International Journal of Information Management 33 (2013) 642–654

Contents lists available at SciVerse ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

Viewpoint

A fuzzy linguistic model to evaluate the quality of Library 2.0 functionalities

Rubén Heradio [a], Francisco Javier Cabrerizo [a,*], David Fernández-Amorós [b], Manuel Herrera [c], Enrique Herrera-Viedma [d]

[a] Department of Software Engineering and Computer Systems, Distance Learning University of Spain (UNED), Madrid 28040, Spain
[b] Department of Languages and Computer Systems, Distance Learning University of Spain (UNED), Madrid 28040, Spain
[c] Department of Sociology III, Distance Learning University of Spain (UNED), Madrid 28040, Spain
[d] Department of Computer Science and Artificial Intelligence, University of Granada, Granada 18071, Spain

ARTICLE INFO

Article history:
Available online 10 May 2013

Keywords:
Library 2.0
Quality
Fuzzy linguistic modeling
LibQUAL+

ABSTRACT

Libraries incessantly undergo change determined by evolving user needs. These are often induced by the emergence of previously unavailable tools. Web 2.0 represents an example of such a need-shifting technology, which has led to an embrace of new user interactivity services for many library websites, thus coined Library 2.0. This paradigm shift calls for new evaluation models to include the implementation of Web 2.0 technologies. The aim of this paper is to present such a model, and to evaluate the quality of Library 2.0 functionalities, measuring the quality of the 2.0 services offered through the websites based on user perception. We adopt fuzzy linguistic modeling to represent user perception, and apply aggregation operations to linguistic labels in order to evaluate the quality of the new services. Furthermore, our model subsumes the LibQUAL+methodology, allowing for the identification of specific 2.0 functionalities in need of improvement and of those outstandingly satisfied by the system.

1. Introduction

Libraries form an essential part of academic institutions, enabling and facilitating the exchange and growth of information, knowledge and culture among teachers, students and the general public. In this sense, libraries represent a focal point of academic life and as such serve also a societal purpose of bringing together people around common themes. This purpose is nowadays enhanced and facilitated by the use of technology and, in recent times, by the so-called Web 2.0 (Anfinnsena, Ghineaba, & Cesareb, 2011; Maness, 2006).

The term Web 2.0 was coined by O'Reilly (2005) to describe the trends and business models that survived the technology sector market crash of the 1990s. He noted that the companies which had survived the collapse seemed to have some things in common: they were collaborative in nature, interactive, dynamic, and users created the content in these sites as much as they consumed it. Web 2.0 is essentially a communication hub rather than a web of textual publication. It is a matrix of dialogs, instead of a collection of monologs. It is a user-centered Web in ways it has not been thus far (Maness, 2006).

Developing the idea of Web 2.0 in the library context, the concept of Library 2.0 emerges. According to Curran, Murray, and Christian (2007), Library 2.0 can be seen as a reaction from librarians to the increasingly relevant developments in information and communications technology (i.e., Web 2.0 and social software) and to an environment that is saturated with information available through more easily accessible channels. This reaction comes in the form of increased openness and trust toward library users, and in the development of new communication channels and services that are in tune with social developments. Library 2.0 has multiple facets reflecting the typical means of user participation that Web 2.0 enables. These facets include blogging, tagging, social bookmarking, social networking, podcasting and so on.

Despite the popularity of Library 2.0, there has been much debate on whether or not Web 2.0 applications have a role to play in the modern library and to what extent (Hammond, 2009). Indeed, the Online Computer Library Center (OCLC) survey (Rosa, Cantrell, Havens, Hawk, & Jenkins, 2007) found that US library directors "do not see a role for social networking in libraries", questioning its applicability to the service the library provides to its patrons. According to Rutherford (2008), "the range of literature available on social software use in libraries is insufficient for librarians to thoroughly evaluate the possible benefits and drawbacks of social software when considering an adoption decision".

* Corresponding author at: C/ Juan del Rosal 16, Madrid 28040, Spain. Tel.: +34 91 3988409; fax: +34 91 3989382.
E-mail addresses: rheradio@issi.uned.es (R. Heradio), cabrerizo@issi.uned.es (F.J. Cabrerizo), david@lsi.uned.es (D. Fernández-Amorós), mherrera@poli.uned.es (M. Herrera), viedma@decsai.ugr.es (E. Herrera-Viedma).

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http://dx.doi.org/10.1016/j.ijinfomgt.2013.04.001

Hammond (2009) also notes that there is a lack of research to discover how Web 2.0 applications are being used in libraries. Therefore, after the few years that have elapsed since the appearance of Web 2.0 technologies and the relevance and interest in their implementation in libraries, it is necessary to analyze what types of services and technologies are most appropriate for library web sites and to what extent they have been implemented (Buigues-Garcia & Gimenez-Chornet, 2012). As the Library 2.0 model enables and encourages participation of the user/client not only in the use of the service but also in its management, the evaluation of the Library 2.0 functionalities needs to be judged by its users. Different quality evaluation models of digital libraries based on user perception have been proposed (Cabrerizo, López-Gijón, Ruiz-Rodriguez, & Herrera-Viedma, 2010; Heradio, Fernández-Amorós, Cabrerizo, & Herrera-Viedma, 2012). However, these models have not taken into account the new dimension of the libraries, i.e., the impact of Web 2.0 on library websites. This paper falls into such a research area, by proposing a new quality evaluation model that helps decision makers at libraries to improve Web 2.0 services.

The aim of this paper is to present a quality evaluation model of the functionalities of the Library 2.0. The proposed model measures the quality level of the 2.0 services offered by libraries according to the users' perceptions on those services offered through its web site. Conventional measurement tools used by customers to express their opinions are devised on cardinal scales, but, due to the subjectivity, imprecision and vagueness of human beings when attempting to qualify phenomena related to human perception, it seems natural that they use words in natural language (linguistic terms) instead of numerical values to provide their opinions. In view of the fact that user service evaluation depends largely on what users perceived, soft computing is a good option because it provides the opportunity to represent ambiguity in human thinking with the uncertainty in real life (Zadeh, 1992). Fuzzy logic, which emerged from the theory of fuzzy set (Zadeh, 1965), is one of the techniques of soft computing which can deal with the inherent subjectivity, imprecision and vagueness in the articulation of opinions. The use of words in natural language rather than numerical values is, in general, a less specific, more flexible, direct, realistic, and adequate form to express judgments. Linguistic terms as for example, "satisfied", "fair", "dissatisfied", are regarded as the natural representation of the preference of judgment. These characteristics indicate the applicability of fuzzy set theory (Zadeh, 1965) in capturing the user's preference, which aids in measuring the ambiguity of concepts that are associated with human beings subjective judgment. Since the evaluation results from the different evaluators view of linguistic variables, its evaluation must therefore be conducted in an uncertain, fuzzy environment. For this reason, we use ordinal fuzzy linguistic modeling (Herrera, Herrera-Viedma, & Martinez, 2008; Herrera, Herrera-Viedma, & Verdegay, 1996) to represent users perception and computing tools dealing with words, based on the linguistic aggregation operators LOWA (Linguistic Ordered Weighted Averaging) (Herrera et al., 1996) and LWA (Linguistic Weighted Averaging) (Herrera & Herrera-Viedma, 1997) to compute the quality assessments. In addition, to identify both the 2.0 services in which the service levels should be improved and the 2.0 services satisfied outstandingly by the library, the LibQUAL+methodology (Cook, Heath, & Thompson, 2002) is incorporated to the evaluation model.

The remainder of this paper is structured as follows. Section 2 presents the preliminaries of our work, i.e., the fuzzy linguistic approach for computing with words and the LibQUAL+model, which form the theoretical basis of our approach. Section 3 describes in detail the model we propose. Section 4 sums up the results of applying our model to evaluate the Web 2.0 functionalities supported by the academic library at the Spanish Open University (UNED[1]). As we will see, such evaluation provides experimental evidence of the validity and reliability of our fuzzy linguistic model. Finally, Section 5 presents some conclusions.

2. Preliminaries

The theoretical basis of our contribution relies on the tools summarized in this section. Section 2.1 introduces the ordinal fuzzy linguistic approach that our quality evaluation model applies. Section 2.2 describes the LibQUAL+methodology for quality evaluation of libraries.

2.1. A fuzzy linguistic approach for computing with words

Many problems present fuzzy and qualitative aspects (Herrera, Alonso, Chiclana, & Herrera-Viedma, 2009). In such problems, information cannot be assessed precisely in a quantitative form but it may be done in a qualitative one, and thus, the use of a linguistic approach is necessary. The fuzzy linguistic approach is an appropriate technique to deal with fuzzy and qualitative aspects of problems. It models linguistic information by means of linguistic terms supported by linguistic variables (Zadeh, 1975a, 1975b, 1975c). These are variables whose values are not numbers but words or sentences in a natural or artificial language. A linguistic variable is defined by means of a syntactic rule and a semantic rule. The fuzzy linguistic approach is less precise than the numerical one, however, it presents the following advantages: (i) the linguistic description is easily understood by human beings even when the concepts are abstract or the context is changing, and furthermore, (ii) it diminishes the effects of noise since, as it is known, the more refined the assessment scale is, the more sensitive to noise it becomes (linguistic scales are less refined than numerical scales and consequently they are less sensitive to error occurrence and propagation).

