter ε_5 are $P_{\varepsilon_5}(h_1) = 5.0,9 = 4,5$, $P_{\varepsilon_5}(h_2) = 5.0,4 = 2$, $P_{\varepsilon_5}(h_3) = 5.0,8 = 4$, $P_{\varepsilon_5}(h_4) = 5.0,7 = 3,5$, $P_{\varepsilon_5}(h_5) = 5.0,4 = 2$ and $P_{\varepsilon_6}(h_6) = 5.0,2 = 1$.

Nonmember priority ranking degrees of elements U with respect to the parameter ε_1 are $\tilde{P}_{\varepsilon_1}(h_1) = 1.0,1 = 0,1$, $\tilde{P}_{\varepsilon_1}(h_2) = 1.0,2 = 0,2$, $\tilde{P}_{\varepsilon_1}(h_3) = 1.0,2 = 0,2$, $\tilde{P}_{\varepsilon_1}(h_4) = 1.0,4 = 0,4$, $\tilde{P}_{\varepsilon_1}(h_5) = 1.0,3 = 0,3$ and $\tilde{P}_{\varepsilon_1}(h_6) = 1.0,3 = 0,3$.

Nonmember priority ranking degrees of elements U with respect to the parameter ε_2 are $\tilde{P}_{\varepsilon_2}(h_1) = 3.0,1 = 0,3$, $\tilde{P}_{\varepsilon_2}(h_2) = 3.0,1 = 0,3$, $\tilde{P}_{\varepsilon_2}(h_3) = 3.0,3 = 0,9$, $\tilde{P}_{\varepsilon_2}(h_4) = 3.0,6 = 1,8$, $\tilde{P}_{\varepsilon_2}(h_5) = 3.0,2 = 0,6$ and $\tilde{P}_{\varepsilon_2}(h_6) = 3.0,3 = 0,9$.

Nonmember priority ranking degrees of elements U with respect to the parameter ε_3 are $\tilde{P}_{\varepsilon_3}(h_1) = 2.0,2 = 0,4$, $\tilde{P}_{\varepsilon_3}(h_2) = 2.0,2 = 0,4$, $\tilde{P}_{\varepsilon_3}(h_3) = 2.0,5 = 1$, $\tilde{P}_{\varepsilon_3}(h_4) = 2.0,3 = 0,6$, $\tilde{P}_{\varepsilon_3}(h_5) = 2.0,2 = 0,4$ and $\tilde{P}_{\varepsilon_3}(h_6) = 2.0,2 = 0,4$.

Nonmember priority ranking degrees of elements U with respect to the parameter ε_4 are $\tilde{P}_{\varepsilon_4}(h_1) = 5.0,5 = 2,5$, $\tilde{P}_{\varepsilon_4}(h_2) = 5.0,1 = 0,5$, $\tilde{P}_{\varepsilon_4}(h_3) = 5.0,1 = 0,5$, $\tilde{P}_{\varepsilon_4}(h_4) = 5.0,2 = 1$, $\tilde{P}_{\varepsilon_4}(h_5) = 5.0,1 = 0,5$ and $\tilde{P}_{\varepsilon_4}(h_6) = 5.0,1 = 0,5$.

Nonmember priority ranking degrees of elements U with respect to the parameter ε_5 are $\tilde{P}_{\varepsilon_5}(h_1) = 5.0,1 = 0,1$, $\tilde{P}_{\varepsilon_5}(h_2) = 5.0,5 = 2,5$, $\tilde{P}_{\varepsilon_5}(h_3) = 5.0,1 = 0,5$, $\tilde{P}_{\varepsilon_5}(h_4) = 5.0,1 = 0,5$, $\tilde{P}_{\varepsilon_5}(h_5) = 5.0,5 = 2,5$ and $\tilde{P}_{\varepsilon_5}(h_6) = 5.0,2 = 1$.

Firstly, let us apply the first algorithm to this example by considering only membership degrees and let us evaluate the first components of the score function just by using the membership degrees of the objects.

$S_1(h_1) = 11$, $S_1(h_2) = 10{,}3$, $S_1(h_3) = 10{,}9$, $S_1(h_4) = 10{,}1$, $S_1(h_5) = 10{,}6$ and $S_1(h_6) = 8{,}4$.

According to these values choice object is h_1, which is the same object evaluated in (Jiang et.al., 2011).

