A Web Information System to Improve the Digital Library Service Quality

Francisco Javier CABRERIZO [a,1], María Ángeles MARTÍNEZ [b], Javier LÓPEZ-GIJÓN [c], Francisco CHICLANA [d] and Enrique HERRERA-VIEDMA [e,f]

[a] *Dept. of Software Engineering and Computer Systems, Universidad Nacional de Educación a Distancia, Spain*

[b] *Dept. of Social Work, University of La Rioja (UNIR), Spain*

[c] *Dept. of Library Science, University of Granada, Spain*

[d] *Centre for Computational Intelligence, De Montfort University, UK*

[e] *Dept. of Computer Science and Artificial Intelligence, University of Granada, Spain*

[f] *Dept. of Electrical & Computer Engineering, King Abdulaziz University, Saudi Arabia*

Abstract. To asses the quality of the services provided by a digital library, traditional measures, such as the size of its collection, have usually been utilized. However, service quality also has to be evaluated by considering users' expectations. In addition, as a digital library plays an important role in the educational progress of a society, it is very important not only to measure the quality of its services but also to improve them. In this contribution, we present a web information system which supports the staff of a digital library to carry out decisions with the aim of improving the services offered by it. To do so, this system provides some advice taking into account both objective criteria, related to quantitative data, and subjective criteria, related to users' judgments.

Keywords. Web, LibQUAL+, digital libraries

1. Introduction

The way in which the information is generated and disseminated has been revolutionized in modern times by the advent of the information and communication technology. As a consequence, many organizations, as for example academic institutions, have moved from paper-based systems to become more digital-oriented organizations. The advent of the Internet and the ability of digitizing large quantities of text and images along with making them available over the Web has transformed ways of working [1]. Nowadays, a massive transformation has been undergone by the traditional methods of storing, collecting, processing, and accessing information. For instance, libraries, particularly academic libraries, are now investment heavily on electronic library services with a view to provide seamless access to library collections.

[1]Corresponding Author: Francisco Javier Cabrerizo, Department of Software Engineering and Computer Systems, Universidad Nacional de Educación a Distancia, C/ Juan del Rosal 16, Madrid 28040, Spain; E-mail: cabrerizo@issi.uned.es.

A digital library forms an integral part of the services of a library, applying new technology to provide access to digital collections [2,3,4]. It can be defined as a collection of digital objects, of assured quality, that are created or collected and managed according to internationally accepted principles for collection development and made accessible in a coherent and sustainable manner, supported by services necessary to allow users to retrieve and exploit the resources [5]. As a result, users can access the vast digital collection by using computers connected to the Internet in order to search and retrieve needed information from electronic catalogs, e-journals, and large databases of digitized scholarly information.

Due to the characteristics of the digital libraries with respect to the traditional libraries, the use of the digital libraries has grown significantly in recent time, becoming not only in an indispensable tool in academia but also a personal use is increasing every day. That is, there are a large number of users of digital libraries whose expectations and demands for better service and functionality are increasing, and questions about the utility, usability and cost of digital libraries have started to arise. Defining what makes a digital library a good-quality system can be difficult and hard to summarize, since it depends on which of the many aspects of a digital library are being considered [6]. Anyway, the final objective of a digital library is to enable its users to access human knowledge at any time and anywhere and, in such a way, the quality of the services provided by a digital library needs to be judged by its users. A digital library is intended to serve users and if a digital library is not used, it falls into oblivion and terminate its operation [7]. Therefore, it is necessary to consider the users' opinions in the quality evaluation of a digital library.

In the literature, we can find some quality evaluation models of digital libraries based on users' judgments [8,9,10], which provide the quality that the users perceive on the services offered by the digital libraries. However, in addition to obtain the quality level of the services provided by the digital libraries, it is also important to offer some advice in order to improve them and to fulfill the users' expectations. In such a way, the number of users accessing to the digital libraries will be incremented.