The ordinal fuzzy linguistic approach is very useful for modeling the linguistic aspects in problems (Herrera et al., 1996). It facilitates the fuzzy linguistic modeling very much because it simplifies the definition of the semantic and syntactic rules. It is defined by considering a finite and totally ordered label set $S = \{s_i\}, i \in \{0, \ldots, \mathcal{T}\}$, in the usual sense, i.e., $s_i \geq s_j$ if $i \geq j$. Typical values of cardinality used in the linguistic models are odd ones, such as 7 or 9, with an upper limit of granularity of 11 or no more than 13, where the mid term represents an assessment of "approximately 0.5", and the rest of the terms being placed symmetrically around it. These classical values seems to fall in line Miller's observation about the fact that human beings can reasonably manage to bear in mind seven or so items (Miller, 1956). The semantics of the linguistic term set is established from the ordered structure of the label set by considering that each linguistic term for the pair $(s_i, s_{\mathcal{T}-i})$ is equally informative. Therefore, it assumes a finite set of labels to express the linguistic assessments. It could be improved by incorporating the possibility of using modifiers as it is proposed in (Di Lascio, Gisolfi, & Loia, 1996). However, this is not the focus of our proposal.

An advantage of the ordinal fuzzy linguistic approach is the simplicity and efficiency of its computational model for computing with words. It is based on the symbolic computation (Herrera et al., 1996; Herrera & Herrera-Viedma, 1997). This technique acts by direct computation on labels by taking into account the order of such linguistic assessments in the ordered structure of linguistic terms. This symbolic tool seems natural when using the fuzzy linguistic approach, because the linguistic assessments are simply

[1] UNED stands for Universidad Nacional de Educación a Distancia.

approximations which are given and handled when it is impossible or unnecessary to obtain more accurate values. This approach has been satisfactorily used to define different linguistic quality evaluation models (Carrasco, Villar, Hornos, & Herrera-Viedma, 2012; Herrera-Viedma, Pasi, López-Herrera, & Porcel, 2006; Herrera-Viedma & Peis, 2003; Herrera-Viedma, Peis, Morales-del-Castillo, Alonso, & Anaya, 2007).

Usually, the ordinal fuzzy linguistic model for computing with words is defined by establishing:

1. A *negation* operator, which is defined from the semantics associated to the linguistic terms as: $\text{Neg}(s_i) = s_j | j = \mathcal{T} - i$.
2. *Comparison* operators, which are based on the ordered structure of linguistic terms:
   - Maximization operator: $\text{MAX}(s_i, s_j) = s_i$ if $s_i \geq s_j$.
   - Minimization operator: $\text{MIN}(s_i, s_j) = s_i$ if $s_i \leq s_j$.
3. A *distance* operator D between linguistic labels s_i and s_j, which is computed as:

$$D(s_i, s_j) = s_k \quad \text{where} \quad k = \begin{cases} i - j & \text{if } i > j \\ j - i & \text{otherwise} \end{cases} \tag{1}$$

4. Adequate *aggregation* operators of ordinal fuzzy linguistic information. In the following subsections, two of such operators are described.

2.1.1. The LOWA operator

An important aggregation operator of ordinal linguistic values based on symbolic computation is the LOWA operator (Herrera et al., 1996), which is based on the Ordered Weighted Averaging (OWA) operator defined by Yager (1988). It is used to aggregate non-weighted ordinal fuzzy linguistic information, i.e., linguistic information values with equal importance.

Definition 1. Let $A = \{a_1, \ldots, a_m\}$ be a set of labels to be aggregated, then the LOWA operator, ϕ, is defined as:

$$\begin{aligned} \phi(a_1, \ldots, a_m) &= W \cdot B^T = C^m\{w_k, b_k, k = 1, \ldots, m\} \\ &= w_1 \odot b_1 \oplus (1 - w_1) \odot C^{m-1}\{\beta_h, b_h, h = 2, \ldots, m\} \end{aligned} \tag{2}$$

where $W = [w_1, \ldots, w_m]$ is a weighting vector, such that, $w_i \in [0, 1]$ and $\Sigma_i w_i = 1$. $\beta_h = w_h / \Sigma_2^m w_k$, and $B = \{b_1, \ldots, b_m\}$ is a vector associated to A, such that, $B = \sigma(A) = \{a_{\sigma(1)}, \ldots, a_{\sigma(m)}\}$, where, $a_{\sigma(j)} \leq a_{\sigma(i)} \; \forall \, i \leq j$, with σ being a permutation over the set of labels A. C^m is the convex combination operator of m labels. If $m = 2$, then it is defined as:

$$C^2\{w_i, b_i, i = 1, 2\} = w_1 \odot s_j \oplus (1 - w_1) \odot s_i = s_k, \tag{3}$$

such that, $k = \min\{\mathcal{T}, i + round(w_1 \cdot (j - i))\}$, $s_j, s_i \in S$, $(j \geq i)$, where *"round"* is the usual round operation, and $b_1 = s_j$, $b_2 = s_i$. If $w_j = 1$ and $w_i = 0$, with $i \neq j \; \forall \, i$, then the convex combination is defined as: $C^m\{w_i, b_i, i = 1, \ldots, m\} = b_j$.

Example of the LOWA operator. Consider the following set of 9 labels: $S = \{N, EL, VL, L, M, H, VH, EH, T\}$. Suppose that we want to aggregate by means of the LOWA operator the following four labels, $\{EL, VL, EH, T\}$. Assuming this weighting vector $W = [0.3, 0.2, 0.4, 0.1]$ the general expression of the aggregation of labels is:

$$\begin{aligned} \phi(EL, VL, EH, T) &= [0.3, 0.2, 0.4, 0.1](T, EH, VL, EL) \\ &= C^4\{(0.3, T), (0.2, EH), (0.4, VL), (0.1, EL)\} \end{aligned}$$

Then, we obtain the final result applying the recursive definition of the convex combination, C^4, as follows. Firstly, we develop C^4 until its simpler expression in the following steps:

1. For $m = 4$,

$$\begin{aligned} &C^4\{(0.3, T), (0.2, EH), (0.4, VL), (0.1, EL)\} \\ &= 0.3 \odot T \oplus C^3\{(0.29, EH), (0.57, VL), (0.14, EL)\} \end{aligned}$$

2. For $m = 3$,

$$\begin{aligned} &C^3\{(0.29, EH), (0.57, VL), (0.14, EL)\} \\ &= 0.29 \odot EH \oplus C^2\{(0.57, VL), (0.14, EL)\} \end{aligned}$$

Now, we are going to go back solving the simpler cases until to obtain the final result:

1. For $m = 2$,

$$C^2\{(0.57, VL), (0.14, EL)\} = 0.57 \odot VL \oplus (1 - 0.57) \odot EL = VL$$

since as VL = s_2 and EL = s_1 then

$$min\{9, 1 + round(0.57 \cdot (2 - 1))\} = min\{8, 2\} = 2.$$

2. For $m = 3$,

$$\begin{aligned} &C^3\{(0.29, EH), (0.57, VL), (0.14, EL)\} \\ &= 0.29 \odot EH \oplus C^2\{(0.57, VL), (0.14, EL)\} = L \end{aligned}$$

since as EH = s_7 and VL = s_2 then

$$min\{8, 2 + round(0.29 \cdot (7 - 2))\} = min\{8, 3\} = 3.$$

3. Finally, we obtain the final result for $m = 4$,

$$\begin{aligned} &C^4\{(0.3, T), (0.2, EH), (0.4, VL), (0.1, EL)\} \\ &= 0.3 \odot T \oplus C^3\{(0.29, EH), (0.57, VL), (0.14, EL)\} = H \end{aligned}$$

since as T = s_8 and L = s_3 then

$$min\{8, 3 + round(0.3 \cdot (8 - 3))\} = min\{8, 5\} = 5.$$

An important parameter of the LOWA operator is the weighting vector W, which determines its behavior. For instance:

- $\phi(a_1, \ldots, a_m) = \text{MAX}(a_i)$ if $W^* = [1, 0, \ldots, 0]$.
- $\phi(a_1, \ldots, a_m) = \text{MIN}(a_i)$ if $W_* = [0, 0, \ldots, 1]$.
- $\phi(a_1, \ldots, a_m) = \text{Average}(a_i)$ if $W_A = \left[\frac{1}{m}, \frac{1}{m}, \ldots, \frac{1}{m}\right]$.

