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Usability Determination Using Multistage Fuzzy System

[a]Deepak Gupta*, [b]Dr. Anil K Ahlawat

[a]Maharaja Agrasen Institute of Technology (MAIT) Delhi, India

myself.deepakgupta@gmail.com

[b]Krishna Institute of Engineering and Technology (KIET) Ghaziabad, India

Abstract

The evaluation of software is important for enhancing the modification and improvement in a software development process. There are many factors to evaluate a software process. One of the factors is the Quality of software, which cannot be calculated with ease; as Quality of software is dependent on other factors. Software Usability is one of the significant aspects on which quality of software depends. A number of software usability models have been proposed by a number of researchers, each model considers a set of factors. In real world, we are facing many obstacles in implementing any of these proposed usability models as there is a lack in its precise definition and the concept of globally accepted usability. This paper aims to define the term 'usability' using a detailed taxonomy which includes all the aspects of usability and is globally accepted. Generalized Usability Model (GUM) with taxonomy has been proposed in this paper. This paper also shows how to determine the usability of a software application using a fuzzy based system which has been implemented using multistage fuzzy logic toolbox.

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Keywords: usability; quality; software; factors; GUM; evaluation; fuzzy logic; soft computing; fuzzy system.

1. Introduction

Over the few decades the software engineering practices have been changing to produce good quality software products. According to International Standard Organization (ISO) [8] there have been different quality factors like efficiency, effectiveness, reliability, usability etc. All the major Quality factors are listed in the Table 1.

Table 1. Quality of Software.

QUALITY OF SOFTWARE					
Functionality	Reliability	Usability	Efficiency	Maintainability	Portability

Out of the listed quality factors, usability is a significant quality factor that has to be considered during software development. The term usability is derived from user friendly. Many Software Engineering Experts defines usability in their own term.

In simple terms Software Usability is the ease of use, remembrance and learnability of a

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human-made object. Basically, usability will ease the human computer interaction so that the user will communicate better with the software system. Usability can also be defined as an extent to which a product can be used by a specific group of users to achieve the specified usability goals like effectiveness, efficiency and satisfaction. The degree of satisfaction will vary from one user to another.

* Corresponding author.

There are various standard or models which characterize the quality of software and defines the term usability as follows:

a. The ISO/IEC 9126 defines the usability in terms of the effort needed for use [9].

b. The ISO/IEC 9126 again redefines the definition of usability as capability of the software to be understood by user under certain conditions.

c. The ISO 9241-11 defines usability in terms of efficiency, effectiveness, and effectiveness in a specified context of use [8].

d. The IEEE Std.610.12-1990 defines usability in terms of learnability, Input and output efficiency of system [7].

Usability may be different for different software products; it changes from one perception to another perception. The degree of usability will depend on several factors such as-

- Ease of use
- Effectiveness of use
- Subjective satisfaction
- Knowledge & Experience of user to use the software.

In simple terms Software Usability is the ease of use, remembrance and learnability of a human-made object. The object can be a website, software application, tool, book, machine, process, or anything a human interacts with. A usability study must be conducted as a primary job by usability analyst or as a secondary job by designers, marketing personnel, technical writers, and others.

This paper aims to define the term 'usability' using a detailed taxonomy which includes all the aspects of usability and is globally accepted. We will propose a generalized usability model (GUM) and evaluate it using multistage fuzzy logic toolbox.

2. Generalized Usability Model (GUM)

In [2]-[19], we had seen and studied a large number of international standards and usability models, which describe usability but with different attributes in non-homogeneous manner creating confusion among experts for its usage and application. This inconsistent approach among usability model is creating major challenge for evaluation of usability of application. Researchers can't attain consensus for usability's definition and have poor information for deciding a set of usability factor. This research theme requires a hierarchical based usability model which should be consolidated to incorporate consistency in usability. Hence, usability model would be generic so that developers can measure usability without any confusion.

This section proposes a consolidated, hierarchical usability models i.e Generalized Usability Model (GUM) with taxonomy. This model can easily measure the usability of the software product. Specifically, this new model combines' usability factors, attributes, characteristics and data mentioned in various models or standards for software product quality and explain them and their relations in a consistent way.

2.1 The consolidated, hierarchical Generalized Usability Model (GUM):

GUM consists of seven (7) factors representing a specific facet of usability; these factors are decomposed into a total of twenty three (23) attributes, which are further divided into 42 characteristics. The factors, attributes and the characteristics are related to each other in a hierarchical manner.

