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A fuzzy linguistic model to evaluate the quality of Web sites that store XML documents

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Abstract

The development of tools to find quality information on the Web is currently a pressing need. The aim of this paper is to present an evaluation model based on fuzzy computing with words to measure the information quality of Web sites that store XML (*eXtensible Markup Language*) documents. This model evaluates the information quality of Web sites using only users' perceptions, and therefore it is user-centered. Fuzzy linguistic techniques are involved in the quality evaluation process to create a user-friendly framework. This model is composed of two main components, an evaluation scheme to analyze the information quality of Web sites and a computing method of quality ratings of Web sites. The evaluation scheme presents both technical criteria related to the Web site characteristics, and criteria related to the content of XML documents stored in the Web sites. The quality ratings represent the ability of Web sites to meet user requirements. Linguistic quality ratings are obtained by combining linguistic evaluation judgements provided by Web visitors on the different evaluation criteria. The computing method is based on two operators for fuzzy computing with words, the LOWA (*Linguistic Ordered Weighted Averaging*) operator and the LWA (*Linguistic Weighted Averaging*) operator. The later allows to manage relative importance degrees among quality criteria in the evaluation process. This model uses the power of XML Schema language to improve the representation of documents in the Web with semantic characteristics related to their quality and thus it is useful to search quality resources in XML format. Web site quality ratings could be used by Web retrieval systems to help users to find the highest quality XML resources for their information needs. Additionally, this model could be helpful to Web developers to improve the quality of Web sites from a user's point of view.

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1. Introduction

Over the last years, the amount of information available in the Web has been increasing at an explosive rate. Usually, the World Wide Web (WWW or Web) contains hundreds of interconnected pages/sites of widely varying quality for any user query. Therefore, techniques are needed to enable users to deal with this vast amount of Web information [27,28]. However, the main challenge when dealing with the Web is not necessarily its vast amount of information. Other real and important challenges nowadays are: to give personalized information retrieval, to control the spamming, to evaluate the quality of Web resources, to find high-quality information in the Web, etc. In this work, we focus on the problem of quality evaluation in the Web.

The Web can be defined as an information market [6] used by thousands of information consumers to satisfy their information needs. Generally, finding information related to a given interest is easy. The problem is that most current Web retrieval systems provide information to a consumer that is not always quality information. Nowadays, information consumers demand relevant and high-quality information. However, the Web is an unregulated information market and it is not easy to identify and find useful and high-quality information [37]. Furthermore, as it is pointed out in [14], "*well-founded and practical approaches to assess or even guarantee a required degree of the quality of data on the Web are still missing*". Due to the heterogeneity of the Web it is very difficult to define a general approach of Web quality evaluation. Hence, different made-to-measure approaches have been proposed to evaluate the quality on different Web resources. Among these we can cite evaluation models on quality of Web portals of organizations [49], quality of cultural Web sites [10], quality of SGML (*Standard Generalized Markup Language*) documents [13,20], quality of mobile Internet services [8], quality of personal Web sites [25], quality of Web applications [34,35], quality of tourist Web sites [30], quality of e-commerce [2,33], quality of health Web sites [3,39]. In the case of Web sites, evaluation models of the quality of Web sites have been designed by following two different approaches: (i) the use of ad-hoc models [1,3,39] or (ii) the use of well-known models which are being successfully applied in other fields, as done for example by Luis Olsina et. al. in [34,35] where they used the quality evaluation framework for software development or by other authors in [8,25] where their models were based on the information quality framework for information systems proposed in [24,29,42,45]. In this work, we address the quality of content-based Web sites used to store and provide information, as it could be for example the Web site of a research department in a university, and use the quality information framework defined in [24,29,42,45] as reference framework.

Based on the ISO standard three different views to evaluate the quality of Web sites are identified [30,35,40]: users' view, developers' view and manager's view. The first one evaluates the quality based on the use of the Web site, i.e., the quality of service offered by the Web site [1–3,39,8,34,35,53], which is an external quality perspective [40]. In this case, users' participation in the evaluation processes is required and their evaluation judgements are used to derive quality ratings of the Web sites. The aim of Web quality approaches based on the users' view is to help them in finding high-quality Web services. Additionally, site features that contribute to the user satisfaction or dissatisfaction and customer loyalty [8] can also be identified, and therefore these approaches can be reused to help Web developers to improve quality of Web sites [1,8,34,35]. The developers' view approach evaluates the quality based on implementation characteristics of the Web site, such as functionality, efficiency, maintainability, portability [10]. The aim of this approach is to help developers to redesign Web sites. The managers' view approach evaluates the quality of Web sites based on economic criteria such as cost or productivity. These last two approaches draw an internal quality perspective [40]. They do not require the participation of general users, that is, quality ratings are obtained by heuristic procedures guided by specialist users in order to identify specific software problems of the Web site. Obviously, manager's or developer's goals are quite different to the user's goals and therefore the combination of the three views in one model could be contradictory. Although both managers' and developers' view approaches are important in order to evaluate the quality of Web sites, we must point out that because the main objective of a Web site is to attend users and the users' view approach is the most important one when evaluating the quality of Web sites. In this work we design tools for evaluating the information quality of content-based Web sites to help users to find high-quality information and thus the use of a user's view based approach is necessary. An important aspect of the user's view based approach is the modelling of users' opinions which are normally qualitative nature. We propose to use the fuzzy linguistic modelling [7,16–18,21,50] to represent users' perceptions and to manage the quality ratings. In such a way, we build a flexible and formal framework to work with the qualitative information provided by the users.

In ISO norms (ISO 8402, 1991) [22] the concept of quality is defined as "*the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs*." Based on this definition, the quality of a content-based Web site should be related to set of characteristics that reflect how well it meets the user information needs, and therefore, it should be associated with user satisfaction and external quality criteria. According to [41] there are three factors affecting the way a user perceives and valuates a content-based Web site: content, Web page design, and overall site design. The first factor concerns the information offered by the site, the other factors concern the way in which the site makes content accessible and understandable to its users. Consequently, we identify two types of external characteristics to evaluate the quality of a content-based Web site: (i) technical characteristics related to the design of the Web site (e.g. site structure, layout of web pages, multilingualism, navigation tools, user interface, etc.) and (ii) content characteristics related to the quality of the information content that it provides (e.g. relevance, believability, completeness).

It is well known that most information is represented on the Web by means of HTML pages [46]. In [20] a quality evaluation model of SGML documents based on fuzzy linguistic modelling was proposed. However, this model is not easily exportable to HTML documents due to the functional simplicity of HTML. Nowadays, we observe an evolution of the Web towards a more functional, richer XML based structure. XML is rapidly becoming the Web standard for data representation and exchange [44]. XML is a simple, very flexible text format derived from SGML and intended to make it more usable for distributing materials on the Web [15]. The use of markup languages like XML helps preserve Web device independence, allows content reuse and could improve the activity of multiagent systems [27,28]. XML is characterized by interoperatibility, ease of use, and extensibility, and allows to improve the representation of Web resources. For example in the case of Web documents, XML allows us to describe the content of documents, but also to include new metadata to store information quality assessments (even linked to different quality evaluation schemes) that could be used in future information retrieval processes on the Web. This can be done using XML Schema language [43]. XML Schema language provides enhanced as well as more comprehensive and powerful features than a document type definition (DTD), the traditional mechanism used to describe the structure and content of XML documents.

The aim of this paper is to present a fuzzy linguistic model to evaluate the information quality of Web sites that store XML documents using XML Schemas. This model will allow us to generate quality ratings of the Web sites that have information stored in multiple kinds of XML documents, e.g. scientific articles, opinion articles, etc. In most quality evaluation approaches of Web sites there is no clear distinction between page and site quality [40]. We assume that a Web site is an organized collection of Web pages that store information on one or more interest topics, and include this distinction in our model. The idea consists in evaluating a Web site according to the judgements supplied by all its visitors. After visiting a Web site to examine a stored document the users are invited to complete an evaluation questionnaire on the information quality of the site. Using the information quality framework for information systems proposed in [24,29,42,45], 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 and therefore Web visitors can easily assess them. Visitors provide their evaluation judgements by means of linguistic terms assessed on linguistic variables [50]. Given an area of interest, the quality rating of a Web site is obtained by combining the linguistic evaluation judgements provided by different visitors to the site. To do this, the two operators for fuzzy computing with words, the Linguistic Ordered Weighted Averaging (LOWA) operator [17] and the Linguistic Weighted Averaging (LWA) operator [16], are used. The later allows managing relative importance degrees among quality criteria in the evaluation process. Quality ratings will therefore be linguistic values that express qualitatively the information quality of the Web site with respect to the area of interest. These linguistic quality ratings are incorporated in the representation of Web documents using the power of the XML Schema language, and could be useful to search quality resources in XML format. Thus, when a user requires information the retrieved documents can be provided to him/her together with the associated quality ratings of the Web sites that store them, and in such a way, the users may find easier the highest quality XML resources for their information needs. Additionally, this model could be helpful to Web developers to improve the quality of Web sites from a user's point of view.

