Usability Evaluation of E-Government Using ISO 9241 and Fuzzy Tsukamoto Approach

Vivin Ayu Lestari, Ismiarta Aknuranda , Fatwa Ramdani
Faculty of Computer Science, Brawijaya University
vivinlestari91@gmail.com

***Abstract*— Usability is one of the important criteria to measure the quality of web applications. Therefore, it is pivotal to improve the usability of e-government by combining the features and attributes known to benefit the users in the context of its application. Usability is an important element that determines the success of e-government. Therefore, an approach that helps to determine the level of usability of an e-government quickly and accurately using soft computing techniques is needed. The study used the ISO 9241 and Fuzzy Tsukamoto approach to determine the level of usability of e-government. ISO 9241 was used as a standard to determine the aspects that would be used as an assessment when evaluating usability, while Fuzzy Tsukamoto was used as the calculation for automatically determining the level of usability of e-government. The aspects that are used as input variables are effectiveness, efficiency, satisfaction, and ease of use. The results of accuracy testing using RMSE (Root Means Square Error) towards 10 samples showed 90% accuracy. In addition, there are five different levels of e-government usability, very low, low, medium, high, and very high.**

***Index Terms*— Usability; E-Government; ISO 9241; Fuzzy Tsukamoto.**

I. INTRODUCTION

E-government facilitates government activities that take place with the use of electronic communication between all levels of government, citizens, and businesses. These activities include offering products and services, receive a request, provide and obtain information, and complete financial transactions [1]. In 2002, there were 169 countries that have already implemented e-government to improve the effectiveness and efficiency of services. The number increased to 192 countries by the end of 2007 and therefore, 98% of government in the world already have their government web site [1]. However, e-government focused more on technology rather than user's expectation [2]; consequently, it may result in problems in user performance and satisfaction.

Usability is one of the criteria to evaluate the quality of the success of web applications [3]. It is really important to improve the usability of e-government by combining the features and attributes known to benefit the user in the context of its use. Usability is the extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use [4]. When a web application has a high usability, the level of effectiveness, efficiency and user satisfaction when the web is used will increase simultaneously [2].

One of the methods to determine the usability of a system is usability evaluation. Usability evaluation aims at assessing how easily the user interfaces are used and how to improve the design process so a website is user-friendly [5]. The purpose of usability evaluation is to assess the extent and the degree of the accessibility the functions of a system, to assess the user experience, and identify problems specific to the system [6]. Usability of software is measured by how easily and how effectively it can be used by a series of specific users, given certain types of support, to implement the defined set of tasks, within a defined set of environments [7].

There are various methods used to measure usability [8], namely is a heuristic evaluation [9], questionnaire [10], empirical testing [11], metrics for usability standards in computing [12] and others. In the usability evaluation process, many still use the manual approach to determine the level of usability of a system. Analyzing the research on usability evaluation to determine the level of usability of e-government in [13], it is concluded that data in the study were taken using questionnaires and calculations using the manual approach, in which the aspects are effectiveness, efficiency, satisfaction and ease of use. Consequently, the process to determine the level of usability of the application took a long time and with a high cost. In fact, not only does the usability make the system easy to use but it also includes an understanding of the purpose, context and their experience [13]. Usability is an important element that determines the success of e-government [2]. Based on the elaboration, there is a need to develop an approach that can determine the level of usability of an e-government quickly and accurately by using soft computing techniques such as fuzzy, neural computing, evolutionary computing, machine learning, and probabilistic reasoning. Several techniques of soft computing are fuzzy logic, genetic algorithms, neural networks and others [14]. Such approaches suggested the use of a given tolerance of imprecision, partial truth, uncertainty, and the approach to certain problems to achieve robustness tractability and solutions for a smaller cost. When we have incomplete information ranging phase of software development, software quality models have several characteristics better outcomes, as fuzzy offers section with vagueness and imprecision [15]. Fuzzy Nonlinear Regression modeling technique functions to predict the range of error in the software product. Fuzzy can repair incomplete information in the early stages of the software development cycle and develops software quality models because of the concept of fuzzy deals with unclear concepts in nature. There are several types of fuzzy methods namely Fuzzy Tsukamoto [16] and Fuzzy Mamdani [17].

