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Evaluating the Informative Quality of Web Sites by Fuzzy Computing with Words

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Abstract. In this paper we present a method based on fuzzy computing with words to measure the informative quality of Web sites used to publish information stored in XML documents. This method generates linguistic recommendations on the informative quality of Web sites. This method is made up of both an evaluation scheme to analyze the informative quality of such Web sites and a generation method of linguistic recommendations. The evaluation scheme presents both technical criteria of Web site design and criteria related to the content of information of Web sites. It is oriented to the user because the chosen criteria are user friendly, in such a way that visitors to a Web site can assess them by means of linguistic evaluation judgements. The generation method generates linguistic recommendations of Web sites based on those linguistic evaluation judgements using the LOWA and LWA operators. Then, when a user looks for information on the Web we can help him/her with both recommendations on Web sites which store the retrieved documents and also recommendations on other Web sites which store other documents of interest related to his/her information needs. With this proposal information filtering and evaluation possibilities on the Web are increased.

1 Introduction

The networked world contains a vast amount of data. The exponential increase in Web sites and Web documents is contributing to Internet users not being able to find the information they require in a simple and efficient manner. There exists much debate on the quality of the information available on the Web, and how to recognize useful and quality information in an unregulated market place such as the Internet is becoming a serious problem. Therefore, users require tools to enable them to deal with the vast amount of content available on the Web [9, 10].

Recommender systems evaluate and filter the great amount of information available on the Web to assist people in their search process [13]. In a typical recommender system people provide evaluation judgements or annotations about documents as inputs, which the system then aggregates obtaining recommendations that are stored. Later, these recommendations can be reused to assist other people in their search process. In this sense, recommendations are a kind of plausible measure of the informative quality of Web documents. However, the

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importance of Web sites that provide information should not be underestimated. Therefore, an interesting proposal to improve the performance of recommender systems also consists in generating recommendations on the informative quality of Web sites that store Web documents.

Usually, the quality of Web sites is measured using criteria focused on the effective Web site design (e.g. clear ordering of information, consistent navigation structure, ...). However, from the information consumer's perspective the quality of a Web site may not be assessed independently of the quality of the information content that it provides. The evaluation of Web sites focusing on the quality of the information that it provides is a difficult task that has rarely been studied [12]. In [8] an evaluation scheme of the information quality for analyzing personal Web sites which combines both informative and technical design aspects was proposed. This model is based on the *information quality framework* for the design of information systems defined in [7,11,14,15].

On the other hand, in typical recommender systems is assumed that people express their evaluation judgements by means of numerical values [13]. Sometimes, a person cannot express his/her judgements with an exact numerical value. Then, a more realistic approach may be to use linguistic assessments to express the evaluation judgements instead of numerical values. The *fuzzy linguistic approach* is a tool to manage linguistic information, which is based on the concept of *linguistic variables* [17]. It allows us to model qualitative values typical of human communication for representing qualitative concepts such as "importance" [4,5].

In this paper, we present an evaluation method of informative quality of the Web sites based on fuzzy linguistic techniques. This method allows us to generate linguistic recommendations on quality Web sites. We consider Web sites that have information stored in multiple kinds of documents structured in the XML-format, e.g. scientific articles, opinion articles,... The idea consists in evaluating a Web site according to the evaluations apported by all its visitors. After visiting a Web site to examine a stored document users are invited to complete an evaluation questionnaire about the informative quality of the site. Using the information quality framework proposed in [7,11,14,15], we develop a particular evaluation scheme of Web sites which is oriented to the user. This evaluation scheme considers both technical criteria of Web site design and criteria related to the information content of Web sites. The chosen criteria are easily comprehensible to the users such that Web visitors can easily assess them. Visitors provide their evaluation judgements by means of linguistic terms assessed on linguistic variables [17]. Given an area of interest, the recommendation of a Web site is obtained by combining the linguistic evaluation judgements provided by different visitors to the site. To do this, we use the operators for *fuzzy computing with words* LOWA [3] and LWA [2]. The recommendations obtained are linguistic values that express qualitatively the informative quality of the Web site with respect to the area of interest. Then, when a user requires information together with retrieved documents we can also provide him/her with both recommendations on the informative quality of Web sites that store these documents and

recommendations on other Web sites that could store other documents of interest. In such a way, the filtering of information and evaluation possibilities in the Web are increased.

The paper is set out as follows. The foundation of fuzzy computing with words is presented in Sect. 2. The evaluation scheme for analyzing the informative quality of Web sites is defined in Sect. 3. The generation method of linguistic recommendations is defined in Sect. 4. Finally, in Sect. 5 we present our conclusions.

