Evaluating the Information Quality of Web Sites: A Methodology Based on Fuzzy Computing With Words

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An evaluation methodology based on fuzzy computing with words aimed at measuring the information quality of Web sites containing documents is presented. This methodology is qualitative and user oriented because it generates linguistic recommendations on the information quality of the content-based Web sites based on users' perceptions. It is composed of two main components, an evaluation scheme to analyze the information quality of Web sites and a measurement method to generate the linguistic recommendations. The evaluation scheme is based on both technical criteria related to the Web site structure and criteria related to the content of information on the Web sites. It is user driven because the chosen criteria are easily understandable by the users, in such a way that Web visitors can assess them by means of linguistic evaluation judgments. The measurement method is user centered because it generates linguistic recommendations of the Web sites based on the visitors' linguistic evaluation judgments. To combine the linguistic evaluation judgments we introduce two new majority guided linguistic aggregation operators, the Majority guided Linguistic Induced Ordered Weighted Averaging (MLIOWA) and weighted MLIOWA operators, which generate the linguistic recommendations according to the majority of the evaluation judgments provided by different visitors. The use of this methodology could improve tasks such as information filtering and evaluation on the World Wide Web.

Introduction

Nowadays, we can assert that the World Wide Web is the largest available repository of data with the largest number of visitors searching for information. The World Wide Web is a distributed, dynamic, and rapidly growing information source (Lawrence & Giles, 1998) that has stimulated new and useful research developments in areas such as digital libraries, information retrieval, education, commerce, entertainment, government, and health care (Lawrence & Giles, 1999a; Lawrence & Giles, 1999b). However, it presents some serious handicaps: Its growth is disorganized and uncontrolled, thus contributing to the limitation that bad information thrives on the World Wide Web. As a consequence Internet users have access to bad or poor-quality information (Tyburski, n.d.).

Recognizing the basic differences between publishing on the Web and publishing on paper may help to understand the lack of quality typical of the World Wide Web. In contrast to the printed paper world, on the World Wide Web anyone can publish information, either by simply acquiring space on a Web site and creating an electronic document (using any of the available formats, HTML, XML, Pdf, or PostScript) or by paying someone to create it. The fact is that there are neither rules nor standards governing the type and quality of information that a writer can put on the Web, nor a central control on where and how documents are published (Diligenti, Gori, & Maggine, 2004). In the print world, authors can publish their own studies with their own expenses, but self-published materials generally reach a limited audience. The Web, on the other hand, facilitates the distribution of self-published works, while significantly reducing the cost of production (Tyburski, n.d.). Furthermore, posting articles on the Web instead of publishing in printed books/journals increases their impact on the development of subsequent ideas (Standler, n.d.). Some studies show that many articles published in printed books/journals are never cited in any subsequent article; this means that printed articles have a low impact on

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the development of subsequent new ideas (Garfield, 1998; Hamilton, 1991a; Hamilton, 1991b; Pendlebury, 1991). Hence the amount of Web documents and the number of content-based Web sites on the Internet are continuously and rapidly increasing, although in many cases this happens without efficient information quality control.

For several topics, the World Wide Web contains thousands of relevant documents/sites of widely varying information quality. To cope with this situation, over the past few years many techniques (Web search engines, information filtering systems, Web personalization systems, Web mining) for managing, querying, filtering, and integrating information on the World Wide Web have been developed. The major advances in the design of these techniques have been guided by information quality criteria, that is, criteria aimed at improving the quality of the information provided to users from the World Wide Web. However, some characteristics typical of the World Wide Web, as for example its fast and uncontrollable growth, its heterogeneity, and its freshness requirements (Diligenti, Gori, & Maggine, 2004; Lawrence & Giles, 1998; Lawrence & Giles, 1999a; Lawrence & Giles, 1999b), as well as other problems, such as the bubble of Web visibility (Gori & Numerico, 2003; Gori & Witten, 2005), are still limiting the quality in the information provided by the different Web search techniques. Consequently, in the Web research community the debate on the quality of the information available on the Internet is still open (Alexander & Tate, 1999; Gertz, Ozsu, Saake, & Sattler, 2004; Sweetland, 2000; Tirri, 2003). Identifying useful and high-quality information in a unregulated marketplace such as the World Wide Web is still a crucial problem.

The quality evaluation of content-based Web sites focusing on the user-perceived quality of the stored information is a difficult task that has seldom been studied (Rieh, 2002), and there does not exist a Web information quality framework as a reference point (Gertz, Ozsu, Saake, & Sattler, 2004). As some other authors have (Chae, Kim, Kim, & Ryu, 2002; Katerattanakul & Siau, 1999), we use the information quality framework for information systems (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996) as the basic reference point of our proposal.

The aim of this article is to present a quality evaluation methodology of Web sites based on user perceptions of the quality of the information they provide. In this article, content-based Web sites are considered in which the information is organized in multiple kinds of documents, e.g., scientific articles, and opinion articles, using any of the available electronic formats (HTML, XML, Pdf, or PostScript). This methodology is designed by using tools of fuzzy computing with words (Herrera & Herrera-Viedma, 1997; Herrera, Herrera-Viedma, & Verdegay, 1996; Herrera-Viedma, 2000a;Herrera-Viedma, 2001b) to facilitate user participation. The goal of this methodology is to generate linguistic quality evaluations or linguistic recommendations on such Web sites. To do that, it is composed of two main components, an evaluation scheme to analyze the information quality of Web sites and a measurement method to generate the linguistic recommendations. The evaluation scheme takes into account both technical criteria concerning the structural design of Web sites and criteria related to the content of the Web sites. It is user driven rather than designer driven; i.e., it includes user-perceived Web evaluation indicators such as navigation or believability, rather than quantifiable Web attributes such as code quality or design; that is, it considers Web characteristics and attributes easily understandable to a nonexpert Web visitor, in such a way that Web visitors can assess them by means of linguistic evaluation judgments. Using the information quality framework proposed (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996), we define a user-driven evaluation scheme of Web sites. The measurement method is user centered rather than "site model" centered; i.e., the recommendations are obtained from linguistic evaluation judgments provided by Web visitors rather than from assessments obtained objectively by means of the direct observation of the site model characteristics. Users after visiting a Web site to examine a stored document are required to express their evaluation judgments on the evaluation scheme by means of the specification of linguistic labels. Then, an overall linguistic recommendation concerning the quality of that Web site is obtained by combining the linguistic evaluation judgments provided by different visitors. To combine the judgments we introduce two new majority guided linguistic aggregation operators, the MLIOWA and weighted MLIOWA operators, which adequately implement the idea of fuzzy majority. To define them, we use the majority-guided induced ordered weighted averaging (IOWA) operators (Pasi & Yager, 2002; Pasi & Yager, 2006). In such a way, our methodology allows us to obtain nondistorted recommendations on information quality of the Web sites that really are representative of the majority of individual recommendations provided by different visitors of sites. With this Web quality evaluation methodology the information filtering and evaluation possibilities in the Web are increased. In this way, when a user requires information on the World Wide Web, then not only can content-based Web sites be provided, but also recommendations on their information quality and on Web sites that store similar documents that could be of interest to the user.

