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FUZZY MEMBERSHIP FUNCTIONS ANALYSIS FOR USABILITY EVALUATION OF ONLINE CREDIT HOUR FORM

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Abstract

Every semester, online credits hour form must be filled out by students in the University. Usability is closely related to user experience, but there are still not many considerations in developing an interface. User Experience shows the ease and efficiency felt by users in using the system. The criteria become basic needs or conditions that must be encountered in content for use by the average user. Usability evaluation criteria used in this study consist of learnability, memorability, efficiency, error, and satisfaction. The fuzzy logic system (FLS) is one of the revolutionary findings in the area of uncertainty. In this study, the fuzzy logic identified with membership function in which fuzzy rules are developed using Type-1 (T1) Fuzzy Mmembership Function, consisting of triangular, trapezoidal, Gaussian functions. The aim is to find the most realistic, optimal, but also the simplest form of membership function to reduce computing needs. The use of this membership function in evaluating usability can be used to identify and evaluate software problems to propose an efficient solution. The result shows that Trimf and Trampf membership function produce the highest accuracy value up to 3.98 which means Good for all the value of usability variable compare to Gaussmf. Meanwhile, The Gaussmf membership function has the most stable accuracy value up to 78% with three combinations of respondent data. Last, this developed model can be used as a reference to improve usability on the Online credit hour form.

Keywords: Fuzzy logic, Membership function, Type-1 fuzzy MF, Usability, User experience.

1. Introduction

The current world population is about 7.6 billion, with internet users as much as 4.3 billion; of course, it would not be possible without using a computer [1]. The utilization of computers to access the digital world will continue to provide opportunities for software developers to increase usability [2]. Usability in software correlates with human interaction with computers. Human and computer interaction is closely related to usability or user experience, both of which become essential elements for the success of a software or application [3]. Usability is a quality factor that shows the most critical factor in the acceptance of software engineering systems by end users. It is used to determine the technical relationship with humans in using software as one of the products [4]. Simple software will look complex if the design made incorrectly, whereas complicated software will look easy if the interface design is acceptable to the majority of users. Higher education is one of the institutions that educate, improve the quality, and the quality of human resources, especially students [5]. The use of computers or information and communication technology is also essential in the current era of education [6]. Online credits hour form information system is used by students to choose courses to take in the next half. Both systems have an essential part, namely, usability that is closely related to user experience. User experience is used to demonstrate the ease felt by users and efficiency through the user experience using the system.

Artificial intelligence (AI) can be implemented more in the field of computer science, one of which is on human-computer interaction, especially on usability. The first step in usability evaluation is to identify the criteria that will be used in measuring the success of software/website usability [7]. Usability measurement can be done using several methods; one of the methods to be used in research is the fuzzy logic system. Fuzzy logic is computational and identification methods of data measured efficiently for non-linear modelling systems [8, 9]. Fuzzy logic is one of the findings in the scientific article about uncertainty by Zadeh [10]. It was actively developed in a dynamic model that is appropriate for a particular case [11]. One step in modelling using fuzzy logic is to determine the membership function and fuzzy rules of the fuzzy set by an expert [12], one type of model used to test the relationship between fuzzy rules is the fuzzy inference system (FIS) [13].

Membership function (MF), serves to determine the correlation of each input with the degree of membership (DOM) used in determining usability [14]. This step is carried out to shorten the model trial phase, the success rate of the model, and the measurement of membership optimization used [15]. MF are fuzzy characteristic functions expressed in fuzzy sets with a continuum grades of membership level that have values between 0 and 1 [10, 16, 17]. There are significant differences, namely the combination of MF rules and the nature of the idea of non-statistical fuzzy sets [10].

Evaluation of the feature selective validation (FSV) model has been done with MF of the traditional model and trapezium distribution model. The results of MF of the traditional model are more effective for validating simulations of electromagnetic compatibility systems [18]. Comparison the number of MF in study cases has been done in calculating the incubator temperature changes in egg incubators, using three, five, and seven memberships, with each membership using the Gaussian, trapezoid and triangle models. After testing, using seven MF is very influential in getting fuzzy output and requires fast time in reaching the ideal

temperature of the incubator egg incubator, compared with the system without using fuzzy [19]. Optimizing the use of the MF in identifying quality transformer oil to test three types of simulations with three indicators of inputs, and two types of MF. It can be concluded that the triangular type MF gives better results than the type of MF trapezoid and triangular MF and trapezoid combination [20]. In scholarship acceptance research, the MF is integrated with C4.5 algorithm, the variables used are qualitative variables and quantitative variables to be tested with cross validation, so that data classification and data validation get accurate results. With this test, the results show that the integration of the chosen method gets the lowest error value, compared to the C4.5 algorithm method alone [21].

