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A Semantic Enhanced Framework for Argumentation Based Group Decision Support

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Abstract: By an effective Group Decision Support System (GDSS) group members can be supported to identify the problem, form possible actions, resolve the conflict and achieve the joint goals. Throughout such a group decision making process, argumentation is widely regarded as a good means to propose the ideas, justify possible alternatives and convince others to achieve group consensus. In this paper, argumentation is incorporated into group decision making through semantic approach and a semantic enhanced framework is proposed for argumentation based group decision support. In this framework, argumentative elements are semantically represented, group decision making is computationally modelled, and decision tasks are heuristically evolved. Moreover, a prototype of argumentation based GDSS using the proposed semantic model is developed, and a group decision experiment is conducted to demonstrate the system's effectiveness.

Keywords: argumentation, decision support, group decision making, semantics.

1. Introduction

As group members may have access to complementary information and resource, decision by group could perform better in solving complex problems. In an effective Group Decision Support System (GDSS) group members can be supported to identify the problem, form possible actions, resolve conflicts and achieve joint goals.

In GDSS decision process is commonly divided into a series of steps, e.g., recognizing and analyzing problem, proposing alternatives, designing evaluation model and evaluating alternatives to reach optimization. However, Courtney [4] points out that in ill-structured circumstances decision process may not be a simple clear-cut like this. Rather, phases in decision process very often overlap and blend together. In such a case, the division of knowledge into disciplines and the reduction of complex problems into simple components may inhibit the solving of complex social and management problems. For example, while evaluating the alternatives decision makers may discover new perspectives of the problem which are ignored at the problem analysis stage. Courtney also proposed a multi-perspectives approach that places individual or collective mental model at the heart of the decision process. Such mental models are constantly updated along with the whole decision process. As perspectives of the problem are developed, insights are gained and the mental models are updated. Through the process, conflicts may be detected, new perspectives may be discovered and consensus may be reached within the group. Thus, the decision process may undergo multiple cycles. In early 1970s, Rittel pointed out that wicked problems can not be solved by formal models or methodologies; rather, argumentation, which takes an open ended, dialectic process of collaboratively defining and debating issues, may turn out a powerful way for discovering the structure of wicked problems and then solving them [12].

In recent years, argumentation has been incorporated to augment group decision making. However, in most of the cases, argumentation is only regarded as a way to structure the problem and ascertain interpretations about the problem, but has not been extended to the whole decision making process. In this sense, the argumentation process is largely isolated from the decision process and is thus incapable of feeding effective inputs to the evolution of the decision tasks or the iteration of the decision process. The main reason here is that there is lack of a semantic model of the argumentative information such that decision support tools can fully interpret and make use of this information to analyse the status of the problem solving and to evaluate the solutions to the decision tasks.

In this paper, by formally representing argumentative elements, we propose a semantic enhanced framework for argumentation based group decision support. In particular, based on the analysis of argumentative information, group decision making is computationally modelled, which not only quantitatively evaluates the proposed actions for the decision tasks but also evolves the decision tasks so as for the decision process to iterate better.

The remainder of the paper is organized as follows: Section 2 reviews the related literature. In Section 3, incorporating argumentation into group decision making is investigated and a semantic enhanced framework is proposed for argumentation based group decision support. In particular, argumentative elements are semantically represented and group decision making is computationally modelled. Section 4 presents a prototype system of argumentation based GDSS based on the semantic model and the experiment results. Section 5 gives a summary and some outlooks for future research.

2. Literature Review

Toulmin model [15] and IBIS model [3] are widely applied to argumentation supported systems. These models logically structure users' argumentation by defining participants' utterances and the semantic rhetorical links between the utterances. Comprised of three elements, namely, issues, ideas and arguments, IBIS model focuses on capturing users' deliberations during problem solving. It is often used in knowledge discovery [13], decision task structuring [18] and decision rationale capturing [5], etc. In contrast, comprised of six elements, i.e., claim, ground, warrant, backing, qualifier and rebuttal, Toulmin model is based on non-formal logic and focuses on the reasoning and explanation process of the claims. It is often used in public policy making [16], law [7], etc.