The article is organized as follows. In the next section the problem of evaluating the information quality of Web sites is analyzed. The tool of fuzzy computing with words and the new majority guided aggregation operators are defined in the third section. The Web quality evaluation methodology is introduced in the fourth section. A discussion on the proposed methodology is presented next, and the final section sketches our conclusions.

The Problem of Evaluating the Information Quality of Web Sites

In our opinion, there is not yet a clear and unambiguous definition of the concept of information quality on the World Wide Web, and unfortunately, well-founded and theoretical Web quality frameworks are still missing (Gertz, Ozsu, Saake, & Sattler, 2004). One can probably find as many

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definitions for information quality on the Web as there are papers on information quality. The quality evaluation on the World Wide Web is neither simple nor straightforward. Web quality is a complex concept and its measurement or evaluation is multidimensional in nature (Aladwani & Palvia, 2002). Assuming such a nature, we agree with the definition of Web quality given as an aggregated value of multiple information quality criteria" (Naumann, 2002). On the other hand, other researchers (Mich, Franch, & Gaio, 2003) use the definition of quality given by the International Standards Organization (ISO) to allow the use of the evaluation indicators taken into account in the evaluation of commercial Web sites. The ISO defines *quality* as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs" (ISO 8402, 1994). From this definition two different kinds of requirements for Web document/site quality evaluation emerge:

1. *Technical requirements*: These concern the evaluation of the main characteristics and structure of Web documents/sites. In this category we find evaluation criteria that are indicators of an objective and quantitative nature, e.g., clear ordering of information, broken links, orphan pages, code quality, and navigation.
2. *Content requirements*: These concern the evaluation of how well the Web documents/sites meet the specific user needs. In this category we find evaluation criteria that are indicators of a subjective and qualitative nature, e.g., consistency, accuracy, and relevance.

As mentioned, in Web quality evaluation there is not a general theoretical foundation or framework (Gertz, Ozsu, Saake, & Sattler, 2004). For this reason, many researchers have tried to use other well-founded quality assessment frameworks defined for other fields. One of the more often used is the information quality framework defined in the context of management information systems (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996), used, for example, to define an evaluation methodology of information quality of personal Web sites (Katerattanakul & Siau, 1999) and of mobile Internet services (Chae et al., 2002). This quality framework establishes that the different dimensions (e.g., accuracy, accessibility, relevance) employed to evaluate the information quality of a system can be grouped into four major information quality categories: (1) intrinsic information quality, (2) contextual information quality, (3) representational information quality, and (4) accessibility information quality. The two first categories mainly deal with the "content" aspects of information systems, the others, with some technical design aspects.

A robust and flexible Web quality evaluation methodology should properly combine both kinds of requirements. Some authors (Huizingh, 2000; Naumann, 2002; Robbins & Stylianou, 2003) have proposed Web quality evaluation methodologies that combine both technical and content aspects, but the harsh reality is that the majority of suggested Web evaluation methodologies tend to be more objective than subjective, more quantitative (based on numerical information) than qualitative (based on linguistic information), and do not take into account the user perception (Bovee, Srivastava, & Mak, 2003; Dhyani, Keong Ng, & Bhowmick, 2002; Olsina & Rossi, 2002). However, from the information consumer's perspective the quality of a Web document/site may not be assessed independently of the quality of the information contents that it provides.

An additional drawback of many Web evaluation methodologies is that their evaluation indicators are relevant to Web providers and designers rather than to Web users (Aladwani & Palvia, 2002). A global Web quality evaluation methodology cannot entirely avoid users' participation in the evaluation strategy. User judgments can help to evaluate the information quality of accessed Web documents/sites because the concept of information quality is typically consumer dependent, and the consumer must be the ultimate judge of the Web site's/ document's information quality. The problem here is that the users do not frequently make the effort to give explicit feedback. Web search engines can collect implicit user feedback by using log files. However, these data are still incomplete. To achieve better results of evaluation on the World Wide Web, the direct participation of the user is necessary; i.e., the development of user-centered Web quality evaluation methodologies is a necessity and could provide additional advantages. For example, a user-centered approach to evaluate Web sites would allow users to be more proactively approached to determine their needs—both technical and information related—and their perceptions of Web site organization, terminology, ease of navigation, all of which could be used in a redesign of sites (Aladwani & Palvia, 2002; Huizingh, 2000). Or, for example, in the field of the collaborative recommender systems (Reisnick & Varian, 1997) (information filtering system) that collects ratings of items from many individuals and makes recommendations based on those ratings to a given user) a user-centered Web quality evaluation methodology could contribute a well-founded framework to express ratings or evaluation judgments and to generate the recommendations.

