ISSN-L: 2223-9553, ISSN: 2223-9944
Vol. 2, No. 1, January 2012

FUZZY MULTI CRITERIA EVALUATION FRAMEWORK FOR E-LEARNING SOFTWARE QUALITY

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ABSTRACT

Quality of software is one of several key factors for successful e-learning implementation. Evaluation of e-learning software is a vital stage in deploying e-learning within an organization and it involves broad view and various perspectives which might be considered as a case of multi criteria decision making (MCDM) problem. Such evaluation based on MCDM perspective still left a gap in recent literature which mostly provide qualitative analysis. This study aims to fill the gap by developing a new methodology to evaluate the quality of e-learning software from both qualitative and quantitative analyses. The study proposes the applicability of ISO 9126 software quality metrics as the basis of evaluation framework. It is then extended with MCDM methodology by combining Analytic Hierarchy Process (AHP) and Fuzzy Set Systems to provide an evaluation framework that capable in tackling inconsistency and vagueness of human judgement during evaluation processes.

Keywords: E-learning software, software quality, ISO 9126, fuzzy set theory, analytic hierarchy process.

INTRODUCTION

Information technology has become the main tool in delivering various kinds of services from simple information exchange to complex business financial transactions. Educational sector also affected significantly by information technology known as electronic learning with the main aim at enhanching learning and teaching processes.

The term of e-learning refers to the extensive use of information technology to transfer of skills and knowledge which encompasses computer-based learning, virtual education, distance learning and digital collaboration (Nagy, 2005;). Developed countries have enjoyed many benefits upon implementing e-learning on which teaching contents are digitally created and delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, and CD-ROM (Zhang and Nunamaker, 2004). Its self-paced and interactive features that includes media in the form of text, image, animation, streaming video and audio have been helping distance students to experience learning environment as the real one (Lee and Dziuban, 2002).

It is reported by Lahad, et.al. (2004) that the most prominent benefits of e-learning are less time consuming, simplified administration procedures, active learning paradigm, possiblity to choose what and when to study, and reduce instructor role as face to face learning. Additional advantages of e-learning include no geographical barriers as people from any parts of the world may access it through the Internet and enhancing collaboration and community among learners.

Unfortunetaly, many positive impacts in adopting e-learning could not be enjoyed by their counterparts in developing countries. E-learning cases in developing countries show evidence that many of them do not apply e-learning at all while some others are still strugling in improving its capacity in delivering learning materials electronically as found in universities (Barton, 2010) and private sectors (Ventura and Jang, 2010). Lack of infrastructure, resources and user awareness are cited as the main issues to hinder them from enjoying fruitful e-learning implications (Lahad, et.al., 2004).

This paper argues that one of the key factor for succesful e-learning implementation is the availability of applicable and realiable e-learning software as affirmed by (Rejas-Muslera, 2010). Within the context of developing country circumtances, many considerations should be taken into account in order to appropriately evaluate e-learning software. Therefore, ISO 9126 which is an international standard to provide a framework for the evaluation of software quality is used in this study and further it is combined with a novel Fuzzy Analytic Hierarchy Process to develop a farmework to evaluate e-learning software from the perspective of multi criteria decision making (MCDM) as the fundamental objective of this study.

The rest of this paper is organized as follows. Section 2 presents literature on e-learning evaluation. In section 3, basic concept of fuzzy set theory is described. Then, in section 4, the new fuzzy multi criteria decision making framework is clearly explained and justified. Finally, concluding remarks and future research directions are given in last section.

E-LEARNING EVALUATION

Related Works

Evaluation of e-learning is urgent in order to measure to what extent e-learning implementation has reach its goal. Until recently, e-learning evaluation is still an open topic for researcher to contribute. Selim (2007) and Govindasamy (2001), for example, analyze and evaluate how e-learning affect educational processes by showing several cases, while other papers assess e-learning success factors from availability of advanced infrastructure (Zhang, 2003), richness of media (Liu and Liao, 2009), and active learning environment (Kickul, G. & Kickul, J. 2006).

