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A new expert system for learning management systems evaluation based on neutrosophic sets

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Abstract

There has been a sudden increase in the usage of Learning Management Systems applications to support learner's learning process in higher education. Many studies in learning management system evaluation are implemented under complete information, while the real environment has uncertainty aspects. As these systems were described by development organizations with uncertainty terms such as vague, imprecise, ambiguity and inconsistent, that is why traditional evaluation methods may not be effective. This paper suggests neutrosophic logic as a better option to simulate human thinking than fuzzy logic because unlike fuzzy logic, it is able to handle indeterminacy of information which expresses the percentage of unknown parameters. As previous studies suggested neutrosophic decision maker and neutrosophic expert systems as future work in ecommerce and e-learning applications, this paper presents neutrosphic expert system for learning management systems evaluation. Information for building and validating the neutrosophic expert system is collected from five experts using surveys, and then analysis is done by using Fuzzytech 5.54d software. Finally, the comparison between fuzzy expert system and neutrosophic expert system results show that the neutrosophic logic is capable of representing uncertainty in human thinking for evaluating Learning Management Systems.

KEYWORDS

expert system, knowledge base, Learning Management Systems, neutrosophic logic, system quality

1 | INTRODUCTION

Learning Management Systems (LMSs) are software applications that assist instructors and learners with course management. The use of these applications has been increasing in higher education system as it is a useful tool that support universities in spreading educational resources to the learners in (Chung et al., 2013; Aggarwal et al., 2012). System quality is a wide concept that is associated with system performance and user interface (Almarashdeh et al., 2010). Former studies showed that system quality is an important determinant of user satisfaction and perceived usefulness (Lwoga, 2014). It can be defined as the usability, availability, response time, stability, reliability and suitability of the system (Almarashdeh et al., 2010). Previous researches (Yigit et al., 2014; Dubey et al., 2012) proposed multi-criteria decision making and fuzzy logic approach for LMSs software evaluation which requires availability of complete information. Multi-criteria decision making cannot handle uncertainty, whereas fuzzy logic presents a poor representation of uncertain data as it expresses the true membership degree in a value between 0 and 1. Fuzzy sets do not express the degree of false membership,

and they have no solution when experts have a hesitancy to define membership. This problem demands new approaches based on many valued logic models that deals with uncertainty (Vern & Dubey, 2013).

(Smarandache, 1999) proposed a new approach called neutrosophic logic as an extension of fuzzy logic. Neutrosophy comes from Latin "neuter", which means neutral and Greek "Sophia", which means skill or wisdom. It means knowledge of neutral thought. Neutrosophic logic is a better option to simulate human thinking than fuzzy logic because unlike fuzzy logic, it is able to handle indeterminacy of information which expresses the percentage of unknown parameters (Ansari et al., 2013; Raheja & Dhadich, 2013; Aggarwal et al., 2010a). Expert systems and decision support systems tend to rely not only on true value, but also on false membership. So current systems which are dedicated to simulate human brain are constrained with strict conditions, whereas, neutrosophic logic holds its chance to simulate human thinking and to be utilized for real world problems (Aggarwal et al., 2010a). In neutrosophic logic, the sum of components is not necessarily 1 as in fuzzy logic, but any number between −0 and 3; therefore, neutrosophic logic is able to deal with contradictions

which are true and false at the same time (Smarandache, 1999). Neutrosophic logic is a proposed 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.

This paper proposes neutrosophic expert system for LMSs quality evaluation as a new approach for expert systems. The paper is organized in the following way: Section 1 provides an introduction to the paper; Section 2 presents LMSs system quality concept and its attributes; Section 3 discusses neutrosophic logic and the presented neurtosophic expert system; Section 4 is about developing neutrosophic expert system for evaluating LMSs system quality; Section 5 discusses the results of neutrosophic expert system versus fuzzy expert system; and finally Section 6 concludes the paper.

2 | LMS SYSTEM QUALITY

LMS is an information system that supports management of teaching and learning activities in higher educational institutes. Development of information systems is not easy as it needs to visualize the complete information system with proper functionality. System quality can be defined as an assessment of an information system from technical and design perspectives (Alshibly, 2014). In (Alla et al., 2013), system quality of LMS is defined as the usability, accessibility, reliability, and stability of the system. It shows that usability factor is an important dimension that affects the system quality which is the main factor that increases or decreases the LMS efficiency. Another research (Aggarwal et al., 2012) concerns with other dimensions of system quality of LMS such as usability, availability, reliability, completeness, system flexibility, response time, and security. In this paper, the concern is on three system quality attributes which are usability, reliability, and accessibility.