A possible way to facilitate the user participation is to embed in the Web quality evaluation methodology those tools of artificial intelligence that allow a better representation of subjective and qualitative user judgments, for example, a soft computing tool called *fuzzy linguistic modeling* (Zadeh, 1975). The use of fuzzy linguistic modeling could increase user participation in the evaluation of the quality of Web documents/sites, because it is a user-friendly tool that helps users to express their judgments in a more natural way (Herrera-Viedma & Pasi, 2003). We have used (Herrera-Viedma & Peis, 2003) the tool of fuzzy linguistic modeling called *ordinal fuzzy linguistic modeling* (Herrera & Herrera-Viedma, 1997; Herrera, Herrera-Viedma, & Verdegay, 1996; Herrera-Viedma, 2001a; Herrera-Viedma, 2001b) to design a user-centered quality evaluation methodology for Web documents. In this article, we apply the same linguistic tool to evaluate the information quality of Web sites that store documents.

The information quality framework defined by several researchers (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996) was proposed by considering that the quality of information systems cannot be assessed independently of information consumers' (people who use the information) opinions. As mentioned, this information quality framework establishes four major information quality categories to classify the different criteria to evaluate the quality of an information system (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996):

1. Intrinsic information quality: This category addresses the very nature of the information. It assumes that information has its own quality. The main "dimension" of the intrinsic information quality is the accuracy of the information. If a reputation for inaccurate information becomes common knowledge for a particular information system, this system is viewed as having little added value and its use will decline. Other dimensions of this category are believability, reputation, and objectivity.
2. Contextual information quality: This category emphasizes the importance of the informative aspects of information but from a task perspective. It highlights the requirement that information quality must be considered within the context of the task at hand; it must be relevant, timely, complete, and appropriate in terms of amount, so as to add value to the tasks for which the information is provided. Therefore, dimensions of this category include valueadded, relevance, completeness, timeliness, and appropriate amount.
3. Representational information quality: This category emphasizes the importance of the technical aspects of the (computer-based) structure of the information. It requires that information systems present their information in such a way that it is interpretable, easy to understand, and easy to manipulate and is represented concisely and consistently. Therefore, some dimensions of this category are understandability, interpretability, concise representation, and consistent representation.
4. Accessibility information quality. This category emphasizes the importance of the technical aspects of computer systems that provide access to information. It requires that the information system be accessible but secure. Therefore, among the dimensions of this category are accessibility and secure access.

Using the preceding information quality framework, a designer-driven information quality framework has been proposed (Katerattanakul & Siau, 1999) to evaluate the informative quality of personal Web sites; it includes the following evaluation dimensions:

1. Intrinsic quality of personal Web sites: accuracy and errors of content and accurate, workable, and relevant hyperlinks.
2. Contextual quality of personal Web sites: provision of author's information.
3. Representational quality of personal Web sites: organization, visual settings, typographical features, and consistency; vividness and attractiveness; and clarity of content.
4. Accessibility quality of personal Web sites: navigational tools provided.

Similarly, we shall use it as basis to define the evaluation scheme of our quality evaluation methodology.

Fuzzy Computing With Words

In this section we present the fuzzy linguistic approach used to develop the processes of fuzzy computing with words in our Web quality evaluation methodology together with new majority guided linguistic aggregation operators.

Ordinal Fuzzy Linguistic Approach

The *fuzzy linguistic approach* is a technique appropriate to dealing with qualitative aspects of problems (Zadeh, 1975). The *ordinal fuzzy linguistic approach* (Herrera, Herrera-Viedma, & Verdegay, 1996) is a linguistic tool used for modeling processes based on the management of linguistic expressions or computing processes with words; this can be useful in group decision making (Herrera & Herrera-Viedma, 1997;Herrera-Viedma, Martínez, Mata, & Chiclana, 2005) or in information retrieval systems (Herrera-Viedma, 2001a; Herrera-Viedma, 2001b).

The ordinal fuzzy linguistic approach 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 $i \geq j$, and with odd cardinality (typically seven or nine labels). The middle term represents an assessment of "approximately 0.5," and the rest of the terms are placed symmetrically around it. The semantics of the linguistic term set is established from the ordered structure of the term set by considering that each linguistic term in the pair $(s_i, s_{\mathcal{T}-i})$ is equally informative. For example, we can use the following set of nine labels to provide the user evaluations: $S = \{T = Total,\ EH = Extremely\_High, VH = Very\_High, H = High, M = Medium, L = Low,\ VL = Very\_Low,\ EL = Extremely\_Low,\ N = None\}$.

In any linguistic approach it is necessary to define some operators that can be applied to linguistic information. An advantage of the ordinal fuzzy linguistic approach is the simplicity of its computational model for computing with words. It is based on a symbolic computation (Herrera & Herrera-Viedma, 1997; Herrera, Herrera-Viedma, & Verdegay, 1996). 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 approximations that are handled when it is impossible or unnecessary to obtain more accurate values.

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Usually, the ordinal fuzzy linguistic model for computing with words is defined by establishing (1) a negation operator, (2) comparison operators based on the ordered structure of linguistic terms, and (3) adequate aggregation operators of linguistic information. In most ordinal fuzzy linguistic approaches the negation operator is defined from the semantics associated with the linguistic terms, such as

$$Neg(s_i) = s_j \mid j = \mathcal{T} - i$$

Usually, two comparison operators of linguistic terms are defined:

Maximization operator:

$$MAX\,(s_i, s_j) = s_i \quad \text{if } s_i \geq s_j$$

Minimization operator:

$$MIN\,(s_i, s_j) = s_i \quad \text{if } s_i \leq s_j$$

An interesting class of linguistic aggregation operators are based on the ordered weighted averaging (OWA) operators (Yager, 1988). Examples of useful linguistic OWA operators to combine linguistic information are the LOWA (Herrera, Herrera-Viedma, & Verdegay, 1996) and LWA operators (Herrera & Herrera-Viedma, 1997).