The Type-1 (T1) Fuzzy MF can be used for hand gesture recognition based on skin color variables, morphological operations, and image extraction of hand movements. The MF is used with three triangular, trapezoidal and Gaussian membership curves. After testing based on movement, the highest accuracy value is 85.83% for the trapezoid MF [22]. Optimizing the use Gaussian and triangular MF can be done by adding the unscented Kalman method and extended Kalman filter (EKF). Tests conducted with a non-linear system model, Gaussian curves are more optimal and stable in system performance [23]. Fuzzy Mamdani is used in the case of automatic watering with humidity variables. The research was conducted using a comparison of three MF, namely trapezoid, Gaussian and triangle. The output produced to show the average duration of watering time which is done for five days, obtained the best MF using Gaussian [24].

The purpose of this study was to analyse accuracy the fuzzy MF and application of FIS for usability evaluation of online credit hour form, and to find the most realistic, optimal, but also the simplest form of MF to reduce computing needs. The criteria used in this study consist of learnability, memorability, efficiency, error, and satisfaction. Usability assessment is done using the FIS, a process that can map fuzzy logic images from all inputs given to the output system. The MF has various types that can be used in processing fuzzy input and output data sets. There are two types of MF, namely using Type-1 Fuzzy MF [25], consisting of triangular, trapezoid, Gaussian functions, and Type-2 (T2) Fuzzy MF which have parameters similar to Type-1 Fuzzy MF with better predictive results than the Gaussian and triangular MF [26]. Usability evaluations will be labelled with the values of all linguistic variables (i.e., very good, good, enough, bad, and very bad) to evaluate usability. Linguistic variables are of great concern in designing fuzzy systems [27].

2. Research Method

This research begins with distributing the questionnaires to the respondents using a purposive sampling technique. Purposive sampling is one of the techniques that can be used in data gathering. Purposive sampling can be applied to research in a number of ways such as in preliminary studies where the researcher is still testing the feasibility of a proposed study [28].

The first step that must be followed to conduct the research is to decide the problem of research. Then we determine the type of information needed in some listed questions into questionnaire and deliver it to the students that use the online credits hour form. The questionnaire was distributed and filled in during one-month period to gain data and valid perspective from the students [28].

Fuzzy logic system (FLS) in this research identifies the MF. This rule was developed by the Type-1 fuzzy MF, consisting of triangular, trapezoids, Gaussian function, and other combination of MF S-shaped and Z-shaped [29]. Set fuzzy Type-1 Fuzzy MF map the input and output system models and consider the data received. In a set fuzzy Type-1, single membership (μ) measures the level of uncertainty of the features received [30]. Figure 1 shows a schematic diagram of the fuzzy control method, starting from determining the input variable, fuzzifier process, compositional rules by determining of MF generated from the fuzzy inference system in MATLAB, and defuzzifier process using the Mamdani fuzzy method.

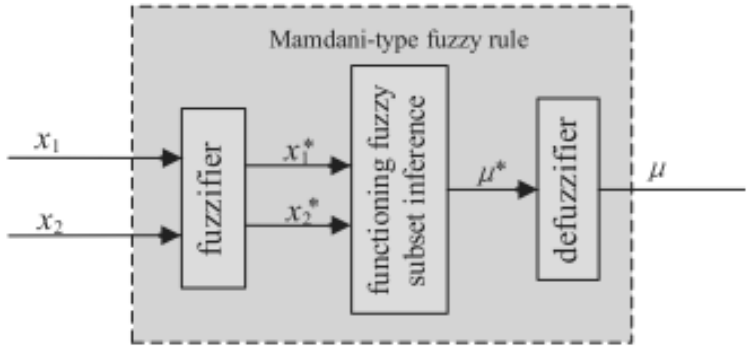


Fig. 1. Schematic diagram of the fuzzy control method [30].

The fuzzification process can be defined as a fuzzy determining variables(x) and fuzzy set [31]. The result of inference engine from input and output in fuzzy, is used to determine the appropriate model for fuzzy Mamdani type [30]. The first thing to do is to determine the level of membership between fuzzy data inputs and fuzzy sets that have been set for each input based on fuzzy system variable rules. Fuzzy Mamdani uses the implication (MIN) for each fuzzy rule in determining fuzzy inference output.

