A Fuzzy Set Approach to Assessing E-Commerce Websites

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Recommended Citation
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ABSTRACT
E-commerce websites assessment plays an important role in finding out how effective corporations’ websites are designed to meet organizational requirements and eventually help increase organizational profits. This paper proposes a fuzzy set approach to assessing e-commerce websites. It provides e-commerce website evaluators with a flexible way to present their evaluation which takes into consideration imprecise and uncertain assessment data. A general e-commerce website assessment framework is presented. A web-based assessment system supporting the assessment framework was developed and tested in assessing websites of the top 120 Fortune corporations.

Keywords
E-commerce website assessment, e-commerce website assessment system, fuzzy set

INTRODUCTION
More and more companies, even small and medium size companies, are investing money in electronic commerce (e-commerce) by setting up commercial websites on the Internet. Companies are interested in finding out how effective their websites are designed to meet organizational strategic requirements and eventually increase organizational profits, in which valid website assessment plays an important role.

However, e-commerce websites assessment is difficult as e-commerce website design as a field of study is generally in the developmental stage. E-commerce website assessment is not impossible, but does represent a challenge. The purposes of e-commerce websites differ, ranging from general publicity, to customer support, on-line information exchange, and Internet sales (Cheung and Huang, 2002). Multiple web features and functions, such as speeding up user tasks, establishing multiple communication channels, providing suitable access to contacts, making the site personal, are presented in literature as general assessment criteria (Li, Huang and Gandha, 2002).

In the e-commerce website assessment process, obviously, evaluators frequently confront human subjective judgments with vagueness. For example, regarding the web feature “speed up user tasks”, they often use linguistic terms “good”, “fair”, “poor” to give their evaluation. But what do these words really mean? Due to assessment evaluators’ different knowledge background, attitudes, motivation, and personalities, these terms do not constitute well-defined measures. A new mechanism is needed to cope with the linguistic judgments present in e-commerce website assessment.

Fuzzy set theory (Zadeh, 1965) was developed to solve problems in which descriptions of activities and observations were imprecise, vague, and uncertain. Fuzzy set theory has been applied in assessment (Biswas, 1995; Chen and Lee, 1999; Echauz and Vachtsevanos, 1995; Kwok, Ma, Voug and Zhou, 2001; Ma and Zhou, 2000; Rantij, 1995; Ross, 1997; Zhou, Ma and Turban, 2001), decision making (Bellman and Zadeh, 1970; Carlsson and Fuller, 1996, Zimmermann, 1987), and other fields (Ragin, 2000; Zimmermann, 2001; Zopounidis, Pardalos and Baourakis, 2001). E-commerce website assessment inevitably involves human thinking and human subjective judgments with incomplete and uncertain information. Fuzzy set theory provides an approach to deal with incomplete, imprecise, and uncertain information by allowing assessment data to be “fuzzy”. Applying fuzzy set theory into the e-commerce website assessment can better and flexibly reflect the natural e-commerce website assessment process.

Although various measures and factors have been proposed to study website content and design (Huizingh, 2000), website quality (Aladwani and Palvia, 2002; Webb and Webb, 2002), customer satisfaction (Shim, Shin and Nottingham, 2002), and customer loyalty (Gefen, 2002), little research has examined the e-commerce website assessment methods, especially, fuzzy set methods. This research attempts to fill this gap by proposing an approach to the assessment of e-commerce websites. The
approach includes a fuzzy assessment model and a web-based assessment system prototype, so as to provide evaluators with a flexible way to present their individual preferences which takes into consideration fuzzy assessment data.

GENERAL E-COMMERCE WEBSITE ASSESSMENT FRAMEWORK

There have been some prior studies proposing some frameworks and models to assess e-commerce websites (e.g., Cell, 2000; Coopee et al., 2000; Cheung and Huang, 2002). Based on a comprehensive literature review, Li, Huang and Gandha presented a generic framework to assess commercial e-commerce websites (2002), which is shown in Table 1 below.