2.1 | Usability

Usability is a significant factor that evaluates system quality software. Usability is an essential quality attribute of interactive software systems that deals with the continuous use of LMS application (Jain et al., 2012). Usability of LMS is directly related to the interactions between users and the system. LMSs are different from other systems as their focus is on how the user can interact to learn through them (Nagpal et al., 2013). There are many models that define usability quality attributes or factors that affect usability (Senol & Gecili, 2014).

- Efficiency: This dimension deals with the user understanding of the software. It indicates whether the system can achieve the users' objectives. The most common measures of efficiency taken by usability researchers are: number of goals/task not achieved, time taken for task completion, unproductive period, and percentage of task not completed.

- Error tolerance: It refers to the number of failures and easy error recovery. The most common measures of error tolerance are: number of times the user couldn't continue the task, number of actions taken that do not solve the problem, time spent on one error recovery, and number of times the user has to restart the application.

- Learnability: The dimension deal with the user ability to understand and learn software in an appropriate time frame.

- Memorability: The possibility of the user to remember basic functions of software even after some period of time.

- User Satisfaction: The software should be easy to use. If the four mentioned requirements are not achieved, user satisfaction is difficult to meet (Bhatnagar et al., 2012).

2.2 | Reliability

There are some uncertainty factors that affect the software reliability, whereas the conventional models deal with software failures (Cao et al., 2014). Conventional software reliability models concern with attributes such as probability of failure, average time to repair, and average time between system failures. Because of uncertain data, imprecise information, and incomplete knowledge in the software reliability assessment, the fuzzy theory can be used (Georgieva & Dimov, 2011). Reliability of LMSs deals with minimum loss in case of software failure, whereas data recoverability is very important. It is defined as follows:

- Fault tolerance: It is the ability of software to recover from failure.

- Maturity: It concerns software failure frequency, where increasing maturity is associated with decreasing of failure.

- Recoverability: It concerns with the ability to return back failed system to full functionality.

2.3 | Accessibility

The accessibility allows individual with or without disabilities to take full advantage of information and services offered by the system (Al & Kamoun, 2012). Accessibility in e-learning refers to a learner's ability to access e-learning resources with minimal effort (Lin, 2010). Tamara et al., in (Almarabeh et al., 2014), define accessibility as learners to access the learning to material whenever and wherever they want without losing important information. The concept of accessibility in e-learning websites concerns with the following:

- Navigability: User interface and navigation must be operable. The interface cannot require interaction that a user cannot perform.

- Robustness: Content must be able to be accessed by a wide variety of users including evolving technologies.

- Understandability: Information and user interface components must be presentable to users in a perceivable way.

3 | NEUTROSOPHIC LOGIC AND NEUTROSOPHIC EXPERT SYSTEM

Neutrosophic logic is an extension of the fuzzy logic, all of which variable x is described by triple values $x = (t, i, f)$ where t is the degree of

true, *f* is the degree of false, and *i* is the level of indeterminacy. For example, the proposition "Tomorrow it will be raining" does not mean a fixed-valued components structure; this proposition may be 40% true, 50% indeterminate, and 45% false at a time; but a second time may change to 50% true, 49% indeterminate, and 30% false (Ansari et al., 2011). Neutrosophic decision making, and neutrosophic expert systems in e-learning are suggested as future work for neutrosophic logic applications (Wang et al., 2005). In neutrosophic logic, the membership functions of inputs of every logical variable *x* is described by the degree of true, the degree of false and the level of indeterminacy as shown in Figure 1.

The presented neutrosophic expert system consists of neutrosophication unit that accepts crisp input. It assigns the appropriate membership functions, neutrosophic knowledge base that maps input to output variable depending on rules that are designed by experts and deneutrosophication unit that maps neutrosophic value to crisp value having a triplet format (true, indeterminacy, false); this differs from the fuzzy expert system which assigns a true input membership value as shown in Figure 2. In which, neutrosophication unit accepts the crisp input and assigns the appropriate membership (true, indeterminacy, false). Input variables are mapped to output using the Neutrosophic rule base. The resulting Neutrosophic output is mapped to a crisp value in deneutrosophication step using defuzzification methods. Neutrosophic sets can handle indeterminate information where an expert is asked about a certain statement to give a degree that the statement is true, false, and indeterminate.

