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Neutrosophic Logic Approach for Evaluating Learning Management Systems

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Abstract. Uncertainty in expert systems is essential research point in artificial intelligence domain. Uncertain knowledge representation and analysis in expert systems is one of the challenges that takes researchers concern as different uncertainty types which are imprecision, vagueness, ambiguity, and inconsistence need different handling models. This paper reviews some of the multivalued logic models which are fuzzy set, intuitionistic fuzzy set, and suggests a new approach which is neutrosophic set for handling uncertainty in expert systems to derive decisions. The paper highlights, compares and clarifies the differences of these models in terms of the application area of problem solving. The results shows that neutrosophic expert system for learning management systems evaluation as a better option to simulate human thinking than fuzzy and intuitionistic fuzzy logic because fuzzy logic can't express false membership and intuitionistic fuzzy logic is not able to handle indeterminacy of information.

Keywords: Uncertainty; Expert System; Fuzzy Set; Intuitionistic Fuzzy Set; Neutrosophic Set, Learning Management Systems.

1 Introduction

Uncertainty is the shortage of knowledge regardless of what is the reason of this deficient data [1]. Modeling uncertainty for solving real life situations is one of the crucial problems of artificial intelligence [2]. Previous researches presented various models that handle uncertainty by simulating the process of human thinking in expert systems, but these models are not enough to express uncertainty in problems [3][4]. Decision making includes ill-defined situations where it is not true or false; therefore it needs novel models to increase understanding of the realization outcome better than crisp [5].

Learning Management Systems (LMSs) are e-learning applications which help instructors in course administration. In higher education, the use of these applications has been rising as it supports universities in spreading educational resources to the learners [6][7]. System quality is an essential determinant of user satisfaction. It includes the usability, availability, stability, response time, and reliability of the system [8][9]. Previous studies [10] in learning management system evaluation are implemented under complete information, while real environment has uncertainty aspects.

This leads to emerging new approaches such as fuzzy, intuitionistic fuzzy and neutrosophic models all of which give better attribute explications. The fuzzy theory which considers the degree of the membership of elements in a set was introduced by Professor Lotfi Zadeh in 1965 [11]. Intuitionistic fuzzy set theory presented as an extension of the fuzzy sets by Attanssov in 1983 [12]. A novel approach proposed by Smarandache to handle indeterminacy information in 1999 called neutrosopic logic [13].

Expert system simulates human expert reasoning to solve issues in particular domain such as diagnosis, repair, decision support, monitoring and control, and evaluation [14][15]. Expert system in uncertainty environment needs to draw conclusion as would a human expert do [14]. Uncertainties types that can emerge include vagueness when information is gradually in natural, imprecision when information is not determined, ambiguity when available information leads to several feasible explications, and inconsistency when the conflicts and paradoxes in obtainable information is found [16][17]. This uncertainty types need models that handle different types of uncertainties [18].

This paper discusses multivalued logic models including fuzzy set, intuitionistic fuzzy set, and neutrosophic set for managing uncertainty in expert systems. The paper is organized as following: Section 1 provides an introduction to the paper; Section 2 presents multivalued logic models differences for managing uncertainty in expert systems; Then Section 3 presents the proposed neutrosophic expert systems for evaluating learning management systems and finally Section 4 presents the conclusion and future work.

2 Multivalued Logic Models for Managing Uncertainty in Expert System

This section explores basic properties and differences of multivalued logic models for handling uncertainty in expert systems.

2.1 Fuzzy Inference System

Crisp set deals with objects belonging to a set or is excluded from it. The fuzzy set theory discusses an aspect in which each object has a related value in the interval between 0 and 1; This indicates the degree of its membership in the set .The basic types of fuzzy logic membership function are triangular, trapezoidal, Gaussian, and bell. In Fuzzy Set Theory, each element x ∈ U (Universe of discourse) is assigned a single membership value. A fuzzy set $A = \{< x, \mu A(x) > | x \in U\}$ in a universe of discourse U is characterized by a membership function, μA, as follows [11]: $\mu A: U \rightarrow [0, 1]$. (1)

Fuzzy inference systems responsible for indicating the mapping from a given an input to an output as shown in Figure 1. It consists of fuzzification of input, knowledge based system, and defuzzification of output as shown in Figure 1 [19] [20]. Fuzzy knowledge base contains the membership functions of the fuzzy sets and set of fuzzy production rules. In fuzzification, the crisp input is converted to a fuzzy output using the membership functions stored in the fuzzy knowledge base. In defuzzification, the fuzzy output is converted to a crisp output using common techniques **:** centroid, bisector, and maximum methods.