<table>
<thead>
<tr>
<th>Web Features and Functions</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Establish Multiple Communication Channels</td>
<td>Coopee et al. (2000)</td>
</tr>
</tbody>
</table>

Table 1. A Generic Commercial Website Assessment Framework

FUZZY ASSESSMENT METHOD

As discussed above, a website feature usually has several sub-features. For example, Establish Multiple Communication Channels feature includes six sub-features: email support, telephone support, frequently asked question (FAQ) section, information updates at set times (up to the minute, hour, …), discussion forums with both other users and experts, and online chat with company’s representatives. To get the evaluation of a website feature, in general, evaluators need to consider the all sub-features comprehensively. In e-commerce websites assessment, since a numerical evaluation is often too complex and too unacceptable, the evaluation is usually described in natural language terms, such as Very Good, Good, Fair, Poor, very poor. A fuzzy assessment method is presented here to adapt the natural language term evaluation.

Let \( G = \{g_1, g_2, \ldots, g_d\} \) be a set of grades (For example, \( G=\{\text{Very Good, Good, Fair, Poor, Very Poor}\} \)) of a website feature (without loss of generality, we assume \( g_1 \) is the best grade and \( g_d \) the worst grade), and \( C = \{c_1, c_2, \ldots, c_n\} \) be the set of sub-features. The evaluator’s evaluation can be represented as fuzzy relation (matrix) \( E \):
\[ \begin{align*}
\mu_i \in [0,1]; & \quad 1 \leq i \leq d \quad \text{and} \quad j = 1, 2, \ldots, n. \quad \mu_{ij} \text{ reflects the relationship between pairs of sub-features } c_i \text{ and grade } g_j. \quad \text{In practice, it may be impractical or not easy for evaluators to specify their subjective judgments using such a matrix. Therefore, in order to simplify this process for those evaluators that can not or do not wish to assign specific numerical values } \mu_{ij}, \text{ qualitative judgment terms are available to evaluators to express subjective judgments. A judgment term is an ordered } d\text{-tuple } <a_1, a_2, \ldots, a_d>, \text{ where } a_i \in [0,1], 1 \leq i \leq d. \quad \text{The values of the judgment term, i.e., } d\text{-tuple, of a sub-feature, represent the degrees that a specific sub-feature belongs to the grades } g_1, g_2, \ldots, g_d \text{ respectively.}
\end{align*} \]

For example, let \( G = \{ \text{Very Good, Good, Fair, Poor, Very Poor} \} \), then a statement “The grade of a sub-feature is less than Very Good” can be expressed as \(<0.7, 0.3, 0, 0, 0>\); and a statement “The grade of a sub-feature is Fair” can be expressed as \(<0, 0, 1, 0, 0>\).

Due to the different importance of the sub-features, the evaluators may want to assign different level of importance to the sub-features. The weights are expressed as a "weight vector" \( W = \{ w_1, w_2, \ldots, w_n \} \).

For a feature of a website, we derived the fuzzy evaluation relation \( E \) and the fuzzy weight \( W \). Then, the process of determining the final grade of the website feature is equivalent to the process of determining a membership value for the website feature in each of the evaluation grades \( g_1, g_2, \ldots, g_d \). This process can be implemented through the composition operation \( W \circ E \). The result is a fuzzy vector (evaluation vector), denoted as \( Y \), containing the membership values for the website feature in each of the evaluation grades \( g_1, g_2, \ldots, g_d \):

\[ Y = W \circ E = (w_1, \ldots, w_n) \circ \begin{bmatrix} \mu_{11} & \mu_{12} & \cdots & \mu_{1d} \\ \mu_{21} & \mu_{22} & \cdots & \mu_{2d} \\ \vdots & \vdots & \cdots & \vdots \\ \mu_{n1} & \mu_{n2} & \cdots & \mu_{nd} \end{bmatrix} = (y_1, y_2, \ldots, y_d), \quad (1) \]

where \( y_j = (w_1 \cdot \mu_{1j}) \oplus \cdots \oplus (w_n \cdot \mu_{nj}) \), and "\( \cdot \)"", "\( \oplus \)" are defined as:

- algebraic product, \( a \cdot b: c = ab \)
- bounded sum, \( a \oplus b: c = a \oplus b = \min \{1, a+b\} \).