Different evaluation models for e-learning quality attributes developed under the condition of complete information availability. Real environment is characterized by imprecise knowledge, incomplete information and uncertain data, this problem leads researchers to use approaches that deals with vagueness like fuzzy logic (Popenţiu-Vlădecescu & Albeanu, 2012; Salmi et al., 2014), and to suggest neutrosophic logic that handle uncertainty for e-Learning quality evaluation (Albeanu & Vlada, 2014). Expert system simulates human expert thinking to solve a problem and take decision in a particular domain which is mainly composed of the user interface, knowledge base, and inference engine (Anuradha & Kumar, 2013). Expert system aims to represent the problem of uncertainty in knowledge to draw conclusion
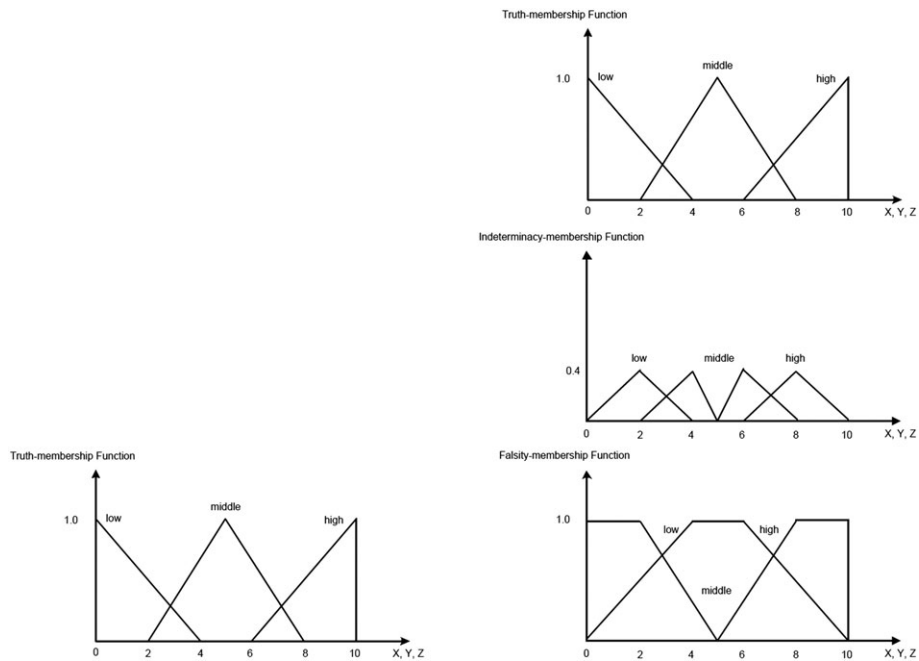

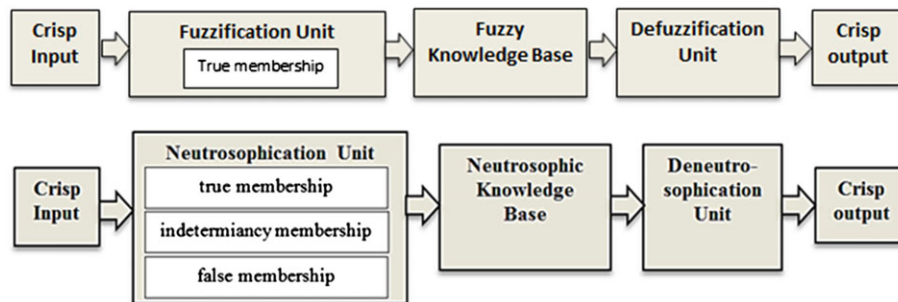**FIGURE 1** Fuzzy vs. Neutrosophic Membership functions of inputs [24]

FIGURE 2 The Difference between Fuzzy Expert System and Neutrosophic Expert System

with the same level of accuracy as would a human expert do (Kaur et al., 2013). Designing an expert system depends on personnel interaction: an expert who has knowledge and solves the problems; a knowledge engineer who encodes the expert's knowledge in inference engine and knowledge base; and a user who uses the system to get advice and information needed (Anuradha & Kumar, 2013; Tripathi, 2011).

4 | THE PROPOSED NEUTROSOPHIC EXPERT SYSTEM FOR EVALUATING LMSS QUALITY

In this section, a neutrosophic expert system is proposed to assess LMS system quality considering three main attributes: usability, accessibility, and reliability are taken to provide a value of system quality.

FIGURE 3 Sample of Survey used to Collect Rules for building Neutrosophic Expert System