An important aspect of an OWA operator is that its behavior is modeled by means of its weighting vector. In this way distinct semantics can be associated with an OWA operator, depending on its weighting vector. A possible aggregation strategy is based on the concept of fuzzy majority, expressed by a linguistic quantifier (Zadeh, 1983). A method (Yager, 1988) has been proposed to define a weighting vector on the basis of the formal definition of a linguistic quantifier; this method is useful in group decision making, when it is necessary to obtain a collective assessment from a set of individual assessments (Herrera & Herrera-Viedma, 1997; Herrera, Herrera-Viedma, & Verdegay, 1996; Herrera-Viedma, Martínez, Mata, & Chiclana 2005; Herrera-Viedma & Peis, 2003). What is expected in these cases is to obtain an aggregated value that synthesizes the majority of the values to be aggregated, i.e., the values that are more similar to each other (Pasi & Yager, 2002; Pasi & Yager, 2006). However, as has been pointed out (Pasi & Yager, 2002; Pasi & Yager, 2006) with the method proposed (Yager, 1988) this semantics is not always achieved, and this shortcoming limits the performance of those systems that use a majority guided Ordered Weighted Averaging (OWA) operator. For this reason, we shall not use the Linguistic Ordered Weighted Averaging (LOWA) and Linguistic Weighted Averaging (LWA) operators to implement the concept of fuzzy majority in our quality evaluation methodology, but we will employ some new operators for performing the linguistic aggregation.

Majority Guided Linguistic Aggregation Operators

Researchers (Pasi & Yager, 2002; Pasi & Yager, 2006) have defined a majority guided induced OWA (IOWA) operator that tries to overcome the problems of the majority guided OWA operators. This IOWA operator combines numerical values in such a way that the final result synthesizes the majority of similar values to be aggregated. Using this operator we propose two majority guided linguistic IOWA operators that allow us to carry out the majority guided aggregation of linguistic information in our information Web quality evaluation methodology.

Definition 1 (Yager & Filev, 1998; Yager & Filev, 1999). An IOWA operator of dimension n is a function $\Phi_W : (R \times R)^n \rightarrow R$, to which a weighting vector is associated, $W = (w_1, \ldots, w_n)$, such that $w_i \in [0, 1]$ and $\sum_i w_i = 1$, and it is defined to aggregate the set of second arguments of a list of n pairs $\{(u_1, p_1), \ldots, (u_n, p_n)\}$ according to the expression

$$\Phi_W((u_1, p_1), \ldots, (u_n, p_n)) = \sum_{i=1}^{n} w_i \cdot p_{\sigma(i)}$$

where $\sigma : \{1, \ldots, n\} \rightarrow \{1, \ldots, n\}$ a permutation such that $u_{\sigma(i)} \geq u_{\sigma(i+1)}, \forall i = 1, \ldots, n - 1$: that is, $(u_{\sigma(i)}, p_{\sigma(i)})$ is the pair with $u_{\sigma(i)}$ the ith highest value in the set $\{u_1, \ldots, u_n\}$.

In the definition the reordering of the set of values to be aggregated, $\{p_1, \ldots, p_n\}$, is induced by the ordering of the values $\{u_1, \ldots, u_n\}$ associated with them. Because of this use of the set of values $\{u_1, \ldots, u_n\}$, Yager and Filev have called them the values of an order inducing variable and $\{p_1, \ldots, p_n\}$ the values of the argument variable (Yager & Filev, 1998; Yager & Filev, 1999).

Definition 2. A majority guided linguistic IOWA (MLIOWA) operator of dimension n is a function $\Phi_Q : (R \times S)^n \rightarrow S$, defined according to the expression

$$\Phi_Q((u_1, p_1), \ldots, (u_n, p_n)) = s_k \in S$$
$$\text{with } k = round\left(\sum_{i=1}^{n} w_i \cdot ind(p_{\sigma(i)})\right)$$

such that

1. $\sigma : \{1, \ldots, n\} \rightarrow \{1, \ldots, n\}$ is a permutation such that $u_{\sigma(i+1)} \geq u_{\sigma(i)}, \forall i = 1, \ldots, n - 1$: that is, $(u_{\sigma(i)}, p_{\sigma(i)})$ is the pair with $\mu_{\sigma(i)}$ the ith lowest value in the set $\{u_1, \ldots, u_n\}$.
2. $u_i = sup_i$, where sup_i is the overall support of value p_i obtained as

$$sup_i = \sum_{j=1}^{n} sup_{ij} \mid sup_{ij} = \begin{cases} 1 & \text{if } |ind(p_i) - ind(p_j)| < \alpha \\ 0 & \text{otherwise} \end{cases}$$

with $\alpha \in \{0, 1, \ldots, \mathcal{T}\}$ and sup_{ij} a binary support function (Yager, 2001) that expresses the support from p_j for p_i or the similarity between both values.
3. $ind : S \rightarrow \{0, 1, \ldots, \mathcal{T}\}$, such that $ind(S_i) = i$.
4. Q is a linguistic quantifier representing the concept of fuzzy majority in the aggregation, which is used to

compute the weighting vector $W = (w_1, \ldots, w_n)$, such that $w_i \in [0, 1]$, $\sum w_i = 1$, and

$$w_i = Q\left(\frac{sup_{\sigma(i)}}{n}\right) \Big/ \sum_{j=1}^{n} Q\left(\frac{sup_{\sigma(j)}}{n}\right)$$

with $Q(sup_{\sigma(i)}/n)$ denoting the degree to which $p_{\sigma(i)}$ represents the majority.

In the MLIOWA operator we assume that all linguistic values to be aggregated are equally important. However, in our methodology, we need to carry out aggregations of weighted information, i.e., when we want to aggregate quality judgments on evaluation criteria with different importance degrees. To do this, we introduce a weighted MLIOWA operator.

Definition 3. A weighted MLIOWA operator of dimension n is a function $\Phi_Q^I : (S \times S)^n \rightarrow S$, defined according to the expression

$$\Phi_Q^I((I_1, p_1), \ldots, (I_n, p_n)) = \Phi_Q((u_1, p_1), \ldots, (u_n, p_n))$$

in which

1. the order inducing values are obtained from the linguistic importance degrees associated with the values to be aggregated as

$$u_i = \frac{sup_i + ind(I_i)}{2}$$

with

$$sup_i = \sum_{j=1}^{n} sup_{ij} \,|\, sup_{ij} = \begin{cases} 1 & \text{if } |ind(I_i) - ind(I_j)| < \alpha \\ 0 & \text{otherwise} \end{cases}$$

where I_i the linguistic importance degree of the value p_i to be aggregated.

