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A New Quality Evaluation Model Generating Recommendations to Improve the Digital Services Provided by the Academic Digital Libraries

*F.J. Cabrerizo
Dept. Software Engineering and Computer Systems
UNED
28040, Madrid, Spain
cabrerizo@issi.uned.es

M.A. Martínez, J. López–Gijón
Dept. Library Science
University of Granada
18071, Granada, Spain
mamartinez@gmail.com
jgijon@ugr.es

B. Esteban, E. Herrera–Viedma
Dept. Computer Science and Artificial Intelligence
University of Granada
18071, Granada, Spain
bernabe@ugr.es
viedma@decsai.ugr.es

Abstract: In modern society, information diffusion and remote education increase rapidly and, consequently, an academic digital library is not just a novelty but also a necessity, associated with the promotion and diffusion of research work that is being carried out. As the services provided by the academic digital libraries are to satisfy users' needs, users' satisfaction is essential for the success of them. Due to it, the improvement of the digital services provided by the academic digital libraries is important in order to satisfy the users' needs. The aim of this paper is to present a new quality evaluation model which takes into account subjective criteria to generate recommendations with the aim of improving the digital services provided by the academic digital libraries.

1 INTRODUCTION

Academic libraries and other "traditionally organized" libraries are undergoing a phase of rapid evolution. The academic libraries have always comprised a "mechanism" of managing and supporting access to documentation, information and knowledge. It is such an integral, functional part of the University, that one could not imagine a University without a library [1].

The main role of academic libraries, and at the same time the basic reason of their existence, has been to support the educational and research work carried out, within an Academic Institution.

However, due to the spectacular growth of the World Wide Web, related to both Web resources (pages, sites, and services) and visitors, the Web is nowadays the main information repository. Its explosive growth has stimulated the development of fast and effective automated systems that support an easy and effective access to the information relevant to specific users' needs [2]. Digital libraries (DLs) [3, 4, 5, 6, 7, 8, 9, 10] are one of these automated systems.

DLs may be defined as information collections that have associated services delivered to user communities using a variety of technologies. The information collections can be scientific, business, or personal data, and can be represented as digital text, image, audio, video, or other media. This information can be digitalized paper or born digital material and the services offered on such information can be varied, and can be offered to individuals or user communities [9]. Furthermore, DLs are components in several types of applications in area such as cultural heritage, health, government, learning, and science.

Due to the fact that academic libraries have always been members of a community that has always targeted on scientific progress, research promotion and innovation, they have always witnessed scientific and technological evolutions, both as recipients of the evolution of knowledge with the acquisition of scientific material as well as institutions implementing all those innovations contributing to the improvement of their organization, and of their ability to better serve their users [11]. For these reasons, they have been initiators in the configuration of this emerging new form of libraries, the DLs.

Academic library users are now offered a variety of academic resources with different forms of interactivity (e.g., academic networks vs off–line libraries) and with different levels of media richness (e.g., text vs graphics–supported). They can obtain research data and publications as needed without the massive investment of capital and infrastructure to house vast physical collections. Information–seeking in DLs has become an indispensable tool in academia, and personal use is increasing every day [12].

Academic DLs can integrate research resources and enable users to seek specific information in virtual space. Increasingly, some sources of information, such as online databases, electronic bulletin boards, and local magnetic or optical databases, are available only in academic form [12]. Empirical evidence has pointed out that users make frequent use of the internet to search for specific academic information. For this reason, there is a large number of users whose expectations and demands for better service and functionality are increasing. Thus, the importance of quality in academic DLs content and services is higher than ever [13].

In [14], Cabrerizo et al. present a model based on fuzzy linguistic information to evaluate the quality of DLs. They defined the quality evaluation of DLs using users' perceptions on the quality of digital services provided through their Websites. To do so, they assumed a fuzzy linguistic modeling to represent the users' perceptions and applied automatic tools of fuzzy computing with words based on the LOWA [15] and LWA [16] operators to compute global quality evaluations of DLs. This model provides to the staff of the academic DL both the quality assessment of the users on each subjective criterion and the global quality assessment of the users on the DL. However, it does not generate to the staff of the academic DL any recommendation for improving the digital services provided by the DLs through their Websites.

The aim of this paper is to present a new quality evaluation model generating recommendations in order to improve the digital services provided by the academic DLs. This new evaluation model takes into account subjective criteria (related with users' judgments) and provides recommendations to im-

prove the digital services and functionality of the academic DLs in order to increase the users' satisfaction with the academic DL. To do so, the system has a set of decision rules that are activated depending on the values of the quality subjective criteria. To obtain the values of the subjective criteria, the system is designed using the model based on fuzzy linguistic information to evaluate the quality of DLs presented in [14] and the LibQUAL+ methodology [17, 18].

