

**World Scientific Proceedings Series on Computer Engineering
and Information Science**

Series Founding Editor: Da Ruan

Series Editor: Jie Lu, University of Technology Sydney

Vol. 1: Computational Intelligence in Decision and Control
*edited by Da Ruan, Javier Montero, Jie Lu, Luis Martínez,
Pierre D'hondt and Etienne E. Kerre*

Vol. 2: Intelligent Decision Making Systems
edited by Koen Vanhoof, Da Ruan, Tianrui Li and Geert Wets

Vol. 3: Computational Intelligence in Business and Economics
edited by Anna M. Gil-Lafuente and José M. Merigó

Vol. 4: Computational Intelligence: Foundations and Applications
*edited by Da Ruan, Tianrui Li, Yang Xu, Guoqing Chen and
Etienne E. Kerre*

Vol. 5: Quantitative Logic and Soft Computing
edited by Guojun Wang, Bin Zhao and Yongming Li

Vol. 6: Methods for Decision Making in an Uncertain Environment
edited by Jaime Gil-Aluja and Antonio Terceño

Vol. 7: Uncertainty Modeling in Knowledge Engineering and
Decision Making
*edited by Cengiz Kahraman, Etienne E Kerre and
Faik Tunc Bozbura*

**Uncertainty Modeling in
Knowledge Engineering
and Decision Making**

Proceedings of the 10th International FLINS Conference

Istanbul, Turkey 26 – 29 August 2012

editors

Cengiz Kahraman

Istanbul Technical University, Turkey

Etienne E. Kerre

Ghent University, Belgium

Faik Tunc Bozbura

Bahcesehir University, Turkey

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

FOREWORD

FLINS, an acronym originally for Fuzzy Logic and Intelligent Technologies in Nuclear Science (1994), has been launched in line with the Belgian Nuclear Research Center (SCK•CEN)'s objective to give PhD and Postdoc researchers the opportunity to carry out future-orientated research. FLINS was initially built within one of the above-mentioned postdoc positions. Later, FLINS has been extended to include the theoretical and practical aspects of computational intelligent systems.

FLINS 2012 follows a successful conferences series: FLINS 1994 in Mol, FLINS 1996 in Mol, FLINS 1998 in Antwerp, FLINS 2000 in Bruges, FLINS 2002 in Gent, FLINS 2004 in Blankenberge, FLINS 2006 in Genova, FLINS 2008 in Madrid, and FLINS 2010 in Chengdu. FLINS 2012 is co-organized by Istanbul Technical University and Bahcesehir University, and cosponsored by the Belgian Nuclear Research Centre (SCK•CEN) and Ghent University in Belgium, and supported by European Society for Fuzzy Logic and Technology (EUSFLAT). It offers a unique international forum to present and discuss recently developed techniques for uncertainty modeling in Knowledge Engineering and Decision Making.

Prof. Da Ruan, the founder of FLINS conferences, was the general chair of all FLINS conferences. Unfortunately, we unexpectedly lost Prof. Da Ruan in July 31, 2011. We are very sad about this irreparable loss of such a great organizer and extremely friendly human being. He was an excellent researcher who encouraged many researchers from different universities to present their works in the international arena and to make collaborations among them. We sincerely hope that this 10th FLINS conference will take place in the spirit of Prof. Da Ruan and that his legacy will be continued for years to come. We will miss Da forever.

The 10th International FLINS Conference (FLINS 2012) is on Uncertainty Modeling in Knowledge Engineering and Decision Making. FLINS 2012 aims at providing an international forum that brings together those actively involved in areas of interest to the uncertainty modeling in Knowledge Engineering and Decision Making, to report on up-to-the-minute innovations and developments, to summarize the state-of-the-art, and to exchange ideas and advances in all aspects of Uncertainty Modeling in Knowledge Engineering and Decision Making.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