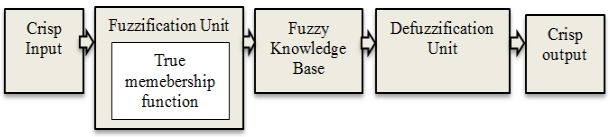

Figure 1: Block Diagram of Fuzzy Inference System

2.2 Intuitionistic Fuzzy Inference System

Atanassov said that the idea of intutuitionistic fuzzy set was a coincidence as he added to the fuzzy set definition a degree of non-membership. The intuitionistic idea incorporates the degree of hesitation [21]. An intuitionistic fuzzy set describes the membership of an element to a set, so that the sum of these degrees is always less or equal to 1. An intuitionistic fuzzy set $A = \{< u, \mu A(u), vA(u) > | u \in U\}$ in a universe of discourse U is characterized by a membership function μA, and a non-membership function vA, as follows [22] [23]**:**

$\mu A: U \rightarrow [0, 1], vA : U \rightarrow [0,1]$, and $0 \leq \mu A(u) + vA(u) \leq 1$. (2)

The membership of an element to a fuzzy set is a single value between zero and one**.** However, it is not true that the degree of non-membership of an element is equal to 1 minus the membership degree as there is a hesitation degree. Intuitionistic fuzzy set is suitable in simulating human imprecise decision making [24]. Figure 2 shows the intuitionistic fuzzy inference system. Fuzzy knowledge base contains the true and false membership functions of the intuitionistic fuzzy sets and set of intuitionistic fuzzy production rules.

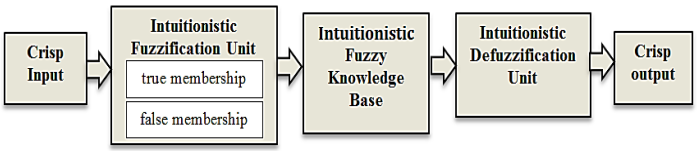

Figure 2: Block Diagram of Intuitionistic Fuzzy Inference System

2.3 Neutrosophic Inference System

Smarandache [13] proposed a novel approach called neutrosophic logic as an extension of fuzzy logic. Neutrosophic logic is an extension of the fuzzy logic, intuitionistic logic, and the three-valued, all of which variable x is described by triple values x= (t, i, f) where t for the degree of truth, f for the degree of false and i for the degree of indeterminacy [20]. Current expert systems are constrained with strict conditions while futuristic expert systems do not depend only on truth value, but also on falsity and indeterminacy membership. So in neutrosophic logic approach, experts are asked about certain statement to give a degree that the statement is true, degree the statement is false; and degree of indeterminate. In neutrosophic logic t, i, and f are independent from each other and there is not restriction on their sum where [25]:

$0 <= t + i + f <= 3$ (3)

Neutrosophic inference system consists of neutrosophication unit that accepts the crisp input and assigns the appropriate membership functions, neutrosophic knowledge base that maps input to output variable, and deneutrosophication unit that maps neutrosophic value to crisp value as shown in Figure 3 [20].