In this contribution, we present a web information system to improve the services provided by a digital library. It considers both subjective criteria related to users' opinions and objective criteria related to the quantitative data of a digital library. As we have mentioned, it is essential to take into account the users' judgments in the evaluation of the quality of a digital library. However, it does not mean that traditional quantitative criteria as, for example, number of volumes owned, have to be excluded. According to the subjective and objective criteria, the web information system provides some advice to improve the service offered by a digital library and, in such a way, to increase the number of users utilizing them. To do so, the web information system is based on a set of decision rules which are activated depending on the values of the subjective and objective criteria. To obtain the value of the subjective criteria, the LibQUAL+ model [11,12] is used, whereas the values of the objective criteria are obtained directly from the data supplied by the staff of the digital library.

This contribution is set out as follows. In Section 2, we present the LibQUAL+ model. The web information system, which generates some advice to improve the quality of the services offered by the digital libraries, is described in Section 3. Finally, we point out some conclusions and future work in Section 4.

2. The LibQUAL+ Model

LibQUAL+ model [11] is the most popular and the best-known library survey. Since 2000, more than 1.100 libraries have participated in LibQUAL+, including college and university libraries, community college libraries, health sciences libraries, academic law libraries, and public libraries [12,13,14,15,16]. It was developed in the United States with the aim of collecting data on the quality of library services. The objective of its designers was to develop a tool that would help libraries better understand their users' perceptions of service quality and to use this information in planning their operations.

It is based on the attribute-based gap model SERVQUAL (SERVice QUALity) [17], which was modified for the libraries at Texas A&M University and at the Association for Research Libraries over several years. SERVQUAL was developed for the for-profit sector in the 1980s by the marketing research group of Parasuraman, Zeithaml, and Berry [17,18,19,20]. Grounded in the gap theory of service quality, the singular precept of SERVQUAL is that "only customers judge quality; all other judgments are essentially irrelevant" [21]. In such a way, service quality is the gap between customer's expectations and perceptions. When experiences exceed expectations, the quality of the service is high, and vice versa [15]. Following that idea, LibQUAL+ is a survey administered by the Association for Research Libraries to measure library users' perceptions of library service quality and to help libraries identify service areas needing improvement.

To do so, the LibQUAL+ survey is composed of twenty-two core questions that measure perceptions concerning three dimensions of library service quality [14]:

- *Affect of service*. This dimension assesses empathy, responsiveness, assurance, and reliability of library employees.
- *Library as place*. This dimension measures the usefulness of space, the symbolic value of the library, and the library as a refuge for word of study.
- *Information control*. This dimension measures how users want to interact with the modern library and include scope, timeliness and convenience, ease of navigation, modern equipment, and self-reliance.

Users respond each question of the survey by giving a score from one to nine on a 9-points Likert scale [22,23] about their minimum acceptable service level, their desired service level, and their perception of the actual service provided by the library. The minimum service level and the desired service level reflect the importance of that service to the user: a low level means that it is not considered very important, and when the minimum or desired service level receive high scores, the issue is important.

Once all users have filled all the surveys, for each question, gap scores are obtained between desired and perceived expectations and between minimum and perceived expectations. The zone of tolerance is the difference between the minimum and desired scores. Optimally, perceived performance assessments should fall comfortably within that zone. A positive gap means that the service performance has surpassed users' expectations, whereas a negative gap indicates that the service performance has fallen short of the expected service. Gap models are by instinct attractive to many research consumers [24] since its interpretation is straightforward. As an example, if the perceived rating on an item is below the minimum, it obviously means that the subject the item evaluates needs improvement. On the other hand, if the perceived rating on an item is very above the desired level of service, it may imply that the item is not a concern to consumers.

In addition to the twenty-two core questions, the survey also asks additional questions on information literacy and overall satisfaction, and some questions concerning the use of libraries and other information sources. In this case, users are asked for their impressions about questions on information literacy and overall satisfaction by giving a score from one to nine, while the questions concerning the use of libraries and other information sources are answered by giving a value among "Daily", "Weekly", "Monthly", "Quarterly" or "Never". Finally, users have the opportunity to give an open feedback and are also asked to give their demographic profile, including age group, sex, discipline, and status, in order to facilitate a group-wise analysis of the results [15].