The paper is set out as follows. The foundation of fuzzy computing with words and the XML documents is reviewed in Section 2. A background on quality of Web sites is presented in Section 3. The fuzzy linguistic model to evaluate the information quality of Web sites is defined in Section 4. An analysis of its performance is shown in Section 5. Finally, in Section 6 we present our conclusions.

2. Preliminaries

In this section, we present the fuzzy tools that allow managing linguistic information and carry out the processes of fuzzy computing with words, and also the definition of the structure of XML documents that are stored in the Web sites to evaluate.

2.1. Tools for fuzzy computing with words

According to Zadeh [52] both linguistic aspects and computing with words processes of problems can be modelled using fuzzy linguistic techniques, being the ordinal approach a widely accepted one [16–18,21]. In this approach a finite and totally ordered label set $S = \{s_i\},\ i\,C\ \{0,\ldots,T\}$ in the usual sense, i.e., $s_i \geqslant s_j$ if $i \geqslant j$, and with odd cardinality (7 or 9 labels) is considered. The mid term represents an assessment of "approximately 0.5", and the rest of the terms are 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 (si, s_{T-i}) is equally informative. For example, we can use the following set of nine labels for the user to provide their evaluations: $\{T = Total,\ EH = Extremely\_High,$ $VH = Very\_High,\quad H = High,\ M = Medium,\ L = Low,\ VL = Very\_Low,\ EL = Extremely$ $Low,\ N = None\}$.

In any linguistic approach aggregation operators of linguistic information are needed. The main advantage of the fuzzy linguistic approach [16,17] when compared with other approaches resides in its simpler and faster computational model. This is based on the symbolic computation and therefore the computation on labels is done by taking into account their position in the ordered structure of labels. Usually, 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 linguistic information. The negation operator is defined from the semantics associated to the linguistic terms as $\mathrm{Neg}(s_i) = s_j | j = T - i$; while for comparison operators of linguistic terms the following two operators are defined: (i) Maximization operator, $\mathrm{MAX}(s_i, s_j) = s_i$ if $s_i \geqslant s_j$; and (ii) *Minimization operator*, $\mathrm{MIN}(s_i, s_j) = s_i$ if $s_i \leqslant s_j$.

In the following subsections, we present two aggregation operators to carry out processes of fuzzy computing with words which are based on symbolic computation

2.1.1. The LOWA operator

The LOWA (*Linguistic Ordered Weighted Averaging*) is an operator for fuzzy computing with words which is used to aggregate non-weighted linguistic information, i.e., linguistic information values with equal importance [17]. The LOWA operator is a recursive operator to combine linguistic information. It is based on the OWA operator [48] and the convex combination of linguistic labels [11], and it is defined as follows:

Definition 1. Let $A = \{a_1,\ldots,a_m\}$ be a set of labels to be aggregate. The LOWA operator, Φ, is defined as $\Phi(a_1,\ldots,a_m) = W \cdot B^{\mathrm{T}} = C^m\{w_k, b_k, k = 1,\ldots,m\} = w_1 \Theta b_1 \oplus (1 - w_1)\Theta$ $C^{m-1}\{\beta_h, b_h, h = 2,\ldots,m\}$, where

- Θ and $\oplus$ stand for the product of a real number by a label and the addition of labels, respectively.
- $W = [w_1,\ldots,w_m]$, is a weighting vector, such that, $w_i \in [0,1]$ and $\sum_i w_i = 1$.
- $\beta_h = w_h/(\sum_{k=2}^{m} w_k),\ h = 2,\ldots,m$, is the expression to compute the weighting vector W in each recursive step h.
- $B = \{b_1,\ldots,b_m\}$ is a non-increasing ordered vector associated to A, i.e., $b_j \leqslant b_i \forall i \leqslant j$ and

- C^m is the convex combination operator of m labels and if $m = 2$, then

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

with $k = \min\{T, i + round(w_1 \cdot (j - i))\}, s_j, s_i \in S, (j \geqslant i)$, being S the label set used to represent arguments a_j, $T + 1$ the cardinality of S, "round" 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 $C^m\{w_i, b_i,\ i = 1, \ldots, m\} = b_j$.

Like OWA operators [48], the LOWA operator is an "*or-and*" operator [17], i.e., its result is located between the maximum and minimum of the set of aggregated linguistic values. If $W^* = [1, 0, \ldots, 0]$ then $\Phi(a_1, \ldots, a_m) = \text{MAX}(a_1, \ldots, a_m)$, while if $W_* = [0, \ldots, 0, 1]$ then $\Phi(a_1, \ldots, a_m) = \text{MIN}(a_1, \ldots, a_m)$. We must point out that the aggregation behaviour of the LOWA operator can be controlled by means of the weighting vector W. In order to classify OWA operators in regard to their localisation between the *and* and *or operators*, Yager [48] introduced a measure of *orness* associated with any vector W, which is defined as

$$\text{orness}(W) = \frac{1}{m-1} \sum_{k=1}^{m} (m - k) w_k.$$

It can be easily shown that orness$(W^*) = 1$, while orness$(W_*) = 0$. Note that the closer the orness measure of W is to one, the nearer W is to the *or operator*; while the closer the orness measure of W is to zero the nearer W is to the *and operator*. Therefore, moving weight up W increases orness(W), while moving weight down W causes a decreasing in orness(W).

An important question of the LOWA operator is the determination of W. A possible solution consists of representing the concept of *fuzzy majority* by means of the weights of W, using a non-decreasing proportional *fuzzy linguistic quantifier* [51], Q, in its computation [48]: $w_i = Q(i/m) - Q((i-1)/m),\ i = 1, \ldots, m$, being the membership function of Q with definition parameters (a, b),

$$Q(r) = \begin{cases} 0 & \text{if } r < a \\ \frac{r-a}{b-a} & \text{if } a \leqslant r \leqslant b \\ 1 & \text{if } r > b \end{cases}$$

with $a, b, r \in [0, 1]$. Some examples of non-decreasing proportional fuzzy linguistic quantifier 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.

For example, the aggregation procedure of the three labels $\{L, H, EH\}$ using the LOWA operator Φ is applied as follows:

(i) A fuzzy linguistic quantifier Q is selected to compute the weighting vector W. The linguistic quantifier "at least half" with parameters (0, 0.5) would result in

$$\begin{aligned} W &= [Q(1/3) - Q(0/3), Q(2/3) - Q(1/3), Q(3/3) - Q(2/3),] \\ &= [0.67 - 0, 1 - 0.67, 1 - 1] = [0.67, 0.33, 0] \end{aligned}$$

(ii) The recursive definition of the LOWA operator Φ_Q is applied

$$\begin{aligned} \Phi_Q(L, H, EH) &= [0.67, 0.33, 0] \cdot [EH, H, L]^{\mathrm{T}} = C^3\{(0.67, EH), (0.33, H), (0, L)\} \\ &= 0.67 \Theta EH \oplus (1 - -0.67) \Theta C^2\{(\beta_1, H), (\beta_2, L)\} \end{aligned}$$

Because $\beta_1 = 0.33/(0.33+0) = 1$ and $\beta_2 = 0/(0.33+0) = 0$ then $C^2\{(\beta_1, H), (\beta_2, L)\} = H$, and therefore

$$\Phi_Q(L, H, EH) = 0.67\Theta EH \oplus (1-0.67)\Theta H$$

Given that $\min\{T = 8, 5 + round(0.67 \cdot (7-5))\} = 6$ and $index(VH) = 6$, we finally have

$$\Phi_Q(L, H, EH) = 0.67\Theta EH \oplus (1-0.67)\Theta H = VH$$

2.1.2. The LWA operator

The *Linguistic Weighted Averaging (LWA)* operator [16] is another important operator for fuzzy computing with words, which is based on the LOWA operator. It is defined to aggregate weighted linguistic information, i.e., linguistic information values with not equal importance.

