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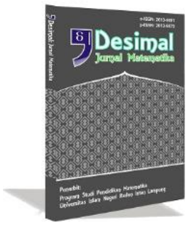

Application of intuitionistic fuzzy sets in determining the major in senior high school

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ABSTRACT

Intuitionistic Fuzzy Set (IFS) is useful to construct a model with elaborate uncertainty and ambiguity involved in decision-making. In this paper, the concept relation and operation of intuitionistic fuzzy set and the application in major of senior high school determination using the normalized Euclidean distance method will be reviewed. Some theorem of relation and operation of intuitionistic fuzzy set are proved. In general, to prove the theorem the definition and some basic relation and operation laws of IFS are needed. The distance measure between IFS indicates the difference in grade between the information carried by IFS. There are science, social, and language majors in senior high school. The normalized Euclidean distance method is used to measure the distance between each student and each major. The major, which each student can choose, has been determined depending on test evaluations. The solution provided is the smallest distance between each student and each major using the normalized Euclidean distance method.

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INTRODUCTION

Fuzzy sets (FS) was introduced by Zadeh (1965). The concept of the fuzzy set has contributed a lot to problem-solving in various fields of fuzzy sets. The idea of fuzzy sets is well received because it can handle ambiguity and vagueness that classical sets (Cantor's set) cannot do. The membership degree of an element in the fuzzy set is a unique real number in [0,1].

Let X be a nonempty set, A is a fuzzy set in X if and only if $A = \{< x, \mu_A(x) > | x \in X\}$ where $\mu_A: X \to [0,1]$ is the membership function for each $x \in X$ on A.

A fuzzy set can accommodate subjective words such as very much, very rough, etc. But in fact, the degree of nonmembership of an element in the set is not always $1 -$ degree of membership, because there may be uncertainty or doubt. Therefore, the generalization of fuzzy sets was proposed by Atanassov in 1983 as an intuitionistic fuzzy set (IFS) which combines degrees of membership, nonmembership, and hesitation whose value is $1 -$ (membership degree +

nonmembership degree) (Atanassov, 1999).

Let X be a nonempty set. An Intuitionistic Fuzzy Set (IFS) A in X is defined as

$$A = \{< x, \mu_A(x), v_A(x) > | x \in X\}.$$

Where the function $\mu_A, v_A: X \to [0,1]$ define the membership degree and the nonmembership degree for each $x \in X$ to the set A respectively. Then,

$$0 \leq \mu_A(x) + v_A(x) \leq 1.$$

According to the fuzzy set, the addition of membership degree and nonmembership degree is minimum zero and maximum one.

$$\pi_A(x) = 1 - \mu_A(x) - v_A(x)$$

called the hesitation on margin of x in A. $\pi_A(x)$ is indeterminacy of $x \in X$ to the IFS A and $\pi_A: X \to [0,1]$. For example let M be an IFS, $\mu_M(x) = 0.6, v_A(x) = 0.3$ then $\pi_A(x) = 0.1$. It means that the degree x belongs to M is 0.6, degree x does not belong to M is 0.3 and the hesitation margin is 0.1.

IFS is a solution to the problem description with linguistic variables given in terms of the membership function being too coarse. The flexibility of IFS in dealing with uncertainty becomes an appropriate tool as a standard of human consistency in defining imperfect facts. IFS is a tool for constructing a model of decision-making accounting for inaccurate information and/or environment like models of negotiations, voting, marketing, management, subjective assessment, etc. (Atanassov, 1999). One of the applications of IFS in management especially environmental management in order to determine the type of erosion(s) affecting some towns for an effective control measure that has to be taken using a distance function (Adamu, 2021).

