Abstract:
In this paper, we present a new method of the group assessment to treat the rate of aggregative software development risk in fuzzy circumstances. Because the proposed assessment method uses the fuzzy numbers which are either single choices or multiple choices in fuzzy mode for the risk item respective to the criteria for the evaluators rather than the linguistic values to evaluate, and it can be closer to the assessment. Moreover, we revise the model by signed distance instead of centroid method, since if the triangular fuzzy number is not an isosceles triangle, then the result of defuzzified method by the signed distance is more appropriate than by the centroid method based on the maximum membership grade principle. Because of the evaluation method in this paper by group of evaluators, the proposed fuzzy assessment model is more useful, objective and justified than the one we have presented before by only one evaluator.

Keywords:
Fuzzy assessment; Rate of aggregative risk

1. Introduction

Many problems and risk occur in the software system development life cycle, such as postponed schedule, increased cost, inefficiency, abandonment, etc., [11]. Those risk and problems will cause huge economic and human impact. Therefore, to establish an effective risk management is an important issue, at beginning, the risk assessment should be appropriately implemented to identify the risk.

In evaluating the rate of risk factors, most decision-makers or project-managers, in fact, viewed those factors as linguistic values (terms), e.g., very high, high, middle, low, very low and etc. After fuzzy sets theory was introduced by Zadeh [21] to deal with problem in which vagueness is present, linguistic value can be used for approximate reasoning within the framework of fuzzy sets theory [22] to effectively handle the ambiguity involved in the data evaluation and the vague property of linguistic expression, and normal triangular fuzzy numbers are used to characterize the fuzzy values of quantitative data and linguistic terms used in approximate reasoning.

Lee [11] classified the risk factors presented by Boehm [2-4], Charette [5], Conger [8], Gilb [9] into six attributes, divided each attribute into some risk items, and built up the hierarchical structured model of aggregative risk and the evaluating procedure of structured model, ranged the grade of risk for each risk item into eleven ranks, and proposed the procedure to evaluate the rate of aggregative risk using two stages fuzzy assessment method. Chen [6] ranged the grade of risk for each risk item into thirteen ranks, proposed the other arithmetic operations instead of the two stages fuzzy assessment method, and defuzzified the trapezoid or triangular fuzzy numbers by the median. Lee [12] presented two algorithms for the group decision making to treat the rate of aggregative risk in software development. Lee [13] presented an algorithm of the group decision makers with crisp or fuzzy weights to tackle the rate of aggregative risk in software development. Chen [7] represented the linguistic value by the trapezoid fuzzy number, presented the other algorithm to evaluate the group assessment of aggregative risk rate and defuzzied the trapezoid fuzzy number by the median rule. Based on [6, 11], Lee [14] presented the other algorithm to tackle the rate of aggregative risk. In [15], Lee et al. presented the other algorithm for the group decision-making for evaluating the rate of aggregative risk.

In previous studies [6-7, 11-15], they used eleven or thirteen linguistic values for ranking the grades of risk to each risk item, where the linguistic values were represented by the triangular or trapezoid fuzzy numbers. But, it is very complicated to compute. Also, the evaluator only chooses one grade from grades of risk for each risk item. It has difficulty in reflecting the evaluator’s incomplete and uncertain thought. Therefore, if we can use fuzzy sense of assessment to express the degree of evaluator’s feelings based on his/her own concepts, the results will be closer to the evaluator’s real thought. Therefore, Lin and Lee [17] synthesized analysis of the aggregative risk. Based on Lin and Lee [17], Lee and Lin
presented the weighted triangular fuzzy numbers, defuzzified by the centroid, and directly tackle the risk rate of each attribute and the rate of aggregative risk from the assessed form. Lin and Lee [18] presented methods to treat the crisp or fuzzy multiple/single choice. Yao and Wu [20] presented the signed distance to rank the fuzzy numbers. Based on [12, 16-18], in this study, we propose the group evaluators to assess the aggregative risk based on either single choices or multiple choices in fuzzy mode, apply the signed distance method to defuzzify, and obtain the rate of aggregative risk. Because of the evaluation method in this paper by group of evaluators, the proposed fuzzy assessment model is more useful and justified than the one they have presented before by only one evaluator [16].