2. the weighting vector is obtained as

$$w_i = Q\left(\frac{u_{\sigma(i)}}{n}\right) \Big/ \sum_{j=1}^{n} Q\left(\frac{u_{\sigma(j)}}{n}\right)$$

We should point out that the use of the ordinal fuzzy linguistic approach in our Web quality evaluation methodology provides a well-founded mathematical framework to represent and deal directly with linguistic information. In such a way, we can generate linguistic quality evaluations from linguistic judgments. This is an important limitation in other Web quality evaluation methodologies (Aladwani & Palvia, 2002; Huizingh, 2000; Katerattanakul & Siau, 1999) that also in some cases use labels to represent assessments, because they lack aggregation operators of linguistic information to generate the global quality values.

An Evaluation Methodology of Information Quality of the Web Sites

In this section we present a methodology to evaluate the information quality of content-based Web sites that store information in electronic documents (in any of the known formats on the Web, e.g., XML, HTML, PostScript, Pdf). As stated, this is a user-oriented evaluation methodology of a qualitative and subjective nature that is based on the evaluation judgments provided by the users. This methodology establishes two instruments to evaluate the information quality of the Web sites: a user-driven evaluation scheme and a user-centered measurement method.

The Evaluation Scheme of Web Sites

Using the information quality framework presented in the Problem of Evaluating the Information Quality of Web Sites we develop an evaluation scheme for analyzing the information quality of Web sites that provide information stored in electronic documents. This evaluation scheme is based both on technical criteria of Web site design and on criteria related to the content of information of Web sites. These criteria are assessed subjectively by users who occasionally visit the Web site because they find some stored documents that satisfy their information needs.

Characteristics. The evaluation scheme proposed presents the following characteristics:

- *It is user driven rather than designer driven.*

  We want to generate recommendations on Web sites from the evaluations provided by the different visitors of Web sites. Therefore, the evaluation scheme should be user driven rather than designer driven from two perspectives:
  - Qualitative perspective: The evaluation scheme necessarily requires the inclusion of dimensions easily understandable to any information consumer (e.g., relevance, understandability) rather than dimensions that can be measured objectively independently of consumers (e.g., accuracy measured by the number of spelling or grammatical errors) or only perceptible by the designers (e.g., code quality or design).
  - Quantitative perspective: The evaluation scheme should not include an excessive number of quality dimensions in order to help users in understanding it and avoiding confusion. As is known, users' capability to cope with concepts is limited to only five to nine concepts at one time (the magical number 7 ± 2 (Miller, 1956)). Furthermore, long and complex evaluation schemes cause user idleness and limit their own application possibilities.
- *It is weighted: i.e., its quality dimensions are not equally important.*

  The quality dimensions of the evaluation scheme do not play equal roles in measuring the information quality of a Web site: i.e., some dimensions should be more influential than others. For example, user opinions on the information quality of the documents stored in the Web site (e.g., the relevance) must be an important dimension of the evaluation scheme.

Information quality dimensions. We define a user-driven and weighted evaluation scheme of content-based Web sites

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that contemplates four quality categories with the following information quality dimensions:

1. Intrinsic quality of Web sites: Accuracy of information is the main determinant of the intrinsic information quality of information systems. We discuss accuracy of Web sites by considering what visitors think about the believability of the information content the Web site provides. As we consider Web sites information sources that are occasionally visited, we are not interested in evaluating the accuracy by means of grammatical and spelling errors or relevant hyperlinks existing in the Web site.
2. Contextual quality of Web sites: This is the most important category in the evaluation scheme. In our evaluation scheme neither the dimension of author's information (Katerattanakul & Siau, 1999) nor appropriate quantity is meaningful. We propose to evaluate this category by considering what visitors think about the relevance, timeliness, and completeness of documents that Web site provides when they search information with respect to a specific topic, i.e., whether documents are relevant to the search topic, documents are sufficiently up to date for the search topic, and documents are sufficiently original and complete for the search topic.
3. Representational quality of Web sites: We analyze this category for the Web sites that provide information stored in electronic documents by taking into account two aspects: the representational aspects of Web site design and the representational aspects of documents stored in the Web site. In the first case, we consider what visitors think about the understandability of a Web site (named *understandability1*), i.e., whether or not the Web site is organized in such a way that visitors easily understand how to access the stored documents. In the second case, we consider what visitors think about under-standability (named *understandability2*) and conciseness of the information content of electronic documents examined.
4. Accessibility quality of Web sites: As do other researchers (Katerattanakul & Siau, 1999) we consider that this category should be assessed by whether or not the Web site provides enough navigation mechanisms that visitors can reach their desired documents faster and more easily. Lacking effective paths to access the desired documents would handicap visitors; therefore, navigation tools are necessary to help users to locate the information they want. We evaluate this dimension by considering what visitors think about navigational tools provided by the Web site.

The evaluation scheme is summarized in Table 1.

TABLE 1. User-driven evaluation scheme of Web sites.

Information quality categories	Information quality dimensions
Intrinsic quality	believability
Contextual quality	relevance, timeliness, originality, completeness
Representational quality	understandability1, understandability2, conciseness
Accessibility quality	navigational tools

Specifying the Measurement Method of the Information Quality of the Web Sites

The measurement method of the information quality of the content-based Web sites that we define is like a multi-person multicriteria decision-making method in which the search alternatives are Web sites. In a multicriteria decision-making method 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 (Fodor & Roubens, 1994; Triantaphyllou, 2000). 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 information quality evaluations or recommendations for Web sites in order to select the Web sites that could better meet the user information needs, but as in a multicriteria decision context, we compute those values according to the assessments provided by a group of persons (Web visitors).

As is known, in multicriteria decision-making processes the chosen aggregation operator is a critical aspect that has a direct influence on the success of the decision process. 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; Yager, 1996; Yager & Kacprzyk, 1997). We do the same in our quality measurement method.