Many IFS applications are performed using the distance measures approach. The distance measure between IFS indicates the difference in grade between information carried by IFS (Szmidt, 2014). There are many applications of distance measure, there are applications of distance measure for the intuitionistic fuzzy set to pattern classification problems (Xiao, 2019), a novel distance measure IFS and application to pattern recognition problems (Chen & Chang, 2015; Hatzimichailidis et al., 2012; Iqbal & Rizwan, 2019; Jiang et al., 2019). Similarity-distance decision-making technique and its applications via Intuitionistic Fuzzy pairs (Ejegwa & Agbetayo, 2022), a novel similarity measure capable of discriminating the difference between patterns (Song et al., 2015), new distance measure with algorithms for pattern recognition and use it to solve medical diagnosis problems (Luo & Zhao, 2018), especially to diagnosis Coronavirus (Kozae et al., 2020), relationships between intuitionistic fuzzy sets and symptoms of the patients to determine the kind of illness and finally compare the methods (Davvaz & Hassani Sadrabadi, 2016). An Application of Intuitionistic Fuzzy Sets to determine the suitable scope for jobbing that will be suitable with the creativity (Khalil & Hasab, 2020). A lot of research has been done on the development of IFS, its measure or similarity, new distance measure for Fermatean fuzzy sets, and its application (Deng & Wang, 2022), where Fermatean fuzzy sets are the development of IFS. The research of Kaur et al. (2019) determination using TOPSIS fuzzy analysis, TOPSIS fuzzy is also a development of IFS, and Intuitionistic multi-fuzzy convolution operator and its application in decision making (Si & Das, 2017). A new application of intuitionistic fuzzy set to decision making will be demonstrated. The decision-making in choosing the right major in senior high school according to the evaluation test. The determination of this major is expected to be the right first step for students for their future careers.

METHOD

In this paper, the concept relation and operation of the Intuitionistic Fuzzy Set (IFS) will be reviewed. Some theorem of relation and operation of IFS will be proved. In general, to prove the theorem the definition and some basic relation and operation laws of IFS are needed. Furthermore, the distance method of IFS is used, especially the normalized Euclidean distance method to determine the major of senior high school. For the application, IFS is used as a tool since it merges the membership degree (marks of the student correct answer), nonmembership degree (marks of the student wrong answer), and the hesitation degree (marks of the question that were not answered by student).

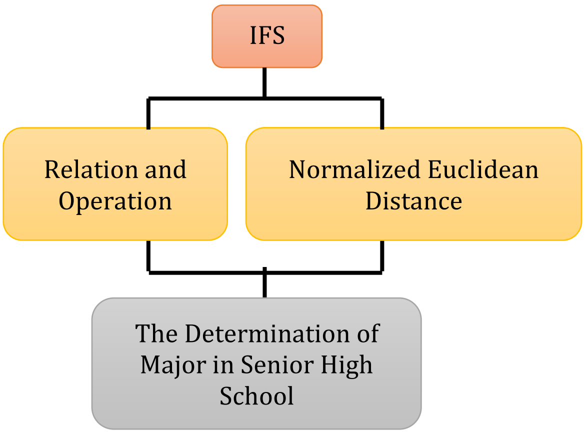

Figure 1. Diagram Scheme

RESULTS AND DISCUSSION

1. Relation and Operation of IFS

Basic relation and operation of IFS (Ejegwa et al., 2014):

a. Inclusion

$A \subseteq B$ if and only if $\mu_A(x) \leq \mu_B(x)$ and $v_A(x) \geq v_B(x)$, for each $x \in X$.

b. Equality

$A = B$ if and only if $\mu_A(x) = \mu_B(x)$ and $v_A(x) = v_B(x)$, for each $x \in X$.

c. Complement

$$A^C = \{< x, v_A(x), \mu_A(x) > | x \in X\}$$

d. Union

$$A \cup B = \{< x, \max\{\mu_A(x), \mu_B(x)\}, \min\{v_A(x), v_B(x)\} > | x \in X\}$$

e. Intersection

$$A \cap B = \{< x, \min\{\mu_A(x), \mu_B(x)\}, \max\{v_A(x), v_B(x)\} > | x \in X\}$$

f. Addition

$$A \oplus B = \{< x, \mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x), v_A(x)v_B(x) > | x \in X\}$$

