Fuzzy Group Decision Support System for Project Assessment

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Abstract
Assessment of projects with multiple criteria is very common in education and business organizations. This paper reports the use of fuzzy set theory for assessment of students’ projects in an education setting. The whole assessment process includes four stages, namely generation of basic assessment criteria, selection of assessment criteria, determination of assessment criteria weights, and fuzzy grading of students’ projects. As a result, a group decision support system (GDSS) has been developed and used to support the assessment process. The experimental results with the use of proposed GDSS show that students are encouraged to work collaboratively and they produce better project results.

1. Introduction
Assessment is one of the most important tasks in the whole teaching and learning process. It has a great influence on the students’ approach to learning and their learning outcomes [5, 7]. In traditional assessment processes, assessment criteria are mainly determined by the lecturers in charge, thus students have little autonomy in what should be assessed. This certainly lowers down the quality of learning. Current education research show that multi-criteria assessment methods are widely used for evaluating students learning [8]. Multi-criteria assessment takes into consideration the various aspects of learning requirements, such as course objectives and industry expectations, it aims to provide an objective method for assessment.

Determination of multi-criteria for assessing students’ projects not only needs to meet the objectives of the course, but also should satisfy the requirements of the whole group. Multiple Attributes Decision Making (MADM) is one of the commonly used mathematics methods for choosing alternatives among a solution set. It well balances the multiple criteria and is mathematically operational [6, 13].

Many of the MADM methods tend to reflect an ideal decision making environment in which decision makers can rationally consider all aspects of the problem, think through these aspects, get all precise information, and then come up with a consensus solution. However, very often in real-life decision making applications, data are imprecise [1, 2, 15, 16]. For example, decision makers often use “good”, “excellent”, and “poor” to evaluate the conditions of learning environment. But what do these words really mean? These terms do not constitute a well-defined boundary.

Fuzzy set theory [14] has been developed to solve problems in which descriptions of activities and observations are imprecise, vague, and uncertain. The term “fuzzy” refers to a situation where there are no well-defined boundaries for the set of activities or observations. A fuzzy set is a class of objects with a continuum of membership grades. A membership function, which assigns to each object a grade of membership, is associated with the fuzzy set. Usually, the membership grades are in [0, 1]. When the grade of membership for an object is one, it means that the object is absolutely in that set. When the grade of membership is zero, it means that the object is absolutely not in that set. Borderline cases are assigned values between zero and one.

Fuzzy set theory was applied in decision making by Bellman and Zadeh in 1970 [1]. They noted that “Much of the decision making in the real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely” and fuzzy set theory can be used to deal with imprecision in decision making. One of the current topics is to apply fuzzy set theory into MADM methods for dealing with the imprecision, uncertainty and fuzziness in human decision making [see, for example, 2, 4, 10, 12, 16].

This paper reports the use of fuzzy set approach to the assessment of students’ projects. For this purpose, a group decision support system (GDSS) has been developed and used. The assessment task was carried out in four steps, namely generation of basic assessment criteria, selection of assessment criteria, determination of assessment criteria weights, and fuzzy grading of students’ projects. The
experimental results with the use of proposed GDSS show that students are encouraged to work collaboratively and they produce better project results.

2. Fuzzy set approach for assessment

A fuzzy set approach is used for the assessment of student projects in several courses in the Department of Information Systems at City University of Hong Kong. The approach consists of four stages, namely generation of basic assessment criteria, selection of assessment criteria, determination of the assessment criteria weights, and fuzzy grading of students’ projects. The stages are described as follows:

2.1 Generation of basic assessment criteria

Students are first exposed to the course objectives (e.g. components for knowledge, skills and attitudes) and industry expectations for the development of information systems. Together with the lecturers, students are invited to brainstorm and contribute the initial basic assessment criteria set.

2.2 Selection of assessment criteria

Let \( C = \{c_1, c_2, \ldots, c_m\} \) represent the basic assessment criteria set. We assign different rates \( Q = (q_1, q_2, \ldots, q_n) \) to \( n \) individual decision makers (i.e. individual students and lecturers) depending on their roles in the assessment task, where \( \sum_{i=1}^{n} q_i = 1 \). Thus the steps for selecting the assessment criteria can be shown below:

**Step 1**: Define a set of linguistic terms that contains the various degrees of preference the decision makers require. In this paper, we use triangular fuzzy numbers to express linguistic terms. A triangular fuzzy number \( A \) is defined as follows [3]:

\[
\mu_A(x) = \begin{cases} 
\frac{x - \alpha}{a - \alpha} & \text{if } x \in [\alpha, a] \\
\frac{x - \beta}{a - \beta} & \text{if } x \in [a, \beta] \\
0 & \text{otherwise}
\end{cases}
\]

Where \( \alpha \leq a \leq \beta \), and \( \alpha \) and \( \beta \) stand for the lower and upper values of the support of the fuzzy number \( A \), respectively, and \( a \) for the modal value. A fuzzy triangular number \( A \) is denoted by \( (a, \alpha, \beta) \).