The rest of the paper is set out as follows. In Section 2, both the quality evaluation model based on fuzzy linguistic information of DLs presented in [14] and the LibQUAL+ methodology, which are the basis of the new quality evaluation model of DLs presented in this paper, are introduced. Section 3 describes the new quality evaluation model which generates recommendations to the staff of the academic DLs with the aim of improving the digital services provided through their Websites. Finally, some concluding remarks are pointed out in Section 4.

2 PRELIMINARIES

In this section we describe the basis of the new quality evaluation model which generates recommendations to the staff of the academic DL to improve its digital services, that is, the quality evaluation model of DLs presented in [14] and the LibQUAL+ methodology [17, 18].

2.1 A model based on fuzzy linguistic information to evaluate the quality of DLs

In [14], Cabrerizo et al. presented a model based on fuzzy linguistic information to evaluate the quality of DLs. They used the information quality framework [19] defined in the context of management information systems as basis of their evaluation model. In this way, they defined an evaluation scheme of DLs that contemplated four quality dimensions together with their digital quality criteria. As it was oriented to users because the user participation in the quality evaluation processes of services is fundamental to correctly draw the situation of the service, they defined a low number of subjective criteria being easily understandable by the users in order that they did not cause the rejection of the users. In this way, the following eleven subjective criteria were defined:

1 *You find what you are looking for.*
2 *Coverage of the DL about search topics.*
3 *Information electronic services about new inputs.*
4 *Added value information profits.*
5 *Global satisfaction degree.*
6 *Understandability of the DL Website.*
7 *Training received.*
8 *Variety of search tools.*
9 *Navigability of the DL Website.*
10 *Satisfaction degree with the computing infrastructure.*
11 *Satisfaction degree with the response time.*

As the development of DLs is to satisfy users' needs, the quality evaluation of DLs was defined using users' perceptions on the quality of digital services provided through their Websites. To do so, users were invited to fill in a survey built on the set of the above eleven subjective criteria.

An ordinal fuzzy linguistic modeling [15, 16, 20, 21] to represent the users' perceptions was assumed as it facilitates the fuzzy linguistic modeling very much because it simplifies the definition of the semantic and syntactic rules. It is defined by considering a finite and totally ordered label set $S = \{s_i\}$, $i \in \{0, \ldots, \mathcal{T}\}$, in the usual sense, i.e., $s_i \geq s_j$, if $i \geq j$, and with odd cardinality (7 or 9 labels). The mid–term represents an assessment of "proximately 0.5", and the rest of the terms being placed symmetrically around it. These classical values seem to fall in line Miller's observation about the fact that human beings can reasonably manage to bear in mind seven or so items [22]. The semantics of the label set is established from the ordered structure of the label set by considering that each label for the pair $(s_i, s_{\mathcal{T}-i})$ is equally informative. For example, the following set of nine labels, S, to provide the users' evaluations can be used:

$S = \{$*N = None, EL = Extremely Low, VL = Very Low, L = Low, M = Medium, H = High, VH = Very High, EH = Extremely High, T = Total*$\}$.

In addition, tools of computing with words based on the linguistic aggregation operators LOWA [15] and LWA [16] to compute the quality assessments were used. In the following, we are going to define the LOWA operator because it is used in the new quality evaluation model which is described in next section.

The *Linguistic Ordered Weighted Averaging* (LOWA) is an operator used to aggregate non–weighted ordinal linguistic information, i.e., linguistic information values with equal importance [15].

Definition 2.1 Let $A = \{a_1, \ldots, a_m\}$ be a set of labels to be aggregated, then the LOWA operator, ϕ, is defined as:

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

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

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

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

$$\mathcal{C}^m\{w_i, b_i,\ i = 1, \ldots, m\} = b_j.$$

The LOWA operator is an "or–and"operator [15] and its behavior can be controlled by means of W. In order to classify OWA operators with regards to their localization between "or" and "and", Yager [23] introduced a measure of *orness*, associated with any vector W : $orness(W) = \frac{1}{m-1}\sum_{i=1}^{m}(m - i)w_i$. This measure characterizes the degree to which the aggregation is like an "or" (MAX) operation. Note that an OWA operator with $orness(W) \geq 0.5$ will be an *orlike*, and with $orness(W) < 0.5$ will be an *andlike* operator.