Characteristics. We have designed a measurement method to generate linguistic recommendations as a measure of the information quality of the Web sites that has two main characteristics:

1. It is a user-centered measurement method: The linguistic recommendations on the Web sites are obtained from individual linguistic judgments provided by the Web visitors rather than from assessments obtained objectively by means of the direct observation of the Web site characteristics.
2. It is a majority-guided measurement method: The linguistic recommendations are values representative of the majority of individual judgments provided by the Web visitors. The aggregation to compute the linguistic recommendations is developed by means of two new majority guided linguistic aggregation operators, the MLIOWA operator and the weighted MLIOWA operator, which additionally overcome the drawback of the classical majority guided aggregation operators to implement the concept of majority in the aggregation processes correctly.

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The quality measurement method. Suppose a general user is searching for information on the Web with respect to a specific interest topic and, at one stage, he/she finds a Web site that may store pertinent information. He/she decides to visit this Web site and inside, he/she finds an electronic document (in any electronic format) that apparently meets his/her information needs. Once the user has examined the document stored in the Web site, he/she is invited to provide his/her individual evaluation judgments on the quality dimensions of the evaluation scheme defined in the previous subsection. When several users have repeated this searching process, the quality measurement method can be applied.

Let us assume a set of content-based Web sites

$$\{Web_1, \ldots, Web_L\}$$

that store information in documents: i.e., each Web site Web_l contains a set of documents D_l. Web sites can be evaluated according to a set of distinct areas of interest or search topics

$$\{\mathcal{A}_1, \ldots, \mathcal{A}_M\}$$

It is important to outline that the proposed evaluation strategy of Web sites allows one to obtain a quality evaluation with respect to a given topic; this means that a visitor is asked to evaluate qualitatively a given site by taking into account the topic to which the documents examined refer. In this way, the same Web site can be distinctly evaluated with respect to distinct topics.

Let

$$\{e_1^{m,l}, \ldots, e_T^{m,l}\}$$

be a set of different visitors of Web_l who provided evaluation judgments on the nine quality evaluation dimensions of the evaluation scheme, i.e.,

$$\{q_1, \ldots, q_9\}$$

when the searched information about the search topic $\mathcal{A}_m$. As we said, the evaluation scheme is weighted, and therefore each dimension q_i is associated with a linguistic importance degree $I(q_i) \in S$. We consider that all quality dimensions of the evaluation scheme are important but not equally important. We can follow the criterion to assign high importance values to the quality dimensions related to the content of the Web site itself (those included in the first and second categories of the evaluation scheme) and importance values close to midterm $s_{T/2}$ to the remaining ones. In particular, the *relevance* should have a high importance.

Let $\{q_1^{t,m}, \ldots, q_9^{t,m}\}$ be a set of linguistic evaluation judgments ($q_i^{t,m} \in S$) provided by each visitor $e_t^{m,l}$ when he/she searched and found information relevant to the search topic $\mathcal{A}_m$ in the Web site Web_l. Then, on the basis of the user evaluation judgments, a linguistic quality evaluation $r_l^m \in S$ is generated on Web_l with respect to the search topic $\mathcal{A}_m$ by means of the application of MLIOWA operators in two steps:

1. Individual aggregation or aggregation per quality dimensions:

   Calculate for each visitor $e_t^{m,l}$ his/her individual linguistic recommendation $r_t^{m,l}$ by aggregating the evaluation judgments provided by the visitor on the quality dimensions by means of the weighted MLIOWA operator $\Phi_{Q_2}^I$ as

   $$r_t^{m,l} = \Phi_{Q_2}^I(I(q_1), q_1^{t,m}), \ldots, (I(q_9), q_9^{t,m})).$$

   Therefore, $r_t^{m,l}$ is a linguistic measure that represents the information quality of the Web site Web_l with respect to topic $\mathcal{A}_m$ according to the majority (represented by the fuzzy linguistic quantifier Q_2) of important linguistic evaluation judgments provided by the visitor $e_t^{m,l}$ on quality dimensions.
2. Collective aggregation or aggregation per visitors:
   Calculate for all visitors their collective linguistic recommendation $r^{m,l}$ by aggregating their respective individual recommendations by means of the MLIOWA operator Φ_{Q_1}

   $$r^{m,l} = \Phi_{Q_1}((u_1, r_1^{m,l}), \ldots, (u_T, r_T^{m,l})).$$

   In this case, $r^{m,l}$ is a measure that represents the informative quality of the Web site Web_l with respect to topic $\mathcal{A}_m$ according to the majority (represented by the fuzzy linguistic quantifier Q_2) of linguistic evaluation judgments provided by the majority (represented by the fuzzy linguistic quantifier Q_1) of visitors.

We can consider that each linguistic recommendation $r^{m,l}$ represents the information quality category of the Web_l with respect to the topic $\mathcal{A}_m$. When we characterize the information quality of all Web sites $\{Web_1, \ldots, Web_L\}$ with respect to a topic $\mathcal{A}_m$ we can establish a classification of Web sites that can be very useful in the information search processes on the World Wide Web.

Example

Suppose we want to measure the information quality of a Web site Web_l that has been visited by six visitors $\{e_1, e_2, \ldots, e_6\}$ when they searched information related to the topic A_1 = *information quality*.

Assuming the set of nine labels given in the section Fuzzy Computing with Words visitors provide linguistic evaluation judgments on the nine quality dimensions shown in Table 2.

Then, applying the measurement method, we obtain the linguistic recommendation on Web_l as follows:

1. Individual aggregation or aggregation per quality dimensions:

Assuming the linguistic importance degrees associated with the information quality dimensions given in Table 3, the linguistic quantifier Q_2 = *most of* defined by the parameters (0.3, 0.8), and using the weighted MLIOWA operator $\Phi_{Q_2}^I$ with $\alpha = 1$ we obtain the individual linguistic recommendations shown in Table 4.

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TABLE 2. Linguistic evaluation judgments.

	e_1	e_2	e_3	e_4	e_5	e_6
q_1	L	M	H	EL	EH	T
q_2	M	VH	EH	L	H	T
q_3	VH	M	VH	M	VH	EH
q_4	H	VH	VH	M	H	VH
q_5	VL	EH	M	L	VH	VH
q_6	EH	T	M	L	VH	H
q_7	T	T	M	M	EH	EH
q_8	VH	EH	H	M	H	EH
q_9	VH	VH	VH	M	H	EH

TABLE 3. Linguistic importance degrees.

