

A Usability Evaluation Methodology of Digital Library

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Abstract— Digital Libraries are information systems that allow managing and preserving digital resources, as well as providing access to them. The designing of these kinds of systems should always be completed having in mind the users. Accordingly, it is of outmost importance that the user interface presents a high level of usability. In this paper, a usability evaluation methodology of Digital Libraries is proposed; specifically for the Web site of Academic Digital Libraries. The methodology offers a evaluation instrument that collects the users' perceptions through four dimensions (effectiveness, efficiency, satisfaction and learnability). In addition, the gap theory of quality service is employed and a fuzzy linguistic approach using aggregation operators, which operate directly with words (linguistic information) is applied. Therefore, the methodology shows to be a significant, innovative contribution to the research area on usability evaluation of digital libraries. It can be useful for both an academic library Web site and an operational digital library. A case study is presented in order to demonstrate the usage of usability evaluation methodology of digital library.

Keywords-digital libraries; usability evaluation methodology; usability dimensions; evaluation instrument; aggregation operators.

I. INTRODUCTION

There are many definitions of usability in the literature, which provide different and complementary points of view, and show the evolution of the term itself along the evolution of knowledge. Usability is the broad discipline of applying sound scientific observation, measurement, and design principles to the creation and maintenance of Web sites in order to bring about the greatest ease of use [1]. According to Nielsen [2], usability focuses mainly on the use of a Web site or an interface and how people use it to carry out their tasks. If a Web site or interface is not able to satisfy the needs of their users, they will not be successful in the long term.

Usability has several international standard definitions. It is a quality attribute that assesses how simple it is to utilize user interfaces. The concept of usability, is also related to methods to improve the easiness of its use throughout the design process.

Digital Libraries (DLs) are information systems that allow to manage and preserve digital resources, and to provide access to them. The design of these systems must be always accomplished bearing in mind the user, so, it is

vitaly important that the user interface has a high degree of usability. In this paper, a usability evaluation methodology for the DLs —specifically for the academic DL Web site— such as a case study of the usability evaluation of the DL Web site in the University of Puebla is presented. The methodology proposes an evaluation instrument, that collects the users' perceptions by four dimensions (effectiveness, efficiency, satisfaction and learnability). In addition, the gap theory of service quality and a fuzzy linguistic model using aggregation operators of linguistic information —which operate directly with words— are used. Therefore, the methodology proves to be a significant and innovative contribution to the area of usability evaluation research of DLs. The same can be applied to a Web site of an academic DL as an operational DL.

The rest of this paper is organized as follows: Section II describes some related works in evaluating DLs. Section III explains the LibQUAL+ methodology. Section IV presents a brief introduction to the linguistic approach. Section V details a usability evaluation methodology. Section VI outlines the conclusions and future work.

II. RELATED WORK

According to the literature, most evaluations have focused on library service quality and its collections. Among the contributions of research on usability evaluation of Web sites, there are those of Hammill [3], who evaluated the usability of the Florida International University libraries' Web site by means of formal usability test and questionnaire, for determining whether its design and organization allow users to easily locate information based on the navigation, the clarity of vocabulary, and the visibility of the different sections. Oulanov and Pajarillo [4] described the results of a usability evaluation study of the Web-based graphical user interface version of the Web bibliographic database of the City University of New York, using questionnaire that determined the affect, efficiency, control, helpfulness, and adaptability as usability attributes. Lee [5] evaluated the usability of a Research Center library Web site in Korea by using a mixture of observation methods, and some formal usability tests; including heuristic evaluation, laboratory usability testing, and remote usability testing. Jeng's usability model [6], which is one of the most cited works on usability evaluation of DL Web sites, carried out usability tests based on tasks, comprising four usability dimensions; effectiveness, efficiency, satisfaction, and learnability, as

well as, some sub-attributes of usability. She also suggested some specific measures for each dimension, although it must be considered that those could vary according to the user's particular skills. Joo, Lin, and Lu [7] proposed a usability evaluation model by means a questionnaire, to survey the three usability criteria: effectiveness, efficiency, and learnability, in academic library Web sites. Alasem [8] used a questionnaire based usability test as a method for evaluating the usability of Saudi Digital Library's interface. In his usability evaluation, he suggested criteria such as efficiency, effectiveness, aesthetic appearance and learnability.

