An Argument-based Collaborative Negotiation Approach to Support Software Design Collaboration

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Abstract - Most software design involves multiple stakeholders and group decision making activities. To reach an agreement in such activities, negotiation is the key task. Our work synthesizes Toulmin’s argument structure and a value-focused objective hierarchy to develop a new negotiation approach for the software design. This approach structures negotiation arguments in order to establish a common ground for a more effective negotiation. In this paper, we introduce this approach, discuss its foundations and main process, and present a case study in which we applied this approach for a real-life software system design project.

Keywords: Software Design, Group Decision, Collaborative Negotiation, Argument Structure

I. INTRODUCTION

Software design always involves multiple stakeholders and group decision making activities. While designing the software, stakeholders from various departments bring their information and expertise to determine major function or to lay out the architecture. However, making this group decision is never easy because their information is overwhelming, decision objectives and criteria are manifold, alternatives may not be clear, and preferences are subjective and often conflicting.

Collaboration, by its definition, means that every member in a team, through social interactions, can seek for useful information together, share objectives and criteria, and make mutually-agreed decisions based on various alternatives and preferences. Collaborative negotiation is one type of collaboration in which stakeholders communicate their opinions, negotiate the alternatives, influence each other’s preferences, and try to resolve conflicts by finding an agreement. However, most past research focused on either individual decision making (e.g. [1, 2]) or a generic negotiation process (e.g. [3, 4]); and in authors’ knowledge very few of them combine both aspects, i.e. identify and organize stakeholders’ objectives and preferences, and then provide a systematic negotiation process to reconcile the conflicts in these organized objectives and preferences.

In this research, we propose a new research approach to identify stakeholders’ objectives and preferences using the framework of Keeney’s value-focus thinking [8] and describe a systematic negotiation process, which generates negotiation arguments based on identified objectives and preferences and then evaluates the arguments by calculating the objectives and preferences to find the most preferred one by the negotiation team. In this paper, we will introduce this approach in section II. In section III we present a case study that is conducted to validate the approach. Section IV concludes this paper and outlines the future work.

II. ARGUMENT-BASED COLLABORATIVE NEGOTIATION APPROACH

There are two foundations in our approach. One is the argument structure that is based on Toulmin’s generic argument structure [9]; the other is an objective hierarchy that is built based on Keeney’s value-focus thinking framework [8]. Argument is developed to persuade or convince others that one’s reasoning is more valid or appropriate in negotiation. Objective hierarchy is used to organize stakeholders’ objectives and preferences, which will be used to generate the arguments. The key step of our negotiation approach is to generate and evaluate arguments by synthesizing the two research foundations. In this section, we will first present the details of these two foundations, and then discuss our approach which is based on the synthesis of these two foundations.

A. Objective hierarchy

Because “values, as the driving force to our decision making, are fundamental to all that we do”, every stakeholder has his own value when he makes any decision. For example, when selecting a platform for developing web service in software system design, an individual contractor who favors open source may always choose Java based frameworks since most of those are open-source to the public and everything is free to use, however, a manager who has more concern with platform and development support may choose .Net as the main platform since using that it is more convenient for him to directly contact Microsoft for customer service instead of asking a question in the public community and desperately waiting for someone to kindly give an answer. Keeney emphasizes that each decision maker pursues his own values in a group decision-making process and the goal for which they participate in this process is to maximize his value.

In our framework, values are classified into fundamental objectives and means objectives. Fundamental objectives concern the ends in a specific decision context and the means objectives are the ways to achieve those ends. In this objective hierarchy, we also define attributes for evaluating how well these objectives are achieved. These attributes describe the objectives and have common interpretation to every stakeholder. They can be used as the common scales to evaluate the negotiation arguments for the degree to which they
achieve the objective (that the attributes belong to) and thus yield independent measurement values for each argument. Then the arguments can be ranked for how well they achieve the objectives. The evaluation results can be either a quantitative value within a pre-defined range, or a qualitative value, e.g. support, neutrality (indifferent or uninterested), opposition, controversy (not support but match the interest for the group).