An important question of the LOWA operator is the determination of the weighting vector W. In [23], it was defined an expression to obtain W that allows to represent the concept of fuzzy majority [24] by means of a fuzzy linguistic nondecreasing quantifier Q [25]:

$$w_i = Q(i/n) - Q((i - 1)/n),\ i = 1, \ldots, n.$$

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

2.2 LibQUAL+ methodology

To improve the evaluation model presented in [14] and to obtain better digital services in DLs, the LibQUAL+ methodology [17, 18] may be used. LibQUAL+, a joint research and development project of Texas A&M and ARL, has emerged as both a process and a tool that enables institutions to address service quality gaps between their expectations and the perceived service delivery, to enhance student and faculty research, teaching, and learning needs. LibQUAL+ has been gradually and carefully applied to a variety of post–secondary library environments, including the health sciences library context and statewide contexts such as OhioLINK. Furthermore, LibQUAL+ aspires to push the frontiers of service quality assessment theory and pioneer the use of large–scale, Web–based, survey applications in a DL environment [18].

LibQUAL+ is a modification of SERVQUAL as it has been tested in the research library environment. SERVQUAL (for SERVice QUALity) was developed for the for–profit sector in the 1980s by the marketing research group of Parasuraman, Zeithaml, and Berry [26, 27, 28, 29]. Grounded in the Gap Theory of Service Quality, the singular percept of SERVQUAL is that "only customers judge quality; all other judgments are essentially irrelevant" [30]. To derive the gaps essential for measuring perceptions of service quality, respondents are asked to establish their judgments across three scales for each question: the desired level of service they would like to receive, the minimum they are willing to accept, and the actual level of service they perceive to have been rendered. The desired scores and the minimum scores establish the boundaries of a zone of tolerance within which the perceived scores should desirably float.

The original SERVQUAL design asked 22 questions across the five survey dimensions. For each question, the user is asked for impressions of service quality according to (1) minimum service levels, (2) desired service levels, and (3) perceived performance. For each question, gap scores are calculated between minimum and perceived expectations and between desired 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. Administrators should be concerned by scores that fall outside the zone and by decreasing trajectories over time. Excellence in service might have been achieved for attributes where the perception of actual service delivery has a higher score than the desired expectation. The difference between the minimum and perceived scores is called the service adequacy score, and the difference between the perceived and desired score is called the service superiority score.

3 A New Quality Evaluation Model to Improve the Digital Services of the DLs

In this section we present a new quality evaluation model which generates recommendations to improve the quality of digital services provided by the academic DLs through their Websites according to subjective criteria related with users' judgments. It is important to note that the aim of these recommendations is to increase the users' satisfaction with the academic DLs and, therefore, the global quality assessment of the users on them.

In the following, we describe how this new system adapts the quality evaluation model of DLs presented in [14] according to the SERVQUAL and LibQUAL+ methodology to obtain the values of the service adequacy score and the service superiority score of each subjective criterion. Furthermore, we show the decision rules which are applied to generate the recommendations.

3.1 Obtaining the values of each subjective criterion

As aforementioned in Section 2, we use the model based on fuzzy linguistic information to evaluate the quality of digital libraries presented in [14] and the LibQUAL+ methodology [17, 18]. In particular, we use the following ten of the eleven subjective criteria as they have greater impact in the users' needs.

- sc_1: *You find what you are looking for.*
- sc_2: *Coverage of the DL about search topics.*
- sc_3: *Information electronic services about new inputs.*
- sc_4: *Variety of search tools.*
- sc_5: *Navigability of the DL Website.*
- sc_6: *Understandability of the DL Website.*
- sc_7: *Added value information profits.*
- sc_8: *Satisfaction degree with the computing infrastructure.*
- sc_9: *Satisfaction degree with the response time.*
- sc_{10}: *Training received.*

It is assumed that to measure the users' perceptions on the quality of digital services provided by the DLs through their Website, users are invited to fill the questionnaire shown in Fig. 1, which has 10 questions: $\{q_1, \ldots, q_{10}\}$.

To adapt the quality evaluation model of DLs presented in [14] according to the SERVQUAL and LibQUAL+ methodology, users are asked for impressions about the above ten subjective criteria according to:

- Minimum service level.
- Desired service level.
- Perceived performance level.