The usability study as in [9] is among the few studies comparing users' performance in multiple operational DLs: ACM, IEEE CS, NCSTRL, and NDLTD. This study used questionnaire and formal usability test, their objective was to identify specific characteristics that aid in the effectiveness (ease of use), likability, learnability and usefulness of DLs. The user's performance was measured by its ease of use, the amount of searching time, and the number of errors made. In [10] explored usability issues (perceived ease of search, satisfaction and perceived ease of browsing) on the design and the interaction in the browse and search function of ACM, IEEE CS, and IEEE Xplore.

LibQUAL+ methodology [11] was developed in the evaluating of the digital library services, provides a useful framework for usability evaluation of digital library. LibQUAL+ uses the gap theory of service quality, as well as other assessment frameworks based on SERVQUAL model [12]. Nowadays, The DigiQUAL project, being an extension of LibQUAL+, developed a service quality model reflecting digital environments [13].

Specialized assessment's works for academic libraries have been limited to assessing the quality service, but the evaluation of the Web site usability of academic libraries has received relatively little attention. Furthermore, these studies use neither the service quality gap nor the linguistic aggregation operators (LOWA and LWA). Regarding works that employ linguistic aggregation operators; these are strictly oriented to the quality of service [14] and they do not utilize the four usability attributes proposed hereby.

This paper provides a methodology that combines methods and principles —dimensions, questionnaire and measurement scale— of usability evaluation and fuzzy logic techniques, focusing on usability evaluation of digital libraries, which can either be academic or operational.

III. LIBQUAL+ METHODOLOGY

The Association of Research Libraries (ARL) in conjunction with the University of Texas A&M, started a project to obtain a standardized measure of the quality library service. The LibQUAL+ methodology is the result of such a project, which allows determining the quality of library services from the users' perception. LibQUAL+ is based on the theory of quality service —assessment applied in the environment of enterprises and organizations— particularly on the SERVQUAL evaluation methodology.

SERVQUAL is the most accepted and extended measurement of quality service. It is based on the principle

that "only customers judge quality; all other judgments are essentially irrelevant" [15]. Thus, customer satisfaction is the key element in SERVQUAL. Service quality is related to diminishing the distance between the customers' expectations and his final perception.

According to SERVQUAL, customers will evaluate, positively or negatively, the quality of a service where their prior perceptions were either higher or lower than expected. Hence, companies or organizations that provide services, where one of the objectives is being observed differently by means of a quality service, must show special interest on exceeding their customers' expectations.

LibQUAL+ looks forward to evaluating the quality of service of a library, considering three dimensions: the affective value provided by the staff, the value of the library space, and the value represented by the information control. Hence, service quality is evaluated through a survey of 22 questions; Minimum required level of service; Expected level of service; and the level perceived by the user. The Expected level and the Minimum required level establish the boundaries of a zone of tolerance within which the perceived scores should desirably float. Based on the users' feedback, it is possible to define two variables for detecting the strengths and weaknesses of a library i.e. Adequacy of Service (the difference between the perceived value and the minimum value) indicating the areas where the library service is below the level expected by the user, and Service Excellence (the difference between the perceived value and the expected value) that identifies areas where the library provides a better service than that expected by the user.

IV. LINGUISTIC APPROACH

The information cannot always be evaluated in a quantitative manner, sometimes it is necessary to do it qualitatively. The existence of qualitative variables inherent to human behavior, or external environment elements, which are difficult to quantify objectively lead individuals to express their opinions better, by using linguistic terms instead of precise numerical values. A linguistic variable differs from a numerical one in that its values are not numbers, but words or sentences in a natural or artificial language [16].

When a linguistic model is used, the existence of a suitable set of terms or labels according to the problem domain is assumed, then, the individuals can express their perceptions. The ordinal fuzzy linguistic model [17] is very useful as it simplifies the computing by eliminating the complexity of having to define a grammar.

An ordinal fuzzy linguistic modeling [16] is used in this paper to represent the users' perceptions with words, based on the linguistic aggregation operators LOWA and LWA [14], in order to evaluate the academic digital libraries Web sites usability.

