Quantifying Website Usability using Fuzzy Approach

Shachi Bhatnagar, Sanjay K. Dubey, Ajay Rana

Abstract:- Usability is one of the most important factors for evaluating the quality of software/website. There are different dimensions through which usability of software can be evaluated. But the concept of usability is complicated. As the evaluation of usability is dependent on user experience, the data becomes difficult to work on as it is fuzzy in nature. There are different types of fuzzy theories are available through which usability can be evaluated even in the presence of uncertain and imprecise data. ISO 9241 states that effectiveness, efficiency and satisfaction are the criteria for usability evaluation. In this paper we are trying to show that if we incorporate the learnability of software with effectiveness, efficiency and satisfaction the usability of software increases with a considerable amount.

Index Terms:- Analytical hierarchy process (AHP), Fuzzy comprehensive evaluation, learnability, usability, usability evaluation, user experience.

I. INTRODUCTION

Time is a very precious thing and today's users are not ready to use uncomfortable software/website and waste time. Hence usability becomes an important criterion for success/ failure of the software system. Half of the software is not used by the user as they do not know how to use them. Software/website does not contain the required learnability so that they can be efficiently used. Most of the times user does not know how to operate the software as proper guidance and documentation are not provided. Many methods are available to evaluate usability. Fuzzy comprehensive evaluation method [1] can be used to prove that when the learnability of software is improved, usability of the software/website also increases.

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II. USABILITY

Usability makes the software quick and efficient to use. It also makes the software easy to learn and remember. Error recovery is much more rapid if the software is usable. Usability of the software when improved benefits both the users and the provider. The user achieves their goals effectively and efficiently. They enjoy interacting with the software system and are not frustrated using it. Usability helps the user to have confidence and trust on the software system. The providers are benefited from usability in many ways, such as reducing development time and cost, user errors, support cost, training time and error. It also helps to increase the investment returns.

Usability has been defined in different ways in literature; some broad definitions of usability from different standards are listed next:

- "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [2].
- "The ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a system or component" [3].

Usability consists of five kinds of attributes [4]:

- **Learnability:** User should be able to start the work in first go which means that the software should be easily learnable.
- **Efficiency:** The software should be efficient to use, the user should be able to understand the software fully and thereafter the yield will be high.
- **Memorability:** Software should be easy to remember so that the user should be able to use the software even after some period of time.
- **Errors:** The software should have low error rate due to which the users will not be able to make errors while using the software.
- **Satisfaction:** The software should be easy and pleasant to use.

III. LITERATURE SURVEY

Usability of the system can be evaluated throughout the software's development life cycle [5]. Shackel suggested that usability is the measure of how much the software is easy to use, effective, flexible and subjectively pleasing. Later on, Shackel's criteria was modified [6] making usefulness, effectiveness, learnability and

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likeability of the software as the criteria's for the assessment of usability as flexibility of a software was difficult to measure and specify. Usability of software can be easily attributed to the combination of learnability, efficiency, Memorability, errors and satisfaction [4]. The idea of Nielsen mainly focused on the attributes that constituted the usability. A new idea came into picture where usability aimed to give long term user satisfaction [7]. He again divided usability as the combination of learnability, retainability and the usage of advance feature. Another of usability definition defined it as the combination of learnability, memorability, efficiency, flexibility, satisfaction, first impression, advance feature usage and evolvability [8]. The system should be relevant to user's needs, efficiency, user's subjective feelings, learnability and system's safety feature, such as grating user the right to undo actions that may lead to errors [9].

As the history suggest that learnability has been considered as one of the main attribute for the measure of usability by many authors. Hence making the learnability of a software/website better we can increase the usability.

Focusing on the user's personal interaction with the software/website, several questionnaires are developed such as Software Usability Measurement Inventory (SUMI) [10], the Questionnaire for User Interaction (QUIS) [11] [12] etc. These questionnaires help us to measure some attributes of the usability. SUMI helps to measure the perceived quality of use of software, either as a developer, a consumer of software, or as a purchaser/consultant.

IV. USABILITY COMPREHENSION EVALUATION METHOD

Following are the steps which gives methodology of fuzzy comprehension evaluation and how AHP is used to weight the evaluation factors.