The concept behind each question is rated on a linguistic term set S. For instance, the linguistic term set presented in Section 2.1 can be used. Then, once the group of users, $\{e_1, \ldots, e_L\}$, have filled all the questionnaires for a given DL, A_m, the system calculates for each subjective criterion, sc_i, its global quality assessment of the minimum service level, MSL_i^m, its global quality assessment of the desired service level, DSL_i^m, and its global quality assessment of the perceived performance level, PPL_i^m, by aggregating the evaluation judgments provided by the group of users on the subjective criterion, sc_i, by means of the LOWA operator ϕ:

$$MSL_i^m = \phi(e_1(q_i^{MSL}), \ldots, e_L(q_i^{MSL})),$$
$$DSL_i^m = \phi(e_1(q_i^{DSL}), \ldots, e_L(q_i^{DSL})),$$
$$PPL_i^m = \phi(e_1(q_i^{PPL}), \ldots, e_L(q_i^{PPL})),$$

where $e_l(q_i^{MSL}) \in S$ is the minimum service level provided by the user e_l on subjective criterion, sc_i, represented by the question q_i, $e_l(q_i^{DSL}) \in S$ is the desired service level provided by the user e_l on subjective criterion, sc_i, represented

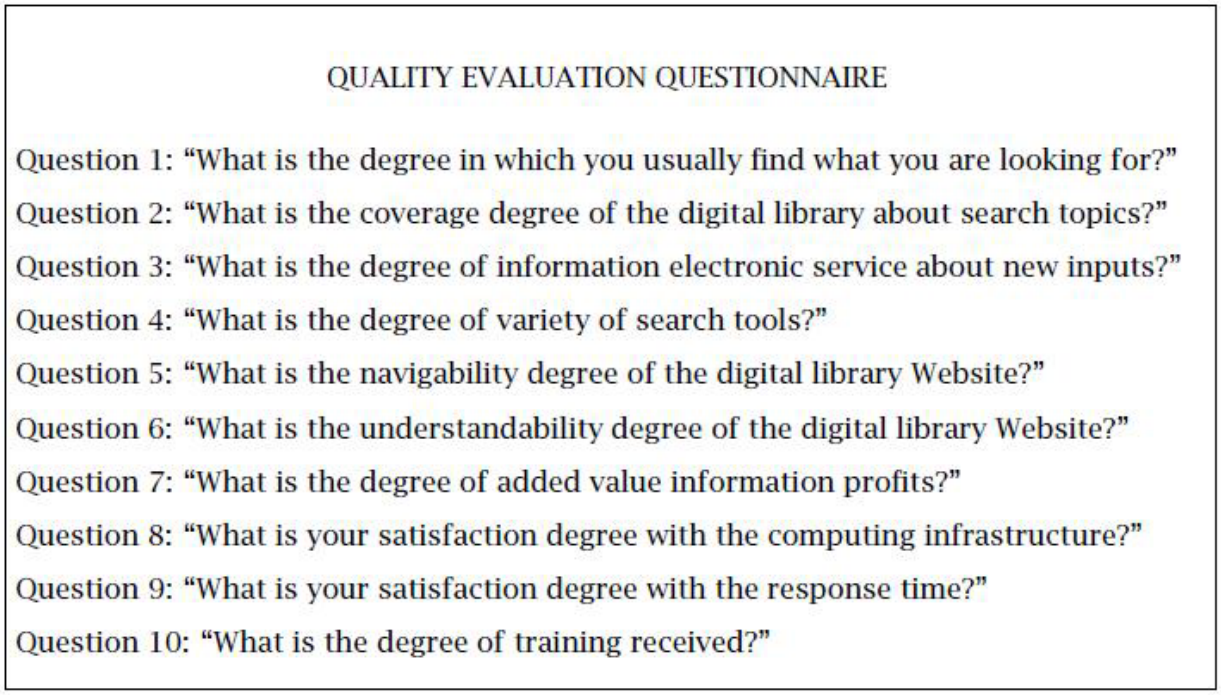

Fig. 1: Quality Evaluation Questionnaire

by the question q_i, and $e_l(q_i^{PPL}) \in S$ is the perceived performance level provided by the user e_l on subjective criterion, sc_i, represented by the question q_i. Therefore, MSL_i^m, DSL_i^m and PPL_i^m, are the linguistic measures that represents the minimum service level, the desired service level and the perceived performance level, respectively, of the DL, A_m, with respect to subjective criterion sc_i according to the majority (represented by the fuzzy linguistic quantifier Q) of linguistic evaluation judgments provided by the group of users $\{e_1, \ldots, e_L\}$.

According to the users' answers, it is defined two scores which can obtain the strengths and weaknesses of a DL, A_m:

$$SA_i^m = I(PPL_i^m) - I(MSL_i^m),$$
$$SS_i^m = I(PPL_i^m) - I(DSL_i^m),$$

where MSL_i^m, DSL_i^m, $PPL_i^m \in S$, SA_i^m is the service adequacy score on the subjective criterion, sc_i, of the DL, A_m, SS_i^m is the service superiority score on the subjective criterion, sc_i, of the DL, A_m, and

$$I : S \to \{0, \ldots, \mathcal{T}\} \mid I(s_i) = i,\ \forall s_i \in S.$$

The service adequacy score identify the digital services of the DL in which the perceived performance level is worse than the minimum service level required by the user, whereas the service superiority score identify the digital services in which the perceived performance level is better than the desired level by the user.