World Scientific Proceedings Series on Computer Engineering and Information Science
— Vol. 7
UNCERTAINTY MODELING IN KNOWLEDGE ENGINEERING AND DECISION MAKING
Proceedings of the 10th International FLINS Conference
Copyright © 2012 by World Scientific Publishing Co. Pte. Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN 978-981-4417-73-0

The FLINS 2012 proceedings consist of a series of invited lectures by distinguished professors and individual presentations. Out of 310 regular submissions from 35 countries, 212 papers were selected after a peer review process. The four invited speeches are entitled as (1) Fuzzy Relational Calculus and Its Applications by Prof. Etienne Kerre, (2) Can Computing with Words Bring Complex Nuclear Risk Management Issues into Focus? by Prof. Ashok W. Deshpande, (3) Decision Support and Warning Systems for Business Intelligence by Prof. Jie Lu, (4) Historical Development of Fuzzy System Models by Prof. Burhan Turksen.

The submitted papers have been divided into the following seven main titles: Part 1. Decision Making and Decision Support Systems, Part 2. Uncertainty Modeling, Part 3. Foundations of Computational Intelligence, Part 4. Statistics, Data Analysis and Data Mining, Part 5. Intelligent Information Processing, Part 6. Productivity and Reliability, and Part 7. Applied Research. We are pleased to announce that seven different international journals devoted their special issues to FLINS 2012. These journals are International Journal of Computational Intelligence Systems (SCI-E indexed, Atlantis Press and Taylor & Francis), Journal of Multiple Valued Logic and Soft Computing (SCI-E indexed, Oldcity Publishing), Knowledge-Based Systems (SCI indexed, Elsevier), International Journal of Nuclear Knowledge Management (Inderscience Publication), Journal of Enterprise Information Management (Emerald), International Journal of Information and Communication Technology (Inderscience Publication), and International Journal of Computational Vision and Robotics (Inderscience Publication).

We thank all contributors, referees, regular and invited sessions' chairs, and program committee members of FLINS 2012 for their kind co-operation and enthusiasm for FLINS 2012, especially to Dr. Basar Oztaysi, Dr. Ayberk Soyer, Dr. Seyda Serdar Asan, Dr. Umur Asan, Dr. Sezi Cevik Onar, Dr. Seda Ugurlu, Dr. Ozgur Kabak, Dr. Irem Ucal Sari, Dr. Murat Engin Unal, and Res. Assist. Pinar Dursun for their key roles that made the proceedings of FLINS 2012 possible in a timely manner. We also thank Chelsea Chin (Editor, World Scientific) for her kind advice and help to publish this volume.

Editors
 Prof. Cengiz Kahraman
 Prof. Etienne E. Kerre
 Assoc. Prof. Tunc Bozbura

CONTENTS

Foreword	v
Invited Lectures	
Fuzzy Relational Calculus and Its Wide Range of Applications <i>Etienne E. Kerre</i>	L-1 L-3
Decision Support and Warning Systems for Business Intelligence <i>Jie Lu</i>	L-5
A Review of Developments from Fuzzy Rule Bases to Fuzzy Functions <i>I. Burhan Türksen</i>	L-8
Can Fuzzy Logic Formalism Bring Complex Environmental Issues into Focus? <i>Ashok Deshpande</i>	L-19
PART 1. DECISION MAKING AND DECISION SUPPORT SYSTEMS	1
Evaluation of Manufacturing Technology of Photovoltaic Cells <i>E. Cables Pérez, M. T. Lamata Jiménez, J. L. Verdegay, M. S. Garcia-Cascales, J. M. Sánchez-Lozano</i>	3
A Multicriteria Dynamic Flow Model for Relief Operations <i>G. Tirado, B. Vitoriano, M. T. Ortuno</i>	9
Future Oriented Positioning Analysis with Bayesian Networks <i>Burak Dereli, Umur Asan, Çiğdem Kadaiççi</i>	15
Aggregation Procedure Based on Choquet Integral for Evaluating Company's Environmental Practices <i>R. De Andrés Calle, T. González-Arteaga</i>	22
A Fuzzy Linguistic Evaluation Model of Digital Libraries Based on the LibQUAL+ Methodology <i>F. J. Cabrerizo, M. A. Martínez, J. López-Gijón, E. Herrera-Viedma</i>	28