A. Description of Fuzzy Comprehensive Evaluation

It is the process in which an objective is evaluated using the fuzzy set theory. Multiple related factors must be considered while evaluating an attribute to get consistent judgment. Steps for fuzzy evaluation are defined as follows [13]:

Steps 1: A set of evaluation factors are determined. Let us assume that the objective is evaluated using n factors, the index set can be represented as M= $\{m_1, m_2 ....m_n\}$.

Steps 2: A set of appraisal grades are determined. The appraised set can be represented as N= (excellent, good, medium, poor, very poor) for specific attribute.

Steps 3: Mapping from M to N is done to get fuzzy appraisal matrix for all n factors. For a specific vector, the appraisal $R_i = \{r_{i1}, v_{i2} ....v_{im}\}$

$$R = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix}$$

Steps 4: The weights of evaluation factors are determined. The weight vectors are formulated by AHP. In this method the importance of each factor should be quantified. The weight vector can be represented as W $(a_1, a_2 ....a_n)$.

Steps 5: The appraisal result is obtained. The appraisal result set of comprehensive evaluation is which is given as

$$U_b = W \times R \qquad (1)$$

B. Determining the weight vector by AHP(Matrix W)

In this paper, the method of AHP is used to determine the weight vector A. The steps of AHP are as follows [14] [15]:

Steps 1: With the help of Table 1 a pair wise comparison is done between n factors. The n×n matrix of weight comparison can be represented as follows:

Table1. Scale of preference in the pair-wise comparison process

Numerical Rating	Judgment of preferences between factor *i* and factor *j*
1	factor *i* is equally important to factor *j*
3	factor *i* is slightly more important than factor *j*
5	factor *i* is clearly more important than factor *j*
7	factor *i* is strongly more important than factor *j*
9	factor *i* is extremely more important than factor *j*
2,4,6,8	intermediate values

$$W = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$$

Each a_{ij} of the matrix represents the importance intensity of factor W_i over factor W_j. The a_{ij} value is supposed to be an approximation of the relative importance of W_i to W_j. Each of a_{ij} (i, j= 1,2.........n) follows $a_{ji}=1/a_{ij}$, for $a_{ij} \neq 0$.

Step 2: Average of normalized columns (ANC) method can be used to estimate the vectors of weights functions. It is presented as

$$w_i = \frac{1}{n} \sum_{j=1}^{n} a_{ij} \Big/ \sum_{i=1}^{n} a_{ij} \qquad (2)$$

Step 3: Consistence ratio defined by Saaty measures how consistence a given matrix is. It is represented as

$$CR = CI/RI \qquad (3)$$

A value of CR < 0.1 is considered acceptable. CI is the consistency index defined as

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$$CI = {(\lambda_{\max} - n)}\Big/{n-1} \qquad (4)$$

Where λ_{max} represents the maximum eigen value of the pair wise comparison matrix, and n is the number of factors. λ_{max} is given by

$$\lambda_{\max} = \sum_{i=1}^{n} {(W\bar{w})_i}\Big/{nw_i} \qquad (5)$$

RI is the average random index, whose value is determined through Saaty's book [14], for 3×3 matrix, the value of RI is 0.58 and for 4×4 matrix, the value of RI is given 0.90.

C. Weighted Hierarchical Index for Evaluating Usability

Usability of a system cannot be measured directly. But its attribute can be constructed in a way that can be measured. ISO provides the basic structure of usability as the measurement of three attributes which are effectiveness, efficiency and satisfaction. So, here we considered two scenarios. First scenario was considered when the user does not know anything about the software/website and evaluate it. Second scenario was when user is provided with all the documentation or material which would help the user to use the software/website. Effectiveness and efficiency are calculated as task success and task completion time [1]. Software Usability Measurement Inventory (SUMI) [10] helps to measure user satisfaction and learnability is measured through a questionnaire prepared by the combination of different question which helps to know how easy it was to use the software/website with the help of documentation or training.

Table 2. Pairwise comparison with respect to user satisfaction (without learnability)

	Effectiveness	Efficiency	Satisfaction	Weights
Effectiveness	1	5	3	0.656
Efficiency	1/5	1	1	0.158
Satisfaction	1/3	1	1	0.187

Note: λ_{max}=3.033, CI= 0.0165, CR=0.028

A single metric is employed to determine the weight vector. In scenario 1, effectiveness, efficiency and satisfaction and in scenario 2, effectiveness, efficiency, satisfaction and learnability are employed. A panel of 10 people was made which consist of 3 software engineers, 3 managers and 4 users to perform pair wise comparison according to Table 1.The matrix were filled for both of the scenario. Consistency of these matrices' is checked by AHP. We found CR<0.1 for both the matrices'. Table 2 shows the matrix which did not consider learnability as a factor and A comes out to be W_1 (0.656, 0.158, 0.187). Table 3 shows the matrix were learnability is considered and A comes out to be W_2(0.410, 0.250, 0.209, 0.106).