3. A Web Information System To Improve the Service Quality of the Digital Libraries

In this section the web information system generating advice to improve the services offered by the digital libraries is described. It presents the following features:

- It is based on a LAMP stack [25,26] (GNU/Linux, Apache Web server, MySQL database, and PHP programming language). In addition, it is fully Web-based, being all its components and options accessible through a Web interface.
- It uses both subjective criteria, related to the users' judgments, and objective criteria, related to the quantitative data of the digital library, to evaluate the quality of the services provided by the digital libraries.
- It is based on some decision rules to generate advice in order to improve the quality of the services. The aim is to increase the users' satisfaction and, therefore, the number of users accessing to the digital library.

In the following, both the subjective and the objective criteria which are used by the web information system are described. Then, the decision rules which are applied to generate the advice are presented.

3.1. Subjective Criteria

An information quality framework defined in the context of management information systems was presented in [31], defining four quality dimensions, namely:

- *Intrinsic quality*. It addresses the very nature of the information, assuming that information has its own quality. The main criterion of this dimension is the accuracy of the information. In such a way, 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. In addition, other criteria of this dimension are: credibility, reputation and objectivity.
- *Contextual quality.* It emphasizes the importance of the informative aspects of information but from a task perspective. This dimension highlights the requirement that information quality must be considered within the context of the task in hand. As a consequence, 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. Hence, some criteria of this dimension are: value-added, timeliness, completeness, relevance, and appropriate amount.

- *Representational quality.* It emphasizes the importance of the technical aspects of the computer-based structure of the information. This dimension requires information systems to present their information in such a way that it is construable, easy to understand, easy to manipulate, and it is represented concisely and consistently. As a result, among the criteria of this dimension are: understandability, interpretability, concise representation, and consistent representation.
- *Accessibility quality.* It emphasizes the importance of the technical aspects of computer systems that provided access to information. This dimension requires the information system to be accessible but secure. Hence, some criteria of this dimension are: accessibility and secure access.

This information quality framework established that the quality of the information systems cannot be evaluated separately from the users' opinions.

According to this framework, in [32], a quality evaluation model of digital libraries based on users' satisfaction was proposed. It defined an evaluation scheme of digital libraries contemplating the above four quality dimensions together with their digital quality criteria. As it was oriented to users, a low number of subjective criteria was defined, being them easily understandable by the users in order that they did not cause the rejection of them. In particular, the digital quality criteria contemplated in each quality dimension are:

- *Intrinsic quality of digital libraries.* To evaluate the intrinsic quality or accuracy of digital libraries, the following subjective criterion was defined: *you find what you are looking for*.
- *Contextual quality of digital libraries.* To evaluate the information quality of the digital libraries within the context, the following subjective criteria were defined: *coverage of the digital library about search topics*, *information electronic services about new inputs*, *added value information profits* and also *global satisfaction degree*.
- *Representational quality of digital libraries.* It was evaluated considering the following subjective criteria: *understandability of the digital library Web site* and *training received*.
- *Accessibility and interaction quality of digital libraries.* It was measured taking into account the following subjective criteria: *variety of search tools*, *navigability of the digital library Web site*, *satisfaction degree with the computing infrastructure* and *satisfaction degree with the response time*.

The web information system presented here makes use of the subjective criteria proposed in the quality evaluation model presented in [32]. In such a way, the subjective criteria considered by the web information system are the following:

1. *You find what you are looking for* (sc_1).
2. *Coverage about search topics* (sc_2).
3. *Information electronic services about new inputs* (sc_3).
4. *Variety of search tools* (sc_4).
5. *Navigability of the Website* (sc_5).
6. *Understandability of the Website* (sc_6).

7. *Added value information profits* (sc_7).
8. *Satisfaction degree with the computing infrastructure* (sc_8).
9. *Satisfaction degree with the response time* (sc_9).
10. *Training received* (sc_{10}).