According to the principles of fuzzy classification, we have \( y_j = \max (y_1, y_2, \cdots, y_d) \). Thus the corresponding grade \( g_i \) is the final grade of the website feature. In the practical evaluation process, we set a parameter \( \delta \) to check if \( |y_i - y_{i+1}| < \delta \), \( i < d \). If it happens, then we can say this website feature is between grades \( g_i \) and \( g_{i+1} \). If \( |y_i - y_j| < \delta \) and \( i < j, j \neq i+1, i \)
<d-1, that means the website feature has strong contradicting sub-feature performance. For example, if we set $\delta = 0.05$ and $Y = \{0.332, 0.334, 0.332, 0, 0\}$, it satisfies $|y_1 - y_3| < \delta$. In this case, evaluators may adjust the sub-feature weights or their judgments to get a new evaluation relation $Y$.

The same method can be applied to evaluate other features, and the overall grade of the website. This assessment method can also be used by a group of evaluators in group assessment setting.

An Example

Assume the set of grades of a website feature is $G = \{Very Good, Good, Fair, Poor, Very Poor\}$. The evaluator is asked to evaluate the communication feature of a website. There are six criteria contribute to communication feature: email support, telephone support, frequently asked question (FAQ) section, information updates at set times (up to the minute, hour, …), discussion forums with both other users and experts, and online chat with company’s representatives. The weights of the six criteria are pre-determined, saying $W = \{0.3, 0.2, 0.2, 0.1, 0.1, 0.1\}$. The judgment terms are specified as 5-tuples corresponding to the grade set $G$, which are shown in Table 2. The values in the right hand-side of the table are set by the evaluator (These values are given by the authors in this example, which can be changed).

<table>
<thead>
<tr>
<th>Judgment term</th>
<th>5-tuple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>&lt;1, 0, 0, 0, 0&gt;</td>
</tr>
<tr>
<td>Less than Very Good</td>
<td>&lt;0.7, 0.3, 0, 0, 0&gt;</td>
</tr>
<tr>
<td>Better than Good</td>
<td>&lt;0.2, 0.8, 0, 0, 0&gt;</td>
</tr>
<tr>
<td>Good</td>
<td>&lt;0, 1, 0, 0, 0&gt;</td>
</tr>
<tr>
<td>Better than Fair</td>
<td>&lt;0, 0.2, 0.8, 0, 0&gt;</td>
</tr>
<tr>
<td>Fair</td>
<td>&lt;0, 0, 1, 0, 0&gt;</td>
</tr>
<tr>
<td>Better than Poor</td>
<td>&lt;0, 0, 0.2, 0.8, 0&gt;</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt;0, 0, 0, 1, 0&gt;</td>
</tr>
<tr>
<td>Better than Very Poor</td>
<td>&lt;0, 0, 0, 0.2, 0.8&gt;</td>
</tr>
<tr>
<td>Very Poor</td>
<td>&lt;0, 0, 0, 0, 1&gt;</td>
</tr>
</tbody>
</table>

Table 2. The Judgment Terms

The judgments given by the evaluator are:

- Email support: Good
- Telephone support: Less than Very Good
- Frequently asked question (FAQ) section: Fair
- Information updates at set times: Better than Fair
- Discussion forums with both other users and experts: Good
- Online chat with company’s representatives: Fair
From Table 2, we get the evaluation relation $E$.

$$E = \begin{pmatrix}
0 & 1 & 0 & 0 & 0 \\
0.7 & 0.3 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0.2 & 0.8 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0
\end{pmatrix}$$

According to equation (1), we get:

$$Y = W \circ E = (0.14, 0.48, 0.38, 0, 0)$$

From $Y$, we can infer that the grade of the communication feature of this website is Good.