The Linguistic Ordered Weighted Averaging (LOWA) is an operator used to aggregate non-weighted ordinal linguistic information, i.e., linguistic information values with equal importance. The Linguistic Weighted Averaging (LWA) is an operator used to aggregate weighted linguistic information, i.e., linguistic information values has different

importance. In order to calculate both operators, this paper follow the definitions established on [18].

V. A USABILITY EVALUATION METHODOLOGY

In this work, a usability evaluation methodology has been developed for the academic DL Web sites based on literature review. Therefore, this methodology takes an approach that requires the establishment of dimensions, as a way to measure usability, based on standards such as ISO 9241-11 [18] and Nielsen's definition [2]. Consequently, it considers four dimensions: effectiveness, efficiency, satisfaction, and learnability represented in twenty items to capture the users' perceptions to assess the usability degree of academic DL Web sites. Furthermore, the methodology uses a fuzzy linguistic model by means of aggregation operators with linguistic information, which handle words directly. They are important to allow sorting and classifying all data from an aggregation process, without any loss of linguistic information. In addition, the model LibQUAL+, which attempts to measure the overall service quality in academic DL is utilized. LibQUAL+ emerged from the SERVQUAL methodology; an instrument based on the gap theory of service quality, which was used to assess private sector institutions.

Deficiencies on usability of DL Web sites could be identified through LibQUAL+. Therefore, the proposed methodology of usability evaluation in this paper, could offer commendations for prioritizing improvements and guaranteeing a proper interface design of DL, based on users' preferences within an institution.

The usability evaluation methodology, consists of different steps; the development, production, implementation, evaluation and reliability of the questionnaire, as well as the results analysis, from where a series of recommendations to improve the usability of DLs Web sites can be provided. The steps for implementing this methodology are:

- A. The identification of dimensions.
- B. The preparation of the questionnaire.
- C. The usability evaluation by aggregating operators.
- D. The presentation of evaluation results.
- E. The commendation of the DL Web site.

A. Dimensions of Usability

The usability is a multidimensional concept. In this paper four dimensions of usability —effectiveness, efficiency, satisfaction and learnability— are proposed to assess the usability of academic digital libraries' Web sites (see Table 1).

In order to define the usability dimensions, the models of Nielsen [19], ISO 9241-11 [18], Shackel [20] Tsakonas [21], Jeng [6], and Xie [22] were revised. Finally, the chosen dimensions were based on the standard definition of ISO 9241-11 [18] and the Nielsen model [19]. Nielsen's model, which is one of the most cited in the area of usability engineering, postulates five attributes: learnability; efficiency; memorization; low error rate (easy error recovery); and subjective satisfaction.

TABLE I. DIMENSIONS OF METHODOLOGY

Dimension	Sub criteria	Definition
Effectiveness		It refers to completion of tasks where users achieve specific goals.
Efficiency		It refers to the resources used for performing a task.
Learnability		The system should be easy to learn and to understand; it should be easy for the user to achieve a task by using the system.
Satisfaction	Ease of use	It refers to the user's perception about the use of the system.
	Information Organization	It is to assess whether the structure, design, and organization of the system reach the users' goals.
	Clear Labeling	It refers to the clear labeling of the DL Web site from the users' point of view, and whether the terminology used is easy to understand.
	Visual Aspect	It evaluates the site design concerning its visual appealing.
	Error Recovery	It has to do with the easy to recover from errors made by the users.
	Navigability	It refers to the easiness that users may have to go from one site to another .

B. Questionnaire

An important part of the usability research has been the designing of a questionnaire. The items for measuring the usability of a DL Web site, were based on the literature on usability evaluation studies. First, it was necessary to establish the dimensions. To be able to generate measurement items; usability frameworks, usability guidelines, and usability testing were reviewed [6][11][19]. All measurement items chosen, were modified to reflect the unique features of academic libraries Web sites. Thus, twenty items establish the questionnaire (see Table 2) to capture the users' perceptions on the rate of usability of academic DL Web sites, based on the proposed usability dimensions. Users must answer the questions about their personal experience when interacting with the DL Web site.