	$I(q_i)$
q_1	EH
q_2	T
q_3	EH
q_4	VH
q_5	VH
q_6	VH
q_7	H
q_8	L
q_9	L

TABLE 4. Individual linguistic recommendations.

$r_1^{1,l}$	$r_2^{1,l}$	$r_3^{1,l}$	$r_4^{1,l}$	$r_5^{1,l}$	$r_6^{1,l}$
M	VH	H	L	VH	EH

TABLE 5. Order inducing values.

$I(q_i)$	sup_i	$u_i(I(q_i))$
EH	6	6.5
T	3	5.5
EH	5	6
VH	5	5.5
VH	5	5.5
VH	5	5.5
H	4	4.5
L	2	2.5
L	2	2.5

For example, the individual linguistic recommendation $r_5^{1,l}$ is obtained from the following expression:

$$r_5^{1,l} = \Phi^I_{Q_2}((EH, EH), (T, H), (EH, VH), (VH, H), (VH, VH), (VH, VH), (H, EH), (L, H), (L, H)) = VH$$

To develop this expression it is necessary to calculate the order inducing values u_i associated to the linguistic importance degrees $I(q_i)$. The results are shown in Table 5.

Then, the induced ordering among linguistic evaluation judgments to be aggregated is

$$(q_8^{t,1}, q_9^{t,1}, q_7^{t,1}, q_2^{t,1}, q_4^{t,1}, q_5^{t,1}, q_6^{t,1}, q_3^{t,1}, q_1^{t,1})$$

Consequently, the weighting vector used in the aggregation of $\Phi^I_{Q_2}$ is

$$W = (0, 0, 0.02, 0.15, 0.15, 0.15, 0.15, 0.18, 0.2)$$

where, for example,

$$w_1 = Q_2\left(\frac{2.5}{9}\right) \Big/ \sum Q_2\left(\frac{u_i(I(q_i))}{9}\right) = \frac{0}{4.14} = 0$$

and

$$w_8 = Q_2\left(\frac{6}{9}\right) \Big/ \sum Q_2\left(\frac{u_i(I(q_i))}{9}\right) = \frac{0.72}{4.14} = 0.18$$

Using this weighting vector the linguistic individual recommendation $r_5^{m,1} = VH = s_6$ is obtained from the ordered linguistic evaluation judgments provided by e_5 (see Table 6) as

$$round(5 * 0 + 5 * 0 + 7 * 0.02 + 5 * 0.15 + 5 * 0.15 + 6 * 0.15 + 6 * 0.15 + 6 * 0.18 + 7 * 0.2) = round(5.92) = 6$$

2. Collective aggregation or aggregation per visitors:

Calculate collective linguistic recommendation $r^{1,l}$ by aggregating the linguistic individual recommendations given in Table 4 by means of the MLIOWA operator Φ_{Q_1}, assuming $Q_1 = Q_2$ and also $\alpha = 1$:

$$r^{1,l} = \Phi_{Q_1}((u_1, M), (u_2, VH), (u_3, H), (u_4, L), (u_5, VH), (u_6, EH)) = \Phi_{Q_1}((3, M), (4, VH), (5, H), (2, L), (4, VH), (3, EH))$$

As the induced ordering on the linguistic individual recommendations by the values u_i is

$$(r_4^{1,l}, r_1^{1,l}, r_6^{1,l}, r_2^{1,l}, r_5^{1,l}, r_3^{1,l})$$

then the weighting vector used in the computation of Φ_{Q_1} is

$$W = (0.02, 0.12, 0.12, 0.22, 0.22, 0.3)$$

where, for example,

$$w_1 = Q_1\left(\frac{2}{6}\right) \Big/ \sum Q_1\left(\frac{u_i}{6}\right) = \frac{2}{3.3} = 0.02$$

and

$$w_6 = Q_1\left(\frac{5}{6}\right) \Big/ \sum Q_1\left(\frac{u_i}{6}\right) = \frac{5}{3.3} = 0.3$$

TABLE 6. Ordered evaluation judgments provided by e_5.

$q_8^{5,1}$	$q_9^{5,1}$	$q_7^{5,1}$	$q_2^{5,1}$	$q_4^{5,1}$	$q_5^{5,1}$	$q_6^{5,1}$	$q_3^{5,1}$	$q_1^{5,1}$
H	H	EH	H	H	VH	VH	VH	EH

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TABLE 7. Ordered individual recommendations.

$r_4^{1,l}$	$r_1^{1,l}$	$r_6^{1,l}$	$r_2^{1,l}$	$r_5^{1,l}$	$r_3^{1,l}$
L	M	EH	VH	VH	H

Using this weighting vector the linguistic collective recommendation $r^{1,l} = VH = s_6$ is obtained from the ordered linguistic individual recommendations (see Table 7) as

$$round(3 * 0.02 + 4 * 0.12 + 7 * 0.12 + 6 * 0.22 + 6 * 0.22 + 5 * 0.3) = round(5.52) = 6$$

Discussion

In this section we analyze some possible applications, drawbacks, and advantages of the proposed qualitative evaluation methodology of content-based Web sites. We also outline some possible improvements.

Applications

This methodology of evaluation of the information quality of content-based Web sites is useful in information search processes on the World Wide Web when it is embedded in the systems used to access and retrieve information: search engines and filtering systems.

1. In search engines: The use of search engines is helpful but usually yields too many results (links to Web sites), most of which are loosely related to the actual interest of the user. The choice of appropriate queries to search engines is crucial, but in any case the user is still required to browse directly through all the suggested pages in order to find the desired ones. In this framework the application of the proposed evaluation methodology can provide users with useful recommendations on the Web sites that could guide their browsing processes.
2. In filtering systems: The purpose of these systems is to learn the user's interests and provide her/him with suggestions of interesting Web sites or pages without the existence of a previous user query. An important variant of filtering systems, applied in e-commerce, are called *collaborative recommender systems* (Reisnick & Varian, 1997). These collect ratings of items from many individuals and make recommendations based on those ratings to a given user. Our evaluation methodology can be embedded in a collaborative recommender system to generate recommendations.