Usually, the aggregation of weighted information involves two activities [16]: (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. In the definition of the LWA operator we use as f the LOWA operator Φ. In [47], Yager discussed the effect of the importance degrees on the aggregation operators "MAX" and "MIN" and suggested a class of functions for importance transformation for each type 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 are non-increasing with respect to the importance degrees. For the MAX aggregation, he suggested a family of t-norms acting on weighted information and the importance degree, which are non-decreasing with respect to the importance degrees. Accordingly, the LWA operator was defined in [16] as follows:

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 Π is defined as $\Pi[(c_1, a_1), \ldots, (c_m, a_m)] = \Phi(h(c_1, a_1), \ldots, h(c_m, a_m))$, 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 assumed for the LOWA operator Φ, such that, $h = \mathrm{MIN}(c_i, a_i)$ if $\mathrm{orness}(W) \geqslant 0.5$, and $h = \mathrm{MAX}(\mathrm{Neg}(c_i), a_i)$ if $\mathrm{orness}(W) < 0.5$.

For example, the aggregation procedure of the three weighted labels $\{(VH, L), (L, H), (M, EH)\}$ using the LWA operator Π is applied as follows:

(i) A fuzzy linguistic quantifier Q is selected to compute the weighting vector W of the LOWA operator Φ. The linguistic quantifier "at least half" would result in $W = [0.67, 0.33, 0]$.

(ii) The *orness* value corresponding to this linguistic quantifier Q is computed

$$\mathrm{orness}(W) = 1/2((3-1)0.67 + (3-2)0.33 + (3-3)0) = 1/2(1.34 + 0.33 + 0) = 0.835.$$

(iii) Because $\mathrm{orness}(W) > 0.5$ then the transformation function $f = \mathrm{MIN}(c_i, a_i)$ is used in the definition of Π

$$\begin{aligned}\Pi[(VH,L),(L,H),(M,EH)] &= \Phi_Q(\mathrm{MIN}(VH,L), IN(L,H), \mathrm{MIN}(M,EH))\\ &= \Phi_Q(L,L,M) = [0.67,0.33,0]\cdot[M,L,L]^{\mathrm{T}}\\ &= C^3\{(0.67,M),(0.33,L),(0,L)\}\\ &= 0.67\Theta M \oplus (1-0.67)\Theta L.\end{aligned}$$

Finally, because $\min\{T = 8, 3 + round(0.67 \cdot (4-3))\} = 4$ and $index(M) = 4$, we have

$$\Pi[(VH,L),(L,H),(M,EH)] = M.$$

2.2. Definition of the structure of documents stored in web sites

In this work, we assume that the target Web sites to be evaluated store documents structured in XML format and these documents are valid XML documents. As we said at the beginning, XML is a simplified version of SGML (optimized for its platform independent use on the Internet) that preserves its extensibility and adaptability. The close relationship between both standards is evident in the fact that all valid XML documents are also valid SGML documents. Despite its name, XML is not really a language, but a metalanguage (i.e., a set of rules governing the development of unique tags for encoding XML documents). That is, XML provides the rules for defining a markup language based on tags.

Valid XML documents are defined by a description of the structure of the document and the content itself marked with tags which corresponds to that structure. The description of the structure of the XML document may be defined by a DTD or a XML schema. Both, DTDs and XML schemas are documents that are used to declare and validate the structure of XML data. In this work the structure of documents is defined through XML schemas. In the following, we show some of the advantages that XML schemas have over previous technologies, such as DTDs:

1. XML schema use XML syntax, so it is not necessary to learn a new syntax to define a data structure.
2. Using XML schemas is easier to describe permissible content for a document, validate the correctness of data, define restrictions on data, define data formats, and convert data between different datatypes.
3. XML schemas allow grouping elements to control the recurrence of elements and attributes.
4. XML schemas are extensible, supporting reusable types and allowing the creation of new datatypes using the inheritance property. Furthermore, XML schemas can be reused and referenced from other schemas. Therefore, XML schemas allow improving representation of Web resources.

Datatypes are to W3C XML schema what classes are to object oriented programming languages. If, instead of writing documentation and processes for each element and attribute (i.e., for each object), we are able to write documentation and process for each type (i.e., each class of objects), and if each of our types is used to describe several elements and attributes, we may hope for gains of productivity [43]. The benefit of building reusable type libraries is potentially huge in terms of interoperability and reusability. With the name space integration XML schemas can connect metadata with elements or attributes. These features can improve the documentation of XML vocabularies by providing a way to attach such information to elements, attributes, or datatypes within their context.

For each document type (scientific article, opinion article, ...) we have to define a different XML schema. The example below shows the structure of a "scientific article" document type.

Example 1

```
⟨?xml version="1.0" encoding="UTF8"?⟩
⟨xsd:schema xmlns:xsd=www.w3.org/2001/XMLSchema
  targetNamespace=www.ugr.es/~glirs/schemas
  xmlns=www.ugr.es/~glirs/schemas
  elementFormDefault="qualified"⟩
  ⟨xsd:element name="article" maxOccurs="unbounded"⟩
    ⟨xsd:complexType⟩
      ⟨xsd:sequence⟩
        ⟨xsd:element name="uri_doc" type="xsd:anyURI"/⟩
        ⟨xsd:element name="title" type="xsd:string"/⟩
        ⟨xsd:element name="authors"⟩
          ⟨xsd:complexType⟩
            ⟨xsd:sequence⟩
              ⟨xsd:element name="author" type="xsd:string" maxOc-
curs="unbounded"/⟩
            ⟨/xsd:sequence⟩
          ⟨/xsd:complexType⟩
        ⟨/xsd:element⟩
        ⟨xsd:element name="abstract" type="xsd:string" minOc-
curs="0"/⟩
        ⟨xsd:element name="introduction" type="xsd:string"/⟩
        ⟨xsd:element name="body"⟩
          ⟨xsd:complexType⟩
          ⟨xsd:sequence⟩
            ⟨xsd:element name="section" maxOccurs="unbounded"⟩
            ⟨xsd:complexType⟩
            ⟨xsd:sequence⟩
              ⟨xsd:element name="titleS" type="xsd:string"/⟩
              ⟨xsd:element name="p" type="xsd:string" maxOc-
curs="unbounded"/⟩
            ⟨/xsd:sequence⟩
          ⟨/xsd:complexType⟩
        ⟨/xsd:element⟩
      ⟨/xsd:sequence⟩
    ⟨/xsd:complexType⟩
  ⟨/xsd:element⟩
  ⟨xsd:element name="conclusions" type="xsd:string"/⟩
  ⟨xsd:element name="bibliography" minOccurs="0"⟩
```

```
        <xsd:complexType>
          <xsd:sequence>
            <xsd:element name="bibitem" type="xsd:string" maxOc-
curs="unbounded"/>
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
  </xsd:complexType>
</xsd:element>
</xsd:schema>
```

According to this schema, the document "article" is composed by an URI to identify the Web resource, a title, at least one author, at most one abstract, an introduction, a body, conclusions and a bibliography. The body is made up of at least one section and each section is composed by its respective title ("titleS") and paragraphs ("p"). The bibliography is made up of at least one "bibitem". All these elements pertain to the *strings* data type. This structure allows arranging the content of the document but there is no reference to the format the documents will be displayed on the clients' browser. Due to this, when a client requests a document the server will dynamically transform it into a browser readable format such as XHTML, HTML, DOC, PDF, etc. (depending on the user's preferences) using XSLT style sheets [9].

A DTD, though extremely useful, has serious deficiencies. It offers only very limited data typing. XML schema is a DTD successor that expresses shared vocabularies and provides a guide for characterizing an XML document's structure, content, and semantics.