C. Evaluation

Before evaluating the usability of the DL Web site of the University of Puebla —which is the case study—, the participants were asked to fill out a pre-questionnaire concerning demographic data —level of education, age, and gender, use frequency of the DL Web site and level of computer skills. The filling of the pre-questionnaire and usability questionnaire, were accomplished by accessing <http://encuiti.netai.net/>. In this case, it is a tool designed and implemented especially for this evaluation study; that allows the capture and analysis of data, by using the aggregation operators for data processing through LOWA and LWA.

A total of 54 users participated in the usability evaluation of the DL Web site of the University of Puebla —including students and teachers, both undergraduate and masters.

The pre-questionnaire was analyzed using frequency charts to determine the type of user, who responded to the survey based on their age, sex, level of education, computer

skills, and Web site usage. The usability evaluation questionnaire was examined bearing in mind the following steps:

TABLE II. QUESTIONNAIRE

Dimension	Item
Effectiveness	Can you usually complete a search task by using the DL Web site?
	Can you successfully find digital resources through the DL Web site?
	Do the digital resources of the DL Web site satisfy your needs of information?
	In general, is the DL Web site useful to help you find the information you are looking for?
Efficiency	Can you complete a task quickly by using the resources of the DL Web site?
	Do you obtain results quickly by using the DL Web site?
	Does the user interface gives you expeditious access to DL resources?
	Is the access to information services (databases, catalogs, etc.) quick and easy to use?
Learnability	Was learning to use the DL Web site easy?
	Are the terms used on the DL Web site easily understandable?
	Is the DL Web site help well organized?
	Are new users able to utilize the services without considerable effort?
Satisfaction	What is your main fulfillment when using the DL Web site?
	What is the rate of navigability of the DL Web site?
	Is the organization and distribution of information on the DL Web site clear?
	Is the language used on the Web site, appropriate and classified by tags clearly enough?
	Is the Web site visually appealing?
	Does the Web site allow an easy error recovery?
	Are he services offered by the DL Web site satisfactory?
Total Usability	What is the general usability of the the DL Web site?

1. The users expressed their judgment by completing the questionnaires (see Table 1).

The scale for this model is $S=\{VL=Very\ Low, L=Low, M=Medium, H=High, VH=Very\ High\}$.

As a result for each one of the users $u_j \in (u_1, u_2, \dots, u_n)$ and for each questionnaire item $i_k \in (i_1, i_2, \dots, i_m)$, m is the total number of questions; there is a tuple $(mv_{jk}, pv_{jk}, ev_{jk})$ of the minimum value — mv —, perceived value — pv — and the expected value — ev —, for each user u_j and for each question i_k .

2. To compute the global users' opinion concerning each item i_k of the tuple $(mv_{jk}, pv_{jk}, ev_{jk})$, the following aggregation operators are used:

2.1 LOWA [14] is used if all users are considered to bear the same importance.

$$\begin{aligned} mv_k &= \Phi_Q(mv_{1k}, \dots, mv_{nk}) \\ pv_k &= \Phi_Q(pv_{1k}, \dots, pv_{nk}) \\ ev_k &= \Phi_Q(ev_{1k}, \dots, ev_{nk}) \end{aligned} \quad (1)$$

2.2 LWA [14] is used when each user is considered to bear a different level of importance.

$$mv_k = \Phi_Q((UI(u_1, i_k), mv_{1k}), \dots, (UI(u_n, i_k), mv_{nk})) \quad (2)$$

$$pv_k = \Phi_Q((UI(u_1, i_k), pv_{1k}), \dots, (UI(u_n, i_k), pv_{nk}))$$

$$ev_k = \Phi_Q((UI(u_1, i_k), ev_{1k}), \dots, (UI(u_n, i_k), ev_{nk}))$$

Where $UI(u_j, i_k) \in S$ is the level of relative linguistic importance assigned to a user u_j for the item i_k .