B. Argument structure

Practicing collaborative design and negotiation dialogue have been found to be positively linked with argument development and critical thinking skills. The work of Buckingham and his colleagues argue that standardizing an argument’s structure facilitates its subsequent communication since important meta-information and relationships can be more easily perceived and analyzed by others [1]. Stephen E. Toulmin’s 1958 work [10] has become commonplace in structuring arguments - Toulmin acknowledges as much in the preface to his 1984 text [11]. For example, Houp, Pearsall and Teheaux’s textbook, Reporting Technical Information, introduces Toulmin logic as providing “a way of checking your own arguments for those overlooked flaws. It can also help you arrange your argument” [6]. The goal of developing arguments in negotiation is to persuade or convince others that one’s reasoning is more valid or appropriate. Toulmin’s structure of argument provides the language symbols and data structures that support the argumentation process. Toulmin’s structure is procedural and the layout of this structure focuses on the movement of accepted data to the claim through a warrant. Toulmin also recognizes three secondary elements that may be present in an argument: backing, qualifier, and rebuttal. Backing is the authority for a warrant, provides credibility for the warrant, and may be introduced when the audience is unwilling to accept the warrant. A qualifier indicates the degree of force or certainty that a claim possesses. Finally, rebuttal represents certain condition or exception under which the claim will fail and hence anticipates objections that might be advanced against the argument to refute the claim [10]. As such, Toulmin’s argument structure becomes a popular mechanism for structuring arguments between negotiating stakeholders. It aims to clarify the reasoning process by encouraging parties to make explicit important assumptions, distinctions, and relationships as they construct and rationalize ideas [1].

C. Synthesis between the Objective Hierarchy and the Generic Argument Structure

Using the Toulmin’s argument structure, which is generally more objective than implicit arguments, it is hard for stakeholders to hide bias because the grounds and backing of an argument are clearly listed and described to support the claims. Therefore, all stakeholders’ perspectives are relatively easy to be fully observed by others through examination of the ground and warrants that the stakeholder expresses [7]. However, there are remaining unresolved issues in most of the above work, such as a clear guide to systematically generate the arguments and evaluating them for the best in an operational negotiation process. Our research try to resolve this challenge by synthesizing the argument structure with the value-focused ‘objective hierarchy’, developing practical methods of generating and evaluating structured arguments (see Figure 1).

![Figure 1 Synthesis between Objective Hierarchy and Argument Structure](image-url)

In Fig. 1, the claim is proposed by the stakeholder and consists of a sequence of actions/objects to implement the task. The data specifies the state of team agreement about the design process (e.g., tasks, objectives) together with any applicable information to support the claim. The state of team agreement can be accomplished by previous design tasks and arguments, such as the results of the previous tasks, the common understanding of the team for these tasks, and the objectives jointly proposed by the team. The applicable information includes stakeholder’s understanding and expectation for the current task and any facts that can be used to justify the proposal. This data describes the initial state of the current task, presents the applicable information, and therefore provides background support for the claim. Stakeholders’ objectives are in the place of warrant, identifying the value that stakeholders want to achieve along with clarification of the relationship between the value and the current state of agreement. These objectives, as warrants, justify that the proposal can achieve the value based on the state of agreement (i.e. data). The attributes of each objective, corresponding to the ‘backing’ component, further explain the objectives by describing their measurement criteria and then validate the relationship amongst the objectives, the proposal and the current state of agreement. Based on these objectives and attributes, the measurement result regarding the achievement of the aforementioned objectives by stakeholder’s own proposal work as a ‘qualifier’ to indicate the degree of desire of the stakeholders for the proposal. Similar results regarding the achievement of the objectives by others’ proposals work as ‘rebuttal’ and describe possible conditions that could fail the claim or suspend the warrant.