3.2 Generating recommendations

From the users' opinions obtained through the surveys filled by the users of the academic DLs, different recommendations may be generated to the staff in order to improve the digital services and functionality of the academic DL to increase the users' satisfaction. To do so, the service adequacy score on each criterion is used. In particular:

- If $SA_i^m > 0$, it means that users' perceptions of the DL, A_m, on the subjective criterion, sc_i, is higher than the minimum service required.
- If $SA_i^m < 0$, it means that users' perception of the DL, A_m, on the subjective criterion, sc_i, is not sufficient (the perceived performance is lower than the minimum service required).

From the service adequacy score on each subjective criterion, the following set of decision rules is applied:

- **Decision rule 1:** If $SA_1^m < 0$, then the following recommendation is generated:
  - *"It seems that users do not find out what they are looking for. Maybe it is due to that the digital library collection is poor. It is advised to increase the digital collection and, in addition, to invest in training of users and to provide better query tools".*
- **Decision rule 2:** If $SA_2^m < 0$, then the following recommendation is generated:
  - *"Users think that the coverage of the academic DL about search topics is poor. It is advised to increase the digital collection and to improve the mechanisms of information diffusion (mailing lists, news pages, etc.)".*
- **Decision rule 3:** If $SA_3^m < 0$, then the following recommendation is generated:
  - *"Users are not well informed about new inputs in the academic DL. It is advised to improve the mechanisms of information diffusion (mailing lists, news pages, etc.)".*
- **Decision rule 4:** If $SA_4^m < 0$, then the following recommendation is generated:

  - *"Users think that the variety of search tools is not appropriate. It is advised to improve both the current search tools and the training of users".*

- **Decision rule 5:** If $SA_5^m < 0$ or $SA_6^m < 0$, then the following recommendation is generated:

  - *"Users think that the navigability/understandability of the academic DL Website is poor. It is advised to improve the Web page design and to use more Web standards".*

- **Decision rule 6:** If $SA_7^m < 0$, then the following recommendation is generated:

  - *"Users think that the academic DL should provide more added value information profits. It is advised to provide more added value information profits, as for example: completing the search results with links to others search engines and providing access to other Websites".*

- **Decision rule 7:** If $SA_8^m < 0$, then the following recommendation is generated:

  - *"Users think that the computing infrastructure of the academic DL is not appropriate. It is advised to improve the computing infrastructure and to increase the number of access points".*

- **Decision rule 8:** If $SA_9^m < 0$, then the following recommendation is generated:

  - *"Users think that the response time of the academic DL is not appropriate. It is advised to improve the system design and to invest in servers more powerful".*

- **Decision rule 9:** If $SA_{10}^m < 0$, then the following recommendation is generated:

  - *"Users have not received training for the use of the academic DL. It is advised to invest in the training of users".*

Furthermore, the quality evaluation model will report the subjective criteria, sc_i, which are satisfied outstandingly by the DL, A_m. To do so, the service superiority score, SS_i^m, on each subjective criterion, sc_i, is used. In this way, if $SS_i^m > 0$, it is considered that the users perceive that the academic DL, A_m, satisfies outstandingly the subjective criterion, sc_i. Then, when a DL obtains a bad evaluation on a subjective criterion, it could be advised by a DL which satisfies outstandingly that subjective criterion in order to improve it. It contributes to increase the communication between the academic DLs with the aim of improving their digital services and functionality and, in this way, to increase the users' satisfaction and, therefore, the global quality assessment of the users on them.

4 Concluding Remarks

Internet access has resulted in academic DLs that are increasingly used by diverse communities for diverse purposes, and in which sharing and collaboration have become important social elements. As academic DLs become commonplace, as their contents and services become more varied, people expect more sophisticated services from their academic DLs. For this reason, we have presented a new quality evaluation system to improve them. This new quality evaluation model takes into account subjective criteria to provide recommendations to the staff of the academic DLs with the aim of improving their digital services and to increase the users' satisfaction.

In the future, we propose to continue this research approach by incorporating to the system, besides the subjective criteria, some objective criteria, such as, total number of accesses to the academic DL, total number of queries on the academic DL, total number of public access points in the University to access to the academic DL and so on, with the aim of increasing and improving the recommendations generated by the system to the staff of the academic DLs.

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