In order to classify OWA aggregation operators with regards to their localization between "or" and "and", Yager (1988) introduced the measure of *orness* associated with any vector W expressed as:

$$\text{orness}(W) = \frac{1}{m-1} \sum_{i=1}^{m} (m - i) w_i \tag{4}$$

This measure, which lies in the unit interval, characterizes the degree to which the aggregation is like an or (MAX) operation. It can be easily shown (Yager, 1988) that $\text{orness}(W^*) = 1$, $\text{orness}(W_*) = 0$, and $\text{orness}(W_A) = 0.5$. Note that the nearer W is to an *or*, the

closer its measure is to one; while the nearer it is to an *and*, the closer is to zero. Therefore, as we move weight up the vector we increase the orness(W), while moving weight down causes us to decrease orness(W). Therefore, an OWA operator with much of nonzero weights near the top will be an *orlike* operator (orness (W) ≥ 0.5), and when much of the weights are nonzero near the bottom, the OWA operator will be *and like* (orness (W) < 0.5).

A number of approaches have been suggested for obtaining the weights w_i (Filev & Yager, 1998). A possible solution is that the weights represent the concept of fuzzy majority in the aggregation of LOWA operator using fuzzy linguistic quantifiers (Zadeh, 1983). Yager (1988) proposed how to compute the weights of the OWA aggregation operator, which in the case of a non-decreasing proportional fuzzy linguistic quantifier Q is given by as:

$$w_i = Q\left(\frac{i}{m}\right) - Q\left(\frac{i-1}{m}\right), i = 1, \ldots, m. \tag{5}$$

The membership function of Q is given by Eq. (6), with $a, b, r \in [0, 1]$. Some examples of non-decreasing proportional fuzzy linguistic quantifiers are: "most" (0.3, 0.8), "at least half" (0, 0.5), and "as many as possible" (0.5, 1). When a fuzzy linguistic quantifier Q is used to compute the weights of LOWA operator, ϕ, it is symbolized by ϕ_Q:

$$Q(r) = \begin{cases} 0 & \text{if } r < a \\ \dfrac{r-a}{b-a} & \text{if } a \le r \le b \\ 1 & \text{if } r > a \end{cases} \tag{6}$$

2.1.2. The LWA operator

Another important aggregation operator of ordinal linguistic values is the LWA operator (Herrera & Herrera-Viedma, 1997). It is based on the LOWA operator and is defined to aggregate weighted ordinal fuzzy linguistic information, i.e., linguistic information values with not equal importance.

As it is known, the aggregation of weighted information involves two activities: (i) the transformation of the weighted information under the importance degrees by means of a transformation function h, and (ii) the aggregation of the transformed weighted information by means of an aggregation operator of non-weighted information f. The transformation function depends upon the type of aggregation of weighted information which is going to be performed. Yager (1987) discussed the effect of the importance degrees on the MAX and MIN types of aggregation and suggested a class of functions for importance transformation in both types of aggregation. For the MIN aggregation, he suggested a family of *t-conorms* acting on the weighted information and the negation of the importance degree, which presents the non-increasing monotonic property in these importance degrees. For the MAX aggregation, he suggested a family of *t-norms* acting on weighted information and the importance degree, which presents the non-decreasing monotonic property in these importance degrees.

Following the above ideas, the LWA operator was defined (Herrera & Herrera-Viedma, 1997). Here, we redefine it to simplify its expression using the *orness* measure and as f the LOWA operator ϕ.

Definition 2. Let $A = \{(c_1, a_1), \ldots, (c_m, a_m,)\}$, $c_i, a_i \in S$, where a_i represents the weighted opinion and c_i the importance degree of a_i, then the LWA operator, Φ, is defined as:

$$\Phi[(c_1, a_1), \ldots, (c_m, a_m)] = \phi(h(c_1, a_1), \ldots, h(c_m, a_m)) \tag{7}$$

where h is the transformation function defined depending on the weighting vector W used for the LOWA operator ϕ, such that, $h = \mathrm{LC}_v^{\rightarrow}$ if orness(W) ≥ 0.5, and $h = \mathrm{LI}_v^{\rightarrow}$ if orness(W) < 0.5.

$\mathrm{LC}_v^{\rightarrow}$ are the following group of linguistic conjunction functions, which are monotonically non-decreasing in the weights:

1. The classical MIN operator: $\mathrm{LC}_1^{\rightarrow}(c, a) = \mathrm{MIN}(c, a)$.
2. The nilpotent MIN operator:

$$\mathrm{LC}_2^{\rightarrow}(c, a) = \begin{cases} \mathrm{MIN}(c, a) & \text{if } c > \mathrm{Neg}(a) \\ s_0 & \text{otherwise} \end{cases} \tag{8}$$

3. The weakest conjunction:

$$\mathrm{LC}_3^{\rightarrow}(c, a) = \begin{cases} \mathrm{MIN}(c, a) & \text{if } \mathrm{MAX}(c, a) = s_T \\ s_0 & \text{otherwise} \end{cases} \tag{9}$$

$\mathrm{LI}_v^{\rightarrow}$ are the following group of linguistic implication functions, which are monotonically non-increasing in the weights:

1. Kleene–Dienes' implication function: $\mathrm{LI}_1^{\rightarrow}(c, a) = \mathrm{Max}(\mathrm{Neg}(c), a)$.
2. Gödel's implication function:

$$\mathrm{LI}_2^{\rightarrow}(c, a) = \begin{cases} s_T & \text{if } c \le a \\ a & \text{otherwise} \end{cases} \tag{10}$$

3. Fodor's implication function:

$$\mathrm{LI}_3^{\rightarrow}(c, a) = \begin{cases} s_T & \text{if } c \le a \\ \mathrm{Max}(\mathrm{Neg}(c), a) & \text{otherwise} \end{cases} \tag{11}$$

Example of the LWA operator. Consider the following set of 9 labels: $S = \{N, EL, VL, L, M, H, VH, EH, T\}$. We want to aggregate by means of the LWA operator the following seven labels, $\{H, N, M, VH, M, L, L\}$ with the following linguistic importance degrees $\{H, L, VH, VH, T, H, L\}$. Suppose the linguistic quantifier Q = "at least half" with the pair (0, 0.5) to represent the concept of fuzzy majority. With this quantifier we have the following weighting vector $W = [0.28, 0.28, 0.28, 0.16, 0, 0, 0]$. As *orness*($W$) ≥ 0.5, then LOWA operator used in the aggregation of LWA operator is an orlike, and thus, we can choose as transformation function h any linguistic conjunction function LC_v, for example, LC_1 = MIN. Then, using the LWA operator we obtain:

$$\Phi((H, H), (L, N), (VH, M), (VH, VH), (T, M), (H, L), (L, L))$$
$$= \phi_Q(MIN(H, H), MIN(L, N), MIN(VH, M), MIN(VH, VH),$$
$$MIN(T, M), MIN(H, L), MIN(L, L)) = \phi_Q(H, N, M, VH, M, L, L)$$

Using the LOWA operator as in the above example, we obtain the following value: $\phi_Q(H, N, M, VH, M, L, L) = H$.

We should point out that the LOWA and LWA operators are the basis of the evaluation model of Library 2.0 functionalities that we present in this paper. We have chosen these operators due to

the following reasons: (i) both operators are complementary (the LWA operator is defined from the LOWA operator) thereby simplifying the design of the evaluation method, (ii) both operators act by symbolic computation and therefore linguistic approximation processes are unnecessary, which again eases the process of computing with words, and finally (iii) the concept of fuzzy majority represented by linguistic quantifiers plays a role in the computation process and so, the assessments on Library 2.0 functionalities are obtained according to the majority of evaluations provided by the users.

2.2. LibQUAL+methodology

In 1999, a major project to develop a standardized measure of library service quality was undertaken by the Association of Research Libraries in collaboration with Texas A&M University. The result of this project is LibQUAL+(Cook et al., 2002), which is an extension of the SERVQUAL tool (Parasuraman, 1994). SERVQUAL has been carefully tested and widely accepted after a dozen years of application in the private sector and elsewhere. From its grounding in the private sector, the SERVQUAL instrument brings a particular theoretical perspective: only customers judge quality; all other judgments are essentially irrelevant. In the same way, LibQUAL+is focused on user perception to measure library service quality and it can be considered as one of the most prominent successes in the field of library and information management (Pors, 2006). In spite of its relatively short life span, LibQUAL+has already been employed in hundreds of libraries both in the USA and in Europe.

The main LibQUAL+research instrument is a survey that consists of 22 core items. For each item, the user rates on a 9-point Likert scale: (i) the minimum acceptable level of service, (ii) the level of service the user personally desires, and (iii) the level of service the user believes libraries currently provide.

Service quality is conceptualized as *gaps* between a customer's minimum and desired expectations of quality of service and his/her perceptions of the quality of the service actually received. A *positive gap* indicates that the service performance has exceeded customers' expectations, whereas a *negative gap* indicates that the service performance has fallen short of the expected service. Gap models are intuitively appealing to many research consumers (Thompson, Cook, & Heath, 2000) since its interpretation is straightforward. For instance, if the perceived rating on an item is below the minimum, it clearly indicates that the item the suject evaluates needs improvement. On the other hand, if the perceived rating on an item is very above the desired level of service, it may suggest that the item is not a concern to consumers.