2 Foundation of Fuzzy Computing with Words

The *ordinal fuzzy linguistic approach* [2,3] is a very useful kind of fuzzy linguistic approach used for modeling the computing with words process as well as linguistic aspects of problems. 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 $i \geq j$, and with odd cardinality (7 or 9 labels). The mid term represents an assessment of "approximately 0.5", and the rest of the terms being placed symmetrically around it. The semantics of the label set is established from the ordered structure of the label set by considering that each label for 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: $\{T = Total, EH = Extremely\_High, VH = Very\_High, H = High, M = Medium, L = Low, VL = Very\_Low, EL = Extremely\_Low, N = None\}$.

In any linguistic approach we need management operators of linguistic information. An advantage of the ordinal fuzzy linguistic approach is the simplicity and quickness of its computational model. It is based on the symbolic computation [2,3] and acts by direct computation on labels by taking into account the order of such linguistic assessments in the ordered structure of labels. Usually, the ordinal fuzzy linguistic model for computing with words is defined by establishing i) a negation operator, ii) comparison operators based on the ordered structure of linguistic terms, and iii) adequate aggregation operators of ordinal fuzzy linguistic information. In most ordinal fuzzy linguistic approaches the negation operator is defined from the semantics associated to the linguistic terms as $Neg(s_i) = s_j \mid j = \mathcal{T} - i$; and there are defined two comparison operators of linguistic terms: i) *Maximization operator*, $MAX(s_i, s_j) = s_i$ if $s_i \geq s_j$; and ii) *Minimization operator*, $MIN(s_i, s_j) = s_i$ if $s_i \leq s_j$. In the following subsections, we present two operators based on symbolic computation.

2.1 The LOWA Operator

The *Linguistic Ordered Weighted Averaging* (LOWA) is an operator used to aggregate non-weighted ordinal linguistic information, i.e., linguistic information values with equal importance [3].

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 $\phi(a_1, \ldots, a_m) = W \cdot B^T = \mathcal{C}^m\{w_k, b_k, k =$*

$1,\ldots,m\} = w_1 \odot b_1 \oplus (1-w_1) \odot \mathcal{C}^{m-1}\{\beta_h, b_h, h = 2,\ldots,m\}$, *where* $W = [w_1,\ldots,w_m]$, *is a weighting vector, such that,* $w_i \in [0,1]$ *and* $\Sigma_i w_i = 1$. $\beta_h = w_h/\Sigma_2^m w_k, h = 2,\ldots,m$, *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.* $\mathcal{C}^m$ *is the convex combination operator of m labels and if m=2, then it is defined as* $\mathcal{C}^2\{w_i, b_i, i = 1,2\} = w_1 \odot s_j \oplus (1-w_1) \odot s_i = s_k$, *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:* $\mathcal{C}^m\{w_i, b_i, i = 1,\ldots,m\} = b_j$.

The LOWA operator is an "or-and" operator [3] and its behavior can be controlled by means of W. In order to classify OWA operators in regard to their localisation between "or" and "and", Yager [16] introduced a measure of *orness*, associated with any vector W:$orness(W) = \frac{1}{m-1}\sum_{i=1}^{m}(m-i)w_i$. This measure characterizes the degree to which the aggregation is like an "or" (MAX) operation. Note that an OWA operator with $orness(W) \geq 0.5$ will be an *orlike*, and with $orness(W) < 0.5$ will be an *andlike* operator.

An important question of the OWA operator is the determination of W. A good solution consists of representing the concept of *fuzzy majority* by means of the weights of W, using a *non-decreasing proportional fuzzy linguistic quantifier* [18]Q in its computation [16]:$w_i = Q(i/m) - Q((i-1)/m), i = 1,\ldots,m$, being the membership function of Q: $Q(r) = \begin{cases} 0 & \text{if } r < a \\ \frac{r-a}{b-a} & \text{if } a \leq r \leq b \\ 1 & \text{if } r > b \end{cases}$ with $a, b, r \in [0,1]$.

When a fuzzy linguistic quantifier Q is used to compute the weights of LOWA operator, ϕ, it is symbolized by ϕ_Q.

2.2 The LWA Operator

The *Linguistic Weighted Averaging* (LWA) operator is another important operator which is defined to aggregate weighted ordinal linguistic information, i.e., linguistic information values with non equal importance [2].