2. Preliminaries.

For the proposed algorithm, all pertinent definitions of fuzzy sets are given below [10, 20, 23].

Let \( D_\sim \) be a fuzzy set on \( \mathbb{R} \) as the \( \alpha \)-level set of \( D_\sim \), where \( 0 \leq \alpha \leq 1 \). \( D_L(\alpha) \) and \( D_R(\alpha) \) are the left and right hand side of \( D(\alpha) \), respectively. \( D_L(\alpha) \) and \( D_R(\alpha) \) exist and are integrable for \( \alpha \in [0, 1] \). In addition, we let \( F \) be the family of all these fuzzy sets \( D_\sim \) on \( \mathbb{R} \).

Let \( \tilde{D} \in F \), then from the decomposition theory, we may represent \( \tilde{D} \) as

\[
\tilde{D} = \bigcup_{0 \leq \alpha \leq 1} \alpha D(\alpha)
\]

As in Yao and Wu [20], we have the following definition.

Definition 2.1. Let \( \tilde{D} \in F \), we define the signed distance of \( \tilde{D} \) measured from 0 as

\[
d(\tilde{D}, \bar{0}) = \frac{1}{\alpha} \int_0^\alpha [D_L(\alpha) + D_R(\alpha)]d\alpha
\]

If \( \bar{C} = (p, q, r) \) is a triangular fuzzy number, then the left endpoint and the right endpoint of the \( \alpha \)-level set of \( \bar{C} \) are \( C_L(\alpha) = p + (q - p)\alpha \) and \( C_R(\alpha) = r - (r - q)\alpha \), respectively. The signed distance of \( \bar{C} \) measured from \( \bar{0} \) is

\[
d(\bar{C}, \bar{0}) = \frac{1}{4}(2q + p + r)
\]

We can show the following proposition.

Proposition 2.1. Let \( \bar{C} = (p, q, r) \) be a triangular fuzzy number. Based on the maximum membership grade principle, (1°) if \( \bar{C} \) is not an isosceles triangle, then to defuzzify \( \bar{C} \) by the signed distance is more appropriate than by the centroid method.

(2°) if \( \bar{C} \) is an isosceles triangle, then to defuzzify \( \bar{C} \) by the signed distance is equal to by the centroid method.

3. The Proposed Fuzzy Assessment Form

We present the fuzzy assessment form for the risk items as follows:

The criteria ratings of risk are linguistic variables with linguistic values \( V_1, V_2, \ldots, V_7 \), where \( V_1 = \) extra low, \( V_2 = \) very low, \( V_3 = \) low, \( V_4 = \) middle, \( V_5 = \) high, \( V_6 = \) very high, \( V_7 = \) extra high. These linguistic values are treated as fuzzy numbers with triangular membership functions as follows.

\[
\bar{V}_1 = (0, 0, \frac{1}{6}), \bar{V}_2 = (\frac{k-2}{6}, \frac{k-1}{6}, \frac{k}{6}), \text{for } k = 2, 3, \ldots, 6
\]

\[
\bar{V}_i = (\frac{5}{6}, 1, 1), i = 7
\]

We let \( V = \{ V_1, V_2, \ldots, V_7 \} \) be the set of the fuzzy linguistic values.

In previous studies [6, 7, 11-15], the evaluator only chooses one grade from grade of risk for each risk item, it ignores the evaluator's incomplete and uncertain thinking. Therefore, if we use fuzzy numbers which are either single choices or multiple choices in fuzzy mode for each item respective the criteria of assessment to express the degree of evaluator’s feelings based on his own concepts, the computing results will be closer to the evaluator's real thought.

Lee and Lin [16] proposed the assessment method of the structured model. In this study, we re-modify the Table 1 and propose the group assessment form as shown in Table 1. Assume there are \( n \) evaluators, saying \( D_1, D_2, \ldots, D_n \), to assess the aggregative risk in software.
development. Also, assume the assessment form for the evaluator \( D_q \) as shown in Table 1.

In Table 1, \( W_{2,q}(i) \) which is the weight of the attribute \( X_i \) assigned by the evaluator \( D_q \), satisfies
\[
\sum_{i=1}^{n} W_{2,q}(i) = 1, \quad 0 \leq W_{2,q}(i) \leq 1
\] (5)
for \( i = 1, 2, \ldots, 6; \ q = 1,2, \ldots, q_n \).