On the other hand, if we apply the second algorithm by considering both membership and non-membership degrees of IFSS, we need to evaluate the first component of the score function for IFSS where $S(h_j) = (S_{1_0}, S_{2_0})$ for $j = 1, 2, 3, 4, 5, 6$, where

$S_1(h_1) = 0{,}9 + 2{,}4 + 1{,}2 + 2 + 4{,}5 = 11,$

$S_1(h_2) = 0{,}7 + 2{,}1 + 1 + 4{,}5 + 2 = 10{,}3,$

$S_1(h_3) = 0{,}8 + 1{,}8 + 0{,}8 + 3{,}5 + 4 = 10{,}9,$

$S_1(h_4) = 0{,}5 + 1{,}2 + 1{,}4 + 3{,}5 + 3{,}5 = 10{,}1,$

$S_1(h_5) = 0{,}6 + 2{,}4 + 1{,}6 + 4 + 2 = 10{,}6$ and

$S_1(h_6) = 0{,}7 + 1{,}5 + 1{,}2 + 4 + 1 = 8{,}4.$

$\tilde{S}_1(h_1) = 0{,}1 + 0{,}3 + 0{,}4 + 2{,}5 + 0{,}1 = 3{,}4,$

$\tilde{S}_1(h_2) = 0{,}2 + 0{,}3 + 0{,}4 + 0{,}5 + 2{,}5 = 3{,}9,$

$\tilde{S}_1(h_3) = 0{,}2 + 0{,}9 + 1 + 0{,}5 + 0{,}5 = 3{,}1,$

$\tilde{S}_1(h_4) = 0{,}4 + 1{,}8 + 0{,}6 + 1 + 0{,}5 = 4{,}3,$

$\tilde{S}_1(h_5) = 0{,}3 + 0{,}6 + 0{,}4 + 0{,}5 + 2{,}5 = 4{,}3$ and

$\tilde{S}_1(h_6) = 0{,}3 + 0{,}9 + 0{,}4 + 0{,}5 + 1 = 3{,}1.$

Thus $S_{1_0}(h_1) = 11 - 3{,}4 = 7{,}6$, $S_{1_0}(h_2) = 10{,}3 - 3{,}9 = 6{,}4$, $S_{1_0}(h_3) = 10{,}9 - 3{,}1 = 7{,}8$, $S_{1_0}(h_4) = 10{,}1 - 4{,}3 = 5{,}8$, $S_{1_0}(h_5) = 10{,}6 - 4{,}3 = 6{,}3$, and $S_{1_0}(h_6) = 8{,}4 - 3{,}1 = 5{,}3$.

According to the score function, h_3 is the choice object, which is different form the choice object h_1 obtained in (Jiang et al., 2011). The difference in results arises because the method, that we proposed in this study, includes an ordering on the parameter set. In this example, if we want to order choice objects, the ordering will be in the form of $h_3, h_1, h_2, h_5, h_4, h_6$, which are written with the help of score function. A change in the priority ranking will lead to a change in result.

Let us apply presented algorithms to the same example mentioned at (Jiang et al., 2011, (Example 1 and Example 4)) but now let us solve the same problem by considering that decision maker has a priority ranking on parameters as $\varepsilon_4 = \varepsilon_5 = \varepsilon_2 = \varepsilon_3 = \varepsilon_1$. Thus, all parameters have same priority ranking values and non-prioritization values which is 5. Therefore, $p_{\varepsilon_1} = 5$, $p_{\varepsilon_2} = 5$, $p_{\varepsilon_3} = 5$, $p_{\varepsilon_4} = 5$, $p_{\varepsilon_5} = 5$ and $np_{\varepsilon_1} = 5$, $np_{\varepsilon_2} = 5$, $np_{\varepsilon_3} = 5$, $np_{\varepsilon_4} = 5$ and $np_{\varepsilon_5} = 5$. It can be thought of as if there is no priority ranking at all as in (Jiang et al., 2011).

Let us apply the second algorithm by considering both membership and non-membership degrees of IFSS. Firstly, we need to evaluate the first component of the score function for IFSS, where $S(h_j) = (S_{1_0}, S_{2_0})$ for $j = 1, 2, 3, 4, 5,6$, where