FIGURE 4 Sample of Survey used to Validate Rules for the built Neutrosophic Expert System
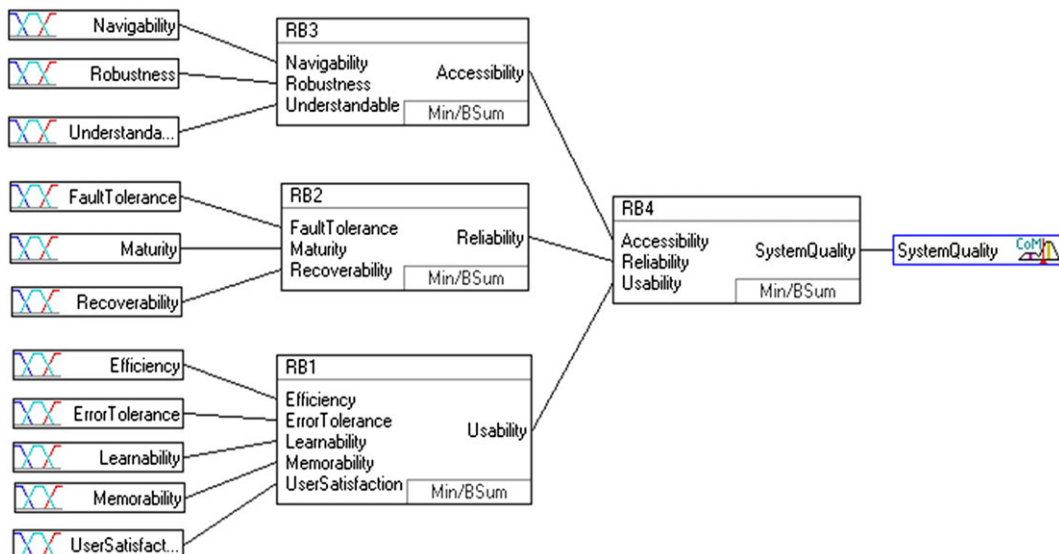

FIGURE 5 LMSs System Quality of Neutrosophic Expert System

Neutrosophic expert system uses neutrosophic logic to map the inputs to true, false, and indeterminacy membership functions. These inputs are obtained from the questionnaire of some domain experts; their option is of degree of truth, indeterminacy, and false. In this paper, five experts (referred in the acknowledgments) help us to develop neutrosophic expert system for evaluating the LMS; experts define the membership function for inputs, knowledge base and membership of output. The researchers conducted two surveys; one for collecting the data needed to build the rules of LMS expert system evaluation, and the other one is for validating the system rules and results after building it as shown in Figures 3 and 4. In (Alshibly, 2014; Aggarwal et al., 2010b), the authors suggested to simulate neutrosophic inference system as currently no software is available for it by designing three fuzzy inference systems representing true, indeterminate, and false value, which can be executed independently of each other using MATLAB Fuzzy logic toolbox. Simulation of the proposed neutrosophic expert system has been carried out by Fuzzytech 5.54 software as there is no need to develop a new system from scratch (http://fuzzytech.com,). Currently, Fuzzytech does not provide with the facility of neutrosophication, so to simulate it, three fuzzy inference systems have been created with the representing true, indeterminate and false value. Fuzzytech allows more building and connecting than fuzzy inference systems. Also, it permits the implementing of true, indeterminacy, and false memberships freely without applying fuzzy membership restrictions which is not provided in the Matlab fuzzy logic toolbox.

Algorithm of the proposed neutrosophic expert system is stated as below:

Step 1. Determine the system requirements represented in inputs, rules, and outputs.

Step 2. Experts define the neutrosophic memberships of inputs variables of the system which are usability, reliability, and accessibility,
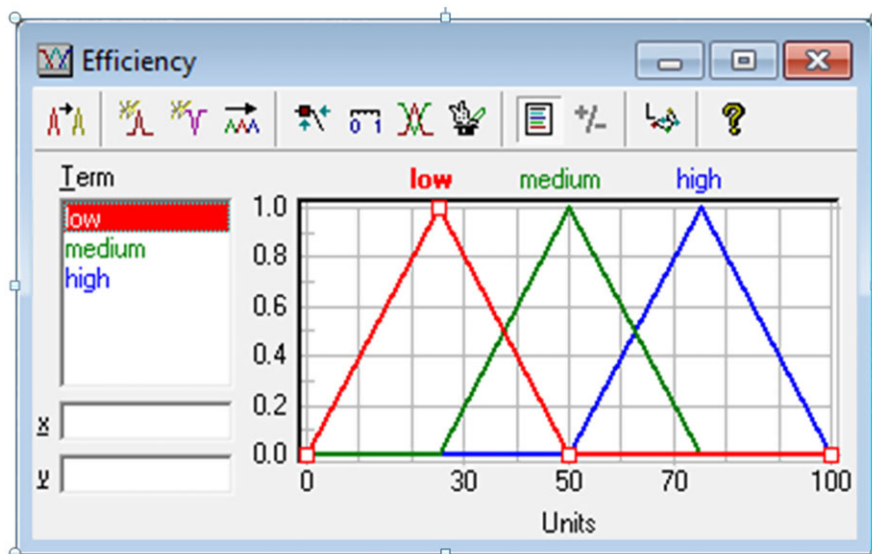