Measuring usability is difficult because it has several dimensions and several characteristics that affect it [7]. Putting all the dimensions and characteristics together to get the usability is a very difficult problem because each of them involves linguistic terms and fuzzy concept [18]. Based on the problems, it is necessary to develop a software with the ability, or approach of an expert when determining the level of usability of e-government so that the usability evaluation process is faster and lesser cost. The study used Fuzzy Tsukamoto because its degree of membership fuzzy method has a range of values from 0 to 1 [16]. Furthermore, fuzzy Tsukamoto has IF-THEN rules that are represented in the fuzzy set. Results inference output of each rule is given by the predicate. The most important aspects to evaluate the usability of e-government are effectiveness, efficiency, satisfaction (ISO 9241-11, 1998). An extra aspect is added that is ease of use. The findings of the study are including five categories of usability of e-government, namely very low, low, medium, high, and very high.

II. FUZZY LOGIC

Fuzzy logic, which was introduced in 1965, is the logic that refers to the principles of human reasoning [19]. Fuzzy logic is the logic of the theory that was developed to address the concept of value between the value of truth 'wrong' and 'right'. Logic in general only recognizes two conditions, namely 'no' or 'yes', 1 or 0, and 'wrong' or 'right'. In contrast to the fuzzy logic, similarity properties adopted a human way of thinking so that the value is not just 1 or 0, but also all possibilities in between the values 0 and 1. In fuzzy logic, the truth, when expressed in terms of the language, is described as true somewhat true, less true, and not true [19].

In general, fuzzy logic has the following stages [20]:

1) *Fuzzification*
   The input value is compared to the input membership functions, usually in the structure of the program loop to determine the extent to which each linguistic variables of each system are correct.
2) *Rule Evaluation*
   The process of listing rules of knowledge using fuzzy input value of current to produce the list of fuzzy linguistic variable output.
3) *Fuzzy Output*
   Consider the raw recommendation for what the system should output in response to current input conditions.
4) *Defuzzification*
   Dissolve some degree of ambiguity by placing the output fuzzy into a composite numerical output.

III. METHODOLOGY

Fuzzy Tsukamoto is a soft computing technique used to overcome the problems of usability evaluation. The technique describes the level of usability of a system. Fuzzy Tsukamoto is one method that is highly flexible and tolerance on existing data. The advantage of Fuzzy Tsukamoto is that it is more intuitive, accepted by many and more suitable for the input received from a human instead of a machine. Figure 1 describes the methodology used in this study.

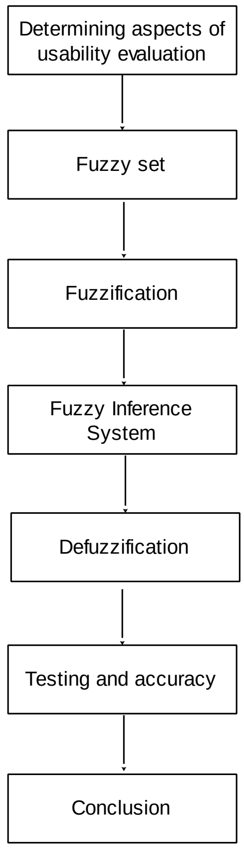

Figure 1: Research Methodology

A. *Determining Aspects of Usability Evaluation*

Aspects of usability that is used to evaluate the usability of e-government are taken from ISO 9241 standards [4] of effectiveness, efficiency, and satisfaction. Aspects of usability defined and described in ISO standards 9241 are as follows:

1) Effectiveness is the accuracy and completeness of which users achieve the goals set.
2) The efficiency of the resources is used in relation to the accuracy and completeness of which users achieve goals.
3) Satisfaction is freedom from discomfort and positive attitudes towards the use of the product

In addition to these three aspects, the author adds an aspect: the ease of use to measure the level of usability of e-government. This aspect is added based on the previous research by Lestari [13] focusing on usability evaluation of e-government where the findings were four important aspects used to measure the usability of e-government.

B. *Fuzzy Set*

A fuzzy set represents the unity of certain conditions in fuzzy variables. There are four variables that are used as input in this study and each variable consists of three linguistic values namely low, medium, and high as shown in Table 1.

Table 1
Fuzzy Set for Evaluation Usability

Fuzzy Set	Linguistic value
	Fuzzy Set
Effectiveness	Low
	Medium
	High
Efficiency	Low
	Medium
	High
Satisfaction	Low
	Medium
	High
Ease of use	Low
	Medium
	High

C. *Fuzzification*

Fuzzification process is changing the input in the form of crisp values into a set of linguistic variables. Uncertainty rate occurs due to the ambiguities and unclear variable values and as the result, these values can be represented by membership functions. The output of fuzzification is a fuzzy value. The fuzzy value is taken as input for fuzzy inference mechanism [21]. Equations (1), (2) and (3) generate the membership degree of effectiveness, efficiency, satisfaction, and ease of use.

