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Group-Based Decision-Making Algorithm on Intuitionistic Fuzzy Soft Sets for Assessment of Andalas University Campus Facilities

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ABSTRACT

The concept of intuitionistic fuzzy soft sets is a mathematical framework that integrates the advantages of intuitionistic fuzzy sets in handling uncertainty with the parametric flexibility of soft sets. Despite its capabilities, existing decision-making mechanisms generally still focus on evaluating objects individually. This poses a significant challenge when decision-makers are faced with situations requiring assessments based on specific groups of objects. This research aims to construct a new decision-making algorithm for intuitionistic fuzzy soft set data that enables an evaluation process based on object groups. This methodology includes selection criteria that are more adaptive to object collections and the formulation of score value computation procedures that combine various parameters. To test its effectiveness, this algorithm is implemented in the case of campus facility assessment. The results of the analysis show that the proposed algorithm is capable of providing objective recommendations for the best group of facilities. This research provides a theoretical contribution to the expansion of intuitionistic fuzzy soft set applications.

Keywords: Intuitionistic Fuzzy Soft Sets; Fuzzy Sets; Strait Soft Sets; Strait Fuzzy Sets; Decision-Making; Group-Based Evaluation; Uncertainty; Membership Degree; Algorithm, UNAND Campus Facilities.

1. Introduction

The decision-making process in real-world contexts involves the integration of objective data and subjective judgments influenced by diverse perceptions and uncertainty. The uncertainty arising from this subjective nature has been a primary motivation for many mathematical researchers to develop more effective frameworks for handling ambiguous information.

In response to the limitations of classical sets, the concept of fuzzy sets was introduced by Zadeh (Zadeh, 1965). Fuzzy sets can address uncertainty by allowing objects to have membership degrees within the interval [0,1]. However, fuzzy sets focus only on a single criterion or parameter; this limitation makes them inadequate in real-world situations requiring analysis based on diverse criteria or parameters. To address this, the concept of soft sets was introduced by (Molodtsov, 1999), offering a flexible framework by associating each parameter with a subset of the object set.

Recognizing the strengths of the two previous concepts, Maji et al. (Maji et al., 2001a) synthesized them to develop the concept of fuzzy soft sets, which can handle uncertainty with diverse parameters. Additionally, (Fatimah and Alcantud, 2021) explain that the development of variations in fuzzy sets allows for richer data representation in multi-attribute decision-making. However, in reality, decision-makers are often faced with situations where there are degrees of rejection or uncertainty that cannot be accommodated by a single membership value alone.

A limitation of fuzzy sets also lies in the requirement that the sum of membership degrees and non-membership degrees must always equal 1, which does not always occur in real-world evaluations due to factors such as information gaps or loss and other considerations. To address these limitations, Atanassov (Atanassov, 1986) introduced the concept of intuitionistic fuzzy sets, which allows the sum of an object's membership and non-membership degrees to be less than or equal to 1. This concept offers simultaneous membership and non-membership degrees (Szmidt et al., 2024). Thao and Chou (Thao and Chou, 2022) introduced new similarity and entropy measures in the application of this concept, which have been shown to provide higher levels of accuracy and reliability in software quality evaluation compared to conventional methods.

Furthermore, intuitionistic fuzzy sets were extended to intuitionistic soft softs by Maji et al. (Maji et al., 2001b), which incorporate the advantages of both intuitionistic fuzzy sets and soft sets. Mukherjee et al. (Mukherjee et al., 2016) have demonstrated the effectiveness of soft-fuzzy intuitionistic sets in modeling real-world problems involving uncertainty. Ma et al. (Ma et al., 2022) introduced a new approach to decision-making based on interval-valued intuitionistic fuzzy soft sets by integrating efficient parameter reduction techniques to minimize data complexity without compromising the accuracy of the final results. Ghosh et al. (Ghosh et al., 2022) integrated the concept of rough approximations into intuitionistic fuzzy soft sets to develop a new similarity measure effective in identifying cancer-causing biomarkers with high diagnostic accuracy. Sonia et al. (Sonia et al., 2022) proposed a new distance measure for interval-valued intuitionistic fuzzy soft sets designed to address the limitations of previous models in more accurately measuring the level of uncertainty in interval-based data.