Study on e-learning software evaluation is an ongoing topic of research. The paper written by Chua and Dyson (2004) might be regarded among the earliest approach in proposing ISO 9126 Quality Model as a useful tool for evaluating e-learning. Basically they discuss how ISO 9126 might be helpful for teachers and educational administrators to detect design flaws in any e-learning software. Their analysis end up with a recommendation to enhance ISO 9126 as uncovered some inherent weaknesses in the model, particularly in terms of usability characteristic. However, the analysis was based on qualitative method.

According to Costabile, et.al (2005), two main consideration should be taken into account in evaluating e-learning application, pedagogic effectiveness and usability. They emphasize that student's interactions with e-learning software must be as natural and intuitive as possible which might be obtained by enhancing pedagogic effectiveness and usability.

Similarly, eLSE (e-Learning Systematic Evaluation) was developed by Lanzilotti, et.al. (2006) which centers its evaluation processes on the aspect of the user-system interaction that had been neglected previous studies. Interaction aspect and the usability of the user are affirmed as crucial aspects for succesful e-learning implementation. Also the study was center its analysis by using qualitative approach.

A case of e-learning evaluation was reported by Covella and Olsina (2006). In this paper, they present a systematic qualitative approach to consistently evaluating quality of software or web applications by actual users in real con-texts of use. Their findings suggest the importance of consistent methodology and the challenges of assessing quality in use with actual users.

ISO 9126 SOFTWARE METRICS

While previous studies have approached this issue from particular aspects and apply quantitative analysis on it, this study proposes a unique way by emplpying multi criteria decision making (MCDM) prespective to approach the issue. Through MCDM approach the evaluation might be performed in both qualitative and quantitative at the same time Chiou et.al. (2005) which is the advantage of the proposed framework in this study.

Considering software engineering perspective, ISO 9126 is a widely accepted standard for appropriately measuring the quality of any kind of software. The strength of ISO 9126 lies mostly on its coverage in software evaluation which includes both quality of design and quality of conformance of any software. ISO 9126 standard classifies its evaluation under six criteria called functionality, reliability, usability, efficiency, maintainability and portability. Each of these criteria consists of several sub criteria as shown in Figure 1.

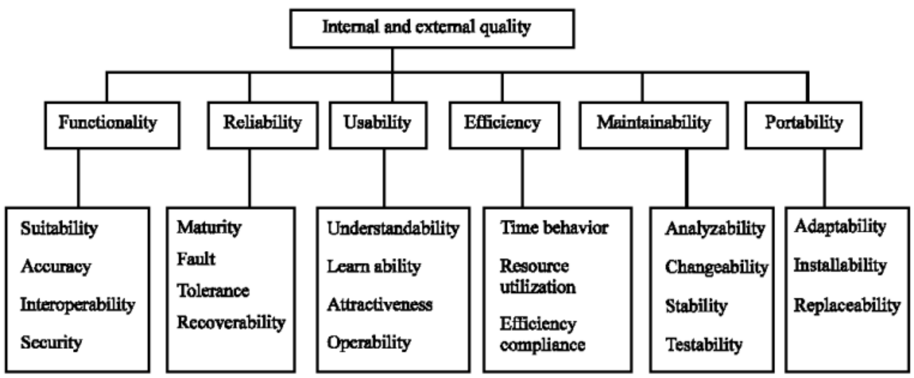

Figure 1. Extended version of ISO 9126

The following parts provide description of each criteria followed by its sub-criteria.

a. *Functionality*. The system must include all the necessary features to accomplish the required task. The criteria is extended into five sub-criteria, these include: (i) accuracy, (ii) suitability, (iii) compliance, (iv) interoperability, and (v) security.

b. *Reliability*. The system must maintain a specified level of performance in case of software faults with the minimum crashes possible. Sensitive data should be protected and correctly recovered. Reliability has also five sub criteria, (i) fault tolerance, (ii) crash frequency, (iii) recoverability, (iv) maturity, and (v) security.

c. *Usability*. The system must be implemented in such a way to allow easy understanding of its functioning and behavior. This criteria has six sub-criteria, (i) understandability, (ii) learnability, (iii) friendliness, (iv) operability, (v) playfulness, and (vi) ethics.

