Contribution Based Priority Assessment in a Web-based Intelligent Argumentation Network for Collaborative Software Development

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ABSTRACT

Decision making is an important aspect in a collaborative software development process which involves a complex process of conflict resolution. The priority of the participants plays a vital role in conflict resolution as the decision making process involves many participants from multiple perspectives. The priority assessment methods used in the process so far are usually static in nature, i.e., the priorities of the participants remain constant throughout the decision making process. In order to make the collaborative system more close to real world scenarios, we incorporate dynamic priority assessment into a web-based collaborative system based on intelligent computational argumentation, which was developed in our previous research work. We evaluate priorities dynamically for each cycle of the decision process based on the contribution of each participant. The contribution is assessed based on impact of each participant’s arguments on the winning design alternative. More successful participants have higher priorities in argumentations during collaboration.

KEYWORDS: Dynamic Priority Assessment, Computational Argumentation, Conflict Resolution, Contribution Evaluation, Fuzzy Logic

1. INTRODUCTION

The increased need of reduction in the cost and time of design and development of a project has resulted in development of many ways of achieving effective collaboration among the participants in the software design process. In order to make the collaboration efficient, there is a need to develop some mechanism to resolve conflicts among them and facilitate reaching a consensus. In our previous research we have addressed this issue of conflict resolution by developing a web based argumentation system for collaborative software development decision making [1]. The system has further been enhanced to detect self-contradicting arguments [2] and to reassess argument strengths based on evidences.

Priority of the participant is one of the basic decision factors in objective decision making in an argumentation system. The priorities are usually assigned based on the roles of the participants in a software development process. These priority assignments usually remain the same throughout the decision process. In real applications, it is essential to update the priorities dynamically. The priorities of the participants can be assessed based on their contributions toward the decision making process. For better understanding, we take up a real world scenario to explain the importance of contribution in priority assessment. For example, many persons have applied for a loan in a bank to set up a small business. The first thing the bank looks for is the person’s credit history. On the basis of this history they are prioritized. A person with a better credit history is given a higher priority. Similarly the priority of a person can be determined dynamically based on the contribution he makes towards a winning design alternative.

This paper discusses the dynamic priority evaluation in a web based intelligent collaborative system [1, 2] to make the decision making process more objective and analogous to the real world scenario of argumentation. The paper is organized as follows. Section 2 presents a review of related work and gives a brief overview of our previous research. Section 3 explains the incorporation of contributions to reassess the priorities of participants in the system. Section 4 presents an example of the argumentation for a collaborative software development design.
which discusses how contributions of participants are used in priority reassessment.

2. BACKGROUND

Requirements prioritization is an essential task when working in a collaborative environment. As the requirements come from different stakeholders with different interests, prioritizing the requirements becomes a challenging task. To develop a successful software project it is essential to have effective negotiation among the stakeholders.

2.1. Related Work

Argumentation systems are built based on a classical model of argumentation developed by Philosopher Toulmin [3]. An earlier method gIBIS (graphical IBIS) represents design dialog as a graph [4]. While capable of representing issues, positions, and arguments, gIBIS failed to support representation of goals (requirements) and outcomes. REMAP [5] (REpresentation and MAintenance of Process knowledge) extended gIBIS by providing the representation of goals, decisions, and design artifacts.

As opposed to these systems, Sillince [6] proposed a more general argumentation model. His model is a logic model where dialogues are represented as recursive graphs and the rules of both rhetoric and logic are used to manage the dialog and to determine when the dialog has reached closure. Potts and Burns [7] outlined a generic model for representing design deliberation and the relation between deliberation and generation of method specific artifacts. It differs from our system in its lack of decision making capabilities. HERMES [8] is a system that not only captures the informal organizational memory embodied in decision making settings, but also helps users during the decision making process. But the drawback of the system is that the weighting factor becomes very ineffective as it does not relate to the position entered.

A scalable reasoning system has been developed in [9], which represents various reasoning artifacts like arguments and evidences. It is similar to our work in that it represents the relationship between two artifacts as support or refute. But, the system does not implement any inference engine for decision-making.

Many prioritization techniques have been proposed based on analytical and mathematical approaches. Analytic Hierarchy Process (AHP) proposed by Saaty [10] uses an exhaustive pair wise evaluation in a hierarchy. This approach was found to be complicated, time-consuming and impractical for large projects. Several researchers proposed techniques to overcome the computation exploitation [11]. All these techniques could not capture the correlation among the requirements for prioritization among different stakeholders.