Furthermore, the use of advanced aggregation operators such as the Aczel-Alsina law within the framework of intuitionistic fuzzy soft sets has been shown to minimize information bias (Ali et al., 2023). Recent research by Aini et al. (Aini et al., 2025) emphasizes that the development of matrix energy-based algorithms on intuitionistic fuzzy soft sets provides higher stability and accuracy in multi-criteria decision-making problems.

The concepts of fuzzy sets and soft sets, along with their extensions, only allow for focusing the analysis on a single object, thus still facing challenges in focusing the analysis on specific groups of objects. Therefore, (Atagün and Kamacı, 2023a) introduced the concept of strait fuzzy sets, designed to focus the analysis on groups of objects through the partition of membership intervals [0,1]. In line with this, strait soft sets were developed by (Atagün and Kamacı, 2023) as a special type of soft set.

(Shodik et al., 2024) and (Putri et al., 2024) successively expanded the scope of soft set applications by applying N-soft sets and fuzzy soft sets to data analysis focused on grouped objects. Recently, these two concepts were extended to strait fuzzy soft sets (Putri, 2024) and strait intuitionistic fuzzy sets (Ashari, 2025), which focus on processing data involving fuzzy soft sets and intuitionistic fuzzy sets in groups.

Based on these theoretical developments, the author was motivated to design a decision-making algorithm that focuses on analyzing groups of objects in intuitionistic fuzzy soft set data. The designed algorithm will generate a decision based on the given intuitionistic fuzzy soft set data. The algorithm was applied to a student's evaluation of campus facilities to identify the best group of facilities.

1.1. Study Objectives

This study aims to:

1) Construct a new decision-making algorithm specially designed for intuitionistic fuzzy soft set environments that shifts the evaluation focus from individual objects to object groups.

2) Develop selection criteria that can effectively handle collections or clusters of objects, ensuring the decision process remains robust under collective uncertainty.
3) Address the limitations of existing IFSS models by providing a mathematical mechanism that accommodates real-world situations where decisions must be made based on partitions or groups of objects.
4) Implement the proposed algorithm in a practical case study, specially for the assessment of campus facilities, to demonstrate its functional utility.
5) Contribute to the theoretical expansion of IFSS applications, providing a foundation for future research in group-based multi-attribute decision-making.

2. Literature

This section contains the basic concepts used to construct decision-making algorithms.

2.1. Intuitionistic Fuzzy Soft Set

Intuitionistic fuzzy soft sets are concepts formed from the synthesis between intuitionistic fuzzy sets and soft sets. This concept is designed to address problems involving uncertainty (through degrees of membership and non-membership in intuitionistic fuzzy sets) with the flexibility of soft set parameters. The combination of intuitionistic fuzzy sets and soft sets is capable of handling more complex real-world data.

Definition 2.1 (Maji et al., 2001b)

Let $V = \{v_1, v_2, \dots, v_n\}$ be a set of objects, $A = \{a_1, a_2, \dots, a_t\}$ be a set of parameters, and $IFS(V)$ be the set of all intuitionistic fuzzy soft sets over V. A pair (F, A) is called an intuitionistic fuzzy soft set over V if F is a mapping from A to $IFS(V)$, that is

$$F: A \to IFS(V).$$

In other words, $(F, A) = \{ (a, \{ (v, \mu_a(v), \nu_a(v)) \mid v \in V, 0 \leq \mu_a(v) + \nu_a(v) \leq 1 \}) \mid a \in A \}$.

2.2. Set Partition

Here is the formal definition of a partition of a set:

Definition 2.2 (Rosen, 2019)

A partition of a set A is a set of one or more subsets of A: A_1, A_2, A_3, ... such that:

1) $A_i \cap A_j \neq \emptyset$ if $i \neq j$.
2) $\bigcup_i A_i = A$.

3. Methodology

This research uses a descriptive qualitative method with a case study approach to explore phenomena in depth through the representation of intuitionistic fuzzy soft sets. Its main focus is not on numbers, but on understanding the context, meaning, and experiences of the subjects in order to provide a detailed depiction of the real cases discussed.