**Step 2**: Assign linguistic term to every criterion \( c_j \) (\( j = 1, 2, \ldots, m \)). An individual decision maker's preference can be denoted by a vector. Then the \( n \) individual decision makers' preference form the matrix \( (v_{ij}) \) (\( i=1, 2, \ldots, n; j=1, 2, \ldots, m \)).

**Step 3**: Aggregate the matrix \( (v_{ij}) \) (\( i=1, 2, \ldots, n; j=1, 2, \ldots, m \)) into the group selection vector \( V = (v_1, v_2, \ldots, v_m) \).

**Step 4**: Rank the vector \( V \) (the elements are fuzzy numbers) in an ascending order. About top seven criteria, for convenience, also denoted as \( C = \{c_1, c_2, \ldots, c_6\} \), are then selected as final agreed assessment criteria set.

2.3 Determination of the assessment criteria weights

A criteria weight determination method [9] which integrated subjective and objective information is used to determine the corresponding assessment criteria weights according to different importance of the assessment criteria. This method makes use of the subjective information provided by decision makers and the objective information to form a two-objective programming model. Thus the weights \( W = (w_1, w_2, \ldots, w_n) \) on the attributes \( C = \{c_1, c_2, \ldots, c_n\} \) can be computed according to the programming model.

2.4 Fuzzy grading system

Self-assessment, peer assessment and group assessment are commonly used in student centered learning environment. Assume there are \( t \) participants of lecturers and students, denoted as \( P = \{p_1, p_2, \ldots, p_t\} \), involved in the evaluation process. Different rates, denoted as \( R = (r_1, r_2, \ldots, r_t) \), are assigned to the individual
participant depending on his/her role in the assessment task, where \( \sum_{i=1}^{n} r_i = 1 \).

In this paper, the evaluation results on projects are marked using a 100-point scale. For example, 80 indicates the learning outcomes to be 80% satisfactory according to the commonly agreed criteria. Thus the evaluation results given by participant \( p_i \) form a vector \((m_{i1}, m_{i2}, ..., m_{im})\), where each \( m_{ij} \in [0,100] \), \( (i=1,2,...,n) \), is the assigned mark with reference to the criterion \( c_i \).

For \( t \) participants involved in the evaluation process, an evaluation matrix \( M=(m_{ij}) \) \( (i = 1, 2, ..., t; j = 1, 2, ..., n) \) is formed. Thus the evaluation results can be obtained by

\[
M' = R*M = (m'_1, m'_2, ..., m'_t)
\]

where \( m'_i = r_1 * m_{i1} + r_2 * m_{i2} + ... + r_t * m_{in} \) and \( *\), \( +\) are the normal mathematical operators for multiplication and addition respectively.

In the case of one lecturer assessing students' project according to the agreed assessment criteria, a vector of evaluation results \( M'=(m'_1, m'_2, ..., m'_n) \) is given.

Letter grades are commonly used to reflect the students’ performance in the University. Thus a letter grade:  

\[
Y = \text{W} \circ E = (w_1, w_2, ..., w_n) \circ (e_1, e_2, ..., e_d)
\]

where \( e_i \) is the mark given to \( c_i \), \( e_i \in [0, 100] \), \( i = 1, 2, ..., n \). With the membership functions \( \mu_b1 \), \( \mu_b2 \), ..., \( \mu_bdf \), the fuzzy mapping \( f \) gives each mark \( m_i \) the degree which belongs to the letter grades \( g1, g2, ..., gd \). Hence, a given 100-point scale mark \( m' \), \( m'_d \) represents the degree that the mark \( m' \) belongs to the letter grade \( g_d \).

A fuzzy mapping can be defined which combines the membership functions together to form a comprehensive letter grade:

\[
f: c_i \rightarrow (\mu_{g1}(m'_i), \mu_{g2}(m'_i), ..., \mu_{gd}(m'_i))
\]

where \( m'_i \) is the mark given to \( c_i \), \( m'_i \in [0, 100] \), \( i = 1, 2, ..., n \). The membership functions \( \mu_{g1} \), \( \mu_{g2} \), ..., \( \mu_{gd} \), the fuzzy mapping \( f \) gives each mark \( m'_i \) the degree which belongs to the letter grades \( g_1, g_2, ..., g_d \) respectively.

For simplicity, we use \( (e_1, e_2, ..., e_d) \) to represent \( (\mu_{g1}(m'_i), \mu_{g2}(m'_i), ..., \mu_{gd}(m'_i)) \). Thus the fuzzy evaluation matrix \( E \) is expressed as \( (e_j) (i = 1, 2, ..., n; j = 1, 2, ..., d) \).