Definition 2. *The aggregation of a set of weighted linguistic opinions,* $\{(c_1,a_1),\ldots,(c_m,a_m,)\}$, $c_i, a_i \in S$, *according to the LWA operator* Φ *is defined as* $\Phi[(c_1,a_1),\ldots,(c_m,a_m)] = \phi(h(c_1,a_1),\ldots,h(c_m,a_m))$, *where* a_i *represents the weighted opinion,* c_i *the importance degree of* a_i, *and* h *is the transformation function defined depending on the weighting vector* W *used for the LOWA operator* ϕ, *such that,* $h = MIN(c_i,a_i)$ *if* $orness(W) \geq 0.5$ *and* $h = MAX(Neg(c_i),a_i)$ *if* $orness(W) < 0.5$.

3 Evaluation Scheme of Informative Quality of Web Sites

3.1 Brief Background about Information Quality Framework

In [7,11,14,15] it was proposed an information quality framework by considering that the quality of the information systems cannot be assessed independently of

the information consumers' opinions (people who use information). This framework establishes four major information quality categories to classify the different evaluation dimensions [7,11,14,15]:

1. *Intrinsic information quality*, which emphasizes the importance of the informative aspects of the information itself. It implies that information has quality in its own right. The main dimension of this category 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 will result in a reduction of use. Other dimensions of this category are: believability, reputation and objectivity.
2. *Contextual information quality,* which also emphasizes the importance of the informative aspects of the information but from a task perspective. It highlights the requirement that information quality must be considered within the context of the task in 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, some dimensions of this category are: value-added, relevance, completeness, timeliness, appropriate amount.
3. *Representational information quality,* which emphasizes the importance of the technical aspects of the computer system that stores the information. It requires information systems to present their information in such a way that it is interpretable, easy to understand, easy to manipulate, and is represented concisely and consistently. Some of its dimensions are: understandability, interpretability, concise representation, consistent representation.
4. *Accessibility information quality,* which emphasizes the importance of the technical aspects of the computer system that provides access to information. It requires the information system to be accessible but secure. Some dimensions of this category are: accessibility and secure access.

Using this quality framework, in [8] a tool to evaluate the informative quality of personal Web sites was proposed, which includes the following dimensions:

1. *Intrinsic quality of Personal Web sites:* i) accuracy and errors of the content, and ii) accurate, workable and relevant hyperlinks.
2. *Contextual quality of Personal Web sites:* provision of author's information.
3. *Representational quality of Personal Web sites:* i) organization, visual settings, typographical features, and consistency, ii) vividness and attractiveness, and iii) confusion of the content.
4. *Accessibility quality of Personal Web sites:* navigational tools provided.

3.2 Definition of the Evaluation Scheme of Documental Web Sites

Using the above information quality framework we develop an evaluation scheme for analyzing the informative quality of Web sites that provide information stored in XML documents. It is defined from the information consumers' perspective, and for this reason we can say that it is oriented to the user. Before presenting

it, we will take into account two considerations: i) We want to generate recommendations on Web sites from the evaluations provided by different visitors to Web sites. Therefore, the evaluation scheme requires the inclusion of subjective dimensions easily comprehensible to the information consumers (e.g. relevance, understandability) rather than dimensions that can be objectively measured independently of the consumers (e.g. accuracy measured by the number of spelling or grammatical errors). And ii) we analyze Web sites that store information in multiple kinds of documents structured in the XML format (e.g. scientific articles, opinion articles) when users visit them occasionally because they store documents which meet their information needs. Therefore, user opinions on the informative quality of these documents (e.g. the relevance) must be an important dimension in the evaluation scheme. Taking into account these considerations, we define an evaluation scheme of Web sites oriented to the user that contemplates four quality categories with the following evaluation 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 that the Web site provides. Given that we consider Web sites as information sources that are visited occasionally, we are not interested in evaluating the accuracy by means of grammatical and spelling errors or relevant hyper-links existing on 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, as in [8], nor the appropriate amount of information are meaningful. We propose to evaluate this category by considering what visitors think about the relevancy, timeliness and completeness of documents that the Web site provides them with when they search for information about particular topic, i.e., if documents are relevant to the search topic, if documents are sufficiently current and up-to-date with regards to the search topic, and if documents are sufficient complete with regards to the topic.
3. *Representational quality of Web sites.* We analyze this category for the Web sites that provide information stored in XML documents from two aspects: i) representational aspects of Web site design and ii) representational aspects of documents stored in the Web site. In the first case, we consider what visitors think about the understandability of the Web site, i.e., whether or not the Web site is well organized in such a way that visitors can easily understand how to access stored documents. In the second one, we consider what visitors think about the understandability, originality and conciseness of the information content of XML documents used.
4. *Accessibility quality of Web sites.* As in [8] we consider that this category must be assessed as to whether or not the Web site provides enough navigation mechanisms so that visitors can reach their desired documents faster and easier. Lacking effective paths to access the desired documents would handicap visitors, therefore navigation tools are necessary to help users locate the information they require. We evaluate this category by considering

what visitors think about the navigational tools of the Web site. The security dimension is not a key aspect on the Web sites that we are considering.