Later a Correlation-Based Priority Assessment framework (CBPA) [12] was proposed. It prioritizes software process requirements gathered from multiple stakeholders by incorporating inter perspective relationships of requirements. However, this framework did not deal with the negative correlations. A web based collaborative system [13] was developed to incorporate priority of participants into an intelligent computational argumentation based collaborative system. However, the priority assessment techniques used in the above methods are static, i.e., the priority value of a participant is not changed no matter how much or little contribution a participant makes in a decision making process. Even if a participant with a high priority based on his/her position in an organization makes a poor judgment and provides an overall poor argumentation, he/she may still keep his/her high priority for next decisions to be made.

2.2. Web Based Intelligent Argumentation System for Decision Making in Collaborative Software Development

A computational argumentation model for collaborative software development decision making has been developed to enable achieving consensus among stakeholders and identifying the most favorable development alternative. The system is developed based on the client-server architecture. On the client side, the system provides a user interface for argumentation based conflict resolution, a whiteboard for sharing designs, and chat rooms for real-time information exchange. On the server side, it manages client communication and an argumentation network. An argumentation dialog for a development issue in an argumentation model can be captured as a weighted argumentation tree as shown in figure 1.
Figure 1. Argumentation Tree

The nodes in the argumentation tree in Figure 1 are design alternatives and arguments. The node denoted by a circle is a Position, i.e., a design alternative, and the nodes denoted by rectangles are Arguments. Arrows represent a relationship (attack or support) from an originating argument node to a terminating argument or position node. The weight assigned to an argument is argument strength. It is the measure of an argument's degree of attack or support of either a position or another argument. The weight value is a real number between -1 and 1. A positive number denotes support and a negative number denotes attack while zero denotes indecision. A fuzzy inference engine is developed using the fuzzy association memory for argumentation reduction. It enables assessment of quantitative impact of indirect arguments on a software development alternative. Favorability of a software development alternative is computed by a weighted summation of strengths of arguments directly attached to it. The position with the maximum favorability factor is the best option.

3. CONTRIBUTION BASED PRIORITY ASSESSMENT

Contribution of a participant is evaluated based on assessment of impact of his/her arguments on the winning design alternative. In an argumentation, participants represent their favorability for a particular position as weights associating their arguments with the position. These weights usually represent attack or support for a particular position. Contribution describes the amount of support or attack from each participant for a winning alternative. It is a real number between -1 and 1. A weight closer to 1 represents a higher positive contribution made to a successful decision. A weight closer to -1 represents a higher negative contribution made to a successful decision.

3.1. Evaluation of Contributions of Participants

The contribution of a participant is evaluated after the argumentation reduction phase [15]. The arguments move up in the argumentation network in the process of argumentation reduction. All the arguments are directly attached to positions at a single level. The evaluation of a participant's contribution is a stepwise procedure as follows:

1) The initial step is to identify and group all the arguments from each participant.

Let \( P_1, P_2, \ldots, P_n \) be stakeholders participating in the argumentation process, where \( n \) is the total number of stakeholders. Assume that a participant \( P_i \) (\( 1 \leq i \leq n \)) has \( M_i \) arguments in an argumentation network. We group these arguments for participant \( P_i \).

2) The weighted summation of strengths of each participant is calculated.

Let \( S_{ij} \) (\( 1 \leq i \leq n, 0 \leq j \leq M_i \)) represent the strength of argument \( A_{ij} \) posted by participant \( P_i \). Assume that \( WS_i \) is the Weighted Summation of the argument strengths of the participant \( P_i \), then

\[
WS_i = \sum_{j=0}^{M_i} S_{ij} \quad 1 \leq i \leq n \quad (1)
\]

Similarly, we calculate the Weighted Summation of the argument strengths \( WS_1, WS_2, \ldots, WS_n \) for all the other participants.

3) The participants are then classified into positive and negative contributors based on their weighted summation values.