3. Work related to the quality of web sites

The debate on how to evaluate and identify the quality of the information available on the Web is still an unclosed matter that involves the efforts of information and computer science researchers. Particularly, the concept of quality of Web sites is still under-defined [1,14,49]. There is considerable confusion in defining and interpreting the meaning of quality for Web sites and it is not easy to establish a general definition. This is due mainly to the heterogeneity and diverse nature of the existing Web sites [49]. There are different types of Web sites, each one with its particular characteristics and goals, e.g. health Web sites [3,39], tourist Web sites [30], commercial Web sites [2,33], content-based Web sites [25,49], etc. Consequently, quality criteria in each evaluation model differ according to the type of Web site. For example, criteria such as information accuracy or information relevance are important for Web sites that provide Web documents or information about products or corporations, while criteria such as easy payment or security/privacy are important for Web sites that market products.

A careful analysis of the different existing approaches allows identifying two types of quality criteria to carry out the quality evaluation process of a Web site [40]:

1. *Internal quality criteria*, which are concerned with issues like maintainability, portability, cost effectiveness, etc. Usually, they are measured objectively by automated procedures. Therefore, their measurement is relatively easy.

2. *External quality criteria*, which are concerned with the quality of Web site in use like accessibility, ease of navigation, reliability, security, etc. Usually, they are measured subjectively by empirical test fulfilled by users. Therefore, their measurement is somehow complex and expensive but necessary to evaluate correctly the quality of a Web site.

As said at the beginning, there are three different views to evaluate the quality of Web sites [30,35,40]: the user's view, the developer's view and the manager's view. Developer's and manager's view quality approaches are based on internal quality criteria while user's view quality approaches are based on external quality criteria. The internal quality criteria based approaches do not permit to detect problems related to typical users of the site while the external one does. Clearly, internal quality criteria are important to improve the development of a Web site. However, there are various reasons for external quality criteria to be considered more important than internal ones to evaluate the quality of Web sites. On the one hand, the Web is a universal information space overcoming barriers created by humans towards people with different cultures or physical limitations [5] and its aim is to help users in their activities by providing information/products/services. Under this point of view, external quality criteria are necessary to evaluate the quality of any Web resource. On the other hand, the Web is an information market with users considered as potential consumers [6]. In this context, the quality of a Web site is related to its success with the customers in terms of attracting new customers and retaining existing customers. Obviously, this is related to the user satisfaction, which can only be evaluated using external quality criteria. Because of this, most of existing quality approaches of Web sites are based on user's view and use external quality criteria [1–3,8,10,25,34,35,39,49]. There are two types of external quality criteria to be taken into account to evaluate the information quality of a content-based Web site [33,41,49]: (i) technical criteria, which are used to evaluate the system quality to make content accessible and understandable (e.g., site structure, layout of web pages, multilingualism, navigation tools, user interface), and (ii) content criteria, which are used to evaluate the information quality presented in a Web site (e.g. relevance, usefulness, believability, completeness).

In Web quality evaluation, one of the main handicaps to overcome is the endemic lack of a theoretical Web information quality framework that can be taken as a reference model [14]. Due to this, many researchers have tried to use other well-founded quality assessment frameworks defined for other fields. Luis Olsina et al. in [34,35] base their Web-QEM model on the ISO/IEC 9126-1 standard [23] defined for development of software and use software quality categories as usability, functionality, reliability and efficiency, which are easily perceptible by the users. Davoli et al. in [10] define their FQT4Web using also the ISO/IEC 9126-1 standard but considering some technical W3C recommendations. They use six quality categories (usability, basic functionality, advanced functionality, accessibility, efficiency and maintainability) and propose to limit the users' participation and to apply fuzzy operators to improve the aggregation procedures. Luisa Mich et al. in [30] present their 2QCV3Q model using classical Ciceronian *loci* as the theoretical reference framework. They assume seven quality categories (identity, content, services, location, management, usability, and feasibility) derived from classical Ciceronian rhetoric rules, basically Kipling's *six honest serving-men* Who-What-Why-Where-When-How plus an examination of resources. Zhang and von Dran in [53] define their quality evaluation model using Kano's model of quality for business [26] as the theoretical reference framework. They use three types of quality categories: basic quality dimension, performance quality dimension and exciting quality dimension. Katerattanakul and Siau in [25] develop their quality evaluation model using the information quality framework for information systems defined in [24,29,42,45]. They assume the following four quality categories: intrinsic quality category, contextual quality category, representational quality category and accessibility quality category. In all cases, in each category appears a set of evaluation criteria to evaluate it. We must point out that among all the theoretical reference frameworks the latter is one of the most used. In fact, it has been satisfactorily applied in others Web contexts such as mobile Internet services [8] or e-commerce [32]. This information quality framework is defined to evaluate information quality of information systems from a consumer's perspective, i.e., assuming that the quality of information cannot be assessed independently of the consumers who use the information. This framework allows information system managers to better understand and meet their information consumers' information quality needs, and therefore it is very appropriate to evaluate the information quality of content-based Web sites.

Finally, we should point out that Web quality evaluation approaches suffer from several limitations:

- They do not provide an adequate theoretical framework to manage qualitative and subjective evaluation judgements provided by the users. As a consequence, most approaches consider quantitative answers in their questionnaires [1,2,8,10,12,25,34,35,49] or qualitative assessments limited to a YES\NO answer [3,39].
- They usually consider all quality categories and criteria as equally important in the evaluation scheme, and those that use importance degrees do not provide adequate operators to model them in the evaluation processes [39,53].
- The length of a questionnaire depends on how precise is the focus of the questions and whether one question leads on to a further questions. Clearly, it is likely that the usual user will be more comfortable with a shorter questionnaire. Most of the questionnaire based approaches do not assume this fact in their Web quality models and propose too long questionnaires (with 25 items or more) to users [1,3,8,10,25,53].
- They also suffer the granularity problem [40], i.e. they do not make a clear distinction between Web page and Web site quality.

4. A fuzzy linguistic model to evaluate the quality of web sites based on XML documents

In this section we present a quality evaluation model for Web sites based on XML documents which addresses the aforementioned drawbacks. This model is user-centered and is based on a fuzzy linguistic approach. It consists of two components, an evaluation scheme containing the evaluation criteria or dimensions to be considered in the evaluation of the quality of Web sites, and a computing method of linguistic quality ratings.

4.1. Evaluation scheme

We propose and develop an evaluation scheme for analyzing the information quality of Web sites that store XML documents based on the information quality framework defined in [24,29,42,45]. In the following subsections we present both this information quality framework and our evaluation scheme.

4.1.1. Information quality framework for information systems

The information quality framework defined in [24,29,42,45] was proposed based on the premise that the quality of information systems cannot be assessed independently of the information consumers' opinions. This framework establishes four major information quality categories to classify the different evaluation dimensions [24,29,42,45]:

1. *Intrinsic information quality*, which emphasizes the importance of the informative aspects of the information itself. This 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 its use. Other dimensions of this category are: believability, reputation and objectivity.
2. *Contextual information quality*. The 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. Some of the dimensions of this category are: value added, relevance, completeness, timeliness, appropriate amount.
3. *Representational information quality*. The information systems must 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 computer systems that provide access to information. It requires that the information system must be accessible but secure. Therefore, some dimensions of this category are: accessibility and secure access.

Using this information quality framework, in [25] a designer-driven model to evaluate the informative quality of personal Web sites is proposed, which includes the following evaluation categories and dimensions:

- Intrinsic quality of personal Web sites. This category presents the following dimensions: (i) accuracy and errors of the content, and (ii) accurate, workable and relevant hyperlinks.
- Contextual quality of personal Web sites. This category presents one dimension: provision of author's information.
- Representational quality of personal Web sites. This category presents the following dimensions: (i) organization, visual settings, typographical features, and consistency, (ii) vividness and attractiveness, and (iii) confusion of the content.
- Accessibility quality of personal Web sites. This category presents one dimension: navigational tools provided.