The 7 factors include Efficiency, Satisfaction, Effectiveness, Memorability, Productivity, Security, and Universality. Based on these factors, the 23 attributes are quantifiable, which consist of either a fuzzy rule or countable data. The relationship between the usability factors and their attributes is depicted in Table 2.

Table 2. Relationship between GUM factors & their Attributes.

	Factors						
Attributes	Efficiency	Effectiveness	Satisfaction	Memorability	Security	Universality	Productivity
Resource	+						
Time	+						

User effort	+						
Economic costs	+						
Likeability/ Attractiveness			+				
Convenience			+				
Aesthetics			+				
Task accomplishment		+					
Operability		+					
Extensibility		+					
Reusability		+					
Scalability		+					
Approachability						+	
Utility						+	
Faithfulness						+	
Cultural universality						+	
Useful User Task output							+
Learnability				+			
Memorability of Structure/ Elements/ Functionality				+			
Comprehensibility				+			
Consistency in Structure/ Of Elements/ Of Functionality				+			
safety					+		
Error Tolerance					+		

GUM is the generalized model and it helps to measure the usability of a software product using its factors and attributes.

3. Fuzzy System Methodology

The concept of Fuzzy Logic is introduced as a way of processing data by allowing partial set membership. The Fuzzy Logic Toolbox acts as a tool for solving problems. Fuzzy logic system uses fuzzy inference, fuzzy data, and fuzzy rules. The fuzzy Inference Systems (FIS) are very important tools as they hold the non-linear universal approximation [28]. It uses FIS and fuzzy rules to express human expert knowledge and experience which can be represented in “if-then” statements. Following the fuzzy inference mechanism, the output can be a fuzzy set of certain features [29]. To design fuzzy expert system for determining usability, the Mamdani fuzzy systems will be utilized due to the fact that the fuzzy rules representing the expert knowledge in Mamdani fuzzy systems and it take advantage of fuzzy sets in their consequences [31].

The general process of constructing such a fuzzy expert system from initial model design to system evaluation is shown in Figure.1.

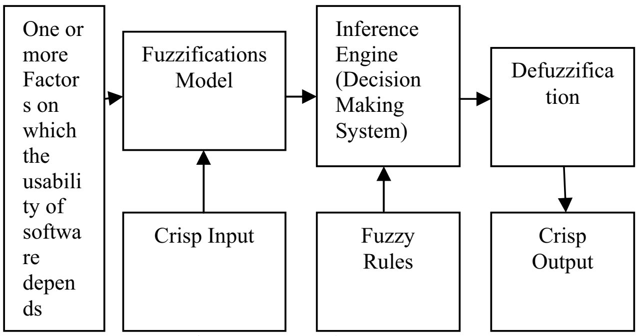

Figure 1. Fuzzy Inference System.

4. Simulation of the GUM Fuzzy System

Step 1) Inputs: Effectiveness (EF), Efficiency (E), Security (S), Universality (U), Productivity (P), Memorability (M), Satisfaction (SA)
Output: Usability (US)

We can write it in the short form notation as
US = [EF E S U P M SA]
Step 2) If the usability factors which involved in the GUM model are considered, it could be seen that the usability factors such as effectiveness, security, universality, productivity are related to the ability of the software to inspire the user to perform the task correctly. On the other hand, efficiency, satisfaction and memorability characteristics reflect the end user's ability to perform the task. With this understanding, the usability factors in the proposed model can be grouped as in Table .3.

Table 3. Grouping of factors.

Group	Critical Factors
Software Related	EF, S, U, and P
End User Related	E, M, and SA

Step 3) GUM model considers all the inputs (the usability factors) together, so that will lead generating too many rules and additionally it will be difficult for the experts to consider all formulates rules with proper emphasis, since each input parameter has three linguistic values (Low, Medium and High). Hence, the GUM with seven usability factors will have a maximum number of $3^7 = 2187$ rules. This means, the Matlab-Fuzzy Tool Box isn't applicable, since the number of inputs is limited to two in the Matlab [26].
Therefore, we had decomposed the factors into sub categories just to minimize a Hugh number of rules. Total six Fuzzy Interface System (FIS) namely sub-us-1, sub-us-2, soft-us, sub-us-3, end-user, and US have been created in Matlab using a Fuzzy Logic toolbox [26]. Consequently, input/output variables, their membership functions, and fuzzy control rules have also been created for each FIS. Table.4. shows an example of FIS.