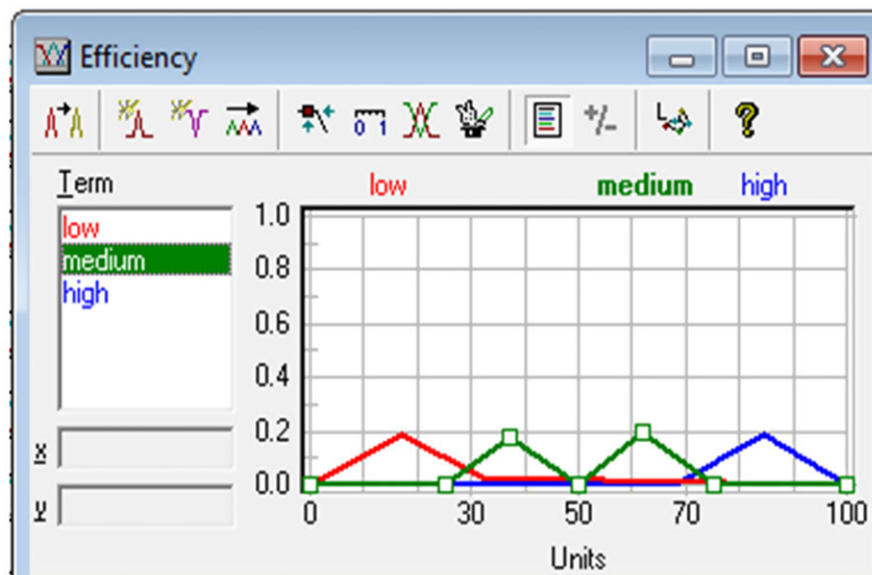**FIGURE 6** Efficiency True Input Membership

FIGURE 7 Efficiency Indeterminacy Input Membership

rules of neutrosophic knowledge base of the system, and the output membership of the system quality.

Step 3. Inputs are presented to appropriate neutrosophic sets using truth, false, and indeterminacy membership functions. This step is called as neutrosophication step.

Step 4. Neutrosophied sets are then used by the inference engine to create the rules which are stored in the neutrosophic.

Step 5. In the final step of cycle, neutrosophic sets is then converted into a single crisp value which has triple format: truth, indeterminacy and false. This is the best representative
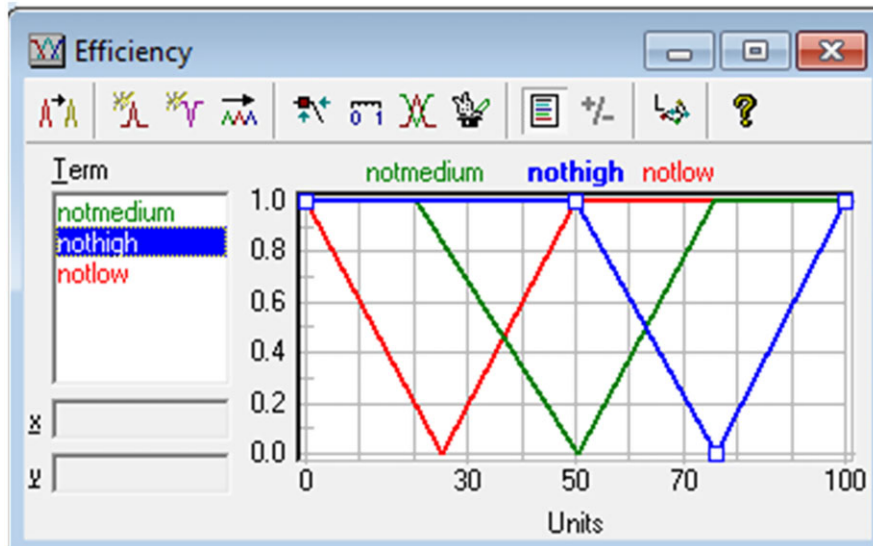

FIGURE 8   Efficiency False Input Membership

#	IF			THEN	
	Accessibility	Reliability	Usability	DoS	SystemQuality
1	very_low	very_low	very_low	1.00	very_low
2	very_low	very_low	low	1.00	low
3	very_low	very_low	medium	1.00	low
4	very_low	very_low	high	1.00	low
5	very_low	very_low	very_high	1.00	medium
6	very_low	low	very_low	1.00	low
7	very_low	low	low	1.00	low
8	very_low	low	medium	1.00	low
9	very_low	low	high	1.00	medium
10	very_low	low	very_high	1.00	medium

FIGURE 9   True System Quality Knowledge Base

#	IF			THEN	
	Accessability	Reliability	Usability	DoS	SystemQuality
1	very_low	very_low	very_low	1.00	medium
2	very_low	very_low	low	1.00	low
3	very_low	very_low	medium	1.00	low
4	very_low	very_low	high	1.00	low
5	very_low	very_low	very_high	1.00	medium
6	very_low	low	very_low	1.00	low
7	very_low	low	low	1.00	low
8	very_low	low	medium	1.00	low
9	very_low	low	high	1.00	medium
10	very_low	low	very_high	1.00	medium