d. *Efficiency*. System response-time must be fast enough to satisfy user needs. Long waiting times result in reduced user interest, de-motivation and boredom leading to unwillingness to use the system. The criteria is then specified into five sub-criteria, these are: (i) response time, (ii) different vendor, (iii) quality, (iv) network speed, and (v) bandwidth.

e. *Maintainability*. Due to rapid technological changes maintainability is so important factors, especially in serving learning environment which continouosly demanding requirements for updated material, and for easy system modifications and enhancements. It has four sub criteria as follows: (i) changeability, (ii) serviceability, (iii) reparability, and (iv) testability.

f. *Portability*. Portability is defined as the ability of the software application to be installed and run by any hardware and also it should be adaptable to different specified environments. It can be decomposed into: (i) adaptability, (ii) installability and (iii) replaceability.

The use of ISO 9126 in evaluating software can be found in literature (Chua and Dyson, 2004; Costabile, et.al., 2005; Lanzilotti, et.al., 2006) in different cases and environment. Considering its wide implementations in various software evaluations as mentioned in literature, the author proposes ISO 9126 to be adopted in evaluating e-learning software. In this paper, ISO 9126 will be employed and serves as framework basis to create an evaluation hierarchy under the sight of multi criteria decision making (MCDM) perspective.

FUZZY ANALYTIC HIERARCHY PROCESS

Fuzzy Set Theory

The fuzzy set theory was introduced by Zadeh (1965) to deal with fuzziness issues in many control systems applications. It was oriented to the rationality of uncertainty due to imprecision or vagueness. Its ability in representing vague data is considered as the major contribution of fuzzy set theory to science and technology. Within the scope of multicriteria decision making, fuzzy set theory has given a significant contribution by accepting uncertainty and inconsistent judgment as a nature of human decision making which was not well tackled in classical AHP (Buckley, 1985).

In fuzzy set theory, triangular fuzzy numbers are represented with a triplet (L, M, U) for Lower, Medium and Upper numbers of fuzzy numbers. Figure 3 shows basic concept of the membership triangular fuzzy numbers.

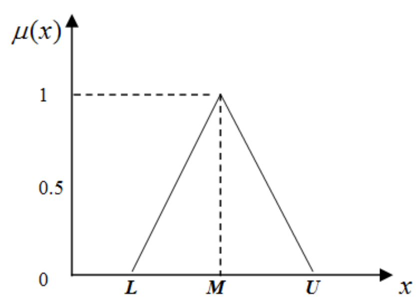

Figure 2. Fuzzy triangular membership function

Let A be a triangular fuzzy number with a triplet (L, M, U). The membership value can be defined as follows

$$u_A(x) = \begin{cases} \frac{x-L}{M-L}, & L \le x \le M \\ \frac{x-L}{M-L}, & L \le x \le M \\ 0, & otherwise \end{cases}$$

Various arithmetic calculations might be applied to these fuzzy membership values. In many cases only few basic operations widely used for triangular fuzzy numbers as explained below.

Let $\tilde{M} = (L_1, M_1, U_1)$ and $\tilde{N} = (L_2, M_2, U_2)$

Thus, fuzzy number reciprocal:

$$\tilde{M}^{-1} = (1/U_1, 1/M_1, 1/L_1)$$

and

$$\tilde{N}^{-1} = (1/U_2, 1/M_2, 1/L_2) \quad (1)$$

Fuzzy number addition:

$$\tilde{M} \oplus \tilde{N} = (L_1 + L_2, M_1 + M_2, U_1 + U_2) \quad (2)$$

Fuzzy number subtraction:

$$\tilde{M} - \tilde{N} = (L_1 - U_2, M_1 - M_2, U_1 - L_2) \quad (3)$$

Fuzzy number multiplication:

$$\tilde{M} \otimes \tilde{N} = (L_1.L_2, M_1.M_2, U_1.U_2) \quad (4)$$

Fuzzy number division:

$$\tilde{M} \div \tilde{N} = (\frac{L_1}{U_2}, \frac{M_1}{M_2}, \frac{U_1}{L_2}) \quad (5)$$

A major contribution of fuzzy set theory is its capability of representing vague and fuzzy values. The theory also allows mathematical operators and programming to apply to the fuzzy domain Buckley (1985).