Based on the concrete meanings (of proposals, objectives, attributes, measurement results) given to the argument components from the objective hierarchy, when the stakeholders cannot agree upon on one task proposal, argument evaluation is taken based on the level of the objectives achievement to get the best choice.
D. Argument Generation and Evaluation

The main strength of our approach is to use the structured arguments that are synthesized with the objective hierarchy to guide the stakeholders to generate and evaluate their arguments in collaborative negotiation. The stakeholders jointly propose an objective hierarchy and declare their perspectives (e.g., preferences) based on the objectives. Then based on the identified objectives and declared perspectives, the stakeholders are guided to systematically generate and exchange their negotiation arguments. If no argument is fundamentally accepted at the end of collaborative negotiation, all the arguments will be evaluated by aggregating stakeholders’ preferences and ranked to recommend an optimal choice or a well-informed team leader will make the choice based on the evaluation results.

As such, there are four steps in this process. The first two steps guide the stakeholders to building the objective hierarchy and declare stakeholders’ perspectives. The next two steps discuss how the arguments are utilized based on the objectives and perspectives collected in the first two steps.

1) Propose an “objective hierarchy” for the identified conflicting design task

Negotiating conflicting implementation proposals of a design task in its baseline design process indicates some differences in the stakeholders’ objectives and perspectives (i.e., preferences for arguments and objectives). These objectives include the “fundamental objectives” (as the values) for which the task is undertaken, and the “means objectives” that helps achieve the fundamental objectives. The stakeholders’ attributes for measuring the proposal about the degree to which the objective are achieved if the proposal is accepted. These attributes describe the objectives and should have a common interpretation to every stakeholder. If an objective does not have any means objectives or any attributes that are naturally used to interpret the objective (e.g., “network bandwidth of integrated system” is a so-called natural attribute of the objective “increase the throughput after the systems integration”), an attribute “support vs. opposition” will be added, based on which stakeholder in later steps can declare their perspective as either support or opposition. According to the goals defined at the beginning of the design process, the stakeholders should be able to identify objectives and attributes in this step.

Since our approach uses an objective hierarchy to organize the objectives and capture their differences, the hierarchy is jointly built by the stakeholders based on their understanding and expectations (“values”) of the design tasks. And the objectives in this hierarchy will be dynamically changed by the social interactions among the stakeholders. In reference to the information in an objective hierarchy, the stakeholders can declare their preferences regarding how important the objectives (i.e. the weights of the objectives) are and how much each proposal is supported or opposed. The latter will be obtained in the next step from the values assigned by the stakeholders for the objectives’ attributes. The weights of the objective are collected in this step after these objectives are declared in the structure. The relative importance of each objective is defined in one-to-ten scale as follows:

1: Lowest important.
2: Very less important;
4: Somewhat less important;
6: Important;
8: Somewhat more important;
10: Very important;

Once an objective hierarchy is established by the team, each attribute of each objective should be assigned a value before the arguments are evaluated. In the case of the added attribute ‘support vs. opposition’, each stakeholder can express their own preferences based on their expertise and understanding and this opinion should describe their position of either supporting or opposing the argument according to how much the objective (to which the attribute belongs) can be accomplished if the argument is accepted.

Since there is no practical way that a complete analytical modeling of negotiation can be fully developed and incorporated for a group of decision makers, our approach takes a rather simplified view by focusing on modeling the dynamic impacts of negotiation, i.e. on the evolving “perspectives” of the stakeholders, as they express their opinions toward the objective hierarchy. These dynamically evolving perspectives are declared for the proposed objectives of which the stakeholders that have common interests or some expertise. In other words, the perspective dynamically depicts a stakeholder’s perceptions of his/her or others’ objectives. These perceptions could include the stakeholders’ intention for their ideas to succeed and their support for or disagreement with how well their own or others’ argument can achieve the objectives, either proposed by themselves or others. Therefore, the perspectives indicate the difference in the stakeholders’ perceptions that cause the conflict in the technical proposals of the tasks and put the negotiation into necessity. Moreover, these perspectives will be further analyzed in order to systematically evaluate the arguments in our negotiation approach.