A FUZZY LINGUISTIC EVALUATION MODEL OF DIGITAL LIBRARIES BASED ON THE LIBQUAL+ METHODOLOGY

F.J. CABRERIZO*

*Dept. of Software Engineering and Computer Systems
Distance Learning University of Spain (UNED), Madrid, 28040, Spain*

M.A. MARTÍNEZ, J. LÓPEZ-GIJÓN, E. HERRERA-VIEDMA†

*Dept. of Library Science
‡Dept. of Computer Science and Artificial Intelligence
University of Granada, 18071, Granada, Spain*

According to the gap model, 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. Following that idea, we present a fuzzy linguistic quality evaluation model based on the LibQUAL+ methodology to evaluate the quality of digital libraries according to user's opinions. To derive the gaps essential for measuring perceptions of service quality, users are asked to establish their judgments across three scales for each digital service of the digital library. It allows the identification of digital services in which service levels should be improved and the identification of digital services satisfied outstandingly by the digital library.

1. Introduction

The World Wide 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.¹ Digital libraries (DLs) 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. Library users are now offered a variety of resources with different forms of interactivity and with different levels of media richness. They can obtain research data and publications as needed without the massive investment of capital and infrastructure to house vast physical collections. As a DL is destined to serve users, if unused, it falls into oblivion and terminates its operation. Hence, one of

* cabrerizo@issi.uned.es.

the main aspects to be considered in DL evaluation is user's perspective, determining the extent to which the DL addresses the real needs of its users.²

Cabrerizo et al.³ presented 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 Web sites. This model provides 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 allow the identification of areas in which service levels should be improved according to the user's expectations. To overcome this drawback, the LibQUAL+ model can be used.⁴ LibQUAL+ is based on the well-known, attribute-based gap model SERVQUAL (for Service Quality) which was developed for the for-profit sector in the 1980s by the marketing research group of Parasuraman, Zeithaml, and Berry.⁵ 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".⁶ According to the gap model, 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. Following that idea, LibQUAL+ is a survey administered by the Association of Research Libraries to measure library user's perception of library service quality and to help traditional libraries identify service areas needing improvement. The survey data allow the identification of areas in which service levels should be improved, and they have also been used to identify best practices and reallocate resources accordingly.

The aim of this paper is to present a quality evaluation model of DLs, based on the LibQUAL+ methodology, which allows obtaining the digital services which should be improved and the digital services satisfied outstandingly by the DL. To do so, users are asked to indicate their minimum acceptable service level, their desired service level, and the perception of the actual service provided by each digital service of the DL. We assume a fuzzy linguistic modeling to represent the user's opinions and apply tools of fuzzy computing with words based on the LOWA operator⁷ to compute the global assessments.

The rest of the paper is set out as follows. Section 2 presents the ordinal fuzzy linguistic modeling for computing with words. Section 3 describes the evaluation model of DLs and Section 4 draws our conclusions.

2. A Fuzzy Linguistic Approach for Computing with Words

The ordinal fuzzy linguistic approach⁷ is a very useful kind of fuzzy linguistic approach used for modeling the computing with words process as well as

linguistic aspects of the problems. It is defined by considering a finite and totally ordered label set, $S = \{s_i, i \in \{0, \dots, T\}\}$, in the usual sense, i.e., $s_i \geq s_j$ if $i \geq j$, and with odd cardinality (7 or 9 labels). The mid-term represents an assessment of "approximately 0.5", and the rest of the terms being placed symmetrically around it. The semantics of the label set is established from the ordered structure of the label set by considering that each label for the pair (s_i, s_{T-i}) is equally informative. For example, we can use the following set of nine labels to provide the user's opinions: {T = Total, EH = Extremely High, VH = Very High, H = High, M = Medium, L = Low, VL = Very Low, EL = Extremely Low, N = None}.