g. Multiplication

$$A \otimes B = \{< x, \mu_A(x)\mu_B(x), v_A(x) + v_B(x) - v_A(x)v_B(x) > | x \in X\}$$

h. Subtraction

$$A - B = \{< x, \min\{\mu_A(x), v_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\}$$

i. Symmetric Subtraction

$$A \triangle B = \{< x, \max[\min\{\mu_A(x), v_B(x)\}, \min\{\mu_B(x), v_A(x)\}], \min[\max\{v_A(x), \mu_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\}$$

j. Cartesian Product

$$A \times B = \{< x, \mu_A(x)\mu_B(x), v_A(x)v_B(x) > | x \in X\}$$

Theorem 1

Let A and B be two IFS in a nonempty set X, then:

a. $A - B = A \cap B^c$
b. $A - B = B - A$ if and only if $A = B$
c. $A - B = B^c - A^c$

Proof: Let $A = \{< x, \mu_A(x), v_A(x) > | x \in X\}$ and $B = \{< x, \mu_B(x), v_B(x) > | x \in X\}$

a. Known $A - B = \{< x, \min\{\mu_A(x), v_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\}$, but $B^C = \{< x, v_B(x), \mu_B(x) > | x \in X\}$ and $A \cap B = \{< x, \min\{\mu_A(x), \mu_B(x)\}, \max\{v_A(x), v_B(x)\} > | x \in X\}$, so

$$A \cap B^C = \{< x, \min\{\mu_A(x), v_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\}$$

Then $A - B = A \cap B^c$

b. Known $A - B = \{< x, \min\{\mu_A(x), v_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\}$ If $A = B$ then $\mu_A(x) = \mu_B(x)$ and $v_A(x) = v_B(x)$, for each $x \in X$, so that $A - B = B - A$. If $A - B = B - A$ then

$$A - B = \{< x, \min\{\mu_A(x), v_B(x)\}, \max\{v_A(x), \mu_B(x)\} > | x \in X\} = \{< x, \min\{\mu_B(x), v_A(x)\}, \max\{v_B(x), \mu_A(x)\} > | x \in X\}$$

such that

$\min\{\mu_A(x), v_B(x)\} = \min\{\mu_B(x), v_A(x)\}$
and
$\max\{v_A(x), \mu_B(x)\} = \max\{v_B(x), \mu_A(x)\}$
for each $x \in X$. Then $\mu_A(x) = \mu_B(x)$ and $v_A(x) = v_B(x)$, for each $x \in X$, then $A = B$

c. Known

$$A - B = \left\{ \begin{matrix} < x, \min\{\mu_A(x), v_B(x)\}, \\ \max\{v_A(x), \mu_B(x)\} > \end{matrix} \middle| x \in X \right\},$$

$A^C = \{< x, v_A(x), \mu_A(x) > | x \in X\}$,
$B^C = \{< x, v_B(x), \mu_B(x) > | x \in X\}$, so

$$B^C - A^C = \left\{ \begin{matrix} < x, \min\{v_B(x), \mu_A(x)\}, \\ \max\{\mu_B(x), v_A(x)\} > \end{matrix} \middle| x \in X \right\}.$$

Then $A - B = B^C - A^C$

Corollary 1

If $A = B$ then $A \triangle B = B \triangle A$

Proof:

If $A = B$ then $\mu_A(x) = \mu_B(x)$ and $v_A(x) = v_B(x)$, for each $x \in X$. From Theorem 1 (b) and definition symmetric subtraction so that,

$$A \triangle B = B \triangle A$$

Theorem 2

Let A and B is IFS on a nonempty set X, then:

1. $A - A = \emptyset$
2. $A - \emptyset = A$
3. $A - B \subseteq A$

d. $A - B = \emptyset$ if and only if $A = B$
e. $A - B = A$ if and only if $B = \emptyset$
f. $A - B = A$ if and only if $A \cap B = \emptyset$