Low membership degree:

$$\mu_{Low}(x) = \begin{cases} 1 \;\; ; x \leq 20 \\ \frac{40-x}{40-20}; \; 20 < x < 40 \\ 0 \;\; ; \; x \geq 40 \end{cases} \tag{1}$$

Medium membership degree:

$$\mu_{Medium}(x) = \begin{cases} 0 \;\; ; x \leq 20 \; or \; x \geq 80 \\ \frac{x-20}{40-20}; \; 20 < x < 40 \\ \frac{80-x}{80-60}; \; 60 < x < 80 \\ 1 \; ; \; 40 \; \leq \; x \geq 60 \end{cases} \tag{2}$$

High membership degree:

$$\mu_{High}(x) = \begin{cases} 1 \;\; ; x \geq 80 \\ \frac{x-60}{80-60}; \; 60 < x < 80 \\ 0 \;\; ; \; x \leq 60 \end{cases} \tag{3}$$

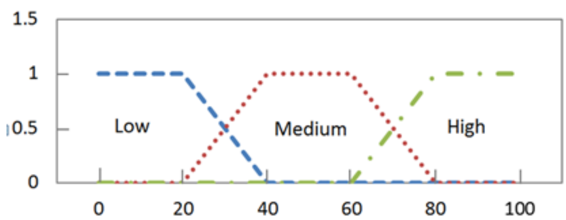

Figure 2: Input Membership Function Effectiveness

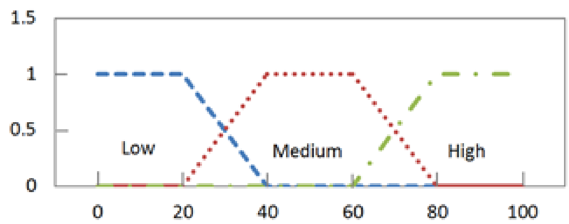

Figure 3: Input Membership Function Efficiency

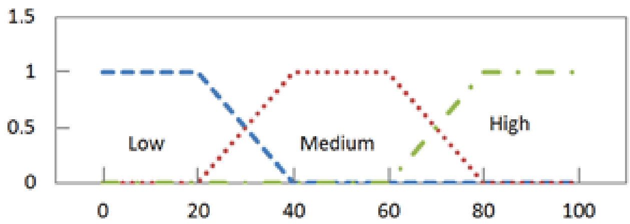

Figure 4: Input Membership Function Satisfaction

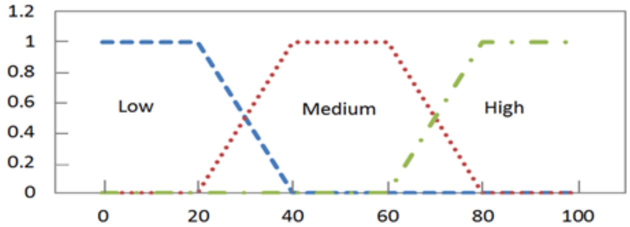

Figure 5: Input Membership Function Easy of Use

Figure 6 shows the output membership function for usability consisting of five linguistic variables namely very low, low, medium, high, and very high. Equations (4), (5), (6), (7) and (8) calculates the degree of the membership function.

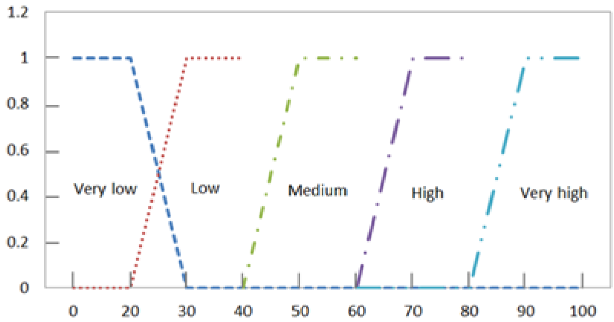

Figure 6. Output Membership Function for Usability

Very low membership degree:

$$\mu_{Very\ low}(x) = \begin{cases} 1 \;\; ; x \leq 20 \\ \frac{30-x}{30-20}; \; 20 < x < 30 \\ 0 \;\; ; \; x \geq 30 \end{cases} \tag{4}$$

Low membership degree:

$$\mu_{Low}(x) = \begin{cases} 0 \;\; ; x \leq 20 \; or \; x \geq 40 \\ \frac{x-20}{30-20}; \; 20 < x < 30 \\ 1 \; ; \; 40 \; \leq \; x < 40 \end{cases} \tag{5}$$