It is important to point out that the users of the digital libraries are invited to fill a questionnaire, which is composed of ten questions, one per each subjective criterion, to obtain the values of the subjective criteria. To do so, the concept behind each question is assessed using a 9-points Likert scale [22].

Users are asked for their opinions about the above ten subjective criteria according to the minimum level of service that they would find acceptable, the desired service level they expect, and their perceived service level. As a result, for each one of the users, $u_j \in \{u_1, \ldots, j_n\}$, and each subjective criterion $sc_k \in \{sc_1, \ldots, sc_{10}\}$, there is a tuple $(MSL_{jk}, DSL_{jk}, PPL_{jk})$ encoding the minimum service level, the desired service level, and the perceived performance level given by the user u_j on the subjective criterion sc_k, respectively.

To obtain the global quality assessment regarding each subjective criterion sc_k, (MSL_k, DSL_k, PPL_k), the opinions given by the users are aggregated by means of the arithmetic mean operator ϕ:

$$\begin{aligned} \text{MSL}_k &= \phi(MSL_{1k}, \ldots, MSL_{nk}) \\ \text{DSL}_k &= \phi(DSL_{1k}, \ldots, DSL_{nk}) \\ \text{PPL}_k &= \phi(PPL_{1k}, \ldots, PPL_{nk}) \end{aligned} \tag{1}$$

where MSL_k, DSL_k and PPL_k stand for the values representing the minimum service level, the desired service level and the perceived performance level, respectively, of the digital library with respect to the subjective criterion sc_k.

Finally, and following the LibQUAL+ model, gap analysis is done for each subjective criterion. Service quality is the gap between user's expectations and perceptions. When experiences exceed expectations, the quality of the service is high, and vice versa. In such a way, four gaps may be identified:

- A positive adequacy gap, which appears when the perceived performance level exceeds the minimum service level accepted by the users. It indicates the extent to which the service surpass the lowest possible level that users will admit.
- A negative adequacy gap, which occurs when the offered service is below the minimum service level accepted by the users.
- A positive superiority gap, that opens up when the perceived performance level exceeds the desired service level.
- A negative superiority gap, that means that the perceived performance level does not reach the desired service level but exceeds the minimum service level accepted by the users.

According to the above considerations, two scores obtaining the strengths and weaknesses of a digital library are defined:

$$\begin{aligned} SA_k &= PPL_k - MSL_k \\ SS_k &= PPL_k - DSL_k \end{aligned} \tag{2}$$

where SA_k is the service adequacy score on the subjective criterion, sc_k, and SS_k is the service superiority score on the subjective criterion, sc_k.

SA_k is an indicator of the extent to which a digital library is meeting the minimum expectations of its users on the subjective criterion sc_k. A negative value of SA_k means that the users' perceived performance level of the service quality is below their minimum service level. It may be used to identify areas needing improvement. A positive SS_k is an indicator of the extent to which digital libraries are exceeding the desired expectations of their users. It can be used to identify services satisfied outstandingly by a digital library.

3.2. Objective Criteria

Before choosing the objective criteria considered by the web information system, it is important to analyze the activity of a digital library from the perspective of the General Systems Theory [27], using one of the classic graphics representing an information system. The General Systems Theory is based on the attempt to build mathematical models in such a way that once they have been developed, they can be used by different disciplines. According to it, we follow authors like Thelwall [28], Ingwersen [29] and Chao [30], which attempt to generate a mathematical basis to validate the assessments that they pose. This mathematical support will be the basis to formulate and establish models.