3. The overall review of all questions of the tuple (mv, pv, ev) is calculated similarly to the previous step, by using aggregation operators:

LOWA [14] is used when all the items are considered to bear the same importance.

$$\begin{aligned} mv_k &= \Phi_Q(mv_1, \dots, mv_m) \\ pv_k &= \Phi_Q(pv_1, \dots, pv_m) \\ ev_k &= \Phi_Q(ev_1, \dots, ev_m) \end{aligned} \quad (3)$$

LWA [14] is used when each item is considered to carry a different level of importance.

$$\begin{aligned} mv &= \Phi_Q((II(i_1), mv_1), \dots, (II(i_m), mv_m)) \\ pv &= \Phi_Q((II(i_1), pv_1), \dots, (II(i_m), pv_m)) \\ ev &= \Phi_Q((II(i_1), ev_1), \dots, (II(i_m), ev_m)) \end{aligned} \quad (4)$$

Where $II(i_k) \in S$ is the level of relative linguistic importance assigned to item i_k .

4. The gap theory of service quality is applied to each item. The tolerance zone is located between the minimum and the expected values. The difference between the perceived and the minimum values, is called Service Adequacy —SA— and the Service Superiority —SS— is the difference between the expected values and the perceived ones. Therefore, for each item i_k , SA_k and SS_k are computed as follows [9]:

$$\begin{aligned} SA_k &= D(pv_k, mv_k) \\ SS_k &= D(ev_k, ev_k) \end{aligned} \quad (5)$$

On the other hand, when utilizing questionnaires for evaluating the usability of a Web site, it is important to verify the reliability of the evaluation instrument it is advisable to use the Cronbach's alpha.

Cronbach's alpha allows to quantify the level of reliability of a evaluation scale, built from k variables observed. Assuming that the variables are related to the qualitative interest data; the k variables should achieve stable, consistent measurements with a high level of correlation among themselves. A questionnaire is considered reliable when Cronbach's alpha is greater than 0.80. The formula for Cronbach's alpha is:

$$\alpha = \left[\frac{k}{k-1} \right] \left[1 - \frac{\sum_{i=1}^k S_i^2}{S_t^2} \right] \quad (6)$$

Where S_i^2 is the item variance i ;

S_t^2 is the item variance of all observed values;
 K in the item number of the questionnaire;

D. Results of the Questionaries

Both a quantitative and a qualitative analysis are accomplished in the usability evaluation of the DL Web site. The qualitative analysis focuses on calculating the aggregation operators LOWA and LWA; It is based on proposed linguistic labels on the scale.

The LOWA operator requires to obtain the combination of the users' perception for each item. Thus, Table 3 summarizes the result of the combined aggregation of the users' perception for the three assessed values: minimum,

perceived, and expected values, regarding the DL Web site as well as their corresponding gap. On the other hand, Figure 1 shows a radar chart that summarizes the user responses to the questionnaire items on the minimum, perceived and expected levels. This type of chart was used to display the results obtained with the LOWA operator. As shown therein, the usability of the minimum value is reflected on the chart with a medium value (orange color), by most users the perceived one (green color) and the expected one (blue color) show a tendency towards a higher level of usability in the DL Web site.

The LWA operator allows perceiving the opinion of all users on items with a different level of importance; which is suitable to evaluate the usability on this paper, because it contemplates four dimensions: efficiency, effectiveness, learnability, and satisfaction. So, the level of importance will vary according to the dimension being assessed. In case of measuring effectiveness, items 1, 2, 3, and 4 would have a Very High (VH) level of importance, while the remaining items present a Very Low (VL) level of importance as shown in Table 4.

TABLE III. RESULTS OF THE LOWA OPERATOR

Item	Minimum	Perceived	Expected	Usability Adequacy	Usability Excellence
1	M	H	H	L	VL
2	M	H	H	L	VL
3	M	H	H	L	VL
4	M	H	H	L	VL
5	M	H	H	L	VL
6	M	H	H	L	VL
7	M	H	H	L	VL
8	M	H	H	L	VL
9	M	H	H	L	VL
10	L	H	H	M	VL
11	L	H	H	M	VL
12	L	H	M	M	L+
13	L	H	M	M	L+
14	L	H	M	M	L+
15	M	H	H	B	VL
16	M	H	H	B	VL
17	L	H	H	M	VL
18	L	H	H	M	VL
19	M	H	H	L	VL
20	M	H	H	L	VL



Figure 1. Radial chart of the LOWA operator.

