Fuzzy Multicriteria Analysis of M-learning System

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Abstract—This article contents description of fuzzy evaluation of m-learning materials. Fuzzy technique for order preference by similarity to ideal solution with multiple evaluators is proposed. Ranking is accomplished by fuzzy multicriteria analysis. Criteria are described by linguistic attributes and linguistic weights. Examples with triangular fuzzy sets are given. The uncertainty of subjective perception in the situation of evaluating learning materials is incorporated by fuzzy sets.

I. INTRODUCTION

An end of the project of creating a learning material cannot be considered in a classical sense because development of such material is a continuous process. The environment, its technical capabilities and the contents of the learning subject are all changing [1]. An information system can be considered a particular kind of application, designed to provide a pool of services to a particular class of users, which have to solve informative problems within a specific context [2]. Several papers have been published on the Web site quality evaluation methodology.

Owing to the availability and uncertainty of information, it is very difficult to obtain the exact assessment data for e-learning criteria [3]. According to [3] some of the criteria which are useful in the survey are presentation, navigability, reliability, external recognition, responsiveness, speed, customer care, access, content relevancy, content richness, content currency, site aesthetics, personalization, authority, assurance, FAQs and help, special services, tailored communication, and trust. In [4] the importance of measuring how students perceive quality of service in online higher education is discussed. The article proposes using the Critical Incident Technique to perform a qualitative analysis. A case study, regarding a completely online university, is presented and the proposed model is used to obtain some preliminary research results. Among these, key quality dimensions from a student point of view are identified. Some of these dimensions are: learning process, administrative processes, teaching materials and resources, etc.

“Quality” is a linguistic variable because its values are linguistic values rather than numerical ones, that is, poor, fair, good, very good, and so forth. To deal with the vagueness of human thought, fuzzy set theory can play a significant role in this kind of decision-making environment [3], [5], [6] and [7]. In [8] the different influence factors of multimedia digital materials for an effective and successful teaching/learning is investigated. The consistent fuzzy preference relation is used to evaluate the importance of these factors. In [9] the development of a methodology to evaluate the quality of e-learning software from both qualitative and quantitative analyses is described. The study proposes the applicability of ISO 9126 software quality metrics as the basis of evaluation framework. It is then extended with MCDM methodology by combining Analytic Hierarchy Process and Fuzzy Set Systems to provide an evaluation framework that is capable in tackling inconsistency and vagueness of human judgment during evaluation processes. In [10] a customer satisfaction evaluation method based on combination of linguistic variables, fuzzy triangular numbers, and fuzzy entropy is described. In [11] a fuzzy approach for facility location selection is proposed based on a fuzzy extension of the technique for order preference by similarity to ideal solution (TOPSIS) method. In this method, the ratings of various alternatives versus various subjective criteria and the weights of all criteria are assessed in linguistic variables represented by fuzzy numbers. Fuzzy numbers try to resolve the ambiguity of concepts that are associated with human being’s judgments. To determine the order of the alternatives, closeness coefficient is defined by calculating the distances to the fuzzy positive ideal solution and fuzzy negative ideal solution.

ISO 9126 is a widely accepted standard for appropriately measuring the quality of any kind of software. This standard classifies its evaluation under six criteria called functionality, reliability, usability, efficiency, maintainability and portability. Each of these criteria consists of several sub criteria. Considering its wide implementations in various software evaluations as mentioned in literature, in [9] ISO 9126 is proposed to be adopted in evaluating e-learning software. Functionality is the set of attributes that bear on the existence of a set of functions and their specified properties. The functions are those that satisfy stated or implied needs. Reliability is the set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time. Usability is the set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users. Usability must address all of the different user environments that the software may affect, which may include preparation for usage and evaluation of results. Efficiency is the set of attributes that bear on the relationship between the level of performance of the software and the amount of resources used, under stated conditions. Maintainability is the set of attributes that bear on the effort needed to make specified modifications while portability bears on the ability of software to be transferred from one environment.