Table 4. Decomposing Inputs & outputs to minimize the total rules.

FIS	Inputs	Output
FIS-1	EF, U	Sub-us-1
FIS-2	S, P	Sub-us-2
FIS-3	E, M	Sub-us-3
FIS-4	Sub-us-1, sub-us-2	Soft-us
FIS-5	Sub-us-3, SA	End-user
FIS-6	Soft-us, End-user	US

Step 4) defining universe of Discourse and fuzzification of usability characteristics:

Each of the seven usability factors have been given a universe of discourse (UOD) of range [0-9] and have been fuzzified with three linguistic values (fuzzy sub set: Low, Medium, and High) using linear triangular membership functions [27]. On the other hand, in order to achieve more accurate output, all the fuzzified output parameters have been fuzzified with four linguistic values (fuzzy sub set: Low, Medium, High, and Very High). Figure 2 shows examples of fuzzified input parameters.

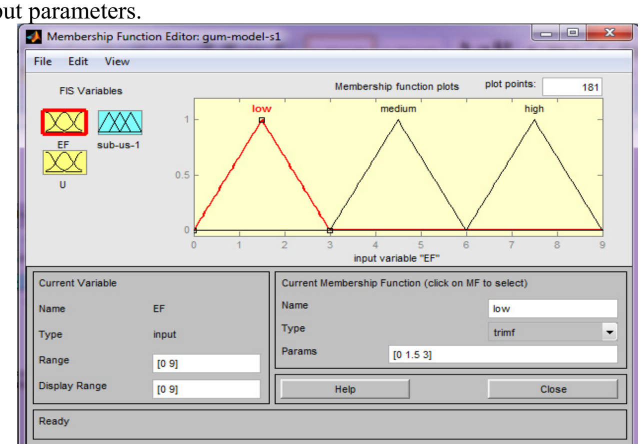

Figure 2. Fuzzified Input Parameter- EF.

Step 5) GUM model consists of total six (6) Fuzzy Interface System (FIS). The first FIS between the the factors EF and U is shown in figure.3.

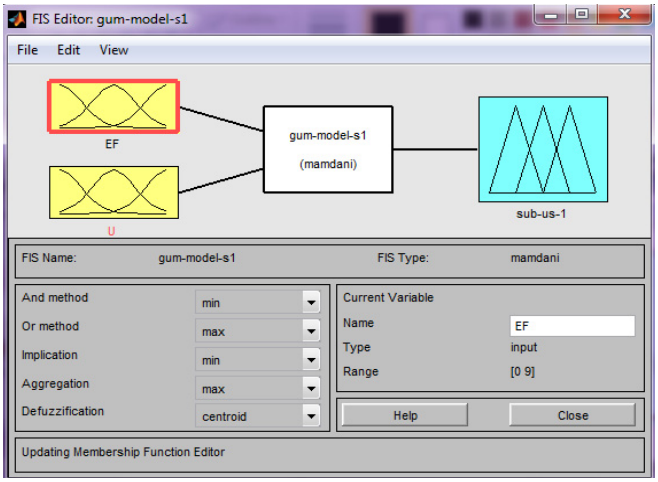

Figure 3. FIS of EF and U.

Step 6) The fuzzy control rules of first fuzzy interface system FIS (sub-us-1) have been defined as follows: EF and U are the fuzzy input variables and sub-us-1 is the fuzzy output variable. Fuzzy linguistic values of input/output variables are set as [Low, medium, high, or very high]. The fuzzy control rules have been defined based on the opinions of academicians, researchers, and GUM developers.

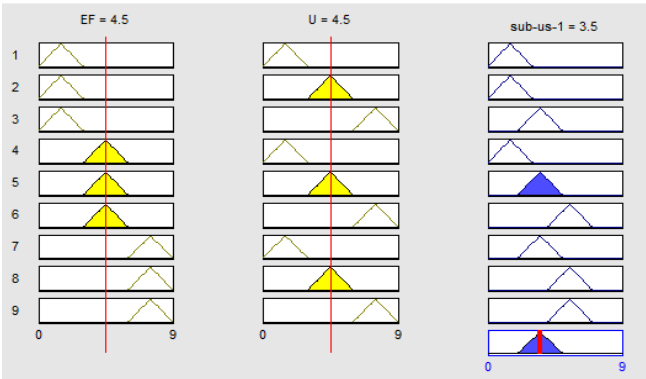

Figure 4. Rule viewer for First FIS (sub-us-1)

As seen from figure. 4., this FIS includes total 9 rules. For all combinations usability is either classified as Low, Medium, or high. The rules of sub-us-2 and sub-us-3 FIS had been defined in the same way.