\( W_{1,q}(i,k) \) which is the weight of the risk item \( X_{ik} \) assigned by the evaluator \( D_q \), satisfies
\[
\sum_{i=1}^{n} W_{1,q}(i,k) = 1, \quad 0 \leq W_{1,q}(i,k) \leq 1
\] (6)
for \( i = 1, 2, \ldots, 6; \ q = 1, 2, \ldots, n; \ n_1 = 1, \ n_2 = 4, \ n_3 = 2, \ n_4 = 4, \ n_5 = 2, \ n_6 = 1; \ k = 1, 2, \ldots, n_k \).

There are two types of assessment for each risk item with respective to the criteria \( L_l \), \( l = 1, 2, \ldots, 7 \), saying single choice and multiple choice in the fuzzy mode [18].

**Type 1:** Single choice in the fuzzy mode for each risk item with respective to the criterion \( L_l \), \( l = 1, 2, \ldots, 7 \), as shown in Table 1.
\[
\sum_{i=1}^{7} m_{i,k}^{(l)} = 1, \quad 0 \leq m_{i,k}^{(l)} \leq 1
\] (7)
for \( l = 1, 2, \ldots, 7; \ k = 1, 2, \ldots, 6; \ q = 1, 2, \ldots, n_k \).

**Type 2:** Multiple choice in the fuzzy mode for each risk item with respective to the criterion \( L_l \), \( l = 1, 2, \ldots, 7 \), as shown in Table 2.
\[
1 \leq \sum_{i=1}^{7} M_{i,k}^{(l)} \leq 7, \quad 0 \leq M_{i,k}^{(l)} \leq 1
\] (8)

Normalizing \( M_{i,k}^{(l)} \) for \( l = 1, 2, \ldots, 7; \ i = 1, 2, \ldots, 6; \ k = 1, 2, \ldots, n_k \), in Table 2 as follows:
\[
m_{i,k}^{(l)} = \frac{M_{i,k}^{(l)}}{\sum_{i=1}^{7} M_{i,k}^{(l)}}
\] (9)
then we have
\[
\sum_{i=1}^{7} m_{i,k}^{(l)} = 1, \quad 0 \leq m_{i,k}^{(l)} \leq 1
\]

So, if the evaluators assess the risk item with respective to the criteria \( L_l \) by multiple choice in the fuzzy mode, we may normalize \( M_{i,k}^{(l)} \) as Eq. (9), and we can have \( m_{i,k}^{(l)} \) which satisfies the Eq. (7).

### 4. The Proposed Fuzzy Assessment Algorithm

Step 1: We average each parameter on the \( n \) evaluators’ assessment data as follows:
Let
\[
W_{i}(i) = \frac{1}{n} \sum_{q=1}^{n} W_{2,q}(i)
\] (10)
\[
W_{i}(k) = \frac{1}{n} \sum_{q=1}^{n} W_{1,q}(i,k)
\] (11)
\[
N_{i}^{(l)} = \frac{1}{n} \sum_{q=1}^{n} m_{i,k}^{(l)}
\] (12)
be the average of the \( n \) evaluators’ assessment data of \( W_{2,q}(i) \), \( W_{1,q}(i,k) \) and \( m_{i,k}^{(l)} \) respectively.

Step 2: By the fuzzy relation [23] on \( X_i \times V \), we can form a fuzzy assessment matrix \( \tilde{R}_l \) as follows:
\[
\tilde{R}_l = \begin{pmatrix}
N_{i1}^{(l)} \tilde{V}_1 & N_{i1}^{(l)} \tilde{V}_2 & \cdots & N_{i1}^{(l)} \tilde{V}_7 \\
N_{i2}^{(l)} \tilde{V}_1 & N_{i2}^{(l)} \tilde{V}_2 & \cdots & N_{i2}^{(l)} \tilde{V}_7 \\
\vdots & \vdots & \ddots & \vdots \\
N_{i6}^{(l)} \tilde{V}_1 & N_{i6}^{(l)} \tilde{V}_2 & \cdots & N_{i6}^{(l)} \tilde{V}_7
\end{pmatrix}
\] (13)

Step 3: By compositional rule of inference, we have
\[
(W_{i}(i), W_{i}(k)) \ast \tilde{R}_l = (\tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_7)
\]
where
\[
\tilde{b}_k = (W_{i}(i)(N_{i1}^{(l)} \tilde{V}_1)) \oplus \cdots \oplus (W_{i}(i)(N_{i6}^{(l)} \tilde{V}_7))
\] (14)
for \( l = 1, 2, \ldots, 6; \ k = 1, 2, \ldots, 7 \).