The defuzzification process is changing fuzzy output to a specified value. The defuzzification process is obtained by the composition of fuzzy rules and will produce numbers in the fuzzy set domain. Fuzzy which is set in a certain range will be taken as the value of crisp output. Some methods used in defuzzification are the centroid method which is produced by taking crispy values at the fuzzy center point, the bisector method which takes crispy values from the fuzzy domain according to membership values such as the total number of membership values In the fuzzy area, the means of maximum (MOM) method obtained by how to take the average value of a domain that has a maximum membership value, the largest method of the maximum method (LOM) obtained by taking the largest value from a domain that has a maximum membership value, the smallest method of the maximum (SOM) obtained by taking the smallest value of a domain having a value maximum membership. This defuzzification step uses the centroid method in determining the fuzzy set obtained from the fuzzy composition rule, then output as a number refers to the fuzzy set domain [24]. The crisp solution is obtained by taking the center point *(d*)* of the fuzzy area output.

A MF for a fuzzy set *A* on the universe of discourse *X* is defined as $\mu A:X \rightarrow [0,1]$, where each element of *X* is mapped to a value between 0 and 1. This value, called membership value or degree of membership, quantifies the grade of membership of the element in *X* to the fuzzy set *A*. MF allow us to graphically represent a fuzzy set. The *X* axis represents the universe of discourse, whereas the y axis represents the degrees of membership in the [0,1] interval. Simple functions are used to build MF. Because we are defining fuzzy concepts, using more complex functions does not add more precision. In this study, three Type-1 Fuzzy MF will be used.

2.1. Triangular membership function curve

The special form of a triangular MF curve $\mu_A(x)$ can be seen in the equation [20], the following Eq. (1).

$$\mu_A(x) = \begin{matrix} 0 \\ \frac{x-a}{m-a} \\ \frac{b-x}{b-m} \\ 0 \end{matrix} \quad \begin{matrix} if\ a \leq a \\ if\ \alpha_1 < x \leq m \\ if\ m < x < b \\ u \geq \gamma_1 \end{matrix} \tag{1}$$

Figure 2 shows the triangular curve is a combination of two linear and has three parameters. While *a*, *b*, mare three-angle from $\mu_A(x)$, defined by a lower limit *a*, an upper limit *b*, and *a* value *m*, obstacle $a < m < b$. This curve is widely used in implementation, because it has a high value of computational efficiency [16].

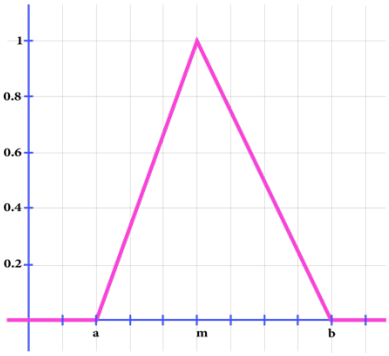


Fig. 2. Triangular membership function curve.

2.2. Trapezoidal membership function

Special form of trapezoidal MF curve (*Π (u)*) can be seen in Eq. (2) [20],

$$\Pi(u) = \begin{matrix} 0 \\ \frac{x-a}{b-a} \\ 1 \\ \frac{d-x}{d-c} \end{matrix} \quad \begin{matrix} if\ (x < a)\ or\ (x > d) \\ if\ a \leq u \leq b \\ if\ b \leq x \leq c \\ if\ c \leq x \leq d \end{matrix} \tag{2}$$

Figure 3 shows the trapezoidal MF curve resembles the membership triangle curve, the difference in the triangular curve is at 1 point or value that has a degree of membership = 1, in the trapezoid curve there are several values or points that have a membership value = 1, where the coordinates of *(u)* from four angle of *Π (u)*

determined by four-parameter (*a*, *b*, *c*, *d*), defined by *a* lower limit *a*, an upper limit *d*, *a* lower support limit *b*, and an upper support limit *c*, for obstacle $a < b < c < d$.

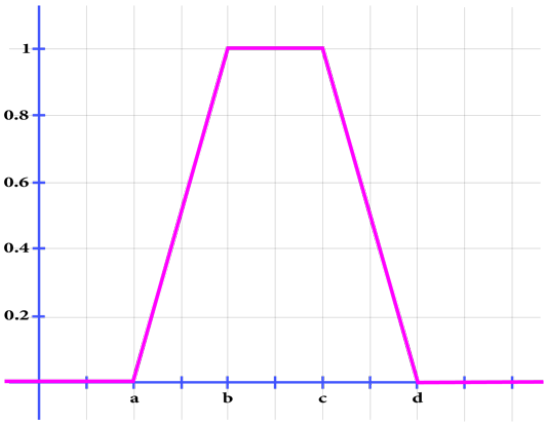


Fig. 3. Trapezoidal membership function curve.