4. Results and Discussions

In this section, we will define several concepts necessary for constructing decision-making algorithms. In an intuitionistic fuzzy soft set, each object has a membership degree and a non-membership degree associated with a parameter. This motivates the author to define the membership degree and non-membership degree of a group of objects based on data in the form of an intuitionistic fuzzy soft set. Here is the formal definition:

Definition 4.1

Let $V = \{v_1, v_2, \dots, v_n\}$ be a set of objects, $V_m = \{V_1', V_2', \dots, V_m'\}$ is a partition of V, $A = \{a_1, a_2, \dots, a_t\}$ is a set of parameters, $\alpha_p = \{Y_1^p, Y_2^p, \dots, Y_p^p\}$ and $\beta_q = \{Y_1^q, Y_2^q, \dots, Y_q^q\}$ are two partitions of $[0,1]$, and $(F, A) = \{(a, \{(v, \mu_a(v), \nu_a(v)) \mid v \in V\}) \mid a \in A\}$ is an intuitionistic fuzzy soft set over V. For $V_i' \in V_m$,

1) The interval $\mu_a(V_i') \in \alpha_p$ is said to be the membership degree of the group of objects $V_i' \in V_m$ associated with the parameter $a \in A$, if for every $v \in V_i'$ it holds that $\mu_a(v) \in \mu_a(V_i')$, and
2) The interval $\nu_a(V_i') \in \alpha_q$ is said to be the non-membership degree of the group of objects $V_i' \in V_m$ associated with the parameter $a \in A$, if for every $v \in V_i'$ it holds that $\nu_a(v) \in \nu_a(V_i')$.

In the previous definition, the degrees of membership and non-membership are subintervals, not numbers. In light of this, it is necessary to define the relation between two subintervals that belong to the same partition.

Definition 4.2

Let $\mathbb{B}[0,1] = \{\alpha_1, \alpha_2, \dots, \alpha_k, \dots\}$ be a collection of partitions of $[0,1]$ and $\alpha_k = \{Y_1^k, Y_2^k, \dots, Y_r^k\}$. For $i, j \in \{1, 2, \dots, r\}$,

1) $Y_i^k < Y_j^k$ if $\inf(Y_i^k) < \inf(Y_j^k)$ and $\sup(Y_i^k) < \sup(Y_j^k)$,
2) $Y_i^k \leq Y_j^k$ if $\inf(Y_i^k) \leq \inf(Y_j^k)$ and $\sup(Y_i^k) \leq \sup(Y_j^k)$,
3) $Y_i^k > Y_j^k$ if $\inf(Y_i^k) > \inf(Y_j^k)$ and $\sup(Y_i^k) > \sup(Y_j^k)$,
4) $Y_i^k \geq Y_j^k$ if $\inf(Y_i^k) \geq \inf(Y_j^k)$ and $\sup(Y_i^k) \geq \sup(Y_j^k)$.

An algorithm for decision-making problems on intuitionistic fuzzy soft set data based on object groups is constructed to solve a real case that will be discussed. The developed algorithm determines that one object is superior to another based on the number of advantages that object holds over the other. The following is the developed algorithm:

1) Input a set of objects $V = \{v_1, v_2, \dots, v_r\}$, a set of parameters A, and an intuitionistic fuzzy soft set (I, A) over V.
2) Choose a partition of V, namely $V_m = \{V_1', V_2' \dots, V_s'\}$ with $s < r$, a partition of membership degrees, namely $\alpha_p = \{Y_1^p, Y_2^p, \dots, Y_p^p\}$, and a partition of non-membership degrees, namely $\beta_q = \{Y_1^q, Y_2^q, \dots, Y_q^q\}$ such that for every $a \in A$ and $V_i' \in V_m$, the following holds: $\mu_a(v) \in \mu_a(V_i') \in \alpha_p$ and $\nu_a(v) \in \nu_a(V_i') \in \beta_q$ for every $v \in V_i'$.
3) Compute the value $|\sigma_i|$, where $\sigma_i = \{k_l \mid \mu_{a_l}(V_k') \leq \mu_{a_l}(V_i') \text{ and } \nu_{a_l}(V_k') \geq \nu_{a_l}(V_i') \text{ for } V_k' \in V_m, a \in A\}$.

4) The set of objects V_j', where $|\sigma_k| = \max_{i\in\{1,2,\dots,s\}}\{|\sigma_i|\}$, is recommended as the best choice.

Application of Algorithms to Decision-Making Problems

At Andalas University, students in Class H evaluated various facilities on their campus based on specific criteria, with the aim of determining which group of facilities the students considered to be the best. The information was obtained through a survey of the students in question and represented as intuitionistic fuzzy soft set.