FIGURE 10   Indeterminacy System Quality Knowledge Base

#	IF			THEN	
	Accessability	Reliability	Usability	DoS	SystemQuality
1	notvery_low	notvery_low	notvery_low	1.00	very_low
2	notvery_low	notvery_low	notlow	1.00	low
3	notvery_low	notvery_low	notmedium	1.00	low
4	notvery_low	notvery_low	nothigh	1.00	low
5	notvery_low	notvery_low	notvery_high	1.00	medium
6	notvery_low	notlow	notvery_low	1.00	low
7	notvery_low	notlow	notlow	1.00	low
8	notvery_low	notlow	notmedium	1.00	low
9	notvery_low	notlow	nothigh	1.00	medium
10	notvery_low	notlow	notvery_high	1.00	medium

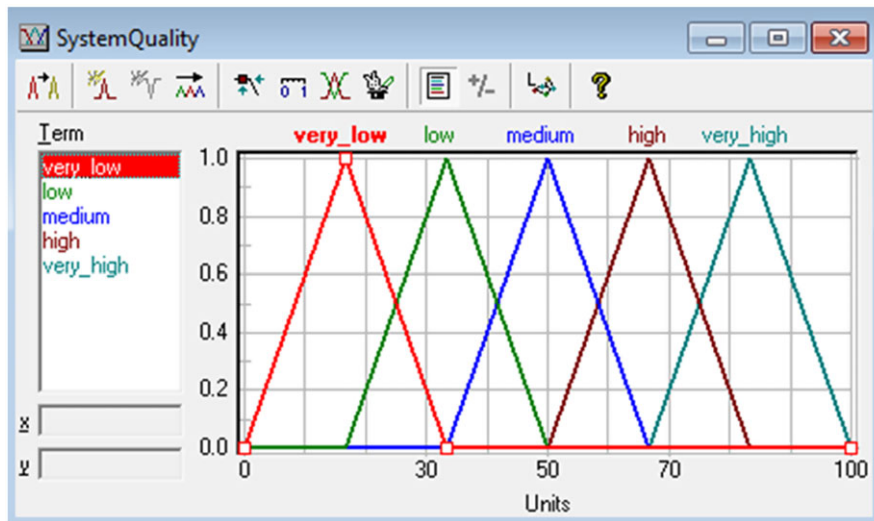**FIGURE 11**   False system quality Knowledge Base

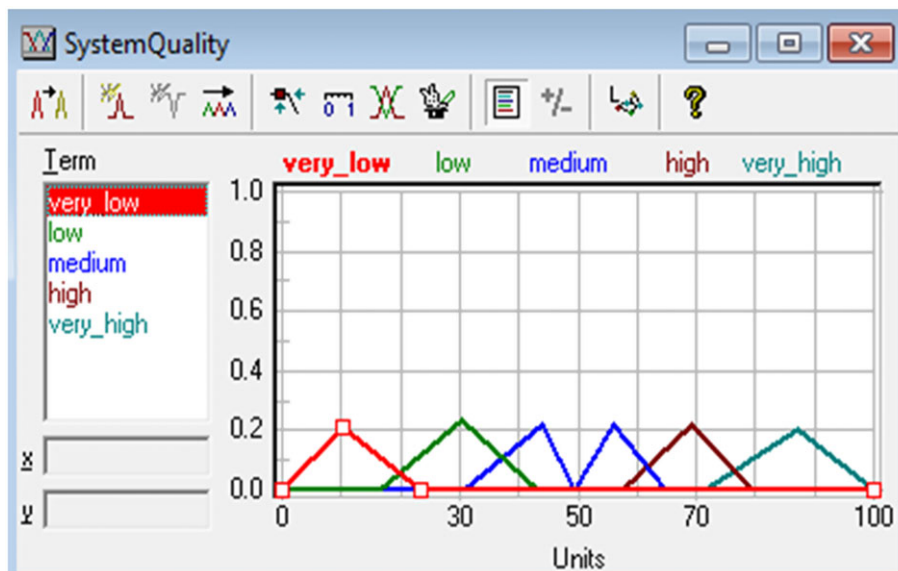**FIGURE 12**   System Quality True Membership

FIGURE 13   System Quality Indeterminacy Membership

of the derived neutrosophic sets. This process is called as deneutrosophication.

Step 6. Developing and implementing the neutrosophic expert system by using inputs, rules, and output is defined earlier to show the results.

Step 7. Validating neutrosophic expert system to ensure that the output of the intelligent system is equivalent to those of human experts when the same inputs are given. Then the results of validation steps are used to determine and fix errors to improve the knowledge base.