$S_1(h_1) = 4{,}5 + 4 + 3 + 2 + 4{,}5 = 18,$

$S_1(h_2) = 3{,}5 + 3{,}5 + 2{,}5 + 4{,}5 + 2 = 16,$

$S_1(h_3) = 4 + 3 + 2 + 3{,}5 + 4 = 16{,}5,$

$S_1(h_4) = 2{,}5 + 3 + 3{,}5 + 3{,}5 + 3{,}5 = 15,$

$S_1(h_5) = 3 + 4 + 4 + 4 + 2 = 17$ and

$S_1(h_6) = 3{,}5 + 2{,}5 + 3 + 4 + 1 = 14.$

$\tilde{S}_1(h_1) = 0{,}5 + 0{,}5 + 1 + 1 + 0{,}5 = 3{,}5,$

$\tilde{S}_1(h_2) = 1 + 0{,}5 + 1 + 0{,}5 + 2{,}5 = 5{,}5,$

$\tilde{S}_1(h_3) = 1 + 1{,}5 + 2{,}5 + 0{,}5 + 0{,}5 = 6,$

$\tilde{S}_1(h_4) = 2 + 3 + 1{,}5 + 1 + 0{,}5 = 8,$

$\tilde{S}_1(h_5) = 1{,}5 + 1 + 1 + 0{,}5 + 1 = 5$ and

$\tilde{S}_1(h_6) = 1{,}5 + 1{,}5 + 1 + 0{,}5 + 1 = 5{,}5.$

Thus $S_{1_0}(h_1) = 18 - 3{,}5 = 14{,}5$, $S_{1_0}(h_2) = 16 - 5{,}5 = 10{,}5$, $S_{1_0}(h_3) = 16{,}5 - 6 = 10{,}5$, $S_{1_0}(h_4) = 15 - 8 = 7$, $S_{1_0}(h_5) = 17 - 5 = 12$, and $S_{1_0}(h_6) = 14 - 5{,}5 = 8{,}5$.

According to the score function, h_1 is the choice object, which is same with the choice object obtained in (Jiang et al., 2011). This arises because priority ranking values and non-prioritization values are taken same that means there is no priority ranking as in (Jiang et al., 2011).

When compared to previous studies on decision-making algorithm based on FSS and IFSS, it has been observed that user priority ranking was not considered. Therefore, this study introduces a novel approach by integrating user priority ranking on the parameter set into decision-making algorithms. The comparative analysis conducted on Example 3.11 and Example 3.12 supports the validity of the proposed methods. When we use weights of parameters to obtain the priority ranking in Example 3.11, the same choice object obtained with the previous studies. Also, as can be seen from Example 3.12, if a priority ranking is assigned to IFSS, the obtained choice object may differ from that of the previous studies. However, if the algorithm is applied without assigning a priority ranking to the IFSS, meaning priority ranking values and non-prioritization values are considered equal, the choice object remains the same as in the previous studies.

Furthermore, the primary distinction between the first and second algorithms is that the first used within FSS, whereas the second is used in IFSS. As a result, the first algorithm employs only the membership degree, while the second utilizes both the membership and non-membership degrees. As can be seen from the Example 3.6 and Example 3.10, even though there is same priority rankings and same membership degrees, different choice objects are obtained by using Algorithm 1 and 2 because of the non-membership degree is used only in Algorithm 2.

In the proposed methods of this study, a large number of parameters may lead to complexity. This is because, with more parameters, the number of comparisons increases, which in turn leads to longer processing times. However, these comparisons are simple calculations made to obtain the most suitable choice object according to the user's priorities. In the proposed methods, if the priority ranking changes, the results will also change, as can be seen in Example 3.12. Additionally, if parameters are reduced or increased, both FSS and IFSS will change, and consequently, the results will also be changed.

The proposed methods can be used in real-world problems involving multi-attribute object selection, such as in economics, industry, engineering, and medicine, to obtain the most suitable choice object based on priority needs.

4. Conclusions and Recommendations

In this study, decision-making methods by using FSS and IFSS were given. These methods incorporates user priority rankings into the decision-making process and utilizes them in the proposed algorithms. The attributes of multi-attribute objects were considered as the parameter sets of FSS and IFSS, and two decision-making methods were proposed based on the user's priority ranking of these attributes. The first method determined the most suitable decision object using only the membership degree, while the second method incorporated both membership and non-membership degrees to make the decision.

An example was provided to demonstrate the application of both methods, highlighting that the results may differ due to the influence of the non-membership degree on the outcome. Additionally, new definitions were introduced for use in algorithms and the methods were applied to examples from some studies in the literature.

For future studies, the presented algorithms can be integrated with experimental reseach using real-world data and computational methods. Moreover, future research could focus on developing the presented methods for group decision-making, in which multiple decision-makers are involved in selecting among multi-attribute objects, by considering the priority rankings on the parameter set of each member in the group to obtain consensus.

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Authors' Contributions

The author has completed the article alone.

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There is no conflict of interest.

Statement of Research and Publication Ethics

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