On the other hand, we have proposed this Web quality evaluation methodology as a way to help users to search information on the World Wide Web: i.e., it is only user oriented. However, if we redefine the measurement method we can add the quality to be designer oriented. To do that, the measurement method would be as follows:

1. *Aggregation per individual quality dimension:* Calculate for each quality dimension q_i a linguistic collective evaluation judgment $q_i^{c,m}$ by aggregating the evaluation judgments provided by all visitors on that quality dimension by means of the MLIOWA operator Φ_{Q_1} as

$$q_i^{c,m} = \Phi_{Q_1}((u_1, q_i^{1,m}), \ldots, (u_T, q_i^{T,m}))$$

   Therefore, $q_i^{c,m}$ is a linguistic measure that represents the information quality of the Web site Web_l with respect to topic $\mathcal{A}_m$ according to the majority (represented by the fuzzy linguistic quantifier Q_1) of individual linguistic evaluation judgments provided by all visitors $e_t^{m,l}$ by considering only the quality dimension q_i. Therefore, this information quality value $q_i^{c,m}$ can be used by a designer to improve the elements of the Web site related to the considered quality dimension.
2. Aggregation per all quality dimensions: Calculate the linguistic collective recommendation $r^{m,l}$ by aggregating the linguistic collective evaluation judgments $q_i^{c,m}$ by means of the weighted MLIOWA operator $\Phi_{Q_2}^I$

$$r^{m,l} = Q_{Q_2}^I((I(q_1), q_1^{c,m}), \ldots, (I(q_9), q_9^{c,m}))$$

Drawbacks and Advantages

The main drawback of the proposed evaluation methodology is that it is strongly dependent on the degree to which users decide to participate by providing their opinions. The problem with asking people for the quality dimensions is that the cost, in terms of time and effort, of providing linguistic evaluation judgments generally outweighs the reward people will eventually receive. To provide evaluation judgments requires selflessness in users because the judgments provided will only help other people who are searching information. How users should be compensated for offering their opinions on quality dimensions is the question. This is a common problem with other Web technologies in which user participation is necessary, for example, recommender systems (Raghavan, 2004).

On the other hand, the main advantage of our evaluation methodology is that it is designed to facilitate user participation. Many Web quality evaluation approaches (Aladwani & Palvia, 2002; Huizingh, 2000; Katerattanakul & Siau, 1999; Mich, Franch, & Gaio 2003; Olsina & Rossi, 2002; Rieh, 2002) assume that user perceptions are necessary to measure the quality of Web sites, but they do not provide enough means to facilitate user participation and to represent and adequately exploit user evaluation judgments. In our evaluation methodology the user-driven evaluation scheme facilitates user participation; the fuzzy linguistic modeling is a good tool to represent user evaluation judgments, and the majority guided linguistic aggregation operators allow adequate use of the user evaluation judgments in order to generate the linguistic recommendations.

Additionally, as it happens with other quality evaluation methodologies (Aladwani & Palvia, 2002; Mich, Franch, &

Gaio, 2003; Olsina & Rossi, 2002), our evaluation methodology is domain independent and can be applied to diverse sectors, such as education, health, digital libraries, and health.

Improvements. The proposed evaluation methodology may be extended to include additional tools to improve the quality of the linguistic recommendations generated. For example, by incorporating user profiles the evaluation methodology can easily generate personalized linguistic recommendations. As is known, the tools of Web site personalization (Eirinaki & Vazirginannis, 2003) are being applied satisfactorily to improve the performance of the search engines and filtering systems because they allow customizing of the content and structure of a Web site to the specific and individual needs of each user. Therefore, in a similar way, we could include them in our evaluation methodology to achieve customized linguistic recommendations.

On the other hand, in our proposal we assume that Web visitors know perfectly the meaning of the linguistic scales used to provide the linguistic evaluation judgments that are expressed in English. However, this is not a realistic assumption because the World Wide Web is a multilanguage tool. Therefore, including in our methodology the possibility of using multilanguage linguistic scales could increase the Web user collaboration in our evaluation methodology. A possible approach could consist of the use of multigranular fuzzy linguistic modeling (Herrera-Viedma, Cordón, Luque, López, & Muñoz, 2003) to represent the linguistic evaluation judgments expressed in different languages.

Conclusions

Traditional methods aimed at controlling the quality of published information have been overcome by Web publishing, which promotes freedom of speech but not information quality.

The analysis of the quality of content-based Web sites focusing on the quality of information that they provide has rarely been studied. In this article, we have shown that this problem can be addressed by using the information quality framework defined for information systems (Huang, Lee, & Wang, 1999; Lee, Strong, Kahn, & Wang, 2002; Strong, Lee, & Wang, 1997; Wang & Strong, 1996).

A methodology has been presented to evaluate the information quality of content-based Web sites by means of fuzzy linguistic techniques. We have considered Web sites that provide information stored in electronic documents. This methodology is proposed to generate linguistic recommendations on such Web sites that can help other users in their future search processes. It is composed of two components, a user-driven evaluation scheme and a user-centered measurement method, to measure the information quality of Web sites. Therefore, this methodology is user oriented because it considers only user evaluation judgments to generate the recommendations. Considerable use is made of fuzzy set technology to provide the ability to describe the information by using linguistic label in a way that is particularly user friendly.

In the future, we propose to continue this research approach in several directions:

1. To improve the generation of recommendations by incorporating information on visitors that supply the evaluation judgments of the Web site, e.g., their levels of expertise in the search topic (specialists, knowledgeable, inexperienced people).
2. To implement a recommender system that incorporates the generation procedure of recommendations for structured documents (Herrera-Viedma & Peis, 2003) and that for Web sites presented in this article.
3. To design other evaluation instruments based on fuzzy linguistic techniques for other kinds of Web sites, e.g., commercial Web sites.
4. To redefine the evaluation approach of Web sites to create a feedback mechanism that can be used by the Web master to improve such design aspects as information content aspects of his/her Web site by considering the visitors' opinions.

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