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Assessment of Academic Integrity in University Students Using a Hybrid Fuzzy-Neutrosophic Model under Uncertainty

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Abstract: This study presents a model based on a fuzzy-neutrosophic approach to evaluate the academic integrity of university students in the context of uncertainty. The central issue of the research lies in the abrupt transition from in-person education to virtual learning caused by the pandemic, which increased fraudulent behaviors in teaching and learning environments, making it difficult to determine the level of academic integrity among students in higher education institutions. To address this issue, variables related to dishonesty—motivation, justification, and opportunities—were analyzed. Three evaluation scenarios were conducted, yielding positive results. The proposed approach, based on fuzzy logic and neutrosophy, effectively measured the academic integrity of students, providing a valuable tool for decision-making by experts in the educational field.

Keywords: Fuzzy logic, neutrosophic, academic dishonesty, uncertainty, academic integrity, COVID-19 pandemic, university students.

1. Introduction

The COVID-19 virus rapidly escalated into a pandemic with devastating effects on society. Almost overnight, schools and universities worldwide closed their doors, impacting 1.57 billion students across 191 countries. The abrupt and sweeping changes to daily life created an unprecedented situation for all organizations, including educational institutions, which were forced to suspend academic activities [1]. This suspension marked the beginning of a shift toward virtual learning, placing significant pressure on students to adapt to the new teaching and learning environment [2]. This transition introduced unique uncertainties and challenges, particularly in assessing students' academic integrity. To address this complex landscape, concepts such as fuzzy logic and neutrosophic models have emerged as innovative approaches capable of handling the ambiguity and imprecision inherent in uncertain situations. These methodologies offer a more accurate and context-sensitive framework for evaluating students' integrity within this evolving educational paradigm.

2. Preliminaries

Fuzzy logic is a reasoning approach that applies multiple truth or confidence values to restrictive categories during problem-solving. [10]. A set is a collection of objects that can be classified based on

their common characteristics. It is defined in two ways: by extension ({a, e, i, o, u}) or by comprehension.

A boolean set A is a map of a reference set S to the set {0, 1}, $A{:}S\rightarrow$ {0,1}, and is defined with a characteristic function.

$$\mu_A = \begin{cases} 1 \; if \; x \; \in A \\ 0 \; if \; x \; \notin A \end{cases} \tag{1}$$

Fuzzy sets give a quantitative value to each element, which represents the degree of membership to the set [3]. A fuzzy set A is an application of a reference set S in the interval [0, 1]

A: $S\rightarrow$ [0,1], and is defined using a membership function: $0 \leq \mu A\ (x) \leq 1$.

The closer the value is to 0, the less we can ensure the membership of an element to a set. On the contrary, the closer the value is to 1, the more we can ensure the membership of the element to the set [4]. It can be represented as a set of ordered pairs of a generic element x, x ∈A and its degree of membership $\mu A(x)$:

$$A = \{(x, \mu^A(x)), \mu^A(x) \in [0,1]\} \tag{2}$$

Working with fuzzy logic can be represented using linguistic variables to enhance the interpretability of data. Linguistic variables are those from natural language, characterized by fuzzy sets defined within the universe of discourse where they are established [3]. To define a set of linguistic terms, the granularity of the uncertainty for the set of linguistic labels to be used must first be determined [4]. The granularity of uncertainty refers to the cardinal representation of the set of linguistic labels employed to convey information. The degree of membership of an element M(x) to a fuzzy set will be determined by membership functions. The membership functions used for the fuzzy system are as follows.

Triangular Function:

This function is defined by its lower limit a, upper limit b, and modal value mmm, where a < m < b [5].

$$\mu(x) = \begin{cases} 0 & \\ \dfrac{x-a}{m-a} & si\ x \leq a \\ \dfrac{b-x}{b-m} & si\ a < x \leq m \\ 0 & si\ m < x \leq b \\ & si\ x \geq b \end{cases} \tag{3}$$

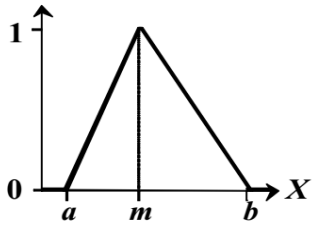


Figure 1. Triangular function

Trapezoidal Function:

This function is defined by its lower limit (**a)** and upper limit (**d)**, along with the intermediate limits (**b)** and (**c)**, which correspond to the lower and upper bounds of the plateau, respectively [5]

$$\mu(x) = \begin{cases} 0 & si\ x \leq a \\ \dfrac{x-a}{b-a} & si\ a < x \leq b \\ 1 & si\ b < x \leq c \\ \dfrac{d-x}{b-c} & si\ c < x \leq d \\ 0 & si\ x > d \end{cases} \quad \textbf{(4)}$$

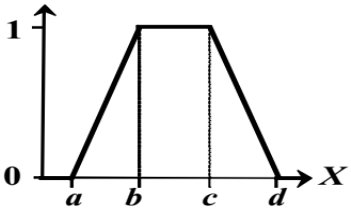


Figure 2. trapezoidal function

On fuzzy sets, logical operations such as intersection (conjunction), union (disjunction), and complement (negation) can be performed. These operations can be carried out using **T-norms and S-Norms**.