Defuzzify (14) by signed distance method, we have
\[
d(\tilde{d}_{b}, \tilde{d}_0) = \sum_{j=1}^{7} W_{i}(i,j) \delta_{y}^{(l)}.(\tilde{V}_{j}, \tilde{0})
\] (15)
for \( l = 1, 2, \ldots, 6; \ k = 1, 2, \ldots, 7 \).

Then, we have the following proposition.

Proposition 4.1.

(1°) The risk rate for the attribute \( X_i \) is
\[
Risk_i = \sum_{k=1}^{7} d(\tilde{b}_k, \tilde{0}) = \sum_{j=1}^{7} \sum_{k=1}^{n} W_{i}(i,j) \delta_{y}^{(l)}.(\tilde{V}_{j}, \tilde{0})
\] (16)
for \( i = 1, 2, \ldots, 6 \).

(2°) The rate of aggregative risk is
\[
Risk_{rate} = \sum_{i=1}^{7} (W_{i}(i) \cdot Risk_i)
\] (17)
5. Numerical Example

Assume that we have the average each parameter of the two evaluators’ assessed data are as shown in Table 3. By the Proposition 1, we have

\[ \text{Rate of attributes } X_1, X_2, X_3, X_4, X_5, X_6 \text{ are respectively.} \]

(2) The rate of aggregative risk is 0.269475.

6. Conclusions

In this paper, we revise the aggregative risk assessment model by signed distance instead of centroid method [16], since if the triangular fuzzy number is not an isosceles triangle, then the result of defuzzified method by the signed distance is more appropriate than by the centroid method based on the maximum membership grade principle.

The proposed assessment method in this paper directly uses the fuzzy numbers which are either single choices or multiple choices in fuzzy mode for the risk item respective to the criteria for the evaluators rather than the linguistic values to do evaluation, so it can be closer to the assessment.

Because of the evaluation method in this paper by group of evaluators, the proposed fuzzy assessment model is more useful and justified than the one we have presented before by only one evaluator [16]. However, if the evaluator is a single one, we may also apply this proposed method to assess the rate of aggregative risk in software development.

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References


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### Table 1: Contents of the Evaluator $D_{q,s}$ Assessment Form (Single Choice in Fuzzy Mode)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Risk item</th>
<th>Weight-2</th>
<th>Weight-1</th>
<th>Linguistic variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$: Personal</td>
<td>$W_{1,q}(1)$</td>
<td>$W_{1,q}(1,1)$</td>
<td>$m_{11,q}^{(1)}$</td>
<td>$V_1$</td>
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<td></td>
<td>$m_{12,q}^{(1)}$</td>
<td>$V_2$</td>
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<td>$m_{17,q}^{(1)}$</td>
<td>$V_7$</td>
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<td>$X_2$: System requirement</td>
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<td>$W_{2,q}(2,1)$</td>
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<td>$X_3$: Schedules and budgets</td>
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### TABLE 2. CONTENTS OF THE EVALUATOR $D_q$'S ASSESSMENT FORM FOR THE ATTRIBUTE $X_i$ (MULTIPLE CHOICES IN FUZZY MODE)

<table>
<thead>
<tr>
<th>Attribute $X_i$</th>
<th>Weight-2 $W_{i,q}(1)$</th>
<th>Linguistic variables $M^{(1)}<em>{i,q}, M^{(2)}</em>{i,q}, M^{(3)}<em>{i,q}, M^{(4)}</em>{i,q}, M^{(5)}<em>{i,q}, M^{(6)}</em>{i,q}, M^{(7)}_{i,q}$</th>
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<td>$X_{i1}$</td>
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### TABLE 3. CONTENTS OF THE EXAMPLE

<table>
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<tr>
<th>Attribute $X_i$</th>
<th>Weight-2</th>
<th>Weight-1</th>
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