The interpretation of the graph, in which the activity of a digital library is shown as an information system, would be as follows. From some system inputs measured as economic investments in the different facets of the digital library, various digital library processes generating resources and assets in the digital library entity are performed. These assets and resources begin some system outputs related to the services provided to the users. In the case of digital libraries, the system inputs, the digital library processes and the system outputs could be measured as follows:

1. System inputs:
    - Amount of money per user.
    - Amount of money spent on e-resource per user.
2. Digital library processes:
    - Megabytes per user.
    - e-Journal per user.
    - Digitization of the library collection.
3. System outputs:
    - Number of e-resources downloaded.
    - Queries on e-journals per user.
    - Accesses to the digital library per user.
    - Queries on the digital library collection per user.
    - Queries-searches on the digital library per user.

Among the quantitative indicators of the system inputs, digital library processes and system outputs, three of them have been selected to be included in the web information system because they are the most related to the circulation of the users through the digital library. That is, the greater the circulation of the users through the digital library, the greater the number of users accessing to the services provided by the digital library. Therefore, if there is a high number of users accessing to the digital library, it is because the digital library services are satisfying the users' expectations. In particular, the objective criteria considered are the following:

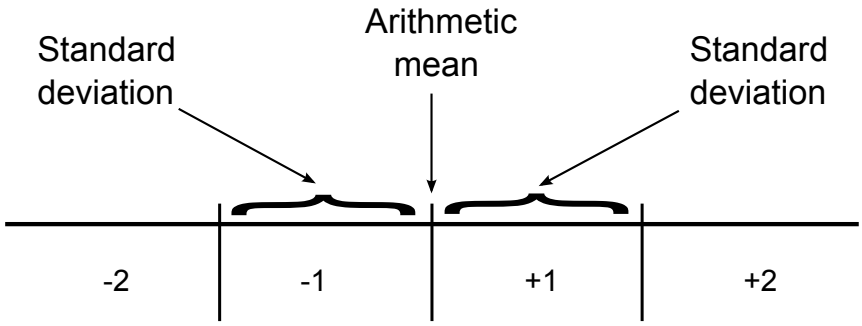

Figure 1. Groups $(-2, -1, +1, +2)$.

1. *Accesses to the digital library per user* (oc_1). This objective criterion is defined as the total number of accesses to the digital library divided by the total number of users.
2. *Queries on the library collection per user* (oc_2). This objective criterion is defined as the total number of queries on the collection of the digital library divided by the total number of users.
3. *Megabytes of the digital library per user* (oc_3). The amount of information provided by a Website should be taken into account as a quality indicator. In a digital library, this amount of information is measured as the total number of megabytes of the digital library divided by the total number of users. It is similar to the size of the collection per capita in the traditional libraries.

In this case, the values of the three objective criteria are directly obtained from the data supplied by the staff of the digital library instead of from the opinions given by the users.

Finally, the service adequacy score of each objective criterion has to be obtained. In this respect, the following calculations are carried out:

- The arithmetic mean of each objective criterion among all the digital libraries which are being evaluated is computed. It establishes if the quality of a digital library on that objective criterion is better or worse than the average quality of the digital libraries on that objective criterion.
- The standard deviation of each objective criterion among all the digital libraries which are being studied is computed. It may be used to distinguish among the digital libraries which are either too far (successfully as well as unsuccessfully) or too close to the average.
- Once the arithmetic mean and the standard deviation have been obtained, the score of each objective criterion is situated in one of the four groups shown in Figure 1.

The meaning of each one of these four groups, in which an objective criterion can be situated, is the following:

- Group -2. The evaluation on that objective criterion is much worse than the average. Therefore, it is urgent to improve it.

- Group -1. The evaluation on that objective criterion is worse than the average. It is important to improve that objective criterion but it is more important to make better the criteria which are in group -2.
- Group $+1$. The evaluation on that objective criterion is better than the average. Hence, it is conveniently satisfied.
- Group $+2$. The evaluation on that objective criterion is much better than the average. As a consequence, it is totally satisfied.

3.3. Generation of Advice

In the following, the way in which the advice is generated by the web information system is detailed. To do so, the decision rules used to provide the advice are described. These decision rules are activated from the values of the service adequacy score of the subjective and objective criteria.