Positive Contribution

Let \( K \) be the number of positive contributors, i.e., the participants whose weighted summation values are greater than zero, where \( 1 \leq K \leq n \). It is desirable to have the positive contribution values of individual participants to lie within the
range 0 to 1.0 for purpose of priority assessment. Since the weighted summation values calculated in equation (1) for a positive contributor may exceed this range, we normalize each positive contributor’s contribution using equation (2).

\[
C_T = \frac{W S_T}{H P} \tag{2}
\]

where \(1 \leq T \leq K\) and HP is the highest positive contribution value among all the participants. From equation (1) and (2),

\[
C_T = \frac{M_T}{\max \left( \frac{\sum_{j=0}^{M_T} S_{T,j}}{\sum_{j=0}^{S_{T,j}}} \right)} \tag{3}
\]

**Negative Contribution**

Let \(L\) be the number of negative contributors, i.e., the participants whose weighted summation values are less than zero, where \(1 \leq L \leq n\).

A basic assumption we use in the dynamic priority reassessment based on contributions is that the contribution values lie within the range -1.0 to 0. Since the weighted summation values calculated in the equation (1) for a negative contributor may exceed this range, to ensure that the contribution values lie within this range, we normalize each negative contributor’s contribution using equation (4).

\[
C_G = \frac{W S_G}{H N} \tag{4}
\]

where \(1 \leq G \leq L\), and HN is the highest negative contribution value among all the participants who have made negative contributions. From equations (1) and (4),

\[
C_G = \frac{M_G}{\min \left( \frac{\sum_{j=0}^{M_G} S_{G,j}}{\sum_{j=0}^{S_{G,j}}} \right)} \tag{5}
\]

In the above procedure, equations (3) and (5) represent a degree of positive or negative contribution made by each participant towards the winning design alternative.

### 3.2. Reassessment of Priority Based Contribution Using Fuzzy Logic

After evaluating the contribution of each participant, the priorities of the participants can be reassessed based on the following heuristic rules:

**General Priority Reassessment Heuristic Rule 1:**
The more contribution to a successful decision a participant makes, the higher the participant’s priority should be.

**General Priority Reassessment Heuristic Rule 2:**
The less contribution to a successful decision a participant makes, the lower the participant’s priority should be.

There are positive and negative contributors. The positive contributors are rewarded and the negative contributors are penalized. Therefore, we have two association matrices for adjusting priority of participants based on their contributions. One is for priority increase based on positive contribution, and the other is for priority decrease based on negative contributions. The general heuristic rules are extended to nine fuzzy inference rules in each of the two fuzzy association matrices. The linguistic labels used for the strength of priority and contribution are High (H), Medium (M) and Low (L). The inputs to the Fuzzy Association Matrix are the contribution (horizontal) and priority (vertical) values of the participants. Figure 2 shows a fuzzy association matrix for priority increase based on positive contributions. We calculate the final priority values using equation (6).

Final Priority \((P_i) = \text{Initial Priority} \ (P_i) + \frac{\text{Output}}{10} \times \text{Initial Priority} \ (P_i) \tag{6}\)

where the value of Output is calculated using the Fuzzy Association Matrix shown in figure 2.

Figure 3 shows Fuzzy Association Matrix for priority decrease based on the negative contribution. We calculate the final priority values using equation (7).

Final Priority \((P_i) = \text{Initial Priority} \ (P_i) - \frac{\text{Output}}{10} \times \text{Initial Priority} \ (P_i) \tag{7}\)
where Output is the value calculated using the Fuzzy Association Matrix shown in figure 3.

```
P  H  M  L
H  H  M  L
M  H  M  L
L  H  M  L
```

**Figure 2. Fuzzy Association Matrix for Priority Assessment of Positive Contribution**

```
P  H  M  L
H  H  M  L
M  H  M  L
L  H  M  L
```

**Figure 3. Fuzzy Association Matrix for Priority Assessment of Negative Contribution**

Using this fuzzy inference engine, we can incorporate contribution to revise the priority of a participant. Fuzzy membership functions are used to quantitatively characterize linguistic labels. In our previous research work, the fuzzy membership function chosen for the priority is the piecewise linear trapezoidal function. The three fuzzy sets are Low, Medium and High and the membership functions for priority are shown in figure 4. The fuzzy membership function chosen for representing contribution is also the piecewise linear trapezoidal function. The three fuzzy sets are Low, Medium and High, and the membership functions for contribution are shown in figure 5.

```
P  H  M  L
H  H  M  L
M  H  M  L
L  H  M  L
```

**Figure 4. Fuzzy Membership Functions for Priority**

**Figure 5. Fuzzy Membership Functions for Contribution**

4. AN APPLICATION EXAMPLE

We illustrate dynamic priority reassessment in an argumentation network with an example. In this example, there are three design issues. They are represented in form of argumentation trees shown in figures 6, 7 and 8. Each of these design issues involves five participants who have posted their arguments either in favor of or against a position.