4.1.2. Evaluation scheme of quality of web sites

Using the above information quality framework we develop an evaluation scheme for analyzing the information quality of Web sites from the information consumers' perspective. To this end, we will take into account the following:

a. Different quality approaches on information quality [1,25,33,49,53] include as the most important content evaluation criteria the following ones: accuracy, relevance, timeliness, completeness, and understandability; and as the most important technical evaluation criteria the following ones: easy to navigate and search tool. Both content and technical evaluation criteria are combined in our evaluation scheme.
b. In our model, we aim to generate quality ratings or recommendations on Web sites from the evaluations provided by different visitors to Web sites. Therefore, the proposed evaluation scheme requires the inclusion of subjective dimensions easily comprehensible to the information consumers (such as relevance, understandability) rather than dimensions that can be objectively measured independently of the consumers (such as the accuracy measured by the number of spelling or grammatical errors).
c. An excessive number of quality dimensions should not be included in the evaluation scheme in order to not confuse the users and help them in understanding it. The reason for this is that user's capability to cope with concepts at one time is limited (the magical number 7 ± 2 [31]). Therefore, a long and complex evaluation scheme would cause the not participation of the user and would eventually limit the evaluation scheme's own application possibilities.
d. We aim to analyse Web sites that store information in multiple kinds of documents structured in XML format (e.g. scientific articles, opinion articles). These Web sites are visited occasionally by users because they store documents which meet their information needs. Therefore, users' opinions on the information quality of these documents (e.g. their relevance) must be taken as an important dimension in the evaluation scheme. As a consequence, we make a clear distinction between Web document quality and Web site quality.

Taking into account the above considerations, we define a user-oriented evaluation scheme of Web sites that contemplates four quality categories with the following evaluation dimensions (see Table 1):

1. *Intrinsic quality of Web sites*. Accuracy of information is the main determinant of the intrinsic information quality of information systems. Given that we consider Web sites as information sources visited occasionally, we are not interested in evaluating the accuracy by means of grammatical and spelling errors or relevant hyperlinks existing on the Web site as in [25]. We rather evaluate the accuracy of Web sites by considering what visitors think about the believability of the information content provided by Web sites.
2. *Contextual quality of Web sites*. In our evaluation scheme neither the dimension of author's information, as in [25], nor the appropriate amount of information are

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	Relevance, timeliness, completeness
Representational quality of Web sites	understandability of Web sites, originality, understandability of documents, conciseness
Accessibility quality of Web sites	Navigational tools

meaningful. We propose to evaluate this category by considering what visitors think on the relevance, timeliness and completeness of the documents Web sites provide them with, when they search for information on particular topic. This is the most important category in the evaluation scheme we propose.

3. *Representational quality of Web sites*. For Web sites providing information stored in XML documents, two aspects from this category are analysed: the representational aspects of Web site design and, the representational aspects of the documents stored in the Web site. For the first one, we consider what visitors think about the understandability of the Web site, i.e., whether or not the Web site is well organized so that visitors can easily understand how to access stored documents. For the second one, we consider what visitors think about the understandability, originality and conciseness of the information content of the XML documents they have used.
4. *Accessibility quality of Web sites*. In this category, whether or not the Web site provides enough navigation mechanisms so that visitors can reach their desired documents faster and easier must be assessed as in [25]. A lack of effective paths to access desired documents would handicap visitors, and 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 search tool dimension is not considered a key aspect for this evaluation category because we assume Web sites visited by users that are using a Web retrieval system external to the site. Similarly, security dimension is unnecessary in a content-based Web site.

4.2. Computing method of linguistic quality ratings

In this section, a computing method of linguistic quality ratings for evaluating the information quality of Web sites based on XML documents is presented. These linguistic quality ratings 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 linguistic quality ratings are obtained by aggregating the linguistic evaluation judgements by means of the LWA and LOWA operators, which are a linguistic family of OWA operators [48]. We use these operators because they allow us to include in the computation of the rankings the concept of "fuzzy majority" [17] represented by the linguistic quantifier used to compute the weighting vector of the OWA operator. In such a way, the linguistic quality ratings are obtained according to the fuzzy majority of the opinions provided about the fuzzy majority of criteria of the evaluation scheme.

4.2.1. The quality evaluation questionnaire

The quality evaluation questionnaire will contain a question for each one of the evaluation dimensions proposed in the evaluation scheme. This means that the questionnaire will consists of nine questions: $\{q_1, \ldots, q_9\}$. As an example, the question for the quality dimension "believability" could be $\{q_1\}$: "In your opinion, what is the degree of believability of this Web site?" The concept embedded in each question is rated on a linguistic term set S. For example, we can use the set of nine linguistic terms proposed in Section 2 to rate all the questions in the questionnaire. In this case, assessing the question q_1 with value

"None" will mean "null believability degree" and with value "Total" means "total believability degree".

This linguistic term set S is defined in another XML schema (see Example 2) which must be referred from each different document type's schema using an xsd:include element.

Example 2. XML schema "Labels.xsd", in which the linguistic term set S is defined through a data type we call "lblrank".

```
⟨?xml version="1.0" encoding="UTF-8"?⟩
⟨xsd:schema                    xmlns:xsd=www.w3.org/2001/XMLSchema
elementFormDefault="qualified"⟩
  ⟨xsd:simpleType name="lblRank"⟩
    ⟨xsd:restriction base="xsd:string"⟩
      ⟨xsd:enumeration value="Total"/⟩
      ⟨xsd:enumeration value="ExtremelyHigh"/⟩
      ⟨xsd:enumeration value="VeryHigh"/⟩
      ⟨xsd:enumeration value="High"/⟩
      ⟨xsd:enumeration value="Medium"/⟩
      ⟨xsd:enumeration value="Low"/⟩
      ⟨xsd:enumeration value="VeryLow"/⟩
      ⟨xsd:enumeration value="ExtremelyLow"/⟩
      ⟨xsd:enumeration value="None"/⟩
    ⟨/xsd:restriction⟩
  ⟨/xsd:simpleType⟩
⟨/xsd:schema⟩
```

We also assume that each quality dimension is not equally important in the evaluation scheme, i.e. a relative linguistic importance degree is assigned to each quality dimension: $\{I(q_1),\ldots,I(q_9)\}$, $I(q_i)\in S$. This will allow to assign a higher importance degree to the quality dimensions related with the Web site contents itself (those included in the first and second category of evaluation scheme) than the remaining ones. In particular, as we said before, users' opinions on the information quality of documents (relevance) should have associated a high importance degree. The particular importance degree associated to each one of the evaluation dimension could be determined and established by the system administrator or an external expert. Another possible way of obtaining these importance degrees would be the design and application of a previous user questionnaire to assess this aspect.

The question of assessing the relevance dimension, q_2, is a very important in our evaluation scheme. Due to this, we propose a meticulous way to evaluate the relevance of the XML documents provided by Web sites for a search topic. It is not evaluated using just a single or global value supplied by a user, but from the evaluation of the relevance of the all the parts that compose the structure of the XML documents following the conceptual evaluation model of Web pages given in [20]. Thus, the evaluation questionnaire of relevance will depend on the kind of XML document to be assessed. An example of this type of questionnaire, to assess believability and relevance, is given in Fig. 1. For example, if an XML document is a "scientific article", then the relevance evaluation questionnaire can be

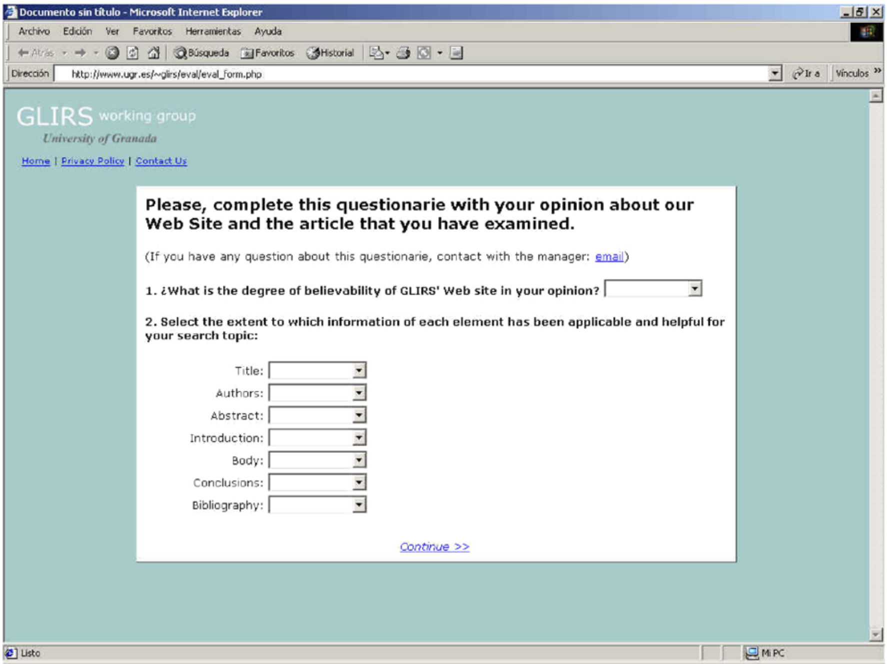

Fig. 1. Quality evaluation questionnaire.

established based on the following set of elements: "title, authors, abstract, introduction, body, conclusions and bibliography". In this case, the relevance evaluation questionnaire would consist of seven questions, with one question being for example "What is the relevance degree of the title element with respect to your search topic?" So, the relevance evaluation questionnaire of a particular XML document type will be designed by taking into account the set of elements, $\{p_1, \ldots, p_9\}$, that defines its structure. 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 modelled by assigning to each $\{p_k\}$ a relative linguistic importance degree $I(p_k) \in S$. This feature is added in the XML schema defining an attribute of importance "rank" (using the lblrank as data type) for each meaningful component of the XML schema (see Example 3).