2.3. Gaussian membership function

Figure 4 shows special form of Gaussian MF *(G (u))* can be seen in the equation down below three [20]. Defined by a central value m and a standard deviation $k > 0$. The smaller *k* is, the narrower the "bell" is. The function used in the previous link to draw gaussian functions uses a different k^1 parameter, the following Eq. (3). The mapping between both parameters is: $k^1 = \frac{1}{2k^2}$

$$G(u) = e^{-\frac{(x-m)^2}{2k^2}} \tag{3}$$

where *m* shows the center of distance from the origin σ representing the width of the curve. *G (u)* has a subtle feature, and there are no zero points at all.

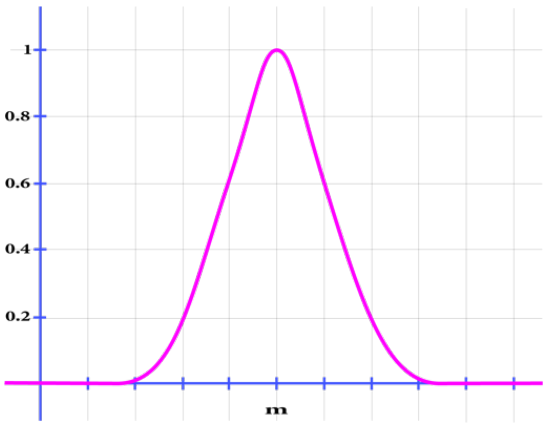


Fig. 4. Gaussian membership function curve.

Each function generated by equation three has a function to form a MF that will be created in the MATLAB for fuzzy logic designer. The next step is by distributing

questionnaire forms with google form to all students as random users who have used online credits hour form for more than two semesters. This distribution is carried out for approximately three-month.

3. Result and Discussion

This study used SPSS to check the validity and reliability of all the questions in the questionnaire. From that calculation, the value of Cronbach's Alpha was around 0.934, which means the question is reliable and can be used for gaining the data. For the test validity, we use expert judgments combine with interview from eight respondents to check the readability of the question. The result shows that the list of question can be understood by the expert and respondents. To gain valid data and perspectives from all randomized students who have used online credit hour forms for more than two semesters, this questionnaire was filled in one period with the total number of people who responded to the questionnaire, up to 150 data. In this study, 150 respondents' data was divided into three sections to compare the accuracy of the amount of data with the MF.

Figure 5 show the first step is to do fuzzification to determine MF. Fuzzy sets obtained, will be included in the fuzzy rule base, and for the accuracy of the final result of usability. The stages in this study will be discussed in Sections 3.1, 3.2, and 3.3.

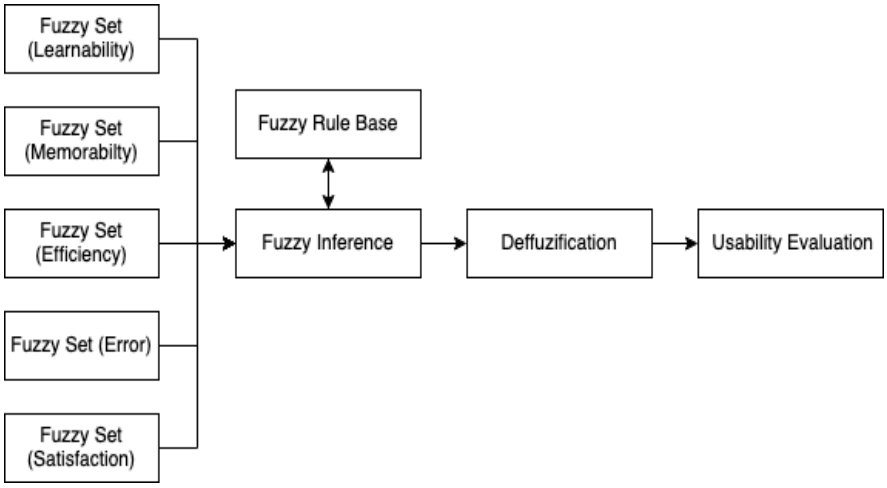
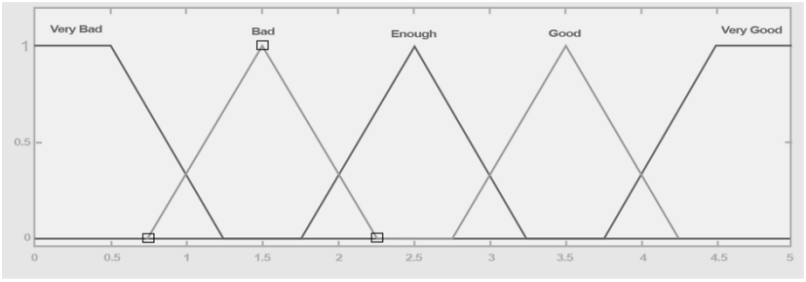