In uncertain environments, system validation includes extensive testing to guarantee that the system provides the correct decisions like an expert in the same field. The testing only compares the system's results with that of experts expected results (Zhu et al., 2011;

Gonzalez & Barr, 2000). The validation is the process of confirming that the output of the expert system is equal to those of human experts when given the same inputs (Knauf et al., 2007). Knauf (Knauf et al., 2007) and Jiri Bartos at al. (Bartoš et al., 2012; Bartos & Walek, 2013) propose methodologies for evaluating system quality under uncertainty where functional and non-functional requirements can be tested which is used in this paper. These methods involve steps which are: identification of criteria for testing that cover the domain and generating a set of questions to validate neutrosophic knowledge base; different tests are prepared that evaluates whether the system is compatible with predefined criteria, where the test does not involve subjective opinions of the tester. Then, a comparison between system responses and five experts' (the same experts who help us in creating
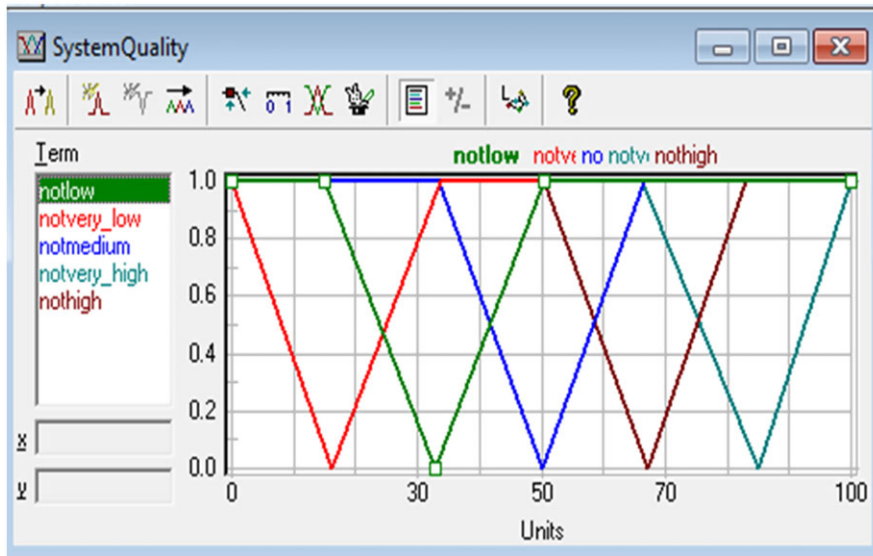

FIGURE 14 System Quality False Membership

TABLE 1 Example of the Applied Neutrosohpic Expert System and Fuzzy Expert System

	Usability					Reliability		
	Efficiency	Error Tolerance	Learnability	Memorability	User Satisfaction	Fault Tolerance	Maturity	Recoverability
1	35	30	45	35	35	50	55	55
2	35	40	45	80	60	50	65	60
3	80	40	70	35	50	50	65	75
4	55	70	55	80	60	80	65	75
5	65	55	65	55	65	65	75	80
6	60	75	60	75	70	55	85	70
7	80	75	75	85	80	80	85	80

F = False; I = Indeterminacy; SQ = System Quality; T = True.

the knowledge base referred in the acknowledgments) responses is performed. The experts' responses express solutions and admit indeterminacy rating of solutions. Then, the results of experimentation steps are used to determine and fix errors to improve the knowledge base.

4.1 | Membership functions for input parameters

As illustrated in Section 2, to evaluate system quality, there are three main linguistic variables: usability, reliability, and accessibility in which three fuzzy inference systems have been created with the representation of true, indeterminate, and false values as shown in Figure 3. As discussed in Section 2, usability is affected by efficiency, learnability, memorability, error tolerance, and user satisfaction. Reliability is affected by fault tolerance, maturity, and recoverability, whereas accessibility is affected by navigability, robustness, and understandability. All these variables have different contributions in the system quality of LMSs software. The neutrosophic sets is represented by three values: true, false, and indeterminacy membership functions, respectively. This step is called the neutrosophication step. The linguistic values input attributes were defined by experts as low, medium, and high. True, indeterminacy, and false membership values for efficiency inputs are shown in Figure 5, Figure 6, and Figure 7, respectively. The other membership values for other input attributes are defined as efficiency which depends on information collected from experts given by a degree of truth, indeterminate, and false.

4.2 | Knowledgebase and evaluation process

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. Three inputs for reliability are considered; each consisting of three terms: then each true, indeterminacy, and false reliability knowledge base consists of 3^3 = 27 rules after considering all the possible combinations of inputs. Also, three inputs for accessibility are considered; each consisting of three terms: then each true, indeterminacy, and false reliability knowledge base consists of 3^3 = 27 rules after considering all the possible combinations of inputs. The knowledge-base rules are designed on the basis of expertise knowledge of e-learning field. A sample of the rules is listed in Figure 9–11 for system quality knowledge base; also, there are other three knowledge bases for usability, reliability and accessibility. Degree of Support (DoS) is the degree to which the Fuzzytech software supports a specific rule in a rule base when calculating an inference from the fuzzy rule. The degree of support allows attaching individual weights to each rule in a rule base range from 0.00 to 1.00. Degree of support is not needed in neutrosophic expert system as fuzzy sets, and rules are represented by degree of truth only, whereas neutrosophic sets and rules are represented by degree of truth, indeterminacy, and false.