D. Fuzzy Member function for Appraisal Matrix R

In this study, the metric of task success is denoted as "0", if participant cannot finish a task and "1" means he completes the test task very well, and intermediate values shows the degree of success. Satisfaction is scaled by SUMI, and is a 3-point scale and learnability is divided on a 7-point scale.

Time completion is the time from the beginning to end to complete a test task. When determining the membership function for factors, corresponding score of each task on each metric would be ranked as "excellent, good, medium, poor or very poor". Table 4 & Table 5 show the membership mapping without learnability and with learnability.

Finally, the factors in fuzzy relation matrix could be calculated as following formula [16]:

R_{ij} = (Number of corresponding average rank) / (Number of the participants)

Table 3. Pairwise comparison with respect to user satisfaction (with learnability)

	Effectiveness	Efficiency	Satisfaction	Learnability	Weights
Effectiveness	1	2	2	3	0.418
Efficiency	1/2	1	2	2	0.250
Satisfaction	1/2	1/2	1	3	0.209
Learnability	1/3	1/2	1/3	1	0.108

Note: λ_{max}=4.144, CI= 0.048, CR=0.053

Table 4. Membership mapping for metric score ranking (without learnability)

Ranking	Very Poor	Poor	Medium	Good	Excellent
Success	$0 \le x < 0.25$	$0.25 \le x < 0.5$	$0.5 \le x < 0.7$	$0.7 \le x < 0.9$	$0.9 \le x \le 1$
Time	$x < 0.3$	$0.3 \le x < 0.6$	$0.6 \le x < 0.8$	$0.8 \le x < 0.95$	$0.95 \le x$
Satisfaction	Maximum disagree	More disagree then others	Maximum undecided	More agree then others	Maximum agree

Table 5. Membership mapping for metric score ranking (with learnability)

Ranking	Very Poor	Poor	Medium	Good	Excellent
Success	$0 \le x < 0.25$	$0.25 \le x < 0.5$	$0.5 \le x < 0.7$	$0.7 \le x < 0.9$	$0.9 \le x \le 1$
Time	$x < 0.3$	$0.3 \le x < 0.6$	$0.6 \le x < 0.8$	$0.8 \le x < 0.95$	$0.95 \le x$

Satisfaction	Maximum disagree	More disagree then others	Maximum undecided	More agree then others	Maximum agree
Learnability	$1 \le x < 2.5$	$2.5 \le x < 3.5$	$3.5 \le x < 5.5$	$5.5 \le x < 6.5$	$6.5 \le x \le 7$

V. CASE STUDY

To show how fuzzy comprehensive evaluation model can be applied to evaluate the usability of the product, a task on a website was conducted as the test task. The usability testing was carried out on 10 typical users under the eyes of one experienced facilitor and an engineer.

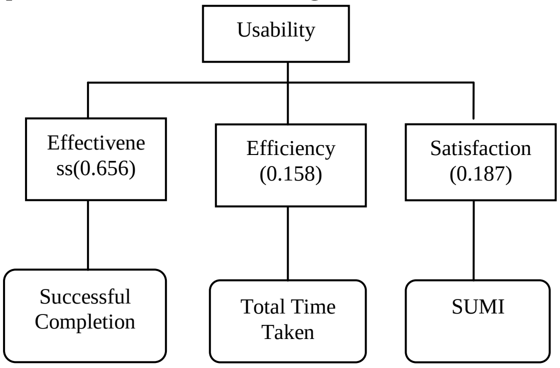

Fig 1. Fuzzy Evaluation Model (Without Learnability)