Theorem 3

Let A, B, C be three IFS in a nonempty set X, and $A \subseteq B \subseteq C$, then:

a. $B - A \subseteq C - A$
b. $B \triangle A \subseteq C \triangle A$

Proof:

a. Given that A, B, C be three IFS in a nonempty set X and $A \subseteq B \subseteq C$, the subset relation is transitive, it means that $A \subseteq B$ and $B \subseteq C$ implies $A \subseteq C$. Then $\mu_A(x) \leq \mu_B(x) \leq \mu_C(x)$ dan $v_A(x) \geq v_B(x) \geq v_C(x)$ for each $x \in X$. Since A is subset of B and C, subtracting A to B and is nothing, so $B - A \subseteq C - A$
b. Because $\triangle$ is extension of $-$, so the result follows from part 1.

Corollary 2

Based on the basic operations, the following relations are obtained:

a. $A \times B = B \times A$
b. $(A \times B) \times C = A \times (B \times C)$
c. $A \times (B \cup C) = (A \times B) \cup (A \times C)$
d. $A \times (B \cap C) = (A \times B) \cap (A \times C)$
e. $A \times (B \oplus C) = (A \times B) \oplus (A \times C)$
f. $A \times (B \otimes C) = (A \times B) \otimes (A \times C)$

Algebra Laws

Let A, B, C be IFS in a nonempty set X, then it applies:

1. Complementary law
$$(A^c)^c = A$$
2. Idempotent laws
$A \cup A = A$ and $A \cap A = A$
3. Commutative Laws
   a. $A \cup B = B \cup A$,
   b. $A \cap B = B \cap A$,
   c. $A \oplus B = B \oplus A$ and
   d. $A \otimes B = B \otimes A$
4. Associative Laws
   a. $(A \cup B) \cup C = A \cup (B \cup C)$,
   b. $(A \cap B) \cap C = A \cap (B \cap C)$,
   c. $(A \oplus B) \oplus C = A \oplus (B \oplus C)$ and
   d. $(A \otimes B) \otimes C = A \otimes (B \otimes C)$
5. Distributive Law
   a. $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$,
   b. $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$,
   c. $A \oplus (B \cup C) = (A \oplus B) \cup (A \oplus C)$,
   d. $A \oplus (B \cap C) = (A \oplus B) \cap (A \oplus C)$,
   e. $A \otimes (B \cup C) = (A \otimes B) \cup (A \otimes C)$,and
   f. $A \otimes (B \cap C) = (A \otimes B) \cap (A \otimes C)$
6. De Morgan's Law
   a. $(A \cup B)^c = A^c \cap B^c$,
   b. $(A \cap B)^c = A^c \cup B^c$
   c. $(A \oplus B)^c = A^c \otimes B^c$
   d. $(A \otimes B)^c = A^c \oplus B^c$
7. Absorption Laws
$A \cap (A \cup B) = A$ and $A \cup (A \cap B) = A$

8. Empty set
   a. $\emptyset^c = X$
   b. $A \cup \emptyset = A$
   c. $A \cap \emptyset = \emptyset$
   d. $A \cap A^c = \emptyset$
9. Universal Set
   a. $X^c = \emptyset$
   b. $A \cup X = X$
   c. $A \cap X = A$
   d. $A \cup A^c = X$

Theorem 4
Let A, B, C be IFS in X and $B \subseteq C$, then we get:
a. $A \oplus B \subseteq A \oplus C$
b. $A \otimes B \subseteq A \otimes C$
c. $A \cup B \subseteq A \cup C$
d. $A \cap B \subseteq A \cap C$
Proof:
a. Given that A, B, C be IFS in X and $B \subseteq C$, it means that : $\mu_B(x) \leq \mu_C(x)$ and $v_B(x) \geq v_C(x)$ for each $x \in X$, if A added to $B \subseteq C$, it is certain that $A \oplus B \subseteq A \oplus C$
b. Given that A, B, C be IFS in X and $B \subseteq C$, it means that : $\mu_B(x) \leq \mu_C(x)$ and $v_B(x) \geq v_C(x)$ for each $x \in X$, if A added to $B \subseteq C$, it is certain that $A \otimes B \subseteq A \otimes C$
c. Given that A, B, C be IFS in X and $B \subseteq C$, it means that : $\mu_B(x) \leq \mu_C(x)$ and $v_B(x) \geq v_C(x)$ for each $x \in X$, if A added to $B \subseteq C$, it is certain that
$$A \cup B \subseteq A \cup C$$
d. Given that A, B, C be IFS in X and $B \subseteq C$, it means that : $\mu_B(x) \leq \mu_C(x)$ and $v_B(x) \geq v_C(x)$ for each $x \in X$, if A added to $B \subseteq C$, it is certain that
$$A \cap B \subseteq A \cap C$$