Framework Development

In this section, a new multi criteria decision making method based on analytic hierarchy process (Saaty, 1980) and fuzzy set theory (Zadeh, 1965) is combined which is served as the basis of calculated judgement for the framework being developed. The use of analytic hierarchy process is preferred considering its wide applications in various disciplines and its maturity in terms of methodology. A new fuzzy analytic hierarchy process framework for e-learning software evaluation is aimed at providing comprehensive evaluation model based on ISO 9126 Software Metrics to deal with inconsistent and vague judgments that possibly occurs as a consequence of human evaluation processes.

Previous studies (Buckley, 1985; Cochran and Chen 2005) showed that vague and fuzzy judgements could not be covered appropriately by classical Analytic Hierarchy Process which use crisp numbers from 1 to 9, therefore fuzzy numbers along with its linguistic variables are utilized in this framework as shown in the following table.

Table 1. Fuzzy scales

Linguistics Vatiable	*Fuzzy Numbers*	*Fuzzy Reciprocal Numbers*
Just Equal	(1,1,1)	(1,1,1)
Slightly Important	(1/2,1,3/2)	(2/3,1,2)
Important	(1,3/2,2)	(1/2,2/3,1)
Strongly Important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very Stongly Important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely Important	(5/2,3,7/2)	(2/7,1/3,2/5)

Comprehensive analysis of the framework is discussed in the following steps:

a. Construction of hierarchy

First of all, the hierarchy of evaluation framework is developed. In this stage, ISO 9126 structure is adopted which basically consist of three (3) layers. It is then completed by adding one more layer of available e-learning software to evaluate at the bottom. The final hierarchy is finally developed in accordance with the Analytic Hierarchy Process structure which consists of four (4) layers, upper first layer is called goal, and the rest layers are criteria, sub-criteria and alternative respectively (see Figure 2).

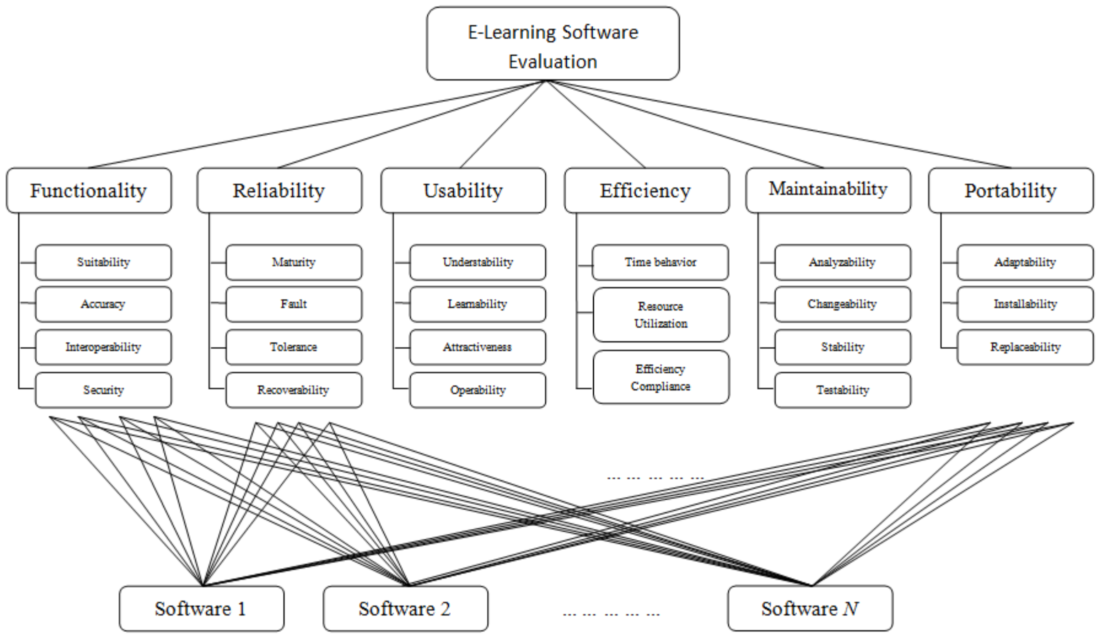

Figure 2. Fuzzy AHP E-Learning Software Evaluation.