Example 3. Defining the attribute of importance "rank" for the "title" element.

```
...
⟨xsd:element name="title"⟩
  ⟨xsd:complexType⟩
    ⟨xsd:simpleContent⟩
      ⟨xsd:extension base="xsd:string"⟩
        ⟨xsd:attribute name="rank" type="lblRank" use="optional"
default="I(title)"/⟩
      ⟨/xsd:extension⟩
    ⟨/xsd:simpleContent⟩
```

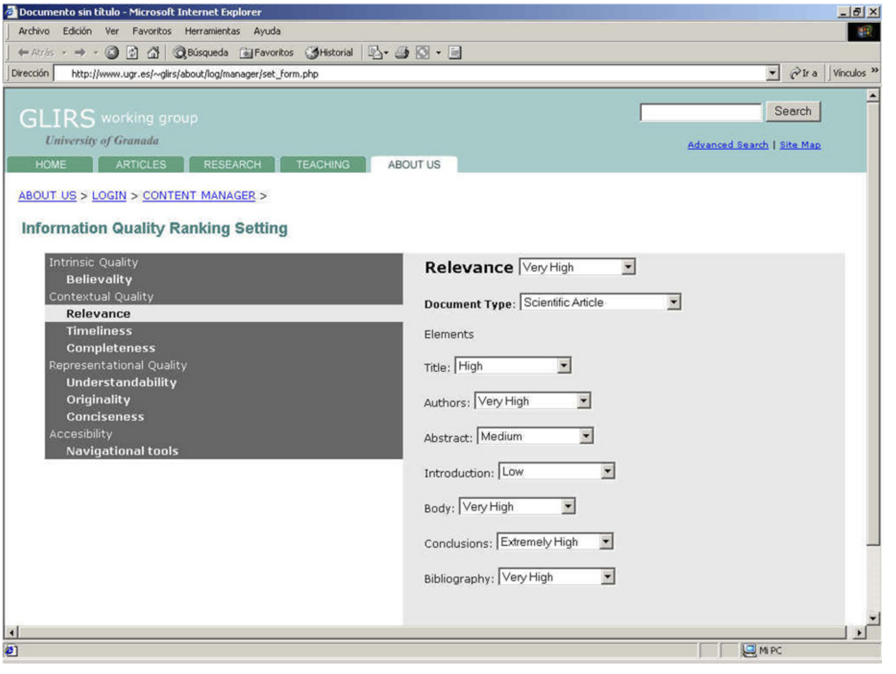

Fig. 2. Example of the evaluation form for the relevance dimension.

```
  ⟨/xsd:complexType⟩
⟨/xsd:element⟩
...
```

The author of document instances will be responsible for assigning the relative importance degree to each element, expressed through the "rank" attribute with a linguistic term from the linguistic term set S defined in "Labels.xsd".

In Fig. 2 a screenshot shows an example of the evaluation form for the relevance dimension with its linguistic importance degrees.

When a user examines a document after a search process, he/she is asked to fill in the above evaluation form. As a result, the system generates an auxiliary "*evaluation file*" in XML format to stores all the assessments made by the user on the different quality dimensions of the web site and the resource itself. These judgements are added as evaluation items containing the URIs of the evaluated resource and web site, the ID of the user that did the appraisals, the time the evaluation was done, and the search topic used to gather that specific resource (e.g. "information quality").

Example 4. *The Evaluation file* containing the user's judgements.

```
⟨?xml version="1.0" encoding="UTF-8"?⟩
⟨evalHistory xmlns=www.ugr.es/~glirs/evalHistory
  xmlns:xsi=www.w3.org/2001/XMLSchema-instance
```

```
    xsi:schemaLocation=www.ugr.es/~glirs/schemas/evalFile.xsd⟩
      ⟨evalItem id="A00345"⟩
        ⟨uri_doc⟩www.ugr.es/~glirs/docs/article/0074⟨/uri_doc⟩
        ⟨uri_site⟩www.ugr.es/~glirs⟨/uri_site⟩
        ⟨user id="Aj5667"/⟩
        ⟨time⟩2005-12-13T13:25:42Z⟨/time⟩
        ⟨searchTopic⟩information quality⟨/searchTopic⟩
        ⟨sRelev⟩ VeryHigh ⟨/sRelev⟩
        ⟨sBelieve⟩VeryHigh⟨/sBelieve⟩
        ⟨sTime⟩Total⟨/sTime⟩
        ⟨sComplete⟩High⟨/sComplete⟩
        ⟨sUnderst⟩Medium⟨/sUnderst⟩
        ⟨sOrig⟩VeryHigh⟨/sOrig⟩
        ⟨sConcise⟩Low⟨/sConcise⟩
        ⟨sNav⟩ExtremelyHigh⟨/sNav⟩
        ⟨docQ⟩
          ⟨title⟩ExtremelyHigh⟨/title⟩
          ⟨authors⟩High⟨/authors⟩
          ⟨abstract⟩Medium⟨/abstract⟩
          ⟨introduction⟩Low⟨/introduction⟩
          ⟨body⟩High⟨/body⟩
          ⟨conclusions⟩VeryHigh⟨/conclusions⟩
          ⟨bibliography⟩Low⟨/bibliography⟩
        ⟨/docQ⟩
      ⟨/evalItem⟩
      ...
  ⟨/evalHistory⟩
```

Example 5. XML Schema ("*evalFile.xsd*") corresponding to the "*evaluation file*" document type.

```
  ⟨?xml version="1.0" encoding="UTF-8"?⟩
  ⟨xsd:schema   xmlns:xsd=www.w3.org/2001/XMLSchema   elementForm
  Default="qualified"⟩
    ⟨xsd:element name="evalItem" maxOccurs="unbounded"⟩
      ⟨xsd:complexType⟩
        ⟨xsd:sequence⟩
          ⟨xsd:element name="uri_doc" type="xsd:anyURI"/⟩
          ⟨xsd:element name="uri_site" type="xsd:anyURI"/⟩
          ⟨xsd:element name="user"/⟩
            ⟨xsd:complexType⟩
              ⟨xsd:attribute  name="id"  type="xsd:string"  use="re-
  quired"/⟩
            ⟨/xsd:complexType⟩
          ⟨/xsd:element⟩
```

```
        <xsd:element name="time" type="xsd:string"/>
        <xsd:element name="searchTopic" type="xsd:string"/>
        <xsd:element name="sRelev" type="lblRank"/>
        <xsd:element name="sBelieve" type="lblRank"/>
        <xsd:element name="sTime" type="lblRank"/>
        <xsd:element name="sComplete" type="lblRank"/>
        <xsd:element name="sUnderst" type="lblRank"/>
        <xsd:element name="sOrig" type="lblRank"/>
        <xsd:element name="sConcis" type="lblRank"/>
        <xsd:element name="sNav" type="lblRank"/>
        <xsd:element name="docQ">
          <xsd:complexType>
            <xsd:sequence>
            <xsd:element name="title" type="lblrank">
            <xsd:element name="authors" type="lblrank">
            <xsd:element name="abstract" type="lblrank">
            <xsd:element name="introduction" type="lblrank">
            <xsd:element name="body" type="lblrank">
            <xsd:element name="conclusions" type="lblrank">
            <xsd:element name="bibliography" type="lblrank">
          </xsd:sequence>
        </xsd:complexType>
      </xsd:element>
    </xsd:sequence>
    <xsd:attribute name="id" type="anyURI" use="required"/>
  </xsd:complexType>
  </xsd:element>
</xsd:schema>
```

The relevance of the XML document and the global quality of the web site are obtained by combining the linguistic evaluation judgements provided by the user on the meaningful components of its corresponding XML schema and the evaluation of the different web site quality dimensions respectively (see Section 4.2.2). The resulting relevance degree for the resource and the global quality value for the web site can be added as an annotation on the resource by defining two new elements we call *docIQ* and *siteIQ*. Using XSLT stylesheets it is possible to display the resulting documents for a query coupled with their corresponding relevance degree represented by a linguistic label, and/or a colour code, and/or a picture, etc. In such a way, future users will take advantage of this extra information to help them in finding in an easy and timely manner quality documents about a topic of their interest.