4.3 | Membership and knowledge base for output

The proposed neutrosophic expert system evaluates system LMSs system quality considering three main criteria; inputs usability, reliability, and accessibility. True, indeterminacy, and false membership values for the system quality are shown in Figure 12, 13 and 14, respectively. Therefore three inputs for system quality are considered; consisting of five terms, then each true, indeterminacy, and false system quality knowledge base consists of 243 rules after considering all the possible combinations of inputs. Three inputs for reliability are considered; each consisting of three terms, true, indeterminacy, and false reliability knowledge base consists of 125 rules after considering all the possible combinations of inputs. This knowledge base rules are collected from experts in e-learning field.

TABLE 1 Continued

| | Accessibility | | | SQ | | | |
	Navigability	Robust	Understand-able	Fuzzy		Neutrosophic	
1	45	55	45	T = 0.4722	SQ = 0.4722	T = 0.4722 I = 0.5000 F = 0.5000	SQ = 0.4931
2	60	60	45	T = 0.5625	SQ = 0.5625	T = 0.5625 I = 0.5000 F = 0.4855	SQ = 0.5193
3	85	55	75	T = 0.5952	SQ = 0.5952	T = 0.5952 I = 0.5000 F = 0.4442	SQ = 0.5378
4	65	65	65	T = 0.6061	SQ = 0.6061	T = 0.6061 I = 0.5000 F = 0.4420	SQ = 0.5460
5	70	75	55	T = 0.6458	SQ = 0.6458	T = 0.6458 I = 0.5000 F = 0.4673	SQ = 0.5446
6	75	70	75	T = 0.6944	SQ = 0.6944	T = 0.6944 I = 0.4544 F = 0.4509	SQ = 0.5837
7	85	80	75	T = 0.7333	SQ = 0.7333	T = 0.7333 I = 0.3775 F = 0.4439	SQ = 0.63362

5 | RESULTS

The final objective of this study was to present a neutrosophic expert system to evaluate LMSs quality. According to the experts' opinions, authors applied it for seven examples for LMSs evaluations, and the following results have been presented. The authors presented neutrosophic expert system for evaluating LMSs quality as illustrated in this paper, and fuzzy expert system which was not clarified as it was used to compare the final results. The results generated by neutrosophic expert system have three components of truth, indeterminacy, and false unlike in fuzzy expert system which represents the true membership value only and has no solution when experts have a hesitancy to define membership. Fuzzy system handle vagueness; while neutrosophic system deals with vagueness when information is naturally graded, imprecision when the available information is not specified, ambiguity when information is unclear, and inconsistent when obtainable information is conflicted information existing in real world.

Table 1 shows the comparison of the results obtained by fuzzy expert system and the proposed neutrosophic expert system. The results shows that fuzzy system is limited as it cannot represent paradoxes as a feature of human thinking. Neutrosophic expert system gives obvious intuition of true, indeterminacy, and false associate with inputs, rules, and outputs.

6 | CONCLUSION AND FUTURE WORK

Artificial intelligence domains like expert systems and decision support systems depend not on true and false information, but also on indeterminate information which is the ignorance value between true and false. For example, if an opinion of an expert is asked about certain statement, then he may say that the possibilities that the statement is true, false and indeterminacy are 0.7, 0.2, and 0.3, respectively. This can be appropriately handled by neutrosophic logic, which have the true, indeterminate, and false membership functions independent of each other, and each can overuse or underuse the limit of [0,1], depending on the depiction of absolute or conditional values, respectively.

In this paper, an expert system for LMSs quality evaluation using a neutrosophic logic approach based on eleven performance criteria which are efficiency, learnability, memorability, error tolerance and user satisfaction for usability; fault tolerance, maturity and recoverability for reliability; and navigability, robustness and understandability for accessibility is presented. Neutrosophic memberships have been used to overcome the uncertainty of concepts that are associated with human expert judgments. Neutrosophic expert system validation has been performed on the basis of Knauf validation framework to improve knowledge base.

With the ever-growing number of LMSs, task of selecting the most suitable LMS becomes even more important. Multi-criteria decision-making methods help in taking decisions involving multiple criteria. Taking a decision could correspond to choose the best alternative from a set of alternatives or to choose a small set of good alternatives by analyzing the different criteria. For future work, we will consider a new hybrid neutrosophic multi-criteria decision-making process for selecting the most appropriate LMS in an educational organization.

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