The priorities are reassessed based on the contributions made by the participants towards the design issues. The contribution is evaluated with the help of the final weights representing the strengths of the arguments after the argumentation reduction process. The output of this process is a one-level argumentation tree which contains arguments and their strengths posted by each participant.

The weighted summation of all the arguments for each participant is then calculated. The normalized contribution of each positive contributor is the ratio of the individual’s contribution to the highest positive contribution value among all the positive contributors. The normalized contribution of each negative contributor is the ratio of the individual contribution to the highest negative contribution value among all the negative contributors.

We calculate the contributions of the participants towards the winning design alternative. The notation Pi denotes the ith participant. In this example, we show the impact of contribution on priority reassessment using participant P3.

**Design Issue 1**

Initial priority values are assigned heuristically to the participants based on their roles. The argumentation scores calculated for the two positions under design issue 1 are:

<table>
<thead>
<tr>
<th>Position 1</th>
<th>Position 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.677</td>
<td>0.100</td>
</tr>
</tbody>
</table>

Position 1 is identified as the winning design alternative. Therefore, we calculate the contribution of participants towards Position 1.
Contribution towards Position 1: Only four participants participate in the argumentation about this position. The Weighted Summation (WS) of the argument strengths is calculated for each participant using equation (1).

Figure 6. Design Issue 1

Figure 7. Design Issue 2

Figure 8. Design Issue 3

For participant P3, it is

\[ WS(P_3) = -0.5 \]

The normalized positive contribution \((C_P)\) and the negative contribution \((C_N)\) for each participant is calculated based on equation (3) and (5), respectively. For participant P3, we have

\[ C_P(P_3) = -1.0 \]

Participant P3 contributes negatively to the design issue 1. We calculate its new priority based on the fuzzy rules in the Association Matrix in figure 3. The inputs are the fuzzy membership values of contribution and the initial priority. The output is the percentage decrease in the priority.

The fuzzy membership values for the priority and contribution of P3 are calculated using figure 4 and figure 5, respectively.

\[ P_P(0.4) = 0 \quad C_P(-1.0) = 1.0 \]
\[ P_M(0.4) = 0.5 \quad C_M(-1.0) = 0 \]
\[ P_L(0.4) = 0.5 \quad C_L(-1.0) = 0 \]

\[ w_1 = \min [P_P(0.4), C_P(-1.0)] = 0.5 \]
\[ w_2 = \min [P_L(0.4), C_L(-1.0)] = 0.5 \]

\[ \text{Output} = \frac{w_1 \times P(M,H) + w_2 \times P(L,H)}{w_1 + w_2} \]

where \(P(M,H)\) is the priority value when contribution is high and priority is medium and \(P(L,H)\) is the priority value when contribution is high and priority is low. Thus,
Output = \((0.9 \times 0.5 + 0.9 \times 0.5)/(0.5 + 0.5)\)
\[= 0.9\]

The modified priority of participant \(P_3\) is calculated using equation (7).

Modified Priority \((P_3) = 0.4 - (0.09 \times 0.4) = 0.364\)

Similarly, the modified priority values calculated for all the other participants are given below.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Contribution</th>
<th>Initial Priority</th>
<th>Modified Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0.892</td>
<td>0.4</td>
<td>0.436</td>
</tr>
<tr>
<td>P2</td>
<td>1.0</td>
<td>0.6</td>
<td>0.654</td>
</tr>
<tr>
<td>P3</td>
<td>-1.0</td>
<td>0.4</td>
<td>0.364</td>
</tr>
<tr>
<td>P4</td>
<td>0.892</td>
<td>0.7</td>
<td>0.763</td>
</tr>
<tr>
<td>P5</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The participants \(P_1, P_2,\) and \(P_4\) have made positive contributions in selecting the winning position and the participant \(P_3\) has made negative contribution. This fact is reflected in their updated priority values.