To allow these elements being included as annotations in any document (independently of its type) we should define a new XML schema "*evalIQ.xsd*".

Example 6. The XML schema ("*evalIQ.xsd*") defining the labels to store the fuzzy operators' output.

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd=www.w3.org/2001/XMLSchema
```

```
  elementFormDefault="qualified"⟩
    ⟨xsd:element name="docIQ" type="lblrank" minOccurs="0"/⟩
    ⟨xsd:element name="siteIQ" type="lblrank" minOccurs="0"/⟩
⟨/xsd:schema⟩
```

This "*evalIQ.xsd*" schema can be referred from each document type schema through a *xsd:include* element.

Summarizing, after examining a document, a visitor is invited to complete a quality evaluation questionnaire associated to that document that is comprised of 8 questions and a relevance evaluation questionnaire. Therefore, the number of valuable components directly depends on the document type of the selected resource.

An example of a document instance according to the XML schema defined in Example 1 may be the following.

Example 7. In this example the author has defined the relative importance degrees for all the elements in the article instance, and both the relevance degree for the document and the global quality of the web site are also annotated.

```
⟨?xml version="1.0" encoding="UTF-8"?⟩
⟨article xmlns=ww.ugr.es/~glirs/schemas
        xmlns:xsi=www.w3.org/2001/XMLSchema-instance
        xsi:schemaLocation=www.ugr.es/~glirs/schemas/
article.xsd⟩
  ⟨uri_doc⟩www.ugr.es/~glirs/schemas/article/0074⟨/uri_doc⟩
  ⟨title rank="High"⟩ AIMQ: a methodology for information quality
assessment.⟨/title⟩
  ⟨authors rank="VeryHigh"⟩
    ⟨author⟩Yang W. Lee⟨/author⟩
    ⟨author⟩Diane M. Strong⟨/author⟩
    ⟨author⟩Beverly K. Kahn⟨/author⟩
    ⟨author⟩Richard Y. Wang⟨/author⟩
  ⟨/authors⟩
  ⟨abstract rank="Medium"⟩ Information quality (IQ) is critical in
organizations. Yet, despite a decade of active research and prac-
tice, ...
  ⟨/abstract⟩
  ⟨introduction rank="Low"⟩
  ⟨introduction⟩ Information quality (IQ) has become a critical
concern of organizations and active area of Management Information
Systems (MIS) ...
  ⟨/introduction⟩
  ⟨body rank="VeryHigh"⟩
    ⟨section⟩
      ⟨titleS⟩ Dimensions of IQ⟨/titleS⟩
      ⟨p⟩ In our earlier research, we empirically derived the IQ
dimensions that are important to information consumers ...
```