TABLE I. SCALE OF SUPPORT VS. OPPOSITION

| 10 Strong Support: | the proposal will most likely help achieve the objective |
| 8 Support: | the proposal will likely help achieve the objective |
| 6 (1) Neutrality (fair, unknown or uninterested): | the proposal may not either contribute to or harm the achievement of the objective. (2) Controversy: | the proposal may have some effect in achieving the objective, but the decision maker is not clear the effect. |
| 4 Opposition: | the proposal will likely bring negative effects in achieving the objective. |
| 2 Strong Opposition: | the proposal will most likely bring detrimental effects in achieving the objective. |
| 1 Strongest Opposition: | the proposal will definitely |
Although stakeholder’s perspectives are often highly subjective in nature, a quantitative method is needed to define the measurement scales of the perspectives and further analyze these perspectives for argument evaluation. We define a one-to-ten scale (see Table I) to measure the stakeholder’s perspectives of either supporting or opposing the arguments. When the task proposals were being evaluated, for the ‘support vs. opposition’ attribute, stakeholders declared their perspectives about the proposal’s value based on their expertise and understanding.

3) Argument generation

While generating the negotiation arguments, claims and data are collected from the baseline design process representing technical decisions. Warrant, backing, qualifiers and rebuttals are obtained from the objective hierarchy and stakeholders’ perspective models.

By using our approach, stakeholders will have a better understanding of each other because they share not only their claims, but also their underlining reasons and desires (e.g., perspectives). For example, Figure 2 shows the details of an argument of an engineer, whose claim for the task “define quality requirements” is to define the attributes of performance and security for the integrated system. The data describes the initial state (of this task) which includes design requirements, application constraints and architecture style. To justify the use of the data, the warrant has his fundamental and means objectives that state why the claim is proposed based on the data. The backing of this argument is the attributes of his objectives that further explain the warrant by providing its measurement scales. The measurement result given by the engineer for his own objectives is included in qualifier while the measurement result for the team’s objectives is the rebuttal that describes his perspective regarding the performance regarding how well his argument may achieve the objectives proposed by the entire team.

As the stakeholders’ arguments are generated and exchanged, their objectives and perspective models may evolve due to deepened understanding of each other. If all the stakeholders can jointly agree on a particular argument claim, they can take that claim as the final resolution. The evaluation method analyzes the stakeholder perspectives of the objectives within the arguments and compares the argument claims based on the result. In this work, a simple additive weighting function (a.k.a. weighted average) is used to build the evaluation method which ranks the arguments from most desired to least desired assuming stakeholders can characterize the consequences of each argument with certainty. Furthermore, “weighted average” is also applied when evaluating the arguments based on their value for the objective attributes with varying importance. Weighted average, by its definition, means an average that takes into account the proportional relevance and strength of each component, rather than treating each component equally.

The argument evaluation in our work includes three steps: (1) assign objective weights, (2) score the arguments and (3) aggregate the preferences. In these three steps, the objective weights and the score of attribute value (either natural attributes’ or stakeholders’ preferences) of arguments have been defined in previous steps. Therefore, in this step, the preferences and weights are aggregated to derive final argument evaluation results which are used to rank the arguments and select the one that is most preferred by the team. The calculation of final score for an argument defined as follows:

\[
 f_i = \sum_{j=1}^{m} g_{ij} c_i \tag{1}
\]

Where \( f_i \) is the final score for alternative \( A_i \), \( m \) is the number of criteria, \( c_i \) is the normalize weight of attribute \( c_i \), \( g_{ij} \) is the performance grade (score) for argument \( A_i \) with respect to attribute \( c_i \).

Based on the evaluation results, a most preferred argument (i.e. the one with highest evaluation score) will be recommended as the final agreement of the negotiation for the design task. They will move back to check for further decision conflicts with other tasks. These iterations continue until no more conflict is found (i.e. no more negotiation is necessary), and the team moves to the next phases of the software development lifecycle.

III. CASE STUDY

To ensure that our framework can help software engineering team to reach an agreement more efficiently, a real-life software project was used for case studies. The team first used their existing way to collaborate and then applied our approach. Based on both results, we compared the time to reach the agreement. To assist the team to use our approach, a prototype of the argument-based collaborative negotiation (ACN) system, was implemented for stakeholder to follow. In this section, we will first introduce the ACN system and then demonstrate the comparison result.