T-norms specify the conditions that operations must meet to intersect sets.

S-Norms define the conditions for performing unions [3].

Intersections occur in conjunctions and contributions, while unions are present in disjunctions and the global outcome. These operations are performed in expert systems to calculate the certainty factors of production rules. According to **T-Norms and S-Norms**, these operations satisfy the following conditions:

A T-norm operation satisfies the following properties:

Commutative	$T(x,y) = T(y,x)$	(5)
Associative	$T(x,T(y,z)=T(T(x,y),Z).$	(6)
Monotonicity	$T(x,y)>T(x,y)$ si $x\geq x' \cap y\geq y'$	(7)
Boundary Condition	$T(x,1)=x$	(8)

In a fuzzy system, linguistic variables, their corresponding linguistic labels, fuzzy sets, membership functions, inference rules, and certainty factors associated with the system's rules are key components. The system's input consists of qualitative values assigned to the linguistic variables.

These input values are transformed into membership values for fuzzy labels, which correspond to certainty factors. This process is called fuzzification, as it converts numerical values into fuzzy ones.

Once the values are fuzzified, production rules are applied using the certainty values. This step is known as fuzzy inference, during which T-Norms and S-Norms are employed to handle intersections and unions.

After obtaining the membership results for the output fuzzy sets, a numerical value must be derived from these results. This process is called defuzzification, and it is commonly performed using the centroid method, the most widely utilized approach in fuzzy systems.

2.1 Fuzzy Logic Method for Measuring University Students' Integrity

To measure the academic integrity of university students, the inference process based on the **Centroid or Center of Gravity (COG)** is applied in the numerical defuzzification of the value of formative variables. COG-based inference ensures that no coefficients need to be adjusted; it only requires knowledge of the membership functions for each defined label [3]. To infer using COG, the process begins with the membership values for each of the labels associated with the variable to be defuzzified. For each fuzzy output variable, the maximum value of the membership function for each label is truncated based on the value obtained during the inference process [4].

$$GOC = \int \frac{x * \mu(x)dx}{\mu(x)dx} \tag{9}$$

Where μ(x) represents the degree of membership of the element x, which will take values within the universe of discourse, using a defined step size. The smaller the step size, the more accurate the COG result will be.

To measure the academic integrity of university students during the COVID-19 pandemic, a fuzzy system is employed. The input variables are motivation, justification, and opportunity within an academic dishonesty framework, while the output variable is academic integrity. [9]. Each of these input and output variables is composed of the linguistic labels low, medium, and high.

- For the low label, a trapezoidal function is used, with its points on the x-axis at (0,0,0.2,0.5).
- For the medium label, a triangular function is used, with its points on the x-axis at (0.2,0.5,0.8).
- For the high label, a trapezoidal function is used, with its points on the x-axis at (0.5,0.8,1,1).

3 Neutrosophic Method for Measuring the Academic Integrity of University Students

Information aggregation, or information fusion, is the process of combining different data to produce a single output. Aggregation operators are a type of mathematical function used to merge information. They combine **n** values within a domain **D** and return a single value in the same domain.

Table 1. Scale of Linguistic Terms. Source: [6]

Linguistic Term	SVN Numbers
Extremely Good (EG)	(1,0,0)
Very Very Good (VVG)	(0.9, 0.1, 0.1)
Very Good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Moderately Good (MG)	(0.60,0.35,0.40)
Neutral (N)	(0.50,0.50,0.50)
Moderately Bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very Bad (VB)	(0.20,0.85,0.80)
Very Very Bad (VVB)	(0.10,0.90,0.90)
Extremely Bad (EB)	(0,1,1)

Linguistic terms and indeterminacy are represented using SVN numbers and based on information aggregation [6].

Establishing the evaluation framework:
Criteria and alternatives to be evaluated are selected to prioritize the latter. The framework is defined as follows [7]:

- $C= \{c_1, c_2 \ldots, c_n\}$ with $n \geq 2$, a set of criteria
- $E= \{e_1, e_2 \ldots, e_k\}$ with $k \geq 1$, a set of experts
- $X= \{x_1, x_2 \ldots, x_m\}$ with $m \geq 2$, a finite set of alternatives

Information collection:
Information about the preferences of decision-makers is gathered. The utility vector [11] is represented as follows [6]:

$\mathbf{P_j = \{p_{j1}, p_{j2}, \ldots, p_{jk}\}}$, where $\mathbf{p_{jk}}$ is the preference regarding criterion c_k for alternative $\mathbf{x_j}$.
Evaluations will be given using SVN numbers.[11]

To rank alternatives, a scoring function is used:

$$s(Vj)=2+Tj-Fj-Ij$$

Additionally, the precision function is defined as follows[12]:

$$a(Vj)=Tj-Fj$$

Then:

If $s(Vj) < s(Vi)$, Then Vj is less than Vi, denoted as $Vj < Vi$
If $s(Vj) = s(Vi)$
If $a(Vj) < a(Vi)$, Then Vj is less than Vi, denoted as $Vj < Vi$

If $a(Vj) = a(Vi)$, Then Vj and Vi are equal, denoted as $Vj = Vi$

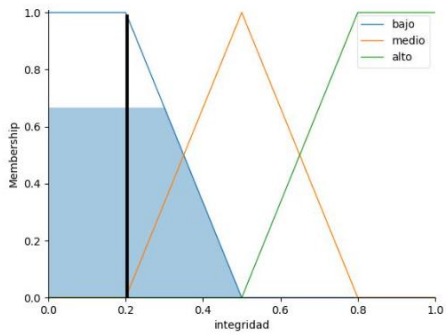
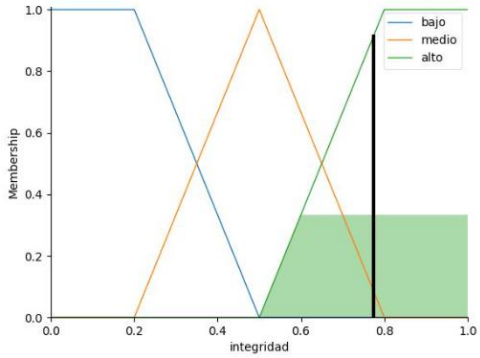
4. Results.

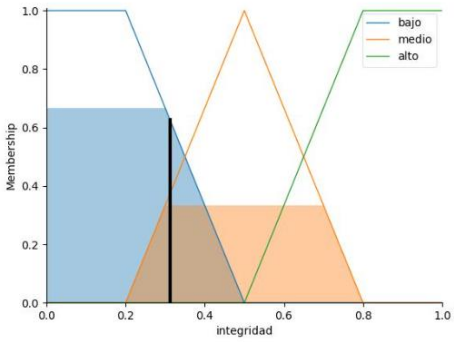
4.1. Fuzzy Logic Approach to Measure the Academic Integrity of University Students

Three scenarios are defined (scenario 1, scenario 2, and scenario 3), considering the input values of the linguistic variables, as shown in Table 1:

Table 2. Scenarios for Simulation

Scenarios	Motivation	Opportunity	Opportunity
Scenario 1	0.9	0.8	0.7
Scenario 2	0.2	0.1	0.4
Scenario3	0.7	0.5	0.7

Variable	Scientific Term	Analysis
Scenario 1		The academic integrity of the university student in scenario 1 is 20.417%, considered to be at a low level.
Scenario 2		The academic integrity of the university student in scenario 2 is 77.407%, considered to be at a high level.

Scenario 3		The academic integrity of the university student in scenario 3 is 31.212%, considered as low to medium level.

3.2 Neutrosophic Approach to Measure the Academic Integrity of University Students

Once the fuzzy measurements are obtained, a conversion is performed from the fuzzy value to the neutrosophic value using the linguistic terms of neutrosophy, resulting in Table 3.

Table 3. Scenarios According to SVN Numbers and Their Respective Linguistic Terms

Scenarios	**SVN Number**	**Linguistic Term**
Scenario 1	(0.20,0.85,0.80)	Very Bad (VB)
Scenario 2	(0.70,0.25,0.30)	Medium (M)
Sscenario 3	(0.30,0.75,0.70)	Bad (B)

The vector used to measure the academic integrity of university students during the COVID-19 pandemic has the following weights: **W= (0.57, 0.26, 0.19).** Subsequently, the opinions of the decision-makers are aggregated using the SVNWA aggregation operator. The results of the neutrosophic measurements according to the previously defined scenarios are shown in Table 4.

Table 4. Results of the Information Aggregation Method.

Scenario	**Aggregation**	**Score**	**Ranking**
Scenario 1	(0.12,0.91,0.88)	0.33	3
Scenario 2	(0.32,0.68,0.68)	0.96	1
Scenario 3	(0.18,0.85,0.82)	0.51	2

According to the scores, the priority will be as follows: **Scenario 2** > **Scenario 3** > **Scenario 1**. As a result of the aggregation and scoring, we find that the academic integrity of Scenario 1 ranks 3rd, the last position. Therefore, the measurement of the university student in this scenario was significantly impacted during the COVID-19 pandemic. It is up to the experts to decide what academic actions to take.

4. Conclusions (authors also should add some future directions points related to her/his research)

The fuzzy-neutrosophic approach under uncertainty, implemented to measure the academic integrity of university students during the COVID-19 pandemic, is based on the following: utilizing the factors of opportunity, justification, and motivation within an academic dishonesty context, and conducting fuzzy and neutrosophic measurements according to the established scenarios.

The theory of fuzzy logic applied to analyze and evaluate the academic integrity of university students during the COVID-19 pandemic enables the acquisition of accurate data compared to other qualitative methods.

Neutrosophic explicitly expresses the truth, uncertainty, and falsehood in the measurements of university students' academic integrity.

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