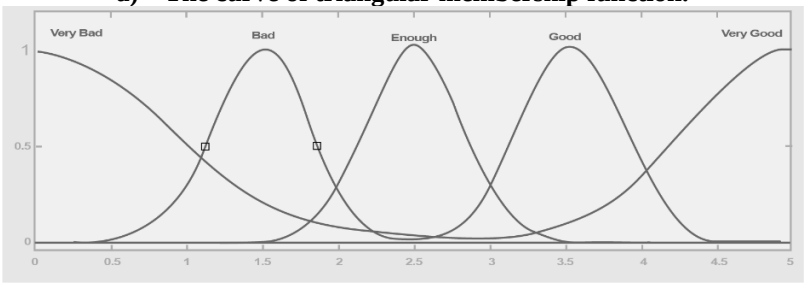
Fig. 5. Structure fuzzy logic for usability evaluation membership function.

3.1. Fuzzification

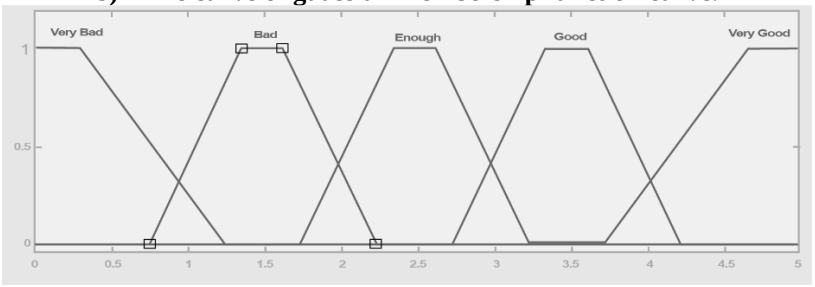
Fuzzification stage in this study will determine the membership value of input variable learnability, memorability, efficiency, error, and satisfaction, and will be divided into five linguistic variables i.e.: very bad, bad, enough, good, very good then the output variable usability. The fuzzy output consists of functions using a Type-1 fuzzy MF function, which consists of triangular, trapezoidal, Gaussian functions corresponding to three different data inputs. Type-1 MF for the usability evaluation mode can be seen in Fig. 6.



a) The curve of triangular membership function.



b) The curve of gaussian membership function curve.



c) The curve of trapezoid membership function curve.

Fig. 6. The curve of membership function for usability evaluation.

The model designed in this study uses the fuzzy Mamdani method with three Type-1 Fuzzy MF, which can be seen above in Fig. 2. A MF triangular of defuzzification expression according to Eq. (1). The details of the Eq. (1) can be seen in Eq. (4-8) for usability values in linguistic variables. It will be divided into five categories, i.e.: very bad, bad, enough, good, very good collection of all input variables:

$$\mu \text{ Very bad } [x] = \begin{cases} 0; x \leq 0{,}0 \\ \frac{0{,}5-x}{0{,}5-0{,}0}; \quad 0{,}0 \leq x \leq 0{,}5 \\ 1; \quad x \geq 0{,}5 \end{cases} \tag{4}$$

$$\mu \text{ Bad } [x] = \begin{cases} 0; x \leq 0{,}75 \; or \; x \geq 2{,}25 \\ \frac{x-0{,}75}{1{,}5 - 0{,}75}; \qquad 0{,}75 \leq x \leq 1{,}5 \\ \frac{2{,}25-x}{2{,}25 - 1{,}5}; 1{,}5 \leq x \leq 2{,}25 \end{cases} \tag{5}$$

$$\mu \text{ Enough } [x] = \begin{cases} 0; x \leq 1{,}75 \; or \; x \geq 3{,}25 \\ \frac{x-1{,}75}{2{,}5 - 1{,}75}; \qquad 1{,}75 \leq x \leq 2{,}5 \\ \frac{3{,}25-x}{3{,}25-2{,}5}; 2{,}5 \leq x \leq 3{,}25 \end{cases} \tag{6}$$