The evaluation scheme is summarized in Table 1.

Table 1. Evaluation scheme of Web sites oriented to the user

Information Quality Categories	Evaluation Dimensions
Intrinsic quality of Web sites	believability
Contextual quality of Web sites	relevancy, timeliness, completeness
Representational quality of Web sites	understandability of Web sites, originality, understandability of documents, conciseness
Accessibility quality of Web sites	navigational tools

4 Evaluating the Informative Quality of Web Sites

In this section, we present a generation method of linguistic recommendations for evaluating the informative quality of Web sites. These linguistic recommendations are obtained from the linguistic evaluation judgements provided by a non-determined number of Web visitors. After a visitor has used an XML document stored in a Web site, he/she is invited to complete a quality evaluation questionnaire as per the quality dimensions established in the above evaluation scheme. The recommendations are obtained by aggregating the linguistic evaluation judgements by means of the LWA and LOWA operators.

4.1 Development of the Quality Evaluation Questionnaire

The quality evaluation questionnaire provides questions for each one of the dimensions proposed in the evaluation scheme, i.e., there are nine questions: $\{q_1, \ldots, q_9\}$. For example for the quality dimension *believability* the question q_1 can be: "What is the degree of believability of this Web site in your opinion?". The concept behind each question is rated on a linguistic term set S. For example, we can use the set of nine linguistic terms proposed in Sect. 2 to rate all the questions. Furthermore, we assume that each quality dimension does not have the same importance in the evaluation scheme, i.e., it is assigned a relative linguistic importance degree for each quality dimension: $\{I(q_1), \ldots, I(q_9)\},\ I(q_i) \in S$. To

assign these degrees, the quality dimensions related to the Web site content itself (those included in the first and second category of evaluation scheme) should have more importance than the remaining ones. In particular, the *relevancy* has the greatest degree of relative importance.

As we pointed out in Sect. 3.2 and in the above paragraph, the question $q_2 = relevancy$ is very important in our evaluation scheme. For this reason, we propose to evaluate the relevance of the XML documents provided by the Web site for a particular search topic in a more meticulous way. We do not evaluate it directly by means of a particular value supplied by a user. The idea consists in evaluating it from the evaluation of the relevance of the parts that make up the structure of XML documents. To do so, we associate with each XML document an evaluation questionnaire of relevance that depends on the kind of document. For example, if the XML document is a "scientific article" with the DTD,

<!DOCTYPE article [
<!ELEMENT article (title, authors, abstract?, introduction, body, conclusions, bibliography)>
<!ELEMENT title (#PCDATA)>
<!ELEMENT authors (author+)>
<!ELEMENT (author | abstract | introduction) (#PCDATA)>
<!ELEMENT body (section+)>
<!ELEMENT section (titleS, #PCDATA)>
<!ELEMENT titleS (#PCDATA)>
<!ELEMENT conclusions (#PCDATA)>
<!ELEMENT bibliography (bibitem+)>
<!ELEMENT bibitem (#PCDATA)>]

then, we can establish the relevance evaluation questionnaire on the following set of elements of DTD : "title, authors, abstract, introduction, body, conclusions, bibliography". In this case, the relevance evaluation questionnaire would have 7 questions, and for example, a question could be "What is the relevance degree of the title with respect to the search topic?". In other kinds of XML documents we have to choose the set of elements of DTD, $\{p_1, \ldots, p_n\}$, to be considered in the relevance evaluation questionnaire. We assume that each component p_k has a distinct informative role, i.e., each one affects the overall relevance evaluation of XML document in a different way. This is modeled by assigning to each p_k a relative linguistic importance degree $I(p_k) \in S$. As we did in [6], this peculiarity is added in the DTD using the XML syntax [1] to define an attribute of importance "rank" for each meaningful component of DTD, which contains a relative linguistic importance degree. Then, given a search topic (e.g. "recommender systems"), the relevance for an XML document is obtained by combining the linguistic evaluation judgements provided by the visitor regarding the meaningful components of its DTD.

Summarizing, the quality evaluation questionnaire that a visitor must complete is comprised of 8 questions and a relevance evaluation questionnaire which is associated with the document accessed and depends on the kind of document.