In any linguistic approach we need management operators of linguistic information.⁷ Usually, the ordinal fuzzy linguistic model for computing with words is defined by establishing (i) a negation operator, $Neg(s_i) = s_j \mid j = T - i$, (ii) comparison operators based on the ordered structure of linguistic terms: maximization operator, $MAX(s_i, s_j) = s_i$, if $s_i \geq s_j$; and minimization operator, $MIN(s_i, s_j) = s_j$, if $s_i \leq s_j$, and (iii) adequate aggregation operators of ordinal fuzzy linguistic information.

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. It is defined as follows:⁷

Definition 2.1. Let $A = \{a_1, \dots, a_m\}$ be a set of labels to be aggregated, then the LOWA operator, ϕ , is defined as $\phi(a_i, \dots, a_m) = W \cdot B^T = C^m \{w_k, b_k, k = 1, \dots, m\} = w_1 \odot b_1 \oplus (1 - w_1) \odot C^{m-1} \{\beta_k, b_k, k = 2, \dots, m\}$, where $W = [w_1, \dots, w_m]$ is a weighting vector, such that, $w_i \in [0, 1]$ and $\sum_i w_i = 1$. $\beta_h = w_h / \sum_2^m w_k, h = 2, \dots, m$, and $B = \{b_1, \dots, b_m\}$ is a vector associated to A , such that, $B = \sigma(A) = \{a_{\sigma(1)}, \dots, a_{\sigma(m)}\}$, where, $a_{\sigma(i)} \leq a_{\sigma(j)} \forall i \leq j$, with σ a permutation over the set of labels A . C^m is the convex combination operator of m labels and if $m = 2$, then it is defined as $C^2 \{w_i, b_i, i = 1, 2\} = w_1 \odot s_j \oplus (1 - w_1) \odot s_i = s_k$, such that, $k = \min\{T, i + \text{round}(w_1 \cdot (j - i))\}$, $s_j, s_i \in S, (j \geq i)$, 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: $C^m \{w_i, b_i, i = 1, \dots, m\} = b_j$.

The LOWA operator is an "or-and" operator 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", Yager⁸ introduced a measure of *orness*, associated with any vector $W : orness = \frac{1}{m-1} \sum_{i=1}^m (m-i)w_i$. This measure characterizes the degree to which the aggregation is like an "or" (MAX) operation. Note that an OWA operator with *orness*(W) ≥ 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 [8], it was defined an expression to obtain W that allows to represent the concept of fuzzy majority⁹ by means of a fuzzy linguistic nondecreasing quantifier Q :¹⁰

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

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

3. A Fuzzy Linguistic Evaluation Model of DLs Based On the LibQUAL + Methodology

In order to improve the quality evaluation model of DLs presented in [3], the LibQUAL+ methodology is used. Cabrero et al.³ defined an evaluation scheme of DLs that contemplated four quality dimensions together with their digital quality criteria. In particular, we use the following ten subjective criteria proposed in [3] to measure the quality of the digital services provided by a DL:

- 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 Web site.
- sc_6 : Understandability of the DL Web site.
- 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 Web site, users are invited to fill a questionnaire which has 10 questions, $\{q_1, \dots, q_{10}\}$, where each question corresponds with a subjective criterion. To adapt the quality evaluation model of DLs presented in [3] according to the LibQUAL+ methodology, users are asked for impressions about the above ten subjective criteria according to (i) the minimum service level that they are willing to accept, (ii) the desired service level that they would like to receive, and (iii) the perceived performance level, that is, the actual level of service that they perceive to have been rendered.