```
      ⟨/p⟩
    ⟨/section⟩
    ⟨section⟩
      ⟨titleS⟩ Academic's view of IQ dimensions⟨/titleS⟩
      ⟨p⟩ Table 1 summarizes academic research on the multiple
  dimensions of IQ ...⟨/p⟩
    ⟨/section⟩
    ⟨/body⟩
  ⟨conclusions rank="ExtremelyHigh"⟩ We have developed the AIMQ
  methodology for assessing and benchmarking IQ in organizations ...
  ⟨/conclusions⟩
  ⟨bibliography rank=''VeryHigh"⟩
    ⟨bibitem⟩ S.L. Ahire, D.Y. Golhar, M.A. Waller, Development and
  validation of TQM implementation constructs, Decision Sciences
  27 (1) 1996, pp. 23–51.
    ⟨/bibitem⟩
   ⟨/bibliography⟩
   ⟨docIQ⟩VeryHigh⟨/docIQ⟩
   ⟨siteIQ⟩High⟨/siteIQ⟩
  ⟨/article⟩
```

4.2.2. Computing the linguistic quality ratings

Let us suppose that we want to generate a recommendation database for qualifying the information quality of a set of Web sites $\{Web_1, \ldots, Web_L\}$ that stores information in XML documents. These Web sites can be evaluated using a set of different areas of interest or search topics, $\{A_1, \ldots, A_M\}$. Suppose that D_p represents the set of XML documents stored in the Web site Web_p. We consider that each XML document $d_j\, C\, D_p$ represents an evaluation scheme that consists of a finite set of elements of its XML schema, $\{p_1, \ldots, p_n\}$, ψ and its respective relative linguistic importance degrees $\{I(p_1), \ldots, I(p_n)\}$.

Let $\{e_1^{m,p}, \ldots, e_T^{m,p}\}$ be a group of different visitors to the Web site Web_p who have completed the quality evaluation questionnaire $\{q_1, \ldots, q_9\}$ when they searched for information on the topic 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 $e_t^{\mu,p}$. We point out that the assessment q_2^t is achieved from the set of linguistic evaluation judgements $\{e_{t1}^{m,p}, \ldots, e_{tn}^{m,p}\}$ provided by the visitor $e_t^{m,p}$ regarding the set of elements of XML schema, $\{p_1, \ldots, p_n\}$, associated to the particular XML document d_j he/she accessed. Thus, q_2^t is obtained using the weighted linguistic aggregation operator LWA as follows:

$$q_2^t = \Pi[(I(p_1), e_{t1}^{mp}), \ldots, (I(p_n), e_{tn}^{mp})] = \Phi_{Q1}(h(I(p_1), e_{t1}^{m,p}), \ldots, h(I(p_n), e_{tn}^{m,p})),$$

being Q_1 the linguistic quantifier used to calculate the weighting vector W of the LOWA operator Φ. If we assume that Q_1 represents the concept of fuzzy majority (for example "most"), then q_2^t represents the relevance of d_j with respect to the topic A_m according to Q_1 ("most") linguistic evaluation judgements of the visitor $e_t^{m,p}$.

Then, given a search topic A_m, the generation process of a recommendation database for qualifying the information quality of a set of Web sites is obtained using a LWA-LOWA based evaluation method in three steps:

1. Using the of LWA Π, the individual recommendation $r_t^{m,p}$ for the Web site Web_p for visitor $e_t^{m,p}$ is calculated:

$$r_t^{m,p} = \Pi[(I(q_1), q_1^t), \ldots, (I(q_9), q_9^t)] = \Phi_{Q2}(h(I(q_1), q_1^t), \ldots, h(I(q_9), q_9^t)).$$

   $r_t^{m,p}$ represents the information quality of the Web_p with respect to the topic A_m according to q_2 linguistic evaluation judgements of the visitor $e_t^{m,p}$.
2. Using the LOWA operator guided by the fuzzy majority concept represented by a linguistic quantifier Q_3, the global recommendation $r^{m,p}$ for the Web site Web_p is calculated:

$$r^{m,p} = \Phi_{Q3}(r_1^{m,p}, \ldots, r_T^{m,p}).$$

   In this case, $r^{m,p}$ represents the information quality of the Web_p with respect to the topic A_m according to q_2 linguistic evaluation judgements for Q_3 visitors. The value $r^{m,p}$ represents the linguistic information quality of the Web_p regarding to the topic A_m.
3. Store in the recommendation database the recommendation $r^{m,p}$ in order to assist users in their future search processes

Example 8. Let us suppose that we want to measure the information quality of a Web site Web_p related to the topic "A_m =information quality". Also, let us assume that a user $e_1^{m,p}$ after visiting the Web site provided the following the linguistic evaluation judgements on the nine quality dimensions:

$$\{q_1^1 = L, q_2^1 = M, q_3^1 = VH, q_4^1 = H, q_5^1 = VL, q_6^1 = EH, q_7^1 = T, q_8^1 = VH, q_9^1 = VH\}.$$

In this example, for simplicity we are also assuming that $q_2^1 = VH$ is already the aggregated value obtained from the evaluations given by the visitor on the quality of the parts of XML schema. If the linguistic importance degrees associated with the information quality dimensions are $\{I(q_1) = EH, I(q_2) = T, I(q_3) = EH,\ I(q_4) = VH, I(q_5) = H, I(q_6) = H, I(q_7) = L, I(q_8) = H, I(q_9) = L\}$, and the linguistic quantifier $Q_{2=}$ "*at least half*" defined by the parameters (0,0.5) is used to compute the weighting vector of the LOWA operator Φ_{Q2} used in the LWA operator Π, then this user's linguistic information quality rating $r_1^{m,p}$ for the Web site Web_p is obtained according to the following expression:

$$\begin{aligned} r_1^{m,p} &= \Pi[(EH, L), (T, M), (EH, VH), (VH, H), (H, VL), (H, EH), (L, T), (H, VH), (L, VH)] \\ &= \Phi_{Q2}(h(EH, L), h(T, M), h(EH, VH), h(VH, H), h(H, VL), h(H, EH), \\ &\quad h(L, T), h(H, VH), h(L, VH)). \end{aligned}$$

The weighting vector W and corresponding *orness* value obtained using the linguistic quantifier q_2 are: $W =$ (2/9, 2/9, 2/9, 2/9, 1/9, 0, 0, 0, 0) and orness$(W) = 0,77$. Consequently, we use the transformation function $h =$ MIN and then

$$\begin{aligned} r_1^{m,p} &= \Phi_{Q2}(\mathrm{MIN}(EH, L), \mathrm{MIN}(T, M), \mathrm{MIN}(EH, VH), \mathrm{MIN}(VH, H), \\ &\quad \mathrm{MIN}(H, VL), \mathrm{MIN}(H, EH), \mathrm{MIN}(L, T), \mathrm{MIN}(H, VH), \mathrm{MIN}(L, VH)) \\ &= \Phi_{Q2}(L, M, VH, H, VL, EH, L, H, L) = H. \end{aligned}$$

If we further assume that eight other users visited the Web site Web_p and that their respective individual linguistic information quality ratings were $\{r_2^{m,p} = VH, r_3^{m,p} = L, r_4^{m,p} =$

$H, r_5^{m,p} = M, r_6^{m,p} = VH, r_7^{m,p} = VL, r_8^{m,p} = VH, r_9^{m,p} = M\}$, then taking $Q_3 = Q_2$ the global recommendation $r^{m,p}$ for the Web site Web_p would be:

$$r^{m,p} = \Phi_{Q3}(H, VH, L, H, M, VH, VL, VH, M) = H.$$

Remark. It is worth pointing out that our aim was the generation of quality ratings to evaluate the information quality of Web sites in order to help Web retrieval systems to find high quality XML resources. Clearly, appropriate changes in the presented computing method would result in the provision of important information for Web site designer to improve it. For example, by combining in the first place the linguistic evaluation judgements provided by each user in each evaluation dimension and afterwards in each evaluation category, the results could be presented using appropriate quality chart for the Web site designer to visualise in a quick and easy way the areas that need improvement in the Web site.

5. Analysis of the proposed Web quality evaluation model

There are several limitations and benefits associated with using the proposed web quality evaluation model.

5.1. Limitations

The main limitations or drawbacks of the proposed model are related to the user's participation. These are:

- It is a user-dependent model: The quality of Web sites can only be evaluated if users' perceptions can be gathered, which normally is not an easy task. Due to this, the proposed model is recommended to be used in Web systems that provide some kind of reward to users that agree to provide their evaluation judgements.
- It uses little information about users: The proposed model does not use all the users' information that would be desirable. The model is user-centered and is designed to compute quality ratings using only the evaluation judgements provided by the users. Therefore, the performance of the model could be improved if user profiles would also be used in the computation process of quality ratings. In such a way, we could characterize personalized and high-quality information, an aspect which is desirable in the current Web.

5.2. Benefits

On the other hand, the main benefits or advantages of the proposed model are:

- It can be easily adapted to different domains such as health, education, etc.
- It uses fuzzy linguistic techniques to model evaluation judgements and the quality ratings and, in such a way, the subjectivity typical of user-system interactions can be managed efficiently. Additionally, this fuzzy tool allows modelling the information in a linguistic way which is closer to the humans.

- It allows weighing the importance of the different quality criteria by means of the LWA operators.
- Diverse application possibilities of the proposed model in the current Web technologies. For example, the proposed model may be useful:

1. To the current Web services publish and discovery model. This model presents three main actors [36]: the traditional actors, the Web service provider and the Web service consumer, and a new actor called the Web service QoS (Quality of Service) certifier. The Web service provider offers the Web service. In our particular Web context, the Web service provider publishes the information in XML format. Our model could easily help the information provider to detect defects in the information provided by analyzing, for example, the quality charts of Web sites. The Web service consumer needs the Web service offered by the provider. Clearly, the Web service consumer requires relevant and high-quality information to satisfy his/her information needs. Our model could easily help the consumer to choose among the retrieved documents by analyzing, for example, the quality ratings of Web sites as confidence measures. The certifier's task consists in verifying the quality of the information supplied by the provider. Our model could be used by the certifier as a rule to verify the quality of services offered by a Web site, and in particular, to verify the quality of the information provided by a Web site.
2. Embedded in some of the Web retrieval systems, as it could be the filtering systems [38]. Information filtering is a name used to describe a variety of processes involving the delivery of information to people who need it. The first filtering systems were developed based on document contents. However, it is known that filtering process involving human beings results in more effective filtering. This idea is supported by the *collaborative filtering systems* or *recommender systems* [38]. In these systems, people collaborate to help one another to perform filtering by recording their reactions to documents they read. Recommender systems evaluate and filter the great amount of information available on the Web to assist people in their search processes [38]. 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 processes. In this sense, recommendations are a kind of plausible measure of the information quality of Web documents. However, the importance of Web sites that provide information should not be underestimated. Therefore, an interesting proposal to improve the performance of recommender systems would be that of generating also quality ratings of Web sites that store Web documents.

6. Conclusions

In this work, we have defined a model to evaluate the quality of Web sites that store XML documents using only users' perceptions on aspects related with the information offered by the sites. We have applied fuzzy linguistic techniques to represent both users' judgements and quality ratings, in user friendly way as the information can be modelled in a linguistic way which is closer to the humans.

In the Web, most of information is stored in HTML format. However, the XML format is being used and is well established in the development of new Web applications.

Also, XML is the reference standard of the future Web, the so-called Semantic Web. The Semantic Web is an extension of the present Web, in which the information is gifted of a well defined meaning, permitting a better cooperation between humans and machines. It is based on two main ideas: the ''semantic'' mark up of resources and the development of ''intelligent'' software agents capable to understand and to operate with these resources at semantic level [4]. XML together with RDF are the basis of the Semantic Web. In this new Web framework the notion of quality plays an important role. With our proposal we introduce a new approach to evaluate XML resources that introduces in the Semantic Web the ability of incorporating quality into the information discovery process.

In the future, we identify several areas of research:

- To apply our Web quality evaluation model to other types of Web sites, e.g., e-learning Web sites, digital library Web sites, etc.
- To adapt and improve our evaluation model to face the new scenario sketched by the Semantic Web and its associated technologies (ontology vocabularies, RDF, RDF Schema, etc.) thanks to the facilities of XML Schema for associating metadata with elements or attributes.
- To incorporate in our model new tools of management of linguistic information, as for example tools of management of multi-granular linguistic information [19]. These could support evaluation judgements assessed on different linguistic expression domains and could also help or facilitate the users in the expression of their perceptions.
- To incorporate in our model graphic representation tools to help the Web developers to visualize in an easy and quick way the quality of Web sites. Quality radar charts is a good example of graphic representations that may be very useful [2,10,30] to identify easily the limitations of the Web sites and to compare different development states of Web sites.

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