3.3.1. Objective Criteria: Decision Rules

To describe the decision rules obtained from the objective criteria, first, it is necessary to point out that the group of each objective criterion is noted as G(.). For example, the group of the objective criterion oc_3 is G(oc_3). Additionally, due to the high correlation between the objective criteria oc_1 and oc_2, we get a measure of the group which is composed of both criteria: $\mathrm{G}(oc_{12}) = (\mathrm{G}(oc_1) + \mathrm{G}(oc_2))/2$. From the group in which each objective criterion is, the following decision rules are applied:

- Decision rule 1: If $\mathrm{G}(oc_{12}) < 0$, and $\mathrm{G}(oc_3) < 0$, then the following advice is generated:
  - *The number of users accessing to the digital library is low. Furthermore, the digital collection is poor. Maybe it causes the low number of users. It is recommended to increase and improve the digital collection.*
- Decision rule 2: If $\mathrm{G}(oc_{12}) < 0$, and $\mathrm{G}(oc_3) > 0$, then the following advice is generated:
  - *The number of users accessing to the digital library is low, although the digital collection is appropriate. It is recommended to train better to the users and to improve the query tools. In addition, it would be recommendable to give grants to the users for buying computers.*
- Decision rule 3: If $\mathrm{G}(oc_{12}) > 0$, and $\mathrm{G}(oc_3) < 0$, then the following advice is generated:
  - *Although the digital library has a good number of accesses and queries, the digital collection is poor. It is recommended to increase and improve the digital collection.*

3.3.2. Subjective Criteria: Decision Rules

According to the surveys filled by the users, different recommendations may be generated. To do so, from the service adequacy score, SA_k, of each subjective criterion, sc_k, and, in some cases, also taking into account the objective criteria to improve the guidance, the following set of decision rules is applied:

- Decision rule 4: If $SA_1 < 0$, and $\mathrm{G}(oc_3) < 0$, then the following advice is generated:
  - *It seems that users do not find out what they are looking for. Maybe it is due to that the digital collection is poor. It is recommended to increase and improve the digital collection.*
- Decision rule 5: If $SA_1 < 0$, and $\mathrm{G}(oc_3) > 0$, then the following advice is generated:
  - *It seems that users do not find out what they are looking for. However, the digital collection is appropriate. It is recommended to invest in training of users and to provide better query tools.*
- Decision rule 6: If $SA_2 < 0$, then the following advice is generated:
  - *Users think that the coverage of the digital library about search topics is poor. It is recommended to increase the digital collection and to improve the mechanisms of information diffusion (mailing lists, news pages, etc.).*
- Decision rule 7: If $SA_3 < 0$, then the following advice is generated:
  - *Users are not well informed about new inputs in the digital library. It is recommended to improve the mechanisms of information diffusion (mailing lists, news pages, etc.).*
- Decision rule 8: If $SA_4 < 0$, then the following advice is generated:
  - *Users think that the variety of search tools is not appropriate. It is recommended to improve both the current search tools and the training of users.*
- Decision rule 9: If $SA_5 < 0$, or $SA_6 < 0$, then the following advice is generated:
  - *Users think that the navigability / understandability of the digital library Website is poor. It is recommended to improve the Website design and to use more Web standards.*
- Decision rule 10: If $SA_7 < 0$, then the following advice is generated:
  - *Users think that the digital library should provide more added value information profits. It is recommended to provide more added value information profits, as for example: completing the search results with links to other search engines and providing access to other Websites.*
- Decision rule 11: If $SA_8 < 0$, then the following advice is generated:
  - *Users think that the computing infrastructure of the digital library is not appropriate. It is recommended to improve the computing infrastructure and to increase the number of access points.*
- Decision rule 12: If $SA_9 < 0$, then the following advice is generated:
  - *Users think that the response time of the digital library is not appropriate. It is recommended to improve the system design and to invest in servers more powerful.*