4.2 Generation Method of Linguistic Recommendations

Suppose that we want to generate a recommendation database for qualifying the informative quality of a set of Web sites $\{Web_1, \ldots, Web_L\}$ which stores information in XML documents. These Web sites can be evaluated from a set of different areas of interest or search topics, $\{\mathcal{A}_1, \ldots, \mathcal{A}_M\}$. Suppose that D_l represents the set of XML documents stored in the Web site Web_l. We consider that each XML document $d_j \in D_l$ presents an evaluation scheme composed of a finite set of elements of its DTD, $\{p_1, \ldots, p_n\}$, and its respective relative linguistic importance degrees $\{I(p_1), \ldots, I(p_n)\}$. Let $\{e_1^{m,l}, \ldots, e_T^{m,l}\}$ be the set of different visitors to the Web site Web_l who completed the quality evaluation questionnaire $\{q_1, \ldots, q_9\}$ when they searched for information about the topic $\mathcal{A}_m$. In the quality evaluation scheme each question q_i is associated to its respective linguistic importance degree $I(q_i)$. Let $\{q_1^t, \ldots, q_9^t\}$ be a set of linguistic assessments provided by the visitor $e_t^{m,l}$. We must point out that the assessment q_8^t is achieved from the set of linguistic evaluation judgements $\{e_{t1}^{ml}, \ldots, e_{tn}^{ml}\}$ provided by the visitor $e_t^{m,l}$ regarding the set of elements of DTD, $\{p_1, \ldots, p_n\}$, associated to the XML document accessed d_j. Then, q_8^t is obtained using the LWA operator as follows: $q_8^t = \Phi[(I(p_1), e_{t1}^{ml}), \ldots, (I(p_n), e_{tn}^{ml})] = \phi_{Q_3}(h(I(p_1), e_{t1}^{ml}), \ldots, h(I(p_n), e_{tn}^{ml}))$, being Q_3 the linguistic quantifier used to calculate the weighting vector W. If we assume that Q_3 represents the concept of fuzzy majority then q_8^t is a measure of significance that represents the relevance of d_j with respect to the topic A_l according to Q_3 linguistic evaluation judgements provided by $e_t^{m,l}$ on the meaningful elements of DTD associated with d_j. Then, given a search topic $\mathcal{A}_m$, the generation process of a linguistic recommendation $r_l^m \in S$ for a Web site Web_l is obtained using a LWA-LOWA based evaluation method in the following steps:

1. Calculate for $e_t^{m,l}$ his/her individual recommendation $r_t^{m,l}$ by means of LWA Φ: $r_t^{m,l} = \Phi[(I(q_1), q_1^t), \ldots, (I(q_9), q_9^t)] = \phi_{Q_2}(h(I(q_1), q_1^t), \ldots, h(I(q_9), q_9^t))$. $r_t^{m,l}$ is a measure that represents the informative quality of the Web site Web_l with respect to topic $\mathcal{A}_m$ according to the Q_2 linguistic evaluation judgements provided by the visitor $e_t^{m,l}$.
2. Calculate the global recommendation $r^{m,l}$ by means of an LOWA operator guided by the fuzzy majority concept represented by a linguistic quantifier Q_1 as $r_t^i = \phi_{Q_1}(r_1^{m,l}, \ldots, r_T^{m,l})$. 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 Q_2 evaluation judgements provided by the Q_1 visitors or recommenders. $r^{m,l}$ represents the linguistic informative category of Web_l with respect to the topic $\mathcal{A}_m$.
3. Store the recommendation $r^{m,l}$ in order to assist user future search processes.

5 Conclusions

The analysis of the quality of Web sites focusing on the quality of information that they provide has rarely been studied. In this paper, we have shown that

this problem can be studied using an information quality framework defined for information systems [7]. We have presented an approach to evaluate the informative quality of Web sites by means of fuzzy linguistic techniques. We consider Web sites that provide information structured in XML documents. This approach is proposed to generate linguistic recommendations on such Web sites that can help other users in their future search processes. In this approach we have defined an evaluation scheme and an evaluation method to measure the informative quality of Web sites. This approach is a user oriented approach because it considers only the visitors' evaluation judgements to generate the recommendations. Considerable use is made of fuzzy set technology to provide the ability to describe the information in a way, using linguistic labels, that is particularly user friendly.

In the future, we propose to continue this research approach by designing other evaluation tools based on fuzzy linguistic techniques for other kinds of Web sites, e.g., commercial Web sites.

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