TABLE IV. LWA OPERATOR FOR THE EFFECTIVENESS DIMENSION

LWA: Effectiveness		
Minimum	Perceived	Expected
M	H	H

On the other hand, concerning the quantitative analysis, item 20 has been planted to measure the satisfaction of the user’s overall usability of the DL Web site. Figure 2 displays that 21 out of the 54 respondents have a High (H) overall satisfaction when evaluating the DL Web site usability; while 12 of them show a VH level; 16 show a Medium (M) value, and the other 5 present a Low (L) value.

As mentioned above, the evaluation questionnaire reliability, was calculated using Cronbach's alpha, obtaining a value equal to 0.91 for the minimum value; 0.91 for perceived value; and 0.92 for the expected value, which means such a reliability is fairly acceptable.

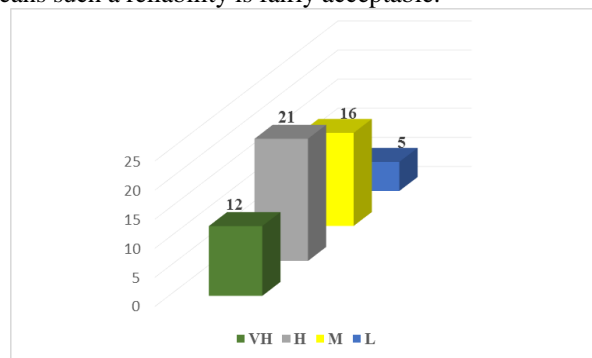


Figure 2. Chart of the Total Usability (20 items).

E. Commendations

On the whole, the usability evaluation results of the DL Web site in the University of Puebla, have been satisfactory. However, the adequacy gap indicates that the improvement should focus primarily on two-dimensions; learnability and satisfaction.

In the former, the adjustments should be directed to improve the functions of help. So, it is advisable to follow the guidelines provided by ISO, IBM and Microsoft, in order to meet the standards of the interface design. Thus, improving, incorporating, and maintaining the support functions visible (in addition to video tutorials) for guiding users—especially the novices—.

While in the latter, the changes should be oriented to improve the navigability, the interface and the error recovery. Consequently, including icons or links that allow return to a previous state of the system or even the main menu of the library is recommended as well as messages, which clearly inform and orient about the task of search being performed. As for the interface, three commendations are made: To modify its organization to simplify and improve its navigability; to focus on the services offered by the library, eliminating or reducing those that are strange to it, and using a clear terminology that would improve the appearance of the Web site. These interface adjustments help to simplify the management system errors. All the

aforementioned would facilitate the usability of the DL Web site in the University of Puebla, as a result, an excellent service can be provided.

VI. CONCLUSIONS AND FUTURE WORK

In this work, an innovative methodology for evaluating the usability of digital libraries has been developed. In developing the methodology, the basic principles of usability (establishing four dimensions, the questionnaire and the measurement scale) have been combined with models of service quality (the gap theory of service quality) and fuzzy logic models (LOWA and LWA linguistic operators) specifically applied in evaluating the usability of DLs.

This methodology could be used to evaluate any Web sites. However, some particular questions (such as responsive design and real time responses) should be analyzed, which are out of reach on this analysis.

In this research a measuring instrument (questionnaire) with 20 questions that collects user perceptions based on the four dimensions proposed to evaluate the usability of DL is intended. Moreover, the use of aggregation operators of linguistic information with a measurement scale was raised five linguistic labels. The gap in quality service has set the pace to suggest a number of commendations for improving the BUAP DL Web site.

Cronbach's alpha was used for verifying the reliability of the measurement instrument, resulting in a value close to 1, indicating a rather acceptable measurement instrument. A qualitative study was also carried out using descriptive statistics to compare the results with those obtained with the aggregation operators, which showed that the use of these operators is appropriate for the methodology.

Future work will focus on applying the survey again after a trial using the DL Web site in order to accomplish a comparative analysis, improving the survey tool used in such a manner that allows diverse linguistic quantifiers be used to calculate the weights of aggregation operators.

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