The minimum service level, the desired service level, and the perceived performance level behind each question are rated on a linguistic term set S . Once the group of users. $\{e, \dots, e, \lambda\}$ 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 opinions provided by the group of users on the subjective criterion, sc_i , by means of the LOWA operator ϕ :

$$MSL_i^m = \phi_Q \left(e_1(q_i^{MSL}), \dots, e_L(q_i^{MSL}) \right), \quad (2)$$

$$DSL_i^m = \phi_Q \left(e_1(q_i^{PSL}), \dots, e_L(q_i^{PSL}) \right), \quad (3)$$

$$PPL_i^m = \phi_Q \left(e_1(q_i^{PPL}), \dots, e_L(q_i^{PPL}) \right), \quad (4)$$

where $e_i(q_i^{MSL}) \in S$ is the minimum service level provided by the user e_i on subjective criterion, sc_i , represented by the question q_i , $e_i(q_i^{PSL}) \in S$ is the desired service level provided by the user e_i on subjective criterion, sc_i , represented by the question q_i , and $e_i(q_i^{PPL}) \in S$ is the perceived performance level provided by the user e_i on subjective criterion, sc_i , represented by the question q_i . MSL_i^m , DSL_i^m and PPL_i^m are the linguistic measures that represent 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. According to the users' answers, it is defined two scores which can obtain the strengths and weaknesses of a DL, A_m :

$$SA_i^m = I(PPL_i^m) - I(MSL_i^m), \quad (5)$$

$$SS_i^m = I(PPL_i^m) - I(DSL_i^m), \quad (6)$$

where 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 $I : S \rightarrow \{0, \dots, T\} \mid I(s_i) = i, \forall i \in S$.

The service adequacy score is calculated by subtracting the minimum score from the perceived score on any given question. It is an indicator of the extent to which DLs are meeting the minimum expectations of their users. A negative service adequacy gap score indicates that the users' perceived level of service quality is below their minimum level of service and can be used by DLs to identify areas needing improvement. The service superiority score is calculated by subtracting the desired score from the perceived score on any given question

and is an indicator of the extent to which DLs are exceeding the desired expectations of their users.

4. Concluding Remarks

We have presented a fuzzy linguistic model based on the gap theory of service quality to evaluate the quality of the DLs. In the future, we extend the concept of quality to other new services of the DLs, such as Library 2.0.

Acknowledgments

This paper has been developed with the financing of FEDER funds in FUZZYLING-II Project TIN2010-17876, Andalusian Excellence Projects TIC-05299 and TIC-5991, and "Proyecto de Investigación del Plan de Promoción de la Investigación UNED 2011 (2011V/PUNED/0003)".

References

1. S. Lawrence and C. Giles, Searching the World Wide Web, *Science* **280**, 98 (1998).
2. A. Shiri, Metadata-enhanced visual interfaces to digital libraries, *Journal of Information Science* **34**, 763 (2008).
3. F.J. Cabrerizo, J. López-Gijón, A.A. Ruiz and E. Herrera-Viedma, A model based on fuzzy linguistic information to evaluate the quality of digital libraries, *Int. Journal of Inf. Technology & Decision Making* **9**, 445 (2010).
4. C. Cook, F. Heath, M. Kyriolidou, Y. Lincoln, B. Thompson and D. Webster, *NDSL Evaluation Workshop* (2003).
5. A. Parasuraman, V.A. Zeithaml and L.L. Berry, SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality, *Journal of Retailing* **64**, 12 (1988).
6. V.A. Zeithaml, L.L. Berry and A. Parasuraman, *Delivering Quality Services - Balancing Customer Perceptions* (The Free Press, New York, 1990).
7. F. Herrera, E. Herrera-Viedma and J.L. Verdegay, Direct approach processes in group decision making using linguistic OWA operators, *Fuzzy Sets and Systems* **79**, 175 (1996).
8. R.R. Yager, On ordered weighted averaging aggregation operators in multicriteria decision making, *IEEE Transactions On Systems Man and Cybernetics* **18**, 183 (1988).
9. J. Kacprzyk, Group decision making with a fuzzy linguistic majority, *Fuzzy Sets and Systems* **18**, 105 (1986).
10. L.A. Zadeh, A computational approach to fuzzy quantifiers in natural languages, *Computers & Mathematics with Applications* **9**, 149 (1983).