In addition, as noted by Anastasi and Urbina (1997): "in the context of studies on attitude change, investigators have shown that results may be influenced by such conditions as the participant's perception of what the experimenter expects, the desire to protect one's own image, and the wish to please or frustrate…". Therefore, many personality measures incorporate scales that evaluate whether respondents are replying randomly, in contradictory ways, or in ways that intentionally make them look either more or less favorable. One important benefit of using a gap measurement model, such as LibQUAL+, is that it inherently incorporates a natural random-response scale. On each item a user's rating of desired performance should never be below the minimally acceptable performance rate. Intra-individual counts of such aberrations can be used to compute "lie" or "random response" scores for each respondent, and the average of such counts across a sample characterizes the integrity of a data set as a whole. Furthermore, the distances of aberrant responses on a single item (the difference between a desired rating that is below a minimum rating and the minimum rating response) characterize the degree of aberrance. Similarly, for a given individual the intra-individual sum of aberrant distances characterizes an individual's degree of aberrance, while the average aberrant distance for all data again characterizes a data set as a whole (Thompson et al., 2000).

3. A model based on fuzzy linguistic information to evaluate the quality of Library 2.0 functionalities

In this section, we present a model based on fuzzy linguistic information to evaluate the quality of Library 2.0 functionalities. Previously, we review some aspects on the implementation of Web 2.0 technologies in libraries and its evaluation.

3.1. Library 2.0 functionalities

Web 2.0 is based on a few underlying principles among which the following capture the essence of Web 2.0 as opposed to other digital technologies and the Web (1.0) itself: (i) the Web is the platform; (ii) the user controls their own data; and (iii) the architecture encourages participation (O'Reilly, 2005). The combination of these principles has enabled the production of Web-based applications that have evolved the Web into a participative Web. Thus, the natural overlap of intention and purpose between Web 2.0 (as a technology) and libraries (as a driver of knowledge integration) has lead to development and research in the area of Library 2.0 (Anfinnsena et al., 2011). Some of the Web 2.0 tools commonly used to support the idea of Library 2.0 are:

1. *RSS feeds* update users about the additions or changes which take place on Web sites of interest. For example, the UNED library provides news feeds on RSS to inform students about activities and events held in the University. King and Brown (2009) note the similarity in the functioning of RSS and e-mail and predict increased use and popularity of RSS feeds in the future. De Maio et al. (2012) remark RSS feeds are important to support students in their learning path and develop a decision support systems based on soft-computing approach focused on RSS.
2. A *blog* is a personal journal published on the web consisting of discrete entries named posts, which are typically displayed in reverse chronological order so the most recent post appears first. Blogs are usually the work of a single individual, occasionally of a small group, and are often themed on a single subject. King and Porter (2007) suggest that blogs in academic libraries could be used for internal communication, to facilitate academic debate and to communicate with patrons, promoting new books and providing subject guides, current awareness and customized catalog searches.
3. *Podcasts* are used to exchange and share audio and video[2] programmes among patrons over the Internet. According to Lee (2006), a podcast is a catchy tool to market library services and attract new users. King and Brown (2009) note that libraries can share pictures, events, and instructions by podcast. The standard way of getting audio streams over podcast is by subscribing to the specific podcast. Students can listen to lectures through podcasting instead of reading in the text format. Audio streams of lectures and book readings may be beneficial for students who are visually challenged or have poor reading and comprehension competencies. Podcasts are frequently used to broadcast speeches and interviews of important personalities (Tripathi & Kumar, 2010).
4. A *wiki* is a piece of server software that allows users to freely create and edit Web page content using a Web browser. Libraries and academic institutions have been using Wikis for group

[2] Some authors prefer to use the specific term *vodcast* for video program exchanging.

learning, for sharing knowledge, experiences and open source products, and also to provide subject guides (Frumkin, 2005).

As pointed by Casey and Savastinuk (2007): "just as Web 2.0 implies that it is radically different from an earlier web, Library 2.0 implies that it is also radically new". So, although there exist many different quality evaluation models of digital libraries in the literature (Heradio et al., 2012), we believe that new research proposals should emerge for Library 2.0. There is, however, a certain lack of literature on the topic. The following points summarize some of these proposals:

1. In (Linh, 2008), Linh analyzes what types of Web 2.0 technologies have been applied in Australasian university libraries, as well as their purposes and features. Linh (2008) uses a checklist[3] that includes features and criteria that emerged from the content analysis of literature on Web 2.0 in libraries. The checklist is based primarily on the usability evaluation of library web sites (Keevil, 1998) and the list of checkpoints for web content accessibility guidelines 1.0 (Chisholm, Vanderheiden, & Jacobs, 1999). The content design of the checklist is based on a questionnaire to evaluate perceptions and usage of library podcasts (Jowitt, 2008), and a questionnaire to study the use of blogs for library communication (McIntyre & Nicolle, 2008). Linh's checklist has also been used by Tripathi and Kumar (2010) to evaluate the Web 2.0 tools of 277 university libraries located in Australia, Canada, the UK and USA.
2. Kataria and Anbu-K. (2009) propose a model for the Learning Resource Center (LRC)[4] to harness the different facets of Web 2.0 and exemplify the impact of Web 2.0 technologies (blogs, RSS, etc.) especially in the enhancement of usage of LRC resources and services. To measure such impact, the authors use a questionnaire with 22 questions: 10 *yes-or-no* questions, 10 rated on Likert scales and 2 open questions.
3. Gavrilis, Kakali, and Papatheodorou (2008) present a prototype of an Online Public Access Catalog (OPAC) that utilizes Web 2.0 technologies to deliver improved search and retrieval services. Some of these new services include social tag annotations, user opinions and ranks, and tag-based similarity searches. To evaluate the prototype a questionnaire rated on a 7-point Likert scale is used. In particular, the questionnaire tries to measure (i) how important is the social tagging for the user information seeking process, (ii) the difference in information search success between the usage of tags and the subject terms recorded in the library catalog and (iii) ease of access to the new services.
4. To discover the engagement level of UK public libraries with Library 2.0, Hammond (2009) carries out an experiment with 498 participants. Her research is focused on the usage of just one tool: blogging. Hammond elaborated a questionnaire with 39 questions including *yes-or-no* answers, multiple choice and open questions.
5. By using different questionnaires that were distributed to 168 randomly selected Israeli librarians, Aharony (2009) reports that (i) personality characteristics (resistance to change, cognitive appraisal, empowerment and extroversion or introversion), (ii) computer expertise, (iii) motivation, (iv) importance, and (v) capacity toward studying and integrating different applications of Web 2.0, influence librarians' use of Web 2.0. Aharony used 9 questionnaires rated by means of Likert scales.

[3] A *checklist* is a questionnaire composed of *yes-or-no* answers, named *checkpoints*.
[4] Jaypee Institute of Information Technology University, Noida, UP, India.

3.2. A quality evaluation model of Library 2.0 functionalities

In this section, we present the model based on fuzzy linguistic information to evaluate the quality of Library 2.0 functionalities according to user's satisfaction. The main characteristics of the model are the following:

- It presents a set of subjective criteria related to the Library 2.0 functionalities and a computation instrument of quality assessments.
- It is assumed that the quality level of the 2.0 services offered by the library is measured through user's perceptions on those services offered through its web site.
- It uses the ordinal fuzzy linguistic modeling (Herrera et al., 1996) to represent the users' perceptions and performs computing with words based on the linguistic aggregation operators LOWA (Herrera et al., 1996) and LWA (Herrera & Herrera-Viedma, 1997) to compute the quality assessments.
- It uses the LibQUAL+methodology in order to identify both the 2.0 services in which the service levels should be improved and the 2.0 services already satisfied by the library.

Taking into account these considerations, we define a quality evaluation model of Library 2.0 functionalities which presents two elements: (i) an evaluation scheme that contains the subjective criteria, and (ii) a computation method to generate quality assessments of Library 2.0 functionalities.

3.2.1. Evaluation scheme

To elicit user opinion regarding the quality of Library 2.0 functionalities, we adapt Linh's checklist (Linh, 2008), which is a questionnaire with 95 *yes-or-no* questions. However, as this number of questions is excessive, we define a low number of subjective criteria being easily understandable by the users in order to avoid user rejection. We propose the evaluation scheme shown in Fig. 1, which is composed of twenty four subjective criteria about the Web 2.0 tools commonly used in the libraries. Furthermore, as we are interested in obtaining the quality level of the 2.0 services offered by the library, for all of its twenty four items (subjective criteria), users are asked to indicate the minimum level of service that they would find acceptable, the desired service level they expect, and their perceived service level (i.e., its formulation is similar to the LibQUAL+survey). In this way, we are able to identify both the 2.0 services in which the service levels should be improved and the 2.0 services satisfied outstandingly by the library.