$$\mu \text{Good}\,[x] = \begin{cases} 0; x \le 2{,}75 \text{ or } x \ge 4{,}25 \\ \frac{x-2{,}75}{3{,}5-2{,}75}; \quad 2{,}75 \le x \le 3{,}5 \\ \frac{4{,}25-x}{4{,}25-3{,}5}; 3{,}5 \le x \le 4{,}25 \end{cases} \tag{7}$$

$$\mu \text{Very\_good}\,[x] = \begin{cases} 0; x \le 3{,}75 \text{ or } x \ge 5{,}25 \\ \frac{x-4{,}5}{5{,}25-4{,}5}; \quad 3{,}75 \le x \le 4{,}5 \\ 1\,; x \ge 5{,}25 \end{cases} \tag{8}$$

3.2. Fuzzy rule inferences and defuzzification

The next step, the result from processing and functioning fuzzy rule inferences the subset of fuzzy itself from five-sequence matrix. The next step, the result of processing and the number of fuzzy rules function from this study can be made with $n^x = 5^5$, resulting in a 3.125 fuzzy rule from five usability evaluation criteria, five linguistic variables, and one designed output. Figure 6 shows the relationship between variables in determining fuzzy rules in this study uses AND, which corresponds to the steps in determining fuzzy rules. The MF of the fuzzy set will be taken, and the AND function is to take the minimum function. For each fuzzy rule, the MF in the fuzzy set will be defined in Eq. (9) [16]. The defuzzification step uses the centroid method in determining the fuzzy set obtained from the fuzzy composition rule, then output as a number refers to the fuzzy set domain.

Usability evaluation models are designed using MF taken from fuzzy input and output rules that are created and stored in data. Fuzzy determination rules by composed of a set of production rules of the form, the following Eq. (9):

$$r_1 = IF\ (x_1 A_1\ AND \ldots AND\ x_1\ is\ Ai_1)\ THEN\ (y\ is\ B) c_1 \tag{9}$$

The sample rules that will be formed are:

- **Rule 1:** IF (Learnability is Very Good) and (Memorability is Very Good) and (Efficiency is Very Good) and (Error is Very Good) and (Satisfaction is Very Good) THEN (Usability is Very Good)
- **Rule 127:** IF (Learnability is Very Good) and (Memorability is Very Good) and (Efficiency is Very Good) and (Error is Good) and (Satisfaction is Very Bad) THEN (Usability is Good)
- **Rule 1373:** IF (Learnability is Very Good) and (Memorability is Very Good) and (Efficiency is Enough) and (Error is Very Bad) and (Satisfaction is Very Bad) THEN (Usability is Enough)
- **Rule 2879:** IF (Learnability is Very Good) and (Memorability is Bad) and (Efficiency is Very Bad) and (Error is Very Bad) and (Satisfaction is Very Bad) THEN (Usability is Bad)
- **Rule 3215:** IF (Learnability is Very Bad) and (Memorability is Very Bad) and (Efficiency is Very Bad) and (Error is Very Bad) and (Satisfaction is Very Bad) THEN (Usability is Very Bad)

Furthermore, with the rules set, the implication function will be applied with MIN, it can be seen in Eq. (10). Figure 7 represents all variables produces Usability *(U)* fuzzy rules such as Learnability *(L)*, Memorability *(M)*, Efficiency *(Eff)*, Error *(Err)*, and Satisfaction *(S)*.

$$\mu(U) = \min[\mu(L),\ \mu(M),\ \mu(Eff),\ \mu(Err),\ \mu(S)] \tag{10}$$

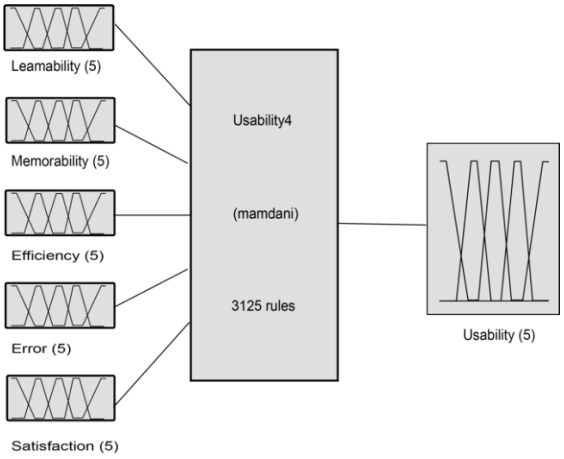


Fig. 7. Usability evaluation models.