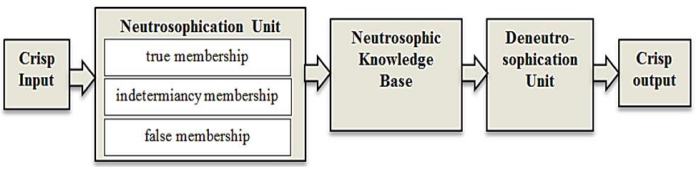

Figure 3: Block Diagram of Neutrosophic Inference System

2.4 Multivalued Logic Models for Handling Uncertainty

A better understanding of the differences and use between the uncertainty models is presented in this section. The selection of the appropriate uncertainty model for a problem is essential to get the desirable results. As mentioned in introduction section, the primary uncertainties types are imprecision, vagueness, ambiguity, and inconsistence. An example of vague information: "the colour of the flower is nearly red", this type of uncertainty can be handled by Fuzzy set. An example of imprecise: "the temperature of the machine is between 88-92 °C", this type of uncertainty can be handled by intuitionistic fuzzy set. An example of ambiguity information: "votes for this candidate is about 60%", and an example of inconsistence: "the chance of raining tomorrow is 70%, it does not mean that the chance of not raining is 30%, since there might be hidden weather factors that is not aware of", these types of uncertainties can be handled by neutrosophic set. Table 1 is concluded from [26-28] that shows multivalued logic models and their ability to express various uncertainty data types.

Table 1: Multivalued Logic Models and Uncertainty Data Types

Uncertainty Models	Uncertainty Data Types			
	Vague-ness	Impre-cision	Ambi-guity	Incon-sistent
Fuzzy	✓			
Intuitionistic Fuzzy	✓	✓		
Neutrosophic	✓	✓	✓	✓

3 Neutrosophic Expert System for Evaluation of Learning Management System

3.1 Neutrosophic Expert System Algorithm

Developing neutrosophic expert system is shown in Figure 4:

1- Determine the system requirements represented in inputs, rules and outputs.
2- Experts define the neutrosophic memberships of inputs variables of the system, rules of neutrosophic knowledge base of the system and output membership of the system quality.
3- Inputs are expressed in neutrosophic sets using truth, falsity and indeterminacy membership functions. This step is called as neutrosophication step.
4- Creating neutrosophic set rules for three knowledge bases for true, false and indeterminacy.
5- Neutrosophic sets are converted into a single crisp value which has triplet format truth, indeterminacy and false. This process is called as deneutrosophication.

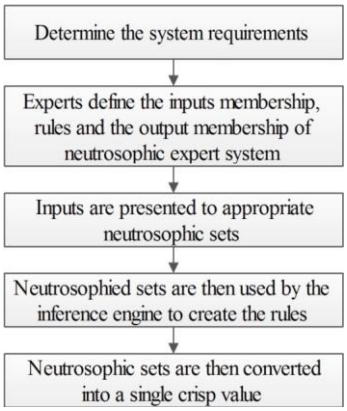

Figure 4: Steps for Developing Neutrosophic Expert System

3.2 Membership Functions for Input Attributes

LMS system quality is described by higher education organizations with uncertainty terms which are imprecise, vague, ambiguity and inconsistent. That is why conventional evaluation methods may not be virtuous. System can be defined as the stability, reliability, usability, availability, response time and adaptability attributes of the system. It quality is an important determinant of user satisfaction and system performance [29][30][31]. Previous studies in learning management system evaluation are implemented under complete information, while real world has uncertainty aspects. This leads us to illustrate the multivalued logic approaches differences such as fuzzy, intuitionistic fuzzy, and suggest a new one which is neutrosophic model to evaluate LMSs. In Table 2, a representation for each input attribute in usability using fuzzy, intuitionistic fuzzy and neutrosophic expert system for evaluating LMSs usability.

Table 2: Multivalued Logic Models Input Memberships

Type1 Fuzzy	Intuitionistic Fuzzy	Neutrosophic
$\mu_{Low}(x)$ in [0,1], $\mu_{Medium}(x)$ in [0,1], $\mu_{High}(x)$ in [0, 1], Where $\mu(X)$ is membership function.	$\mu_{Low}(x)$ in [0,1], V_{Low} in [0,1], $\mu_{Medium}(x)$ in [0,1], V_{Medium} in [0,1], $\mu_{High}(x)$ in [0,1], $V_{High}(x)$ in [0,1], Where $\mu(X)$ is membership function, $V(x)$ is a non-membership function and $0 \le \mu(x) + V(x) \le 1$.	$T_{Low}(x)$, $I_{Low}(x)$, $F_{Low}(x)$, $T_{Medium}(x)$, $I_{Medium}(x)$, $F_{Medium}(x)$, $T_{High}(x)$, $I_{High}(x)$, $F_{High}(x)$, Where T(x) is membership/truth value, I(x) is indeterminacy value, F(x) is a non-membership/False value.