Our proposed evaluation scheme presents the following characteristics:

1. *It is user driven*. One of the main aspects to be considered in library evaluation is the user perspective, determining the extent to which the library addresses the real needs of its users. This is even more important for Library 2.0 functionalities, since their goal is to enhance user participation (i.e., users create content as much as they consumed it). So, our evaluation scheme has adopted a user centered approach. It includes questions easily understandable by any user, rather than user-independent objective measures. In addition, since long and complex evaluation schemes may cause user idleness and limit their own application possibilities, the scheme we propose has a reduced number of items (i.e., just twenty-four items).
2. *It is weighted*. An essential issue regarding the evaluation of library quality is the relative importance of each criterion; i.e., survey items usually have varying degrees of relevance and, consequently, such difference should be taken into account when the evaluation data is processed. Several works have tried to identify which quality criteria are the most important when a

Category 1 – Use of RSS :

1. RSS usefulness to inform you about library news and events
2. RSS usefulness to inform you about new books, journals and e-resources databases
3. Adequacy ofi nstructions on how to use RSS
4. Adequacy ofl inks on library's web site/pages to download RSS
5. Usability of RSS items (e.g., items in RSS are searchable and classified into topics)

Category 2 – Use of Blogs :

6. Blog usefulness to inform you about library news and events
7. Blog usefulness to inform you about new books, journals and e-resources databases
8. Blog usefulness to publish book and journal reviews/discussions
9. Blog usefulness for information literacy
10. Adequacy ofi nstructions on how to use Blogs
11. Blog recentness (i.e., how recent are the latest postings)
12. Adequacy of blog links (i.e., they point to relevant Internet resources, to similar blogs, etc)
13. Blog usability (e.g., entries are searchable by keywords, entries are browsable by topics or by date, etc)

Category 3 – Use of Podcasts :

14. Podcast usefulness to inform you about library news and events
15. Podcast usefulness to inform you about new books, journals and e-resources databases
16. Podcast usefulness to provide guidance to use resources and other library facilities
17. Podcast usefulness for information literacy
18. Adequacy ofi nstructions on how to use Podcasts
19. Podcast usability (e.g., a transcript accompanies each podcast, podcasts are searchable by keywords, podcasts are browsable by topics, etc)

Category 4 – Use of Wikis :

20. Wiki usefulness as subject guides
21. Wiki usefulness to provide resource listings
22. Adequacy ofi nstructions on how to use Wikis
23. Wiki editability (e.g., users can create new pages, edit an existing page, upload files, etc)
24. Wiki usability (e.g., it provides a link to the library home page, a keyword search engine, etc)

Fig. 1. Evaluation scheme to assess the quality of Library 2.0 functionalities.

library is evaluated. For instance, an experiment conducted by Kani-Zabihi, Ghinea, and Chen (2006) shows that *finding information easily and quickly in libraries* and *being able to be easily familiarized with libraries* are the two most important requirements for a digital library. On the other hand, Xie (2008) reports that *interface usability* and *system performance* are the most important criteria. Regarding Library 2.0 specifically, Holmberg, Huvila, Kronqvist-Berg, and Widén-Wulff (2009) performed an experiment where 29 Finnish library professionals answered freely to the open ended question *what is Library 2.0?*. Using co-word analysis, the authors conclude that the seven core components of Library 2.0 are: (i) *interactivity*, (ii) *users*, (iii) *participation*, (iv) *libraries and library services*, (v) *web and Web 2.0*, (vi) *social aspects*, and (vii) *technology and tools*. Among them, interactivity is the most important part of Library 2.0. Note that interactivity can be the interaction between the librarians and the customers or library users, but also between library staff or between users of the library services. This interaction enables participation where the users can contribute to the content of libraries and library services using new ways and new web-based tools or so called Web 2.0 tools. The evaluation scheme we propose supports taking into consideration criteria by giving different weights to items in Fig. 1. Moreover, users may play different roles in measuring library service quality, i.e., some users may be more influential than others in some questions as it is not always valid that all group of users have equal importance with respect to the decision being made. This is because the degree of relevancy, knowledge, and experience may not be equal among them. Our model also supports giving different weights to groups of users.

3.2.2. Computation method

The computation method of the evaluation model presented in this paper is like a multi-person multi-criteria decision-making problem (Xu, 2011). In such problems, the goal consists of searching the best alternatives according to the assessments provided by a group of experts with respect to a set of evaluation criteria. To do that, through the aggregation of the experts' assessments, the quality of alternatives is measured and, later, the exploitation of those quality values leads to the selection of the best alternatives. In our case, the goal consists of computing quality evaluations of Library 2.0 functionalities, but as in a multi-criteria decision context, we compute those values according to the assessments provided by a group of users.

A critical aspect that has a direct influence on the success of the decision process in multi-criteria decision-making processes is the chosen aggregation operator. The quantifier guided aggregation operators based on the OWA operator constitute a successful tool to aggregate information because of its flexibility: i.e., it allows representation in the aggregations of different interpretations of the concept of majority by means of the fuzzy linguistic quantifier

(Yager, 1988). We do the same in our computation method, which has the following main features:

1. *It is a user-centered computation method*. The quality assessment is obtained from individual linguistic judgments provided by their users rather than from assessments obtained objectively by means of the direct observation of the Library 2.0 functionalities.
2. *It is a majority guided computation method*. The quality assessments are values representative of the majority of individual judgments provided by the users of the Library 2.0 functionalities. The aggregation to compute the quality assessments is developed by means of the LOWA and LWA operators.

Fig. 2 depicts a panoramic view of the computation method we propose, which is composed of the following steps:

Step 1 Users express their opinion by filling the questionnaire described in Subsection 3.2.1. In the same way that LibQUAL+uses a 9-point Likert scale, our model uses the following set of 9 labels: $S = \{\mathsf{N} = \text{None}, \mathsf{EL} = \text{Extremely Low}, \mathsf{VL} = \text{Very Low}, \mathsf{L} = \text{Low}, \mathsf{M} = \text{Medium}, \mathsf{H} = \text{High}, \mathsf{VH} = \text{Very High}, \mathsf{EH} = \text{Extremely High}, \mathsf{T} = \text{Total}\}$.

As a result, for each one of the users $u_j \in \{u_1, u_2, \ldots, u_n\}$ and each questionnaire item $i_k \in \{i_1, i_2, \ldots, i_{24}\}$, there is a tuple $(\text{MSL}_{jk}, \text{DSL}_{jk}, \text{PPL}_{jk})$, that encodes the *Minimum Service Level*, the *Desired Service Level*, and the *Perceived Performance Level*, provided by the user u_j on the item i_k, respectively.

Step 2 To get the global user opinion regarding each item i_k, $(\text{MSL}_k, \text{DSL}_k, \text{PPL}_k)$, the LOWA and LWA operators are used. If all users have the same importance, Step 2.1 is proceeded, else Step 2.2 is proceeded.

Step 2.1 For each item i_k, its correspondent tuple $(\text{MSL}_k, \text{DSL}_k, \text{PPL}_k)$ is computed using the LOWA operator as:

$$\begin{aligned} \text{MSL}_k &= \phi_Q(\text{MSL}_{1k}, \ldots, \text{MSL}_{nk}), \\ \text{DSL}_k &= \phi_Q(\text{DSL}_{1k}, \ldots, \text{DSL}_{nk}), \\ \text{PPL}_k &= \phi_Q(\text{PPL}_{1k}, \ldots, \text{PPL}_{nk}), \end{aligned} \tag{12}$$

where MSL_k, DSL_k and PPL_k are the linguistic measures that represents the minimum service level, the desired service level and the perceived performance level, respectively, of the library with respect to item i_k, according to the majority (represented by the fuzzy linguistic quantifier Q) of linguistic evaluation judgments provided by the group of users.

Step 2.2 For each item i_k, its correspondent tuple $(\text{MSL}_k, \text{DSL}_k, \text{PPL}_k)$ is computed using the LWA operator as:

$$\begin{aligned} \text{MSL}_k &= \Phi_Q((\text{UI}(u_1, i_k), \text{MSL}_{1k}), \ldots, (\text{UI}(u_n, i_k), \text{MSL}_{nk})), \\ \text{DSL}_k &= \Phi_Q((\text{UI}(u_1, i_k), \text{DSL}_{1k}), \ldots, (\text{UI}(u_n, i_k), \text{DSL}_{nk})), \\ \text{PPL}_k &= \Phi_Q((\text{UI}(u_1, i_k), \text{PPL}_{1k}), \ldots, (\text{UI}(u_n, i_k), \text{PPL}_{nk})), \end{aligned} \tag{13}$$

where $\text{UI}(u_j, i_k) \in S$ is the relative linguistic importance degree assigned to user u_j for item i_k.

Step 3 To get the global user opinion regarding all items, (MSL, DSL, PPL), the LOWA and LWA operators are used. If all items have the same importance, Step 3.1 is proceeded, else Step 3.2 is proceeded.

Step 3.1 Tuple (MSL, DSL, PPL) is computed using the LOWA operator as:

$$\begin{aligned} \text{MSL} &= \phi_Q(\text{MSL}_1, \ldots, \text{MSL}_{24}), \\ \text{DSL} &= \phi_Q(\text{DSL}_1, \ldots, \text{DSL}_{24}), \\ \text{PPL} &= \phi_Q(\text{PPL}_1, \ldots, \text{PPL}_{24}), \end{aligned} \tag{14}$$

where MSL, DSL and PPL are the linguistic measures that represents the global minimum service level, the global desired service level and the global perceived performance level, respectively, achieved for the library, according to the majority (represented by the fuzzy linguistic quantifier Q) of linguistic evaluation judgments provided by the group of users about all items.