Theorem 5
Let A and B be two IFS in X, then:
a. $A \cap B = A$ or $A \cap B = B$ if and only if $A = B$
b. $A \cup B = A$ or $A \cup B = B$ if and only if $A = B$
Proof:
a. Known $A = B$ it means that $\mu_A(x) = \mu_B(x)$ dan $v_A(x) = v_B(x)$, for each $x \in X$, so from idempotent law we get $A \cap B = A$ or $A \cap B = B$
b. Known $A = B$ it means that $\mu_A(x) = \mu_B(x)$ dan $v_A(x) = v_B(x)$, for each $x \in X$, so from idempotent law we get $A \cup B = A$ or $A \cup B = B$

Definition 1
Let X be a nonempty set such that A, B, C be IFS in X. Then the distance measure d between IFS A and B is a mapping $d: X \times X \rightarrow [0, 1]$ satisfying the following axioms:
(i) $0 \leq d(A, B) \leq 1$ (boundedness)
(ii) $d(A, B) = 0$ if and only if $A = B$.
(iii) $d(A, B) = d(B, A)$ (symmetric)
(iv) $d(A, C) + d(B, C) \geq d(A, B)$
(v) if $A \subseteq B \subseteq C$ then $d(A, C) \geq d(A, B) \geq d(B, C)$

The distance measure is a term that describes the difference between intuitionistic fuzzy sets and can be considered as a dual concept of the similarity measure. We make use of the four distance measures in Tugrul et al. (2017) between intuitionistic fuzzy sets, which were partly based on the geometric interpretation of intuitionistic fuzzy sets, and have some good geometric properties. There are Hamming distance, Euclidean distance, normalized Hamming distance, and normalized Euclidean distance. In this paper, the normalized Euclidean distance is used.

Definition 2
The normalized Euclidean distance of IFS A and B in X
$$d_{n-E}(A, B) = \left(\frac{1}{2n}\sum_{i=1}^{n}\left(\left(\mu_A(x_i) - \mu_B(x_i)\right)^2 + \left(v_A(x_i) - v_B(x_i)\right)^2 + \left(\pi_A(x_i) - \pi_B(x_i)\right)^2\right)\right)^{\frac{1}{2}}$$
$X = \{x_1, x_2, x_3, \dots, x_n\}$ for i = 1, 2, 3, ..., n.

2. The determination of major in senior high school using the normalized Euclidean distance method.

This section presented an application of IFS theory to determine the major in senior high school.

Let $M = \{science, social, language\}$ be the set of major in senior high school, $S = \{s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8\}$ be the set of student, $L = \{Bahasa,\ English,\ Science,\ Mathematics\}$ be the set subject evaluation test.

The intuitionistic fuzzy set is used as a tool with the membership degree μ (the degree of correct answers) the nonmembership degree ν (the degree of incorrect answers) and the hesitation degree π (the degree associated with questions failed to answer).

Table 1 indicates the average marks secured by students in Bahasa, English, Science, and Mathematics in the test evaluation and the major.