At the top level, we define the goal of e-learning software evaluation. Subsequently, six (6) criteria namely functionality, reliability, usability, efficiency, maintainability and portability available at the second level of hierarchy. Then, third level is called sub-criteria which contains 22 sub-criteria in total derived from each criteria at the above level, for example functionality criteria has four sub-criteria, suitability, accuracy, interoperability and security and so forth. Finally, all available e-learning software that will be evaluated are listed at the bottom level of the hierarchy called alternative.

b. Pairwise Comparison by Decision Makers

According to the analytic hierarchy process methodology Saaty (1980), each of criteria, sub-criteria and available alternatives should be compared pairwisely. The process of such pairwise comparison follows linguistics variables determined by AHP method formed in a list of questionnaire.

Questions to perform pairwise comparison will be like, '*How important is Functionality compare to Usability* ?'. Available answers are presented in the form of six linguistic variables to choose namely *Just Equal, Slightly Important, Important, Strongly Important, Very Strongly Important*, and *Absolutely Important* (see table 1). While in AHP, all answers trasformed into crisp scales (1,3,5,7 or 9), in this framework, all answers are translated into its corresponding fuzzy scale as well as the reciprocal ones as described in table 1.

c. Aggregating Fuzzy Weights

The next step is to aggregate all fuzzy numbers derived from previous step. In this process called fuzzy weight aggregation, fuzzy geometric mean method described by Buckley (1985) and (Zadeh, 1970) is applied.

Although several aggreration methods available, this choice is based on its ability to shorten the gap effects of very high or low values, which in turn significantly reduce estimation bias. The aggregation procedure is as follows.

$$\tilde{w}_j = (\tilde{w}_j \otimes \tilde{w}_j \otimes \tilde{w}_j \otimes .... \otimes \tilde{w}_j)^{1/n} \quad (6)$$

Later, we will obtain $\tilde{w}_j = (l, m, u)$ as the fuzzy aggregation numbers of each pairwise comparison.

d. Defuzzification

Defuzzification is the process of converting fuzzy weights obtained from previous step into crisp values (Buckley, 1980). We apply a widely used defuzzification method called Centre of Gravity (CoG) or Centroid method as formulated below.

$$w_j = \frac{(l + m + u)}{3} \quad (7)$$

Using CoG method is stated as proper way to accurately representing fuzzy sets into crisp vales of A, B, and C as the lower, median, and upper fuzzy values (Cochran and Chen 2005).

e. Calculating final weight

In this last step of comprehensive analysis of the framework, defuzzified numbers obtained in the previous step are calculated based on classical AHP matrix multiplications to obtain final weight. Finally, the rank of available alternatives will be obtained in the form of crisp numbers.

CONCLUSION

Evaluation of e-learning software is vital for succesful e-learning implementation. In addition to that, the need to evaluate e-learning software has led to the need in having a comphrehensive evaluation framework which accomodates different perspectives. Considering the complexity of software e-learning evaluation as multicriteria decision making issue, this study employs ISO 9126 to serve as a generic model to capture all required elements in assessing the quality of e-learning software.

In the absense of such evaluation tool, this study aims to develope and propose a new framework for e-learning sofware evaluation. To do so, the Analytic Hierarchy Process (AHP) approach is used in combination with Fuzzy Set Theory to develop a new Fuzzy AHP framework based on ISO 9126 model. In particular, Fuzzy AHP proposed by Buckley (1985) is adopted and modified to meet the requirement of a simple but comphrehensive e-learning software evaluation and capable in tackling inconsistency and vagueness of human judgement during evaluation processes.

The framework also has several advantages such as simplified fuzzy calculation (with only five simple steps), ability to evaluate large number of e-learning software, and it also supports group evaluation environment as group decision making is also enabled within the framework. Practical application of the novel framework by applying it in a real case study is one of future direction of this study along with developing a web based version of the evaluation evaluation framework to enable online evaluation.

ACKNOWLEDGEMENTS

The study is an extended result of TPSDP 2006 Teaching Grant Research supported by Ministry of National Education, Republic of Indonesia.

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