Step 3.2 Tuple (MSL, DSL, PPL) is computed using the LWA operator as:

$$\begin{aligned} \text{MSL} &= \Phi_Q((\text{II}(i_1), \text{MSL}_1), \ldots, (\text{II}(i_{24}), \text{MSL}_{24})), \\ \text{DSL} &= \Phi_Q((\text{II}(i_1), \text{DSL}_1), \ldots, (\text{II}(i_{24}), \text{DSL}_{24})), \\ \text{PPL} &= \Phi_Q((\text{II}(i_1), \text{PPL}_1), \ldots, (\text{II}(i_{24}), \text{PPL}_{24})), \end{aligned} \tag{15}$$

where $\text{II}(i_k) \in S$ is the relative linguistic importance degree for item i_k.

Step 4 Gap analysis is done for each item. According to LibQUAL+, the minimum and the desired scores establish the boundaries of a *zone of tolerance* within which the perceived scores should desirably float. The difference between the perceived and minimum scores is called the *Service Adequacy* (SA) gap, and the difference between the desired and perceived scores is called the *Service Superiority* (SS) gap. The computation of SA and SS relies on the *linguistic distance* defined by Eq. (1). So, for each item i_k, SA_k and SS_k are computed as:

$$\begin{aligned} \text{SA}_k &= D(\text{PSL}_k, \text{MSL}_k) \\ \text{SS}_k &= D(\text{DSL}_k, \text{PSL}_k) \end{aligned} \tag{16}$$

Fig. 3 depicts the three possible cases for gaps SA and SS. The cases when the perceived level of service falls out of the zone of tolerance are denoted as SA^- and SS^+. SA^- means that the library is not meeting its users' minimum expectations, i.e., the perceived score is lower than the minimum one. Likewise, SS^+ means that the library is exceeding its users' desired expectations, i.e., the perceived score is higher than the desired one. Therefore, SA^- can be used to identify Library 2.0 functionalities needing improvement, whereas SS^+ is an indicator of the extent to which Library 2.0 functionalities are exceeding the desired expectations of the users.

4. Experimental evaluation

This section reports the use of the quality model proposed in this paper to evaluate the academic library at the UNED. In addition, such evaluation provides experimental evidence of the validity and reliability of our fuzzy linguistic model.

4.1. Participants

With more than 260,000 scholars, UNED is, in terms of the number of students, the largest university of Spain and the second-largest in Europe, next to the Open University in the UK. At this

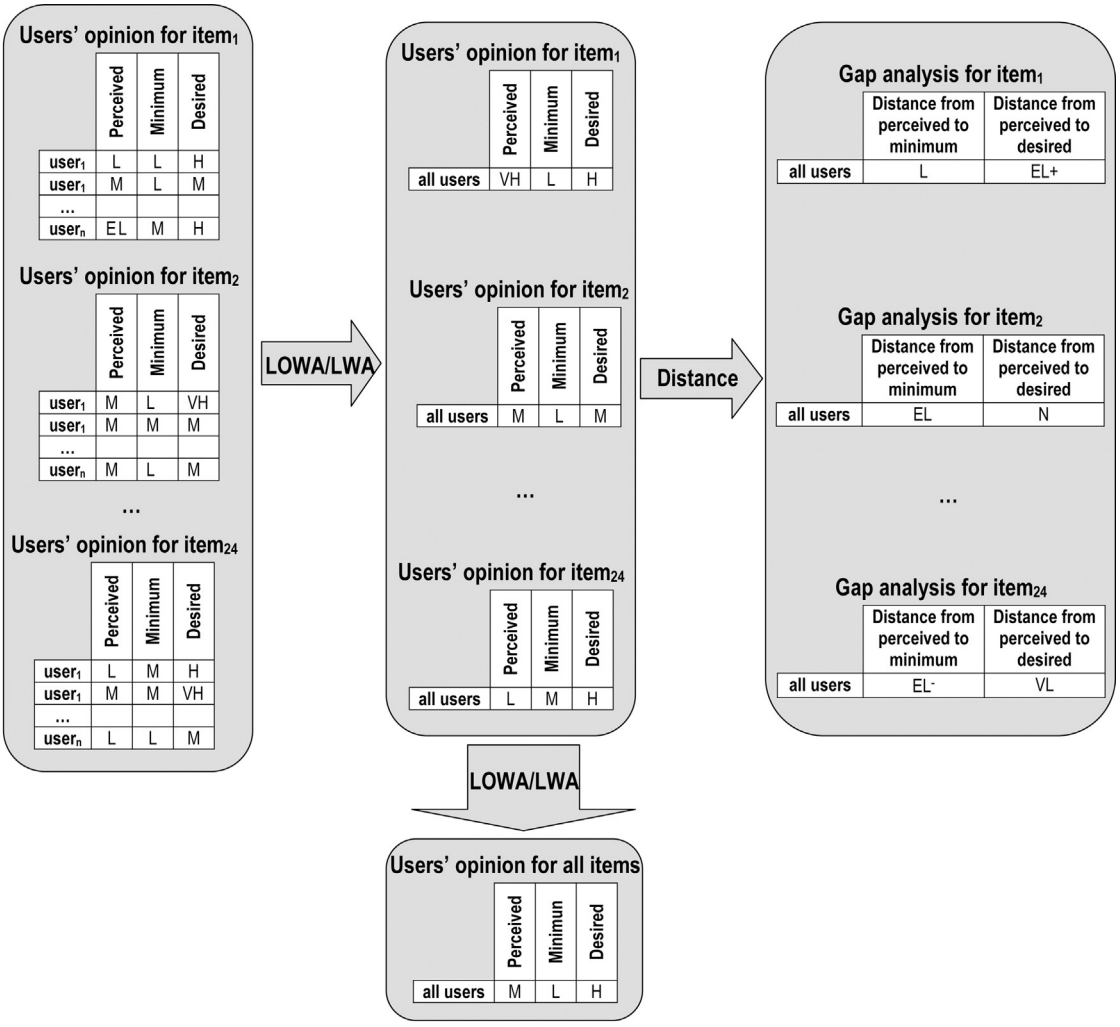

Fig. 2. Schema of our quality evaluation approach.

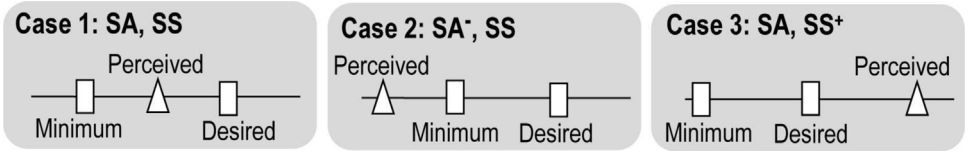

Fig. 3. Possible cases for gaps SA and SS.

moment, the UNED library provides the following 2.0 functionalities:

1. *Podcasts*: the main UNED podcast repository is *Canal UNED*,[5] which offers media authored by the UNED research and teaching staff, such as television and radio programs.
2. *Blogs*: UNED library includes the following blogs, each one oriented to a specific issue:
   (a) *El marcapáginas*[6] tries to encourage reading and promotes the visibility of quality books.
   (b) *Recursos de investigación al día*[7] supports research information, including news, advertisements about seminaries and training courses, and a calendar of research events.
   (c) *MediaBlog*[8] and *Blog del Canal UNED*[9] support the media library. They include information regarding recently acquired and created material, media reviews, links, and events.
   (d) *Comunicación interna*[10] is oriented to the UNED library staff. It includes information about developments in the field of library and information science.

[5] http://www.canaluned.com/.
[6] http://marcapaginasuned.blogspot.com/.
[7] http://referenciauned.blogspot.com/.
[8] http://mediatecauned.blogspot.com/.
[9] http://canaluned.blogspot.com/.
[10] http://bibliotecauned.blogspot.com/.

Table 1
Users' opinion and gap analysis for the UNED library.

	Users opinion (LOWA)			Gap analysis	
Items	Perceived	Minimum	Desired	SA	SS
$Item_1$	VH	H	EH	EL	EL
$Item_2$	H	M	VH	EL	EL
$Item_3$	M	H	VH	EL^-	VL
$Item_4$	H	H	VH	N	EL
$Item_5$	L	M	H	EL^-	VL
$Item_6$	H	H	VH	N	EL
$Item_7$	H	H	VH	N	EL
$Item_8$	H	H	EH	N	VL
$Item_9$	L	H	EH	VL^-	M
$Item_{10}$	M	M	H	N	EL
$Item_{11}$	L	H	EH	VL^-	M
$Item_{12}$	H	H	EH	N	VL
$Item_{13}$	M	M	VH	N	VL
$Item_{14}$	M	M	H	N	EL
$Item_{15}$	H	M	VH	EL	EL
$Item_{16}$	L	M	H	EL^-	VL
$Item_{17}$	L	H	VH	VL^-	L
$Item_{18}$	M	M	H	N	EL
$Item_{19}$	VH	H	VH	EL	N

(e) *BiblioUNED abierta*[11] is a miscellaneous blog that includes general information about the UNED library.