Figure 8 explains the MF used with T1, triangular, gaussian, and trapezoid, with fuzzy rules obtained of 3.125. This is done to prove the most challenging, optimal and also the simplest MF to increase computing needs. With the difference in the number of data entries and MF, it can be seen that the accuracy of the data is obtained.

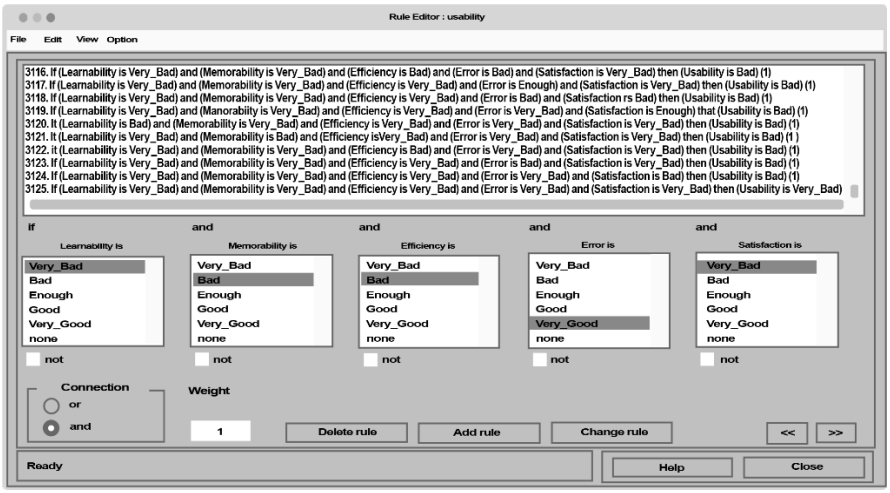


Fig. 8. Fuzzy rule usability.

Figure 9 show the result of surface model that evaluate the usefulness of the model. It is intended to know the mapping between input and output variables. Based on the fuzzy inference system that has been made, data is retrieved using a questionnaire distributed to users as users.

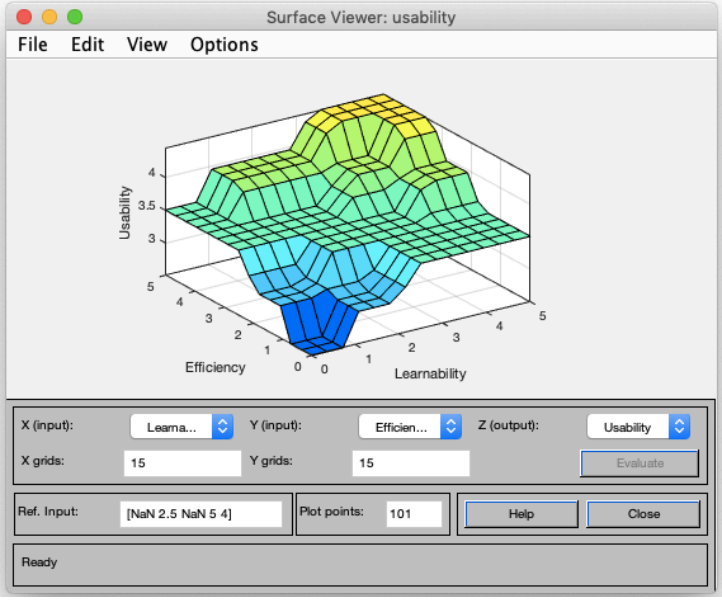


Fig. 9. Surface model usability evaluation.

3.3. Analysis membership function models

The data obtained will be obtained and adjusted to the accuracy with fuzzy with three different MF. 150 respondents were divided into 3 sections amounts of data to compare the accuracy of the amount of data to MF are expected to get better results.

Table 1 shows the results of the comparison between manual calculation usability based on three types of grouping of respondents produce a variety of values. Based on limited respondent data, more specific results will be acquired. It is because the tendency of data with a limited number of respondents will make the distribution (variation) of data more heterogeneous, which means that one choice can only represent one respondent (not representing other data). Therefore, the result will be less (not) valid because they do not represent all respondents even though the large amount of respondent data will make the distribution (variation) of the data become more homogeneous. Later on, it also can produce more accurate and valid results in accordance with the analysis that needs to be sought. Meanwhile the accuracy MF models can be seen in Table 2.