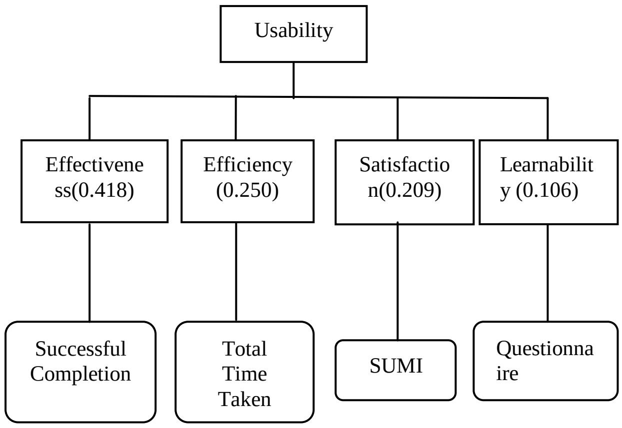

Fig 2. Fuzzy Evaluation Model (With Learnability)

Figure1and 2 shows the methods through which usability is measured. Effectiveness, efficiency, satisfaction and learnability are the usability factors. These factors produce metrices which are obtained by different ways as shown in the figure.

A. Fuzzy Appraisal Matrix

In scenario 1 according to equation 2, the fuzzy appraisal matrix for three factors (without learnability) was obtained. The process is illustrated in Table 6 indicating the membership for task success.

Similarly other membership mapping function can be obtained. The matrix R is given as

$$R_1 = \begin{bmatrix} 0 & 0 & 0.3 & 0.4 & 0.3 \\ 0 & 0.2 & 0.4 & 0.4 & 0 \\ 0 & 0.2 & 0.3 & 0.5 & 0 \end{bmatrix}$$

In scenario 2 according to equation 2, the fuzzy appraisal matrix for four factors (with learnability) was obtained. The process is illustrated in Table 7 indicating the membership for task success.

Similarly other membership mapping function can be obtained. The matrix R is given as

$$R_2 = \begin{bmatrix} 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0.4 & 0.6 \end{bmatrix}$$

Table 6. Membership mapping for task success value ranking (Without learnability)

	Very Poor	Poor	Medium	Good	Excellent
U1				×	
U2			×		
U3			×		
U4				×	
U5					×
U6					×
U7					×
U8				×	
U9				×	
U10			×		
Total	**0**	**0**	**3**	**4**	**3**
R_j	**0**	**0**	**0.3**	**0.4**	**0.3**

Table 7. Membership mapping for task success value ranking (With learnability)

	Very Poor	Poor	Medium	Good	Excellent
U1					×
U2					×
U3				×	
U4				×	
U5					×
U6					×
U7					×
U8				×	
U9					×
U10				×	
Total	**0**	**0**	**0**	**4**	**6**
R_j	**0**	**0**	**0**	**0.4**	**0.6**

B. The Appraisal Result

The appraisal result set B for scenario 1 (without learnability) is calculated using equation 1

$$U_{b1}=W_1\times R_1= (0.656 \quad 0.158 \quad 0.187)\begin{pmatrix} 0 & 0 & 0.3 & 0.4 & 0.3 \\ 0 & 0.2 & 0.4 & 0.4 & 0 \\ 0 & 0.2 & 0.3 & 0.5 & 0 \end{pmatrix}$$

$$= (0.000 \quad 0.069 \quad 0.316 \quad 0.419 \quad 0.000)$$

The appraisal result set B for scenario 2 (with learnability) is calculated using equation 1

$$B=W_2\times R_2= (0.418 \quad 0.250 \quad 0.209 \quad 0.106)\begin{pmatrix} 0 & 0 & 0 & 0.4 & 0.6 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0.4 & 0.6 \end{pmatrix}$$

$$= (0.000 \quad 0.000 \quad 0.000 \quad 0.347 \quad 0.636)$$

This is the final appraisal vector, and it can be defuzzified to a comprehensive score [17]. Here the appraisal grading is defined as 95, 82, 67, 50, and 31 for excellent, good, medium, poor, very poor. So B can be defuzzified with the help of the following formula:

$$a = \sum_{i=1}^{m} b_i^2 a_i \Big/ \sum_{i=1}^{m} b_i^2 \qquad (6)$$

Based on the values and using the above formula we get usability of scenario 1 (without learnability) as 76.11 and get usability of scenario 2 (with learnability) as 92.01.

VI. Conclusion

As from the obtained result it is very much clear that if learnability of a software/website is improved the usability of the software is also increased manifold. If the user is able to understand what has to be done, proper help, documentation and tutorials are provided then the user finds it very easy to use the software/website and many unusable software/websites can brought again into use.

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