The rating levels definition determines what ranges of values on those scales count as satisfactory or unsatisfactory. Since quality refers to given needs, which vary from one evaluation to another, no general levels for rating are possible: they must be defined for each specific evaluation.
The evaluation of e-learning materials can provide important information for teachers or e-learning material designers in the future e-learning material design. User satisfaction is a measure of the perceived quality of the interface and is the most important evaluation issue for system usability. Student satisfaction was selected to be one of the parameters in the evaluation of the effectiveness of the interactive on-line exercises that was described in [12]. Data about students’ satisfaction as an outcome-variable of the effectiveness of the learning environment were assessed for formative evaluation. Each criterion should independently represent the service quality satisfaction from some aspect. For each of the criteria, it may be derived into several sub-criteria. If necessary, these sub-criteria may also be derived into more sub-criteria, and so on. Attribute hierarchy can present clear concept and relationships among different types of criteria [13].

II. METHODOLOGY

The concept of a linguistic variable appears as a useful means for providing approximate characterization of phenomena that are too complex or ill defined to be described in conventional quantitative terms [14]. Many systems are not amenable to conventional modelling approaches due to the lack of precise or accurate information, due to the strongly nonlinear behaviour, the high degree of uncertainty, or the time varying characteristics. Fuzzy modelling along with other related techniques has been recognized as a powerful tool that can facilitate effective reflection of uncertainties [13]. This is however particularly true in areas where human judgment, evaluation, and decisions are important [15].

The fuzziness and uncertainty of subjective perception situation can be regarded as a fuzzy multiple criteria decision-making (MCMD) problem [13]. The fuzzy multicriteria analysis model used in this project is based on the MAF-DSS (Multiple-Attribute Fuzzy Decision Support System) developed by [16]. The main entities to be considered in the multicriteria analysis are alternatives, criteria, attributes and weights. Users provide the weights for the criteria. Weights express the relative importance, attached by the user, for each criterion.

The steps of the multicriteria analysis are: (a) determination of the evaluation criteria with their respective attributes; (b) collection of evaluation data from the users; (c) collection of weights data for the evaluation criteria; (d) determination of the fuzzy attributes; (e) aggregation algorithm for rating the learning systems.

Here, evaluation of usability of m-learning system will be given as an example. Evaluation of three m-learning environment for three criteria by multiple users will be described. The evaluation criteria are user's satisfaction about the visualization of the learning system, satisfaction about existing help on questions answered wrongly by the user, and satisfaction about the content of the m-learning environment. The predefined answers, as well as the weights of the criteria in the survey are given as three linguistic variables, and represented by three triangular fuzzy membership functions (Fig.1 and Fig. 2). Each attribute of the variables can be presented as triangular fuzzy number. The goal is to get a score about each criterion and also a score considering each criterion for the learning material. This score will show how far is the evaluated criterion from the ideal case for the alternative in question.

The corresponding fuzzy sets are built with open-ended triangular functions.

![Figure 1. Fuzzy triangular membership functions of the criteria](image)

A triangular fuzzy number is defined as:

\[ \tilde{A} = (a, m, n) \]  \hspace{1cm} (1)

where \( a \) is the value for which the membership function has the value exactly 1:

\[ \mu_{\tilde{A}}(a) = 1 \]  \hspace{1cm} (2)

\( m \) is the left spread and \( n \) is the right spread.

If the fuzzy numbers \( \tilde{A} = (a, m, n) \) and \( \tilde{B} = (b, s, r) \) are both larger than zero, their product is defined as:

\[ \tilde{A} \times \tilde{B} = (ab, as + bm - ms, ar + bn + nr) \]  \hspace{1cm} (3)

The distance between the two fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) is defined as:

\[ d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(a - b)^2 + (a - b - m + s)^2 + (a - b + n - r)^2]} \]

Method for preparing the fuzzy decision matrix is proposed by [17].

Let the criteria for a specific alternative be denoted by \( C_{ij} \) and the performance measure of each criterion by the triangular fuzzy number \( \tilde{x}_{ij} = (x_{ij}, \alpha_{ij}, \beta_{ij}) \). The corresponding weight is denoted by the triangular fuzzy number \( \tilde{w}_{ij} = (w_{ij}, \gamma_{ij}, \delta_{ij}) \).