The same method can be applied to evaluate other features. Furthermore, the method can be used to evaluate the overall grade of the website.

**THE E-COMMERCE WEBSITE ASSESSMENT SYSTEM**

An e-commerce website assessment system has been developed and runs on the Web. The underlying technology of the assessment system includes Microsoft 2003 Server, Microsoft SQL Server, and Microsoft Internet Information Server. The system is built using Microsoft ASP.NET.

The assessment system provides five main functions:

- **Website information**: this function is to display the websites to be assessed.
- **Website functions and weights**: this function is to display the main functions, sub-functions, and their weights.
- **Judgment term information**: this function is to display information on judgment terms.
- **Evaluation**: this function is designed for evaluators to express their subjective judgments. The evaluators first select a website, then gives the judgment opinions on the functions of the website (see Figure 1). When the evaluator click submit button, the assessment system aggregates the evaluators’ assessments and gives the results (see Figure 2).

![Figure 1. The Page of Evaluation on Website](image-url)
Administrator functions: this function is designed to be provided to the assessment system administrator to manage the assessment system by setting websites to be assessed, judgment terms, main functions and their weights, sub-functions and their weights, evaluators’ usernames and passwords.

Figure 2. The Page of Evaluation Results

AN EMPIRICAL ASSESSMENT

The websites of the top 120 Fortune corporations (2003 data) were randomly assigned to 60 sophomore and junior from a business college in a state university in the US who took introductory course of management information system. The number of valid assessed websites is 110. The assessment results are shown in table 3 and 4.

The data in table 3 shows that the majority websites were assessed as Very Good and Good. Table 4 shows that the majority main functions were assessed as Very Good, Good, and Fair; however, the websites need to improve the features of Tools to aid user decisions, and Use multimedia.

<table>
<thead>
<tr>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>52% (57/110)</td>
<td>30% (33/110)</td>
<td>9% (10/110)</td>
<td>4.5% (5/110)</td>
<td>4.5% (5/110)</td>
</tr>
</tbody>
</table>

Table 3. Evaluation Results of the 110 Websites of Top 120 Fortune Corporations (Percentage)
Table 4. Evaluation Results of the Main Functions of the 110 Websites

<table>
<thead>
<tr>
<th>Main Function</th>
<th>Very Good</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Features that spend up user tasks</td>
<td>38%</td>
<td>35%</td>
<td>14%</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>2. Establish multiple communication channels</td>
<td>55%</td>
<td>27%</td>
<td>9%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>3. Provide suitable access to contacts</td>
<td>63%</td>
<td>24%</td>
<td>8%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>4. Make the site personal</td>
<td>47%</td>
<td>20%</td>
<td>11%</td>
<td>12%</td>
<td>10%</td>
</tr>
<tr>
<td>5. Company information and advertising</td>
<td>69%</td>
<td>23%</td>
<td>4%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>6. Customer feedback</td>
<td>41%</td>
<td>29%</td>
<td>19%</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td>7. Allow the user to control information detail</td>
<td>37%</td>
<td>27%</td>
<td>20%</td>
<td>10%</td>
<td>6%</td>
</tr>
<tr>
<td>8. Tools to aid user decisions</td>
<td>28%</td>
<td>17%</td>
<td>20%</td>
<td>22%</td>
<td>13%</td>
</tr>
<tr>
<td>9. Use multimedia</td>
<td>18%</td>
<td>15%</td>
<td>15%</td>
<td>25%</td>
<td>27%</td>
</tr>
</tbody>
</table>

SUMMARY

This paper presents a fuzzy set approach to assessment of e-commerce websites. A Web-based assessment system prototype has been developed to support the proposed approach. With the support, the websites of the top 120 Fortune corporations were assessed. The major benefit of the proposed approach is providing flexibility to the evaluators by permitting them to input their evaluation qualitatively, taking into consideration imprecise and uncertain data.

REFERENCES