Table 1. Base Point Over the Major

	Bahasa	English	Science	Mathematics
Science	(0.85, 0.11, 0.04)	(0.87, 0.10, 0.03)	(0.95, 0.03, 0.02)	(0.92, 0.05, 0.03)
Social	(0.85, 0.10, 0.05)	(0.89, 0.09, 0.02)	(0.79, 0.20, 0.01)	(0.89, 0.18, 0.03)
Language	(0.94, 0.03, 0.03)	(0.95, 0.02, 0.03)	(0.80, 0.12, 0.08)	(0.81, 0.13, 0.06)

Each performance is described by three numbers, namely membership μ, nonmembership ν, and hesitation margin π.

Table 2. Student Score Degree

	Bahasa	English	Science	Mathematics
S_1	(0.80, 0.15, 0.05)	(0.82, 0.10, 0.08)	(0.91, 0.05, 0.04)	(0.90, 0.05, 0.05)
S_2	(0.81, 0.14, 0.05)	(0.78, 0.19, 0.03)	(0.70, 0.20, 0.10)	(0.79, 0.18, 0.03)
S_3	(0.91, 0.02, 0.07)	(0.85, 0.12, 0.03)	(0.77, 0.13, 0.10)	(0.81, 0.11, 0.08)
S_4	(0.80, 0.17, 0.03)	(0.97, 0.03, 0.00)	(0.91, 0.09, 0.00)	(0.89, 0.05, 0.06)
S_5	(0.75, 0.16, 0.09)	(0.89, 0.02, 0.09)	(0.75, 0.23, 0.02)	(0.76, 0.18, 0.06)
S_6	(0.95, 0.05, 0.00)	(0.97, 0.01, 0.02)	(0.89, 0.05, 0.06)	(0.88, 0.07, 0.05)
S_7	(0.77, 0.13, 0.10)	(0.89, 0.10, 0.01)	(0.80, 0.17, 0.03)	(0.86, 0.08, 0.06)
S_8	(0.88, 0.02, 0.10)	(0.85, 0.10, 0.05)	(0.89, 0.10, 0.01)	(0.86, 0.05, 0.09)

Table 2 shows the score of student test evaluation and the average marks secured in Bahasa, English, Science, and Mathematics. Table 3 shows the distance between the student and the major using the normalized Euclidean method.

Table 3. Distance of IFS S and M

	Science	Social	Language
S_1	0.039	0.093	0.108
S_2	0.137	0.08	0.116
S_3	0.1	0.071	0.056
S_4	0.061	0.088	0.095
S_5	0.136	0.075	0.104
S_6	0.072	0.097	0.055
S_7	0.086	0.054	0.089
S_8	0.06	0.082	0.078

Based on Table 3, the shortest distance between each student and each major has proper major determination. Student S_1, S_4, and S_8 enroll in the science major, student S_2, S_5, and S_6 enroll in the social major, and student S_3 and S_6 enroll in the language major. The students who are more academically strong, especially in Science and Mathematics have chosen a science major, and relatively weaker students have opted for Social or Language majors. The results of this research are in line with the research of (Meena & Thomas, 2018) which discusses the application of intuitive fuzzy sets in the selection of scientific disciplines. In the research, it is stated that students who are more academically strong have chosen computer science techniques and relatively weaker students have opted for electrical and electronic engineering (Meena & Thomas, 2018).

CONCLUSIONS AND SUGGESTIONS

In this paper, the normalized Euclidean distance method was applied to IFS to investigate the relative choice of the senior high school major of the students. In this research, it is analyzed that the academically stronger students in mathematics and science have opted for Science and relatively weaker students have opted for Social and Language. The application of IFS is significant as it exhibits the most likely choice/trends in the selection of major senior high school.

Eight students were selected randomly to determine the major in senior high school using the normalized Euclidean distance method. Student $\boldsymbol{S_1}, \boldsymbol{S_4}$ and $\boldsymbol{S_8}$ enroll in the science major, student $\boldsymbol{S_2}, \boldsymbol{S_5}$ and $\boldsymbol{S_6}$ enroll in the social major, and student $\boldsymbol{S_3}$ and $\boldsymbol{S_6}$ enroll in the language major. Further, this research can be used for more students. Application for determining the major in high schools is very useful for developing students' abilities according to their fields and supporting their future career paths.

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