Student H is asked to evaluate the following facilities:

1) Discussion Room 3 (v_1),
2) Discussion Room 4 (v_2),
3) Discussion Room 5 (v_3),
4) HIMATIKA Secretariat (v_4),
5) MathDasc Laboratory (v_5),
6) Dean's Gazebo (v_6),
7) Baitul Ilmi Mosque (v_7),
8) Toilet 1 (v_8),
9) Toilet 2 (v_9),
10) One Stall (v_{10}),
11) Buk El Stall (v_{11}), and
12) Biology Cafe (v_{12}),

based on the following criteria:

1) Cleanliness (a_1), and
2) Optimality (a_2),

where facilities are considered as parameters in an intuitionistic fuzzy soft set. It can be seen that the set of objects is $V = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}, v_{11}, v_{12}\}$ and the set of parameters is $A = \{a_1, a_2\}$.

The assessment of student H is presented in an intuitionistic fuzzy soft set in the Table 1.

Table 1. Student H's Assessment

(I_1, A)	a_1	a_2
v_1	$(0{,}85; 0{,}15)$	$(1{,}00; 0{,}00)$
v_2	$(0{,}85; 0{,}15)$	$(0{,}80; 0{,}20)$
v_3	$(0{,}83; 0{,}17)$	$(1{,}00; 0{,}00)$
v_4	$(0{,}39; 0{,}61)$	$(0{,}35; 0{,}65)$
v_5	$(0{,}88; 0{,}12)$	$(0{,}80; 0{,}20)$

v_6	$(0{,}21; 0{,}79)$	$(0{,}30; 0{,}70)$
v_7	$(0{,}72; 0{,}28)$	$(1{,}00; 0{,}00)$
v_8	$(0{,}54; 0{,}46)$	$(1{,}00; 0{,}00)$
v_9	$(0{,}61; 0{,}39)$	$(1{,}00; 0{,}00)$
v_{10}	$(0{,}70; 0{,}30)$	$(1{,}00; 0{,}00)$
v_{11}	$(0{,}55; 0{,}45)$	$(0{,}85; 0{,}15)$
v_{12}	$(0{,}49; 0{,}51)$	$(0{,}90; 0{,}10)$

Based on this assessment, the objects can be grouped into several clusters, namely Discussion Room 3 and Discussion Room 5 (V_1'), Discussion Room 4 and MathDasc Laboratory (V_2'), HIMATIKA Secretariat and Dean's Gazebo (V_3'), Toilet 1 and Toilet 2 (V_4'), Buk El Stall and Biology Cafe (V_5'), Baitul Ilmi Mosque (V_6'), and One Stall (V_7'), so that $V_m = \{V_1', V_2', V_3', V_4', V_5', V_6', V_7'\}$. Then, a partition can be selected for membership degree and degree of membership, namely

$\alpha_p = \{[0; 0{,}21), [0{,}21; 0{,}39], (0{,}39; 0{,}49), [0{,}49; 0{,}61], (0{,}61; 0{,}7), [0{,}7; 0{,}95], (0{,}95; 1), [1{,}1]\}$,

$\beta_q = \{[0{,}0], (0; 0{,}05), [0{,}05; 0{,}3], (0{,}3; 0{,}39), [0{,}39; 0{,}51], (0{,}51; 0{,}61), [0{,}61; 0{,}79], (0{,}79; 1]\}$.

The assessment of student H in Table 1 is transformed by focusing on the object groups, resulting in a new form of assessment presented in Table 2.

Table 2. Student H's Assessment Based on Object Group

	a_1	a_2
V_1'	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$	$([1.00; 1.00]; [0.00; 0.00])$
V_2'	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$
V_3'	$([0{,}21; 0{,}39]; [0{,}61; 0{,}79])$	$([0{,}21; 0{,}39]; [0{,}61; 0{,}79])$
V_4'	$([0{,}49; 0{,}61]; [0{,}39; 0{,}51])$	$([1.00; 1.00]; [0.00; 0.00])$
V_5'	$([0{,}49; 0{,}61]; [0{,}39; 0{,}51])$	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$
V_6'	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$	$([1.00; 1.00]; [0.00; 0.00])$
V_7'	$([0{,}7; 0{,}95]; [0{,}05; 0{,}3])$	$([1.00; 1.00]; [0.00; 0.00])$