3. *RSS*: the content of the UNED podcast repository and blogs has RSS feeds.

In order to evaluate the research content provided by the Web 2.0 functionalities of UNED library, a study was conducted during the first semester of the 2011–12 academic year. The study was focused on the evaluation of the Podcast repository *Canal UNED*, the Blog *Recursos de investigación al día* and their RSS feeds. The research encompassed a group of 34 students that were taking the doctoral program of the UNED Department of Software Engineering and Computer Systems. The students were invited to fill an online questionnaire composed of the items 1–19 in Fig. 1 (i.e., since the UNED library does not provide any wiki functionality, items 20–24 were not included in the questionnaire).

4.2. Results

Table 1 summarizes the result of combining users opinions regarding each item by means of the LOWA operator (i.e., participants were students with the same level of importance) and its corresponding gap analysis. To do so, the linguistic quantifier "as many as possible" with the pair (0.5, 1) was used.

LibQUAL+advises the usage of radar charts to summarize users replies to the questionnaire items on minimum, perceived and desired levels. In our evaluation, we adapted the radar chart notation proposed by LibQUAL+as follows: scores from individual users surveys were combined with the LOWA operator to form one set of aggregate survey data. The minimum, perceived and desired aggregated scores for each survey item were mapped as single points on a line. On a radar chart, these lines (each representing one item) are laid out like spokes on a wheel. The rating scale of the lines goes from N, which is depicted by the center of the chart, to T, which is represented by the outest concentric line in the chart. Fig. 4 depicts the radar chart corresponding to our UNED library evaluation. Line $item_1$ depicts the row $item_1$ in Table 1. So, points corresponding to the values VH, H and EH have been selected on the line.

Following the notation proposed by LibQUAL+, the differences between the points were shaded in the chart: red indicates areas where the perceived score is less than the minimum score, blue is where perceived scores are greater than minimum scores, and yellow indicates that perceived scores are less than desired scores. By looking at the radar chart as a whole, the evaluator can gain an overall understanding of user perceptions of service quality at the library. The color-coding makes it easy to identify areas where improvements may be needed, or where the user expectations are already being met.

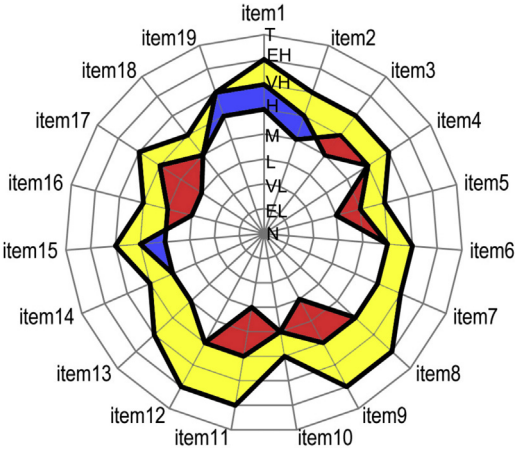

Fig. 4. Radar chart corresponding to the UNED library evaluation.

Table 2
Global user opinion for the UNED library.

	All items		
	Perceived	Minimum	Desired
All users	H	H	VH

Finally, to get an overall library opinion (i.e., the global user opinion regarding the entire library and considering the relative importance of each item), the global user opinion for each item was combined by using the LWA operator. Our evaluation was mainly concerned about the usefulness of the provided functionalities. So, the LWA importance parameter for items 1, 2, 6–9, 14–17 was set to VH, and for the remaining items was set to L. Table 2 summarizes the result of the LWA computation.

In light of these good results, our recommendations to the library staff were limited to the suggestion that they should try to make modest improvements to services corresponding to items 3, 5, 9, 11, 16 and 17 to meet users minimum expectations of service quality.

4.3. Validity

According to Worthen, Borg, and White (1993), the validity of a measure is "the degree to which it accomplishes the purpose for which it is used", i.e., if the model measures what it purports to measure.

To evaluate the validity of our approach, we have followed a *convergent* strategy, i.e., analyzing if its results correlate with the

Table 3
Correlation tests between Linh's model and our fuzzy linguistic approach.

	Perceived		
	Correlation factor *r*	*t*	*p*-value
RSS	0.7063794	5.6452	3.039e−06
Blogs	0.859224	9.5006	7.82e−11
Podcasts	0.8370405	8.6541	6.872e−10
All categories	0.6764817	5.1962	1.123e−05

[11] http://usuariosbibliotecacentraluned.blogspot.com/.

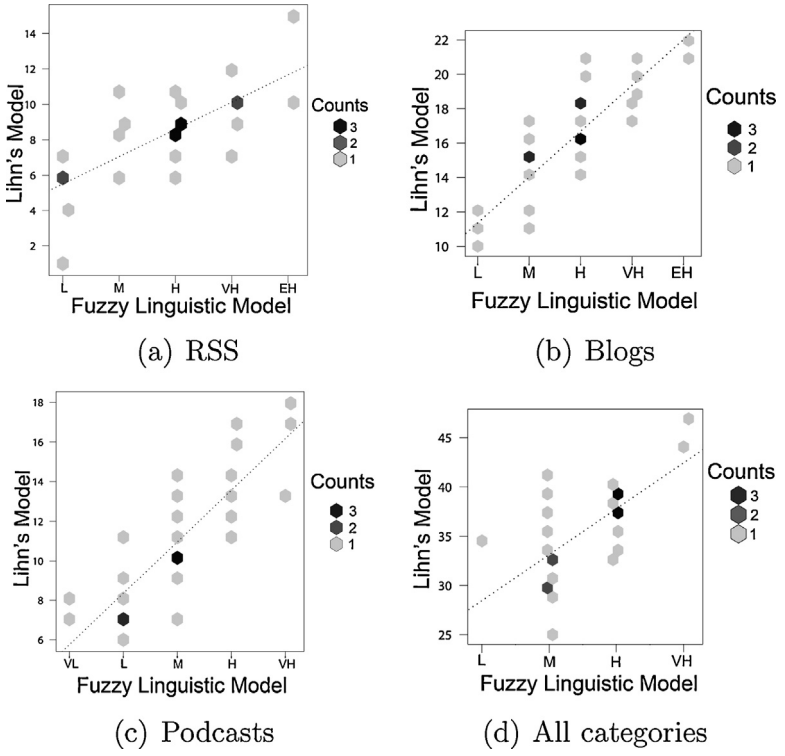

Fig. 5. Convergent validity between our fuzzy linguistic approach and Linh's model.

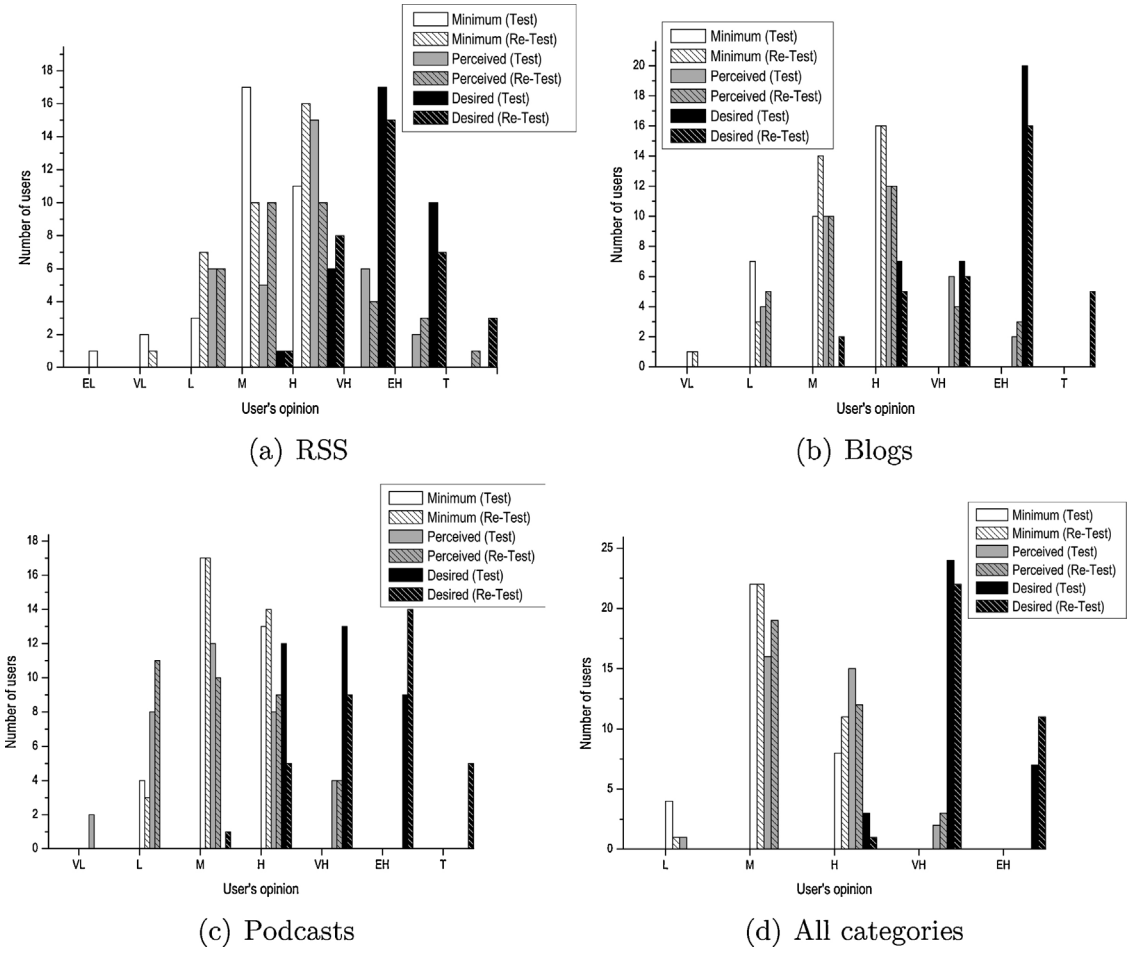

Fig. 6. Test–retest reliability.