Table 2 shows the result of the accuracy MF models from three functions, such as: Trimf, Gaussmf, and Trapmf with three different data variants using 3.125 fuzzy rules. Fuzzy rules resulting from a five-order matrix with five input variables (learnability, memorability, efficiency, error, and satisfaction), five parameters (very good, good, enough, bad, and very bad), and one output designed to be determined in linguistic variables in each MF. MF test results are performed with several different data, with the same case, Trimf has an accuracy value of up to 80% for the amount of testing data 50 and 150 random questionnaire data. Testing with Gaussmf has a stable value with three different test data, namely 50, 100, and 150 data. Trapmf testing with three different amounts of data has the greatest accuracy value of 80% for the amount of data 50, or the smallest data test, the larger the data being tested, the more inaccurate the results.

Table 1. Comparison result manual calculation vs membership function models.

Usability evaluation using manual calculation	Usability evaluation using membership function		
	Trimf	Gaussmf	Trapmf
3.58	3.98	3.91	3.96

Table 2. The accuracy membership function models.

Membership function	Accuracy membership function		
	50 data	100 data	150 data
Trimf	80%	79%	80%
Gaussmf	78%	78%	78%
Trapmf	80%	79%	79%

Figure 10 describes an accuracy MF using 50 and 100 data of respondents. The result shows that the percentages of accuracy have same value between the Trimf and Trapmf MF. For 150 respondents data (the maximum number of respondent) it shows that the stable accuracy value is to 78% with the Gaussmf MF. The Gaussmf MF also shows that from three variations number of the respondent data will have valid and stable value accuracy at 78%.

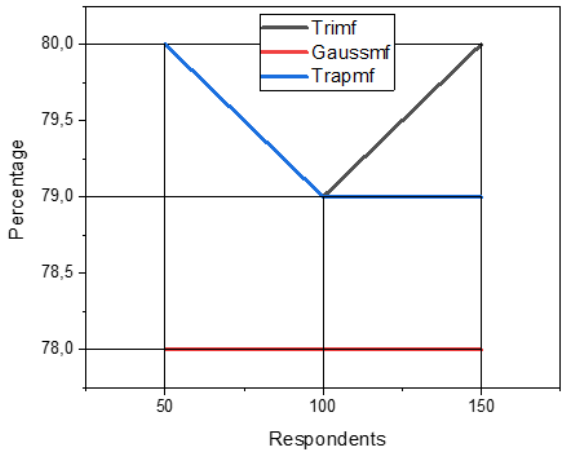


Fig. 10. Percentage of accuracy membership function.

4. Conclusions

Based on the results and discussion, the fuzzy logic identified with MF, and fuzzy rules are developed using Type-1 fuzzy MF, consisting of triangular, trapezoids, Gaussian functions. In this study, 150 respondents' data is divided into three sections to compare the accuracy of the amount of data to MF with fuzzy rules obtained at 3,125. The aim is to find the most realistic, optimal, but also the simplest form of MF to reduce computing needs. The use of this MF in evaluating usability can be used to identify and evaluate software problems to propose an efficient solution. Trimf and Trampf MF produce the highest accuracy value up to 3.98 which means Good for all the value of usability variable compare to Gaussmf. Meanwhile the Gaussmf MF has the most stable accuracy value up to 78% with three combinations of respondent data. The highest value accuracy for usability

with Trimf and Trapmf MF performed produces a value of 3.98 (Good), for all usability variable values. The Gaussmf MF with 3 different amounts of respondent data, has a stable accuracy value of 78%. The purpose of this developed model is that it can be used as a reference to improve usability on the online credit hour form. Gaussmf MF testing needs to be done with different cases and different amount of data, to see the accuracy of the data. Therefore, our work in the future will focus on comparing the accuracy of the data between the Type-1 fuzzy MF and Type-2 fuzzy MF, so it can be used as a reference in the election of the MF appropriately and implemented to reduce the computational requirements.

Nomenclatures

d^*	Fuzzy area output
LOM	Obtained by taking the largest value from a domain that has a maximum membership value
MIN	Implication
MOM	Method is obtained by how to take the average value of a domain that has a maximum membership value
SOM	obtained by taking the smallest value of a domain having a value maximum membership
T1	Type-1 Fuzzy Membership Function
T2	Type-2 Fuzzy Membership Function

Greek Symbols

μ	Single membership
$\mu(A)$	Gauss membership function curve
$\Delta(u)$	Triangular membership function curve
$\Pi(u)$	Trapezoidal membership function curve

Abbreviations

Gaussmf	Gauss Membership Function
Trapmf	Trapezium Membership Function
Trimf	Triangular Membership Function

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