Next, σ_i will be found for each $V_i' \in V_m$. Based on Table 2, the results are obtained as follows:

$\sigma_1 = \{1_1, 2_1, 3_1, 4_1, 5_1, 6_1, 7_1, 1_2, 2_2, 3_2, 4_2, 5_2, 6_2, 7_2\}$,

$\sigma_2 = \{1_1, 2_1, 3_1, 4_1, 5_1, 6_1, 7_1, 2_2, 3_2, 5_2\}$,

$\sigma_3 = \{3_1, 3_2\}$,

$\sigma_4 = \{3_1, 4_1, 5_1, 1_2, 2_2, 3_2, 4_2, 5_2, 6_2, 7_2\}$,

$\sigma_5 = \{3_1, 4_1, 5_1, 2_2, 3_2, 5_2\}$,

$\sigma_6 = \{1_1, 2_1, 3_1, 4_1, 5_1, 6_1, 7_1, 1_2, 2_2, 3_2, 4_2, 5_2, 6_2, 7_2\}$,

$\sigma_7 = \{1_1, 2_1, 3_1, 4_1, 5_1, 6_1, 7_1, 1_2, 2_2, 3_2, 4_2, 5_2, 6_2, 7_2\}$.

Then the cardinality of each σ_i is calculated as follows:

$|\sigma_1| = 14,$

$|\sigma_2| = 10,$

$|\sigma_3| = 2,$

$|\sigma_4| = 10,$

$|\sigma_5| = 6,$

$|\sigma_6| = 14,$

$|\sigma_7| = 14.$

It can be seen that $\max\{|\sigma_i| \mid i = 1,2, \dots, 7\} = 14$, so the groups of objects V_1', V_6' and V_7' are recommended as the best group.

Based on the results of the algorithm, it can be concluded that the best facility groups are Discussion Room 3 and Discussion Room 5 (V_1'), Baitul Ilmi Mosque (V_6'), and One Stall (V_7').

5. Conclusion and Future Recommendations

Based on the results and discussion above, several points can be concluded as follows:

1) The algorithm is designed to make the best decisions based on data in the form of intuitionistic fuzzy soft sets, starting from the input of the sets, selection of partitions, calculation of the values $|\sigma_i|$, and choosing the group of objects with the highest $|\sigma_i|$ as the best object group.
2) The algorithm is applied to a case to find the best facility group from several existing facilities at the Faculty of Mathematics and Natural Sciences, Andalas University, based on a student's evaluation. The best facility groups are Discussion Room 3 and Discussion Room 5 (V_1'), Baitul Ilmi Mosque (V_6'), and One Stall (V_7').
3) This study can be further developed by constructing formal definitions of new concepts, such as the development of fuzzy soft sets into strait soft sets and the development of intuitionistic fuzzy sets into strait intuitionistic fuzzy sets.

Based on the findings of this study, several points can be proposed for future research:

1) Future research could extend the group-based algorithm to interval-valued intuitionistic fuzzy soft sets to better capture extreme uncertainty where membership degrees are not fixed numbers.
2) Further studies could incorporate automated weighting methods to determine the importance of each parameter objectively, rather than relying on subjective weight assignments.
3) Investigating the integration of the proposed group evaluation logic into intuitionistic fuzzy N-soft sets to allow for multi-level rating instead of just binary membership.
4) Future work could focus on developing a user-friendly software or web-based application that automates this algorithm, making it accessible for campus administrators without a mathematical background.
5) The algorithm could be tested in more complex domains such as public policy evaluation, healthcare resource grouping, or supply chain cluster selection to verify its scalability.

Declarations

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Competing Interests Statement

The authors declare no conflict of interest.

Consent for publication

The participant provided consent for the results of assessment to be processed and published in this research article.

Author's contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Informed Consent

Informed consent was obtained from the participant involved in the study.

Availability of data and material

The data used in this study are available upon request from the corresponding author.

Institutional Review Board Statement

Ethical review and approval were waived for this study due to the non-interventional nature of the survey, which did not collect sensitive personal data or involve any physical or psychological risks to the participant.

Ethical Approval

Not applicable

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Declaration of Artificial Intelligence

The authors used Gemini to improve the grammar and phrasing of the manuscript. The final content was reviewed and edited by the authors.

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