The final letter grade of the students’ learning outcomes can be determined by the vector \( Y \):

\[
y_j = \max (y_1, y_2, ..., y_d)
\]

According to the principles of fuzzy classification, we have \( y_j = \max (y_1, y_2, ..., y_d) \). Thus the corresponding letter grade \( g_i \) is the students’ final grade.

### 3. Group decision support system for fuzzy set assessment

A group decision support system (GDSS) has been developed to support the whole process of assessment. By definition, a GDSS [11] is an interactive computer-based system which facilitates solutions of unstructured problems by several decision makers working together as a group. The software components of GDSS include a database, a model base which consists of specialized application programs to be used by the group, and an easy-to-use, flexible user interface.

The proposed GDSS provides individual level and group level supports to two kinds of group decision makers, that is, group leader and normal group members. The main functions of the GDSS include:

(a) **Generation of basic assessment criteria** - this function allows group leader to set fuzzy triangular numbers to describe fuzzy linguistic terms which are usually agreed by group members.

(b) **Fuzzy number definition** - this function allows group members to grade student project comprehensively using the fuzzy grading method.

To let students, especially part-time students, use the GDSS from anywhere at anytime and to allow them use the system very conveniently and friendly, the newest Internet/Intranet techniques are used to build the GDSS. The system has been built as a Web server, called GDSS Server. Due to the nature of the problem and the fact that it involves the processing of a lot of data, a network-based relational database management system Microsoft SQL Server has been chosen for the implementation of the system. The underlying technique of the GDSS Server includes Microsoft NT Server, Microsoft SQL Server, and Microsoft Internet Information Server.

The GDSS Server has been developed using HyperText Making Language (HTML) documents and Java language. The system uses Java JDBC to send and
retrieve information from SQL Server. It makes the system easy to transfer to other platform.

4. Application results

To test the use of the fuzzy set based GDSS presented earlier, an empirical study was conducted in a semester long project of a Distributed Information Systems course. The aim of the project was to educate students to become Information Systems (IS) professionals through the application of knowledge and skills required by the course to a specific business problem. In undertaking the project, the student should demonstrate a clear grasp of the chosen subject matter, a full understanding of the principles being applied, and the ability to manage, evaluate and present the project in a coherent and precise manner. The course invited lecturers as well as students to formulate the assessment requirements. It could encourage students to take an active and responsible role in the whole assessment process.

83 undergraduate students participated voluntarily in this study. They were randomly assigned to two groups: an experimental group (with GDSS support) and a control group (without GDSS support). Each group was divided into two sub-groups consisting of about 20 students. Participants of the experimental group used the fuzzy set based GDSS to complete the proposed assessment task while the participants of the control group completed the task in a traditional face-to-face setting. At the end of the semester, students’ performances in the projects were graded against the evaluation schemes agreed at the beginning of the semester. Each student was also asked to rate his/her satisfaction level of the selected evaluation scheme using a six point Likert-type scale (Strongly Dissatisfactory = 1, Quite Dissatisfactory = 2, Slightly Dissatisfactory = 3, Slightly Satisfactory = 4, Quite Satisfactory = 5, Strongly Satisfactory = 6).

Comparison of project deliverable scores (See Table 1) revealed that the average score of the GDSS mediated group was significantly higher than that of the control group (p=.04), determined by a t-test at the 5% significance level based on a 100 point grading scale. Table 2 suggested that the average score of the satisfaction level of the GDSS mediated group was significantly higher than that of the control group (p=.03), determined by a t-test at the 5% significance level based on a 6 point Likert-type scale. The results indicate that the assessment schemes, generated by the GDSS mediated groups, meet the interests and abilities of students. It also motivates them to learn better.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Non-GDSS mean (standard deviation)</th>
<th>GDSS mean (standard deviation)</th>
<th>t-value</th>
<th>p-value (one tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Grade</td>
<td>77.13 (5.87)</td>
<td>79.27 (4.55)</td>
<td>1.83</td>
<td>0.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Non-GDSS mean (standard deviation)</th>
<th>GDSS mean (standard deviation)</th>
<th>t-value</th>
<th>p-value (one tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction Level</td>
<td>2.29 (0.75)</td>
<td>2.93 (1.07)</td>
<td>1.96</td>
<td>0.03</td>
</tr>
</tbody>
</table>

5. Summary

A fuzzy set approach has been proposed for assessment of students’ projects. It invites students and lecturers concerned to contribute assessment criteria and agree on criteria weights. The agreed criteria are then used to evaluate students’ projects. The proposed fuzzy set approach is implemented in an Internet-based group decision support system (GDSS) specially designed for supporting the assessment process. The experimental results with the use of proposed GDSS show that students are encouraged to work collaboratively and they produce better project results. The proposed fuzzy set assessment method and developed GDSS can also be used in evaluating projects with multi-criteria in other business settings.

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References