Medium membership degree:

$$\mu_{Medium}(x) = \begin{cases} 0 \;\; ; x \leq 40 \; or \; x \geq 60 \\ \frac{x-40}{50-40}; \; 40 < x < 50 \\ 1 \; ; \; 50 \; \leq \; x < 60 \end{cases} \tag{6}$$

High membership degree:

$$\mu_{High}(x) = \begin{cases} 0 \;\; ; x \leq 60 \; or \; x \geq 80 \\ \frac{x-60}{70-60}; \; 60 < x < 70 \\ 1 \; ; \; 70 \; \leq \; x < 80 \end{cases} \tag{7}$$

Very high membership degree:

$$\mu_{Very\ high}(x) = \begin{cases} 1 \;\; ; x \geq 90 \\ \frac{x-80}{90-80}; \; 80 < x < 90 \\ 0 \; ; \; x \leq 80 \end{cases} \tag{8}$$

D. Fuzzy Inference System

Fuzzy Inference System is a system that performs a calculation based on the concept of fuzzy set theory, fuzzy rules, and the concept of fuzzy logic. Before performing a calculation, inference system makes the determination rule base. The rule base is the part that affects the procedure because it determines the control strategy which comprised of a portion of declarative knowledge that included in the membership functions [22]. There are 81 rules that are applied in the study; the total number of the rule is derived from 3^4=81 (4 is the number of input variables used and 3 represent the number of linguistic variables contained in each of the input variables). Some of the rules are listed in Table 2.

Table 2
Sample Rule Base

Rule No	Input Variable				Output Variable
	Effective-ness	Effici-ency	Satis-faction	Ease of Use	
1	Low	Low	Low	Low	Very Low
2	Low	Low	Low	Medium	Very Low
3	Low	Low	Low	High	Low
.					
.					
.					
81	High	High	High	High	Very High

E. Defuzzification

The next stage is called the defuzzification. The defuzzification method of Tsukamoto is the average centered (Center Average Defuzzier). It is formulated in the Equation (9) [23]:

$$Z = \sum_{i=1}^{n} \propto izi \quad \frac{\sum_{i=1}^{n} \propto izi}{\sum_{i=1}^{n} \propto i} \tag{9}$$

In Equation (9), Z is the result of defuzzification, whereas the αi is the value of the membership antecedent, and zi is the product of each of the inference rules.

IV. Testing and Accuracy

The next stages after defuzzification are analyzing the accuracy and testing from the results that have been obtained previously. The purpose is to increase public confidence. One method of evaluation is RMSE (Root Means Square Error). RMSE is selected to analyze accuracy by comparing analysis in the field directly. The RMSE equation is as follows [24]:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \tag{10}$$

where X_{obs} was observed values, and X_{model} has modeled values at time/place *i*.

The test procedures started by entering the data level of usability on each aspect of usability (effectiveness, efficiency, satisfaction, and ease of use) into the application and then the system would calculate in accordance to the method of Fuzzy Tsukamoto. The results of the calculation then are compared to the predictions of experts. The results of the accuracy testing of the four input variables are shown in Table 3.

Based on the data in Table 3, the result of the accuracy analysis using fuzzy inference systems is 90%. The percentage shows that the accuracy of the system is high. Therefore, Fuzzy Tsukamoto evaluation can be used to determine the level of usability of a system, in particular for e-government.

V. Conclusion

Based on the study, Fuzzy Tsukamoto can be used to determine the level of usability of e-government with four aspects of assessment namely effectiveness, efficiency, satisfaction, and ease of use. RMSE then calculates the level of inter-relationship between the level of usability generated by the system and expert predictions. The result is 90% accuracy. For further studies, evolutionary algorithms can be used to optimize the fuzzy rules and improve the accuracy of the system.

Table 3
Data Comparison of Accuracy

System	Variable Input				Expert predictions	Prediction system	Result
	Effectiveness	Efficiency	Satisfaction	Ease of Use			
S1	80	81	90	74	High	Very High	0
S2	50	60	75	83	Medium	Medium	1
S3	70	60	90	70	Medium	Medium	1
S4	60	65	75	62	Medium	Medium	1
S5	92	90	87	85	Very High	Very High	1
S6	80	81	70	74	High	High	1
S7	50	60	60	40	Medium	Medium	1
S8	50	30	22	40	Low	Low	1
S9	25	30	22	25	Low	Low	1
S10	25	20	22	25	Very Low	Very Low	1

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