3.3 Knowledgebase and Evaluation Process

The proposed neutrosophic model evaluates system LMSs system quality considering one main criterion: usability. A usability criterion is derived into several attributes

as following: usability can be evaluated by efficiency, learnability, memorability, error tolerance and user satisfaction attributes. In the proposed neutrosophic model, five inputs for usability are considered; each consisting of three terms, then each true, indeterminacy, and false usability knowledge base consists of 3^5= 243 rules after considering all the possible combinations of inputs. In fuzzy expert system depend on true knowledge base; while in intuitionistic fuzzy set expert rely on true and false knowledge base. Sample of the rules for true, false, indeterminacy are listed in Figure 5, 6, and 7.

No. of Rules	Efficiency	Error Tolerance	Learnability	Memorability	User Satisfaction	Usability
1	low	low	low	low	low	v. low
2	med	low	low	low	low	v.low
3	high	low	low	low	low	low
…						
243	high	high	high	high	high	v.high

Figure 5: True Usability Knowledge Base

No. of Rules	Efficiency	Error Tolerance	Learnability	Memorability	User Satisfaction	Usability
1	low	low	low	low	low	low
2	med	low	low	low	low	low
3	high	low	low	low	low	low
…						
243	high	high	high	high	high	high

Figure 6: False Usability Knowledge Base

No. of Rules	Efficiency	Error Tolerance	Learnability	Memorability	User Satisfaction	Usability
1	low	low	low	low	low	low
2	med	low	low	low	low	low
3	high	low	low	low	low	low
…						
243	high	high	high	high	high	med

Figure 7: Indeterminacy Usability Knowledge Base

4 Discussion

The authors presented fuzzy, intuitionistic fuzzy, neutrosophic expert system for evaluating LMSs quality. The neutrosophic expert system represents three components of truth, indeterminacy, and falsity unlike in fuzzy expert system which expresses the true membership value only and has no solution when experts have a hesitancy to define membership. Fuzzy system handles vagueness; while intuitionistic fuzzy system deals with vagueness and imprecision.

Neutrosophic system handles vagueness, imprecision, ambiguity, and inconsistent uncertainties types. For example; a vote with two symbols which are: A and B is occurred, in which some votes can't be determined if it's written A or B.

Table 1 shows the comparison of fuzzy, intutuionistic fuzzy, and neutrosophic expert system and their ability to represent different uncertainty data types. In Table 2, a representation for input attributes for usability using fuzzy, intuitionistic fuzzy and neutrosophic expert system for evaluating LMSs usability. The results show that fuzzy and intuitionistic fuzzy system is limited as it cannot represent paradoxes which are a feature of human thinking.

Conclusion and Future Work

Artificial intelligence disciplines like decision support systems and experts systems depend on true and indeterminate information which is the unawareness value between true and false. For example, if an opinion of an expert is asked about certain statement, then he may say that that the statement is true, false and indeterminacy are 0.6, 0.3 and 0.4 respectively. This can be appropriately handled by neutrosophic logic.

In this paper, a proposal for neutrosophic expert system for LMSs quality evaluation based on efficiency, learnability, memorability, error tolerance and user satisfaction for usability. Though, neutrosophic systems using varies according to the problem and available knowledge.

Future work will deal with the implementation of neutrosophic expert system for LMSs system quality evaluation. Neutrosophic Logic is a new approach for evaluating the system quality attributes of various systems that can adapt variations and changes. This is an assertion to use neutrosophic logic approach for assessing the system quality of LMSs.

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