A. Argument-based collaborative negotiation system

The goal of our ACN system is to help users more effectively apply our negotiation approach. It was implemented
as a web-based application that uses Java Servlet Page (JSP).
The system provides the link to each step of the negotiation
process (i.e. the process indicator) and also reminds users what
to do, such as the explanation of claim or warrant during the
negotiation phase. Each stakeholder can view each other’s
proposed argument and the reason behind it. When
stakeholders realize that there are different implementations in
their software design tasks, they can activate the negotiation
process. In addition, the system also provides tracking function
for the evolving concepts and stakeholder perspective. Once
the stakeholders start to choose a claim, the ACN system can
automatically give the evaluation result from their proposed
options. Therefore, the team can take the claim with the best
score and continues their design work.

B. The case study in real-life software design

We have applied our approach in a real-life team which was
developing a consume software product on mobile devices. In
this section, we will demonstrate one design task “build the
communication protocol” to show the application.

Their existing method for resolving the conflicts was to
explore and discuss each other’s arguments through the
communication tools (e.g. email) or face to face meeting. In
this way, the argument does not contain any specific structure;
thus, one stakeholder just proposes his opinions and tries to get
other’s agreement. Therefore, the argument could be passed
back and forth between team members and be revised based on
the interaction iteratively until everyone in the team agrees.
Below it is a dialog sample between an engineering manager
and an engineer for determining an architecture design style.

Engineering manager: We need a database-centered
architecture and here is why: because the database can help all
the modules communicate with integral data.

Engineer: I see. But I still prefer a client-server application with
Java Messaging Services. The messaging service can also
enable all the modules to send or receive data.

Engineering manager: With database-centered design, we do
not have to use Java Messaging Service.

Engineer: Sure, but why we choose the database-centered if the
same advantage can be achieved by the other way?

Engineering manager: Let me think about it.

The team used the ACN system to conduct their negotiation
in the development. In the beginning, the tool asked the team to
assign a moderator to coordinate the negotiation. Then, through
the aid of the tool, the baseline process was defined, the role of
the stakeholder was identified, and the claim of the task was
written. Figure 3 shows four different claims proposed by
various stakeholders (e.g. product manager, engineering
manager, engineer, and engineering director) regarding the task
– build communication protocol.

C. Comparison

Our goal of the case study was to compare the time that the
team spent for negotiation and the number of rounds for
generating/revising arguments, before the team reaches the
agreement using the existing and proposed approaches
respectively. We measured the time for the entire collaborative
negotiation process, i.e., it included all the development tasks
that need to be discussed and started with an agreement plan by
the team. From the aforementioned case studies that were
conducted in real-life software projects, it shows that this new
approach has shortened the negotiation time and used fewer
rounds to reach the design agreement. From the post-
experiment survey and onsite observation, the negotiation
procedure, arguments, and objective hierarchy helped
stakeholder to use less time to understand each other’s point
and their concerns. The weight values and attributes also
assisted the stakeholder to prioritize the importance of each
claim. Although the value was subjective, it helped the team
members to review themselves’ and others’ opinions and was an aid to reach a more objective result.

IV. CONCLUSION AND FUTURE WORK

This paper describes a research approach to structure arguments with organized objectives and preferences of multiple stakeholders to support their group decision making in collaborative engineering design. It is established based on a synthesis between the generic argument structure and a value-focused objective hierarchy. This synthesis explains how stakeholders can generate the structured arguments according to their objectives and preferences. It helps us to better resolve the challenges in existing practices of generic argument structure by developing feasible ways of evaluating the arguments for the most preferred one by the team. As such, our work has developed a collaborative negotiation approach that utilizes these structured arguments including argument generation from stakeholders’ objectives and preferences and argument evaluation to choose a most preferred argument based on how well the objectives have been achieved. In addition, this paper described a prototype system that we have developed to conduct case studies in real-life software development projects to validate the proposed approach.

Our future research work will develop more objective hierarchy templates in the software design domain and build more accurate and comprehensive models to quantify stakeholders’ perspectives. Furthermore, we plan to thoroughly validate this research framework by conducting more case studies in software industry. When richer application results are gathered, the approach and system will be continuously improved to hopefully leading to the establishment of a scientific foundation for collaboration-based software engineering.

REFERENCES