**Design Issue 2.**

In the process of choosing the winning design alternative we use the reassessed priority values, which are the updated priority values obtained as an output from the first design issue. With these priority values the argumentation scores calculated for the two positions under design issue 2 are:

<table>
<thead>
<tr>
<th>Position 1</th>
<th>Position 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.615</td>
<td>0.490</td>
</tr>
</tbody>
</table>

Position 1 is clearly identified as the winning design alternative. Therefore, we calculate the contribution of participants towards Position 1.

**Contribution towards Position 1:** Only three participants participate in the argumentation about this position. The Weighted Summation (WS) of argument strengths is calculated for each participant using equation (1). For example, the WS value for participant \(P_3\) is

\[\text{WS}(P_3) = -0.79\]

The normalized positive contribution \((C_P)\) and negative contribution \((C_N)\) for each participant are calculated based on equation (3) and (5), respectively. For participant \(P_3\) we have

\[C_N(P_3) = -1.0\]

The modified priority of participant \(P_3\) is calculated using equation (7) as follows:

Modified Priority \((P_3) = 0.364 - (0.09 \times 0.364) = 0.332\)

Similarly, the priority values are calculated for all the other participants. They are given below.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Contribution</th>
<th>Initial Priority</th>
<th>Modified Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0</td>
<td>0.436</td>
<td>0.436</td>
</tr>
<tr>
<td>P2</td>
<td>1.0</td>
<td>0.654</td>
<td>0.72</td>
</tr>
<tr>
<td>P3</td>
<td>-1.0</td>
<td>0.374</td>
<td>0.332</td>
</tr>
<tr>
<td>P4</td>
<td>0.77</td>
<td>0.763</td>
<td>0.83</td>
</tr>
<tr>
<td>P5</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Participant \(P_3\) has negatively contributed to the winning alternative, i.e., Position 1. This is reflected as a decrease in its reassessed priority value. We observe that participants \(P_2\) and \(P_4\) are making more contributions hence their priority value becomes larger.

**Design Issue 3.**

In order to portray the importance of priority in making a better decision we take up the third design issue where the participants \(P_1, P_2,\) and \(P_4\) help in deciding a design alternative based on their credit values with the help of dynamically changing priorities.

In the design issue 3 Position 1 is the winning design alternative as indicated by the following argumentation scores.

<table>
<thead>
<tr>
<th>Position 1</th>
<th>Position 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.941</td>
<td>0.540</td>
</tr>
</tbody>
</table>

**Contribution towards Position 1:** We calculate the contribution of participants towards Position 1. Only four participants participate in the argumentation about this position. The Weighted Summation (WS) of argument strengths is calculated for each participant using equation (1). For participant \(P_3\) we have

\[\text{WS}(P_3) = 0.5\]

The positive contribution \((C_P)\) and the negative contribution \((C_N)\) for each participant are calculated based on the equation (2) and (4), respectively.
C_G(P_2) = 0.83

The modified priority of participant P_3 is calculated using equation (6).

Modified Priority (P_3) = 0.332 + (0.09*0.332) = 0.36

The participant P_3 has contributed positively to the winning alternative, i.e., Position 1 which is reflected as an increase in its reassessed priority value.

Similarly, the modified priority values are calculated for all the other participants as given below.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Contribution</th>
<th>Initial Priority</th>
<th>Modified Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>1.0</td>
<td>0.436</td>
<td>0.48</td>
</tr>
<tr>
<td>P2</td>
<td>0.83</td>
<td>0.72</td>
<td>0.78</td>
</tr>
<tr>
<td>P3</td>
<td>0.83</td>
<td>0.34</td>
<td>0.36</td>
</tr>
<tr>
<td>P4</td>
<td>0.5</td>
<td>0.83</td>
<td>0.9</td>
</tr>
<tr>
<td>P5</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

5. CONCLUSION AND FUTURE WORK

The main contribution of this paper is the development of a dynamic contribution based priority assessment for a web-based collaborative intelligent computational argumentation system. The incorporation of contributions of participants on decisions made (based on argumentation) in priority assessment allows successful contributors to carry higher priorities in the argumentation process. As a result, the argumentation process is more objective and this will very likely improve the quality of decisions and is closer to the real world scenario of collaborative engineering design. This is one of the ways to assess the priorities dynamically.

In the future, the proposed argumentation method and the priority assessment tools used as described will be evaluated using real applications, where there will be a number of users to reflect the system dynamics.

6. ACKNOWLEDGEMENT

This research is supported by the Intelligent Systems Center in the University of Missouri-Rolla.

7. REFERENCES