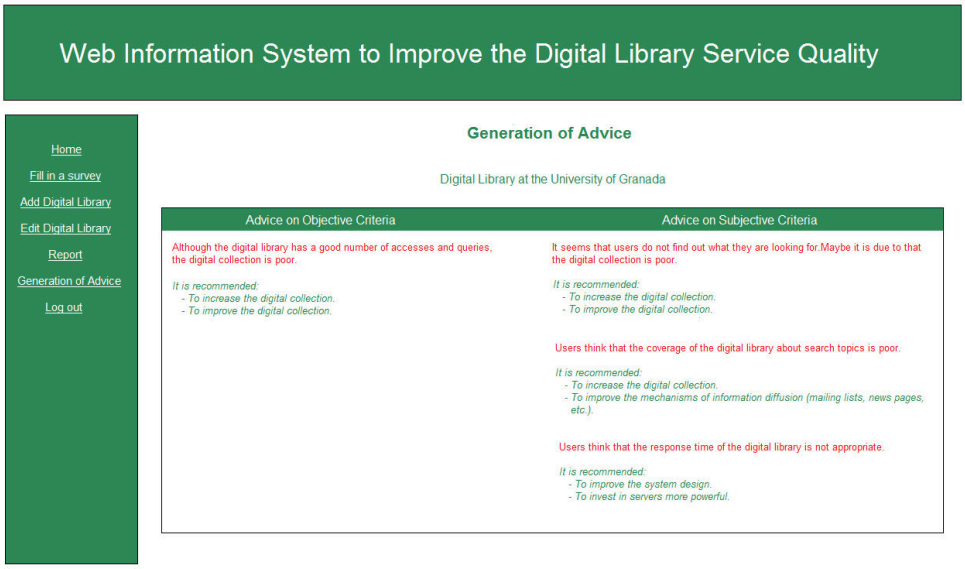

Figure 2. Generation of advice.

- Decision rule 13: If $SA_{10} < 0$, then the following advice is generated:
  - ∗ *Users do not receive training in the use of the digital library. It is recommended to invest in the training of users.*

An example of the advice generated by the web information system is shown in Figure 2. The advice is divided into two columns and each recommendation is composed of two parts. The first one, in red color, indicates the problem detected. The second one, in green color, provides the suggestions proposed to solve the problems detected. The advice is expressed in natural language in order to facilitate its understanding to the staff of the digital library.

4. Conclusions and Future Work

In this contribution, we have presented a web information system which generates some advice in order to improve the services offered by the digital libraries and, in such a way, to increase the number of users accessing and using the digital libraries. To do so, the web information system is based on several decision rules which are activated according to the values of both subjective and objective criteria.

In the future, it is worth continuing this research in several directions, which are summarized as follows:

- The process of quality evaluation is centered on humans, coming with their inherent subjectivity, imprecision and vagueness in the verbal expression of opinions [33]. Therefore, the theory of fuzzy sets [34], proposed by Zadeh, is a more adequate tool to represent the opinions given by the users. In addition, the information expressed by the humans is inherently non-numeric and partial evaluations, pref-

erences, judgments, and weights are usually given linguistically. Hence, it would be desirable to use a fuzzy linguistic modeling to represent the users' judgments [35,36,37].

- The web information system considers that all the users' opinions are equally important. However, users do not play equal roles in measuring library service quality. That is, some users should be more influential than others in some questions. It would be interesting to take into account the level of expertise or importance of the users when aggregating their opinions [38,39].
- To use the service superiority score with the aim of reporting the digital libraries satisfying outstandingly the subjective criterion in which the digital library evaluated has obtained a bad result.
- To incorporate to the web information system different kinds of graphical outputs, as radar plots and ball graphs, to better understand the different quality assessments on each criterion that draw the quality situation of a digital library.
- To include information from the users' opinions provided in social media by applying appropriate methods as those developed in [40,41].
- Ten subjective criteria are used by the web information system to provide the advice. However, depending on the digital library style, this probably would be different. In addition, other parameters could be specified by the digital library. Therefore, it would be desirable to design a model (ontology [42,43,44]) that can be projected on any digital library and through it the criteria can be elicited.

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