For each fuzzy number the lower and upper points \( \alpha \)-cuts are calculated for \( \alpha = 1 \) denoted by \( x_{ij}^{L} \) and \( x_{ij}^{U} \). This way the fuzzy numbers are represented by intervals. Intervals are calculated for each criterion by normalizing. Normalization is taking into account every alternative:

\[ [\tilde{h}_{ij}]_{\alpha}^{L} = [\tilde{x}_{ij}]_{\alpha}^{L} / \sqrt{\sum_{\alpha=1}^{m} ([\tilde{x}_{ij}]_{\alpha}^{L})^2 + ([\tilde{x}_{ij}]_{\alpha}^{U})^2} \]  \hspace{1cm} (5)
\[ [\bar{a}_{ij}]^u = [\bar{x}_{ij}]^u / \sqrt{\sum_{k=1}^{m} \left( [\bar{x}_{ij}]^{L_k}_{u} \right)^2 + \left( [\bar{x}_{ij}]^{U_k}_{u} \right)^2} \]  

\[ \bar{a}_{ij} = \bar{x}_{ij} / \sum_{k=1}^{m} \left( [\bar{x}_{ij}]^{L_k} \right)^2 + \left( [\bar{x}_{ij}]^{U_k} \right)^2 \]  

\( m \) is the total number of alternatives and \( n \) is the total number of criteria.

\( i = 1, \ldots, m \) and \( j = 1, \ldots, n \).

The normalized fuzzy interval has to be transformed into fuzzy number:

\[ \bar{N}_{ij} = \left( n_{ij}, y_{ij}, z_{ij} \right) \]  

\( y_{ij} = n_{ij} - [\bar{a}_{ij}]_{u=0}^{L_k} \)  

\( z_{ij} = [\bar{a}_{ij}]_{u=0}^{U_k} - n_{ij} \)

To be consistent with the basic requirement that the weights usually add up to one in a crisp environment, it is required that the sum of the modal values of the fuzzy triangular numbers which represent the criterion weights be equal to one \[ \text{[18]} \].

\[ d_{ik}^+ = \sum_{k=1}^{n} d \left( \bar{v}_{ij}, \bar{v}_{ij}^k \right) \]  

The best alternative according to a particular evaluator is the one with the smallest distance. The final distance, that is the final rank for alternative \( i \) in case of \( K \) evaluators is computed as:

\[ D_i = \sqrt{\prod_{k=1}^{K} d_{ik}^+} \]  

III. NUMERICAL EXAMPLE

Numerical examples are presented in the following tables. Examples are for two evaluators (Evaluator 1 and Evaluator 2), three alternatives (A1, A2, A3) and three criteria (C1, C2, C3) are given. Marks, as well as weights are represented by alternatives in form of linguistic variables: little, middle, much. Criteria are supposed to describe students' satisfaction, and are defined as questions how much the learning environment is attractive, interesting and easy to use. Tables I.-IV. and Tables V.-VIII. correspond to Evaluator 1, and Evaluator 2 respectively. The final distances of the alternatives for every criteria and their summed distance from the ideal solution taking into account both evaluators are in Table IX.

<table>
<thead>
<tr>
<th>TABLE I. NORMALIZED MARKS</th>
</tr>
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<tbody>
<tr>
<td>C1</td>
</tr>
<tr>
<td>A1</td>
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<tr>
<td>A2</td>
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<tr>
<td>A3</td>
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<tr>
<th>TABLE II. MATRIX OF FUZZY NUMBERS</th>
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<tbody>
<tr>
<td>C1</td>
</tr>
<tr>
<td>A1</td>
</tr>
<tr>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
</tr>
<tr>
<td>w</td>
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</tbody>
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<table>
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<tr>
<th>TABLE III. MATRIX OF WEIGHTED FUZZY NUMBERS</th>
</tr>
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<tbody>
<tr>
<td>C1</td>
</tr>
<tr>
<td>A1</td>
</tr>
<tr>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
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<th>TABLE IV. DISTANCES FROM THE IDEAL SOLUTION</th>
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<tbody>
<tr>
<td>C1</td>
</tr>
<tr>
<td>A1</td>
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<tr>
<td>A2</td>
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<td>A3</td>
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As it can be seen from Table IX, alternative A1 has the least final distance from the ideal solution, so it is ranked as the best alternative. It is the closest to the ideal solution regarding all of the criteria.

IV. CONCLUSION

As further development, the effective users’ satisfaction in relation to the category of a site and to the designer’s goals can be evaluated. The gap between user satisfaction and lecturer's expectation can be calculated. Criteria, in which the expectation and satisfaction yield the largest gap, will need to be improved. The lecturer’s goals and future work depends on users’ satisfaction, because the more the users are satisfied, the more they are likely to use the learning system in the way the lecturer has planned. The authors are developing integrated m-learning system in which they plan to test the approach described here. As the m-learning is the part of e-learning, it will be possible to use this approach and the developed system in other e-learning environments.

REFERENCES