Step 7) In this step, Matalab Simulink software (Fuzzy Logic Toolbox) has been employed, in order to develop an approach model for proposed stage wise fuzzy reasoning. This model connects sub-us-1, sub-us-2, sub-us-3, soft-us, end-user, and US. Figure.5 shows a fully functional the fuzzy logic model.

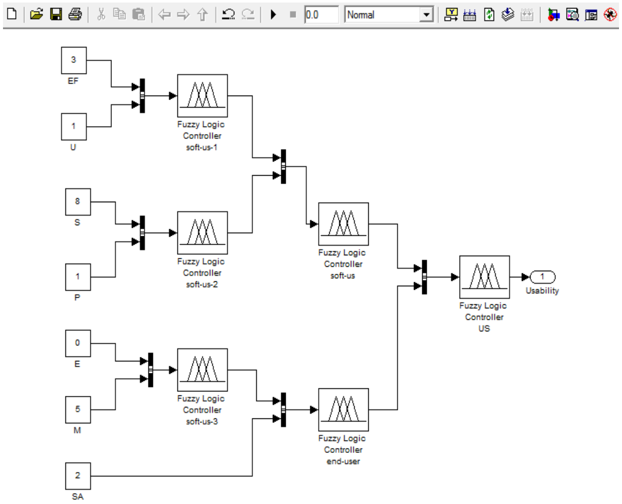

Figure 5. Fuzzy Approach Model of GUM Usability

5. Results

The data set in figure.10 is generated on the basis of the result of questionnaire given to 10 people, who are pursuing their graduation. Each participant is given 5 set of questionnaire consisting of 42 questions. All these 42 questions are used to generate the values of all the 7 factors and 23 attributes specified in the GUM model. The values of the 7 factors based on the inputs received by the participants are given in Table.5.

Table 5. Values for each factor

	EF	**E**	**SA**	**U**	**S**	**P**	**M**
DS1	3	6	2	1	8	1	5
DS2	1	1	3	5	2	4	4
DS3	5	3	7	2	7	8	3
DS4	5	8	4	3	9	4	7
DS5	2	0	4	1	5	7	1
DS6	8	7	9	8	4	3	9

Each DataSet values are applied as an input to GUM model for simulation as shown in step 7) of the proposed fuzzy expert system and the result produced is shown in figure.6.

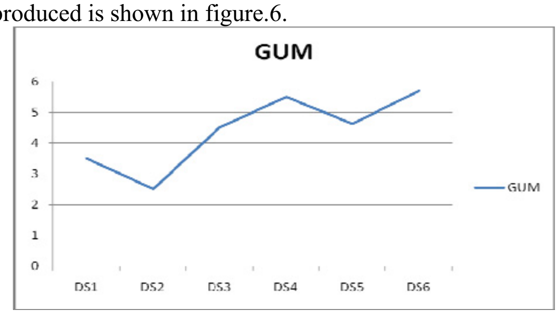

Figure 6.Usabiltiy of the Data Set (DS1-DS6)

As seen in the figure.6, for the GUM model, the usability decreases when any of the given attribute is either missing or having low value.

6. Conclusion

The evaluation of any application software is significant in controlling, managing so that we can be able to enhance the improvement in a software process. For such evaluation of a software application, we have to find its usability. This paper had purposed a usability model for general software application with 7 main factors i.e EF, E, S, U, P, M, and SA. These factors have also been classified with their relevance. We named this model as generalized usability model (GUM). All these factors are further decomposed into 23 attributes. This paper also describes the detailed taxonomy of GUM.

We had also generated the data set to test the proposed usability model. The technique used to generate the data set is questionnaire. Some questions are given to some people who are pursuing their graduation. The questions are based on the 23 attributes of the usability model and based on the result of the questionnaire, the dataset is generated. The purposed model is implementation using multistage fuzzy logic toolbox to measure the usability of a software application. The inputs of this proposed model consists of seven usability factors and it generated the total usability of the application under test.

7. Future Scope

In this paper the given dataset is verified by the fuzzy expert system. This dataset can also be verified by using either fuzzy TOPSIS or Bat Algorithm. We can also rank the various applications using the multistage fuzzy expert system.

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