Table 4
Test-retest correlations.

	Minimum			Perceived			Desired		
	Correlation factor *r*	*t*	*p*-value	Correlation factor *r*	*t*	*p*-value	Correlation factor *r*	*t*	*p*-value
RSS	0.7746297	6.9289	7.6e−08	0.8070336	7.7311	8.159e−09	0.9232732	13.596	7.55e−15
Blogs	0.7507609	6.4292	3.152e−07	0.855209	9.3343	1.19e−10	0.753275	6.4788	2.734e−07
textbfPodcasts	0.7197105	5.8641	1.609e−06	0.76132	6.6422	1.714e−07	0.6169064	4.434	0.000102
All categories	0.569832	3.9226	0.0004351	0.7926829	7.3554	2.3e−08	0.6267832	4.5504	7.304e−05

results obtained by other established model for assessing the quality of Library 2.0 functionalities. In particular, our group of students also assessed the UNED library by using Linh's model (Linh, 2008). Since the assessment was focused on the evaluation of the UNED Podcasts, Blogs and RSS, only items 10–67 of Linh's model were taken into account.

The scatter plots in Fig. 5 depict the relationship between the results of Linh's model and our fuzzy linguistic model. As Linh's model just considers the level of service the user believes a library currently provides, *x*-axes only represent the users' *perceived* rates (i.e., the *minimum* and *desired* levels elicited by our model have been left out from the validity analysis). Figs. 5a–c shows the data points regarding UNED RSS, Blogs, and Podcasts, respectively. Fig. 5d depicts the students' global opinion considering those three categories jointly. Each data point represents one student's opinion. For instance, a data point in Fig. 5a depicts the opinion that a student has about the UNED RSS. Whereas our model questionnaire supports linguistic answers and thus data points are computed aggregating the corresponding items with the LOWA operator, Linh's model questionnaire is a checklist and so data points are computed as the number of "yes" answers for the items (i.e., *y*-axes in Fig. 5 stand for the number of "yes" answers). Since there is significant overlap among the data points, they have been grouped into colored hexagonal cells. The color range goes from light gray (one single point) to black (when a cell groups three points). In addition, Fig. 5 includes the corresponding linear regression lines for each scatter plot.

Table 3 summarizes the Pearson's correlation tests between the results of our approach and Linh's model. Since the *p*-values are minor than 0.01, the tests show that the correlations are statistically highly significant. So our model has a convergent validity toward Linh's model.

4.4. Reliability

According to Mehrens and Lehman (1986), the reliability of a model is "the degree of consistency between two measures of the same thing". In other words, "the measure of how stable, dependable, trustworthy, and consistent a model is in measuring the same thing each time" (Worthen et al., 1993).

To evaluate the reliability of our model we have followed a *test-retest* approach by asking our students to evaluate the UNED library twice, using repeatedly our model in two sessions distanced by a week. Histograms in Figs. 6a–c depicts the results by category (RSS, Blogs and Podcasts). Histogram in Fig. 6c accounts for all categories jointly. Table 4 summarizes the Pearson's correlation tests between the results of the first and second evaluation sessions. Since the tests show strong positive and highly significant correlations, there is experimental evidence of the reliability of our fuzzy linguistic model.

5. Conclusions

Web 2.0 tools may bring change in the relationship between users and libraries by improving the involvement of users in the libraries activities. To use such tools efficiently, it is essential to know if they are meeting user requirements and expectations, and how they could be improved to increase user satisfaction. To do so, we have proposed an evaluation model of Library 2.0 functionalities that provides quality assessment according to users opinions. Using the fuzzy linguistic modeling to represent the users opinions, in a way that is particularly user friendly, and the LibQUAL+methodology, the proposed model is able to identify Library 2.0 functionalities which should be improved and Library 2.0 functionalities satisfied outstandingly by the library. To show the applicability of the evaluation model, we have reported a research conducted at the UNED academic library, where our model has been applied to assess the current implementation of the 2.0 functionalities in the library. Moreover, such case of study reflects experimental evidence of the validity and reliability of our model. As a subject for further research, we intend to implement a recommender system generating recommendations automatically to improve the Library 2.0 functionalities provided by the libraries using the quality assessments provided by the users.

Acknowledgments

This work has been developed with the financing of FEDER funds in FUZZYLING-II Project TIN2010-17876, the Andalusian Excellence Projects TIC-05299 and TIC-5991, and "Proyecto de Investigación del Plan de Promoción de la Investigación UNED 2011 (2011/PUNED/0003)".

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Ruben Heradio received the M.S. degree in Computer Science from the Polytechnic University of Madrid (Spain) in 2000, and the Ph.D. degree from the Universidad Nacional de Educacion a Distancia, UNED (Spain) in 2007. Since 2001 he has been an Assistant Professor at the UNED Department of Software Engineering and Computer Systems. His research and teaching interests include Software Engineering, Computational Logic and E-Learning.

Francisco Javier Cabrerizo received the M.Sc. and Ph.D. degrees in computer sciences from the University of Granada, Granada, Spain, in 2006 and 2008, respectively. He is currently an Associate Professor with the Department of Software Engineering and Computer Systems, Distance Learning University of Spain (UNED), Madrid, Spain. He is a member of the editorial board of the Journal of Universal Computer Science. His research interests include group decision making, decision support systems, consensus models, linguistic modeling, modeling situations with missing/incomplete information, aggregation of information, digital libraries, web quality evaluation, and bibliometric measures.

David Fernandez-Amoros received the M.S degree in mathematics and the M.S degree in Philology from the Universidad Complutense de Madrid (Spain) in 1994 and 2009, respectively, and the Ph.D. degree in Computer Science from the Universidad Nacional de Educación a Distancia (Spain) in 2004. Since November, 2001 he has been an Assistant Professor at the Universidad Nacional de Educación a Distancia (Spain). His research and teaching interests include Software Engineering, Natural Language Processing, Compiler Design and Concurrent Programming.

Manuel Herrera received the PhD in Political Science and Sociology (with Honors) and Bachelor of Geography and History and Philosophy from the University of Granada. Professor of Sociology, Faculty of CC. PP and Sociology at the National University of Distance Education. During the years 1995, 1996 and 1997 has been visiting professor and researcher at the University of Bologna (Italy), at Johns Hopkins University (USA) and Harvard University (USA). Member of the Centre for Social Policy Studies at the University of Bologna. Senior Fellow at the Institute for Policy Studies at Johns Hopkins University (USA). Member of International Research Program at Johns Hopkins University entitled: International Filantropic Program. From April 2000 to May 2004 was Advisor to the Minister of Education, Culture and Sports of the Government of Spain, and during 2006 and 2007 has been as Visiting Scholar at the Center for Comparative Immigration Studies at the University of California-San Diego. His main research interests are sociological theory, social networks, social policy and state intervention in social problems. Author of numerous national and international publications in areas such as social science epistemology, sociological theory, welfare state and new forms of organized altruism.

Enrique Herrera-Viedma is currently a Professor in Computer Science with the Department of Computer Science and Artificial Intelligence, University of Granada. He is Associate Editor of the various ISI journals as IEEE Trans. on Syst. Man and Cybernetics: Systems, Knowledge Based Systems, Soft Computing, Journal of Intelligent and Fuzzy Systems, and Information Sciences; and member of the editorial board of various ISI journals as Fuzzy Sets and Systems, Int. Journal of Information Technology and Decision Making, and Int. J. of Computational Intelligence. Tenth of his papers are classed as highly cited as well as being in the top 1% of the most cited papers in its field. His current research interests include group decision making, consensus models, linguistic modeling, aggregation of information, information retrieval, bibliometric, digital libraries, web quality evaluation, and recommender systems. Dr. Herrera-Viedmas h-index is 37, and he is considered as one of the Most Cited Scientists in Engineering in the ISI Web of Science Essential Science Indicators, i.e., he is in the top 1% of the most cited scientists in the field of engineering and computer science. He has recently published in Science on the new role of the public libraries.