In most of the cases, argumentation model is used to externalize the problem space and generate the solution with evidence, but is not fully integrated into the decision making phase. [2] proposes a framework and protocol for argumentation based group decision making, and points out that group discussion phase is an intelligent stage to recognise problem and generate alternatives. In decision making phase, Decision making model such as analytic hierarchy process (AHP) [6] is used to determine the best alternative based on the group judgment whereas argumentative information is only used as reference for decision makers to evaluate the alternatives.

On the other hand, relation between decision making and argumentation has attracted much interest [11]. [1] proposes an argumentative framework for decision making. In this framework, arguments are distinguished between two different types, i.e., epistemic argument and practical argument. A practical argument may highlight either a positive or a negative feature of candidate decisions by judging over both belief and preference; while an epistemic argument only proves the certainty of information in the related practical argument by only judging over belief. However, this framework has not been implemented in a real group decision making system.

HERMES [10] is a system that augments the decision making process by supporting argumentative discourses among decision makers. HERMES follows IBIS model to model argumentative elements. Compared to IBIS model, the new element defined is the constraint element representing preference relations. In HERMES it's considered good to externalize the criteria underlying the decision tasks. Through argumentation, an argumentation tree will be constructed, the root of which is an issue element that represents the decision tasks followed by the proposed alternative solutions and the evidences to support or challenge the alternatives. Furthermore, the constraint element can also be argued by other argumentative elements which will facilitate group members to evaluate the importance of the criteria for the decision tasks. A Non-monotonic reasoning mechanism and proof standard are provided to determine and update the state of each argument when new argumentative information emerges, with the aim of keeping users aware of the discourse status. Scores of the alternatives for the decision tasks can be computed based on the weights of active positions.

[17] proposes a simplified Toulmin argument model to represent the information structure of group discussion. Here "modality" is designed as a quantitative scale that reflects the expert's attitude to a claim, while premise and warrant are used to provide justification or evidence for the experts' viewpoints. Based on the expert's authority and modality value in the argumentation with regard to a claim, the consensus value of the claims can be synthesised. The higher the consensus value with regard to a claim, the more likely the decision gets accepted within the group.

The above approaches and systems were mainly for incorporating argumentation into decision making process and automatically making decision by evaluating the relevant argumentation. However, there is lack of a semantic model of the argumentative information for both the discussion and the decision making phases. Put in other words, there is no mechanism to explicitly externalize and elaborate perspectives of the decision problem and to evolve the process of group decision making according to Courtney's new paradigm [4] for decision making.

3. Argumentation Based Group Decision Support

The aim of decision support is to produce a possible recommendation that will be considered useful by the users in the decision process where they are involved. In an argumentative context, group decision process can be made as the following three steps:

- Firstly, to propose actions towards the decision tasks and construct arguments in favour and against each alternative.
- Secondly, to evaluate the strength of each argument.
- Finally, to compare different choices based on the quality of their arguments to produce recommendations.

There also may be some intermediate steps such as identifying the criteria of decision tasks and define the preference order of them. Thus, in this kind of argumentation based group decision support systems, on the one hand, there needs to be support to the evaluation process; on the other hand, support to the argumentation process is required. At the end, it not only leads to the "best solution" but also will provide explanation and justification for a choice and further discover the possible questions about the proposed solutions. In the framework for argumentation based group decision making, the model of argumentation and the model of evaluation are the most important components.

3.1 Conceptual Model for Argumentation Based Group Decision Making

Based on the process of argumentation based group decision making as stated above, we sketch a data model for argumentation based group decision making, as depicted in Figure 1. This data model shows the information present in argumentation based group decision making. In the data model, discussion elements are conceptual abstraction of group member's utterances, including question utterance, argumentation utterance and solution/idea utterance. The classification of utterances is inspired by the IBIS information model [3], Toulmin model [15] and Amgoud's argument framework [1]. IBIS is regarded as a useful model to capture the rationale of complex and unstructured problem solving, while Toulmin model and Amgoud's argument framework have good reasoning for decision evaluation.

The group memory embodied by this model will disclose the group rationale for a certain decision task and also can be utilized by agent software to automatically analyze and evaluate group members' contributions and draw a conclusion in a certain structure. In the context of argumentation, one proposed solution may have multiple challenge/support practical arguments. The aggregation of practical arguments will directly affect the judgement about the solution. Likewise, the aggregation of epistemic arguments will indirectly affect the judgement about the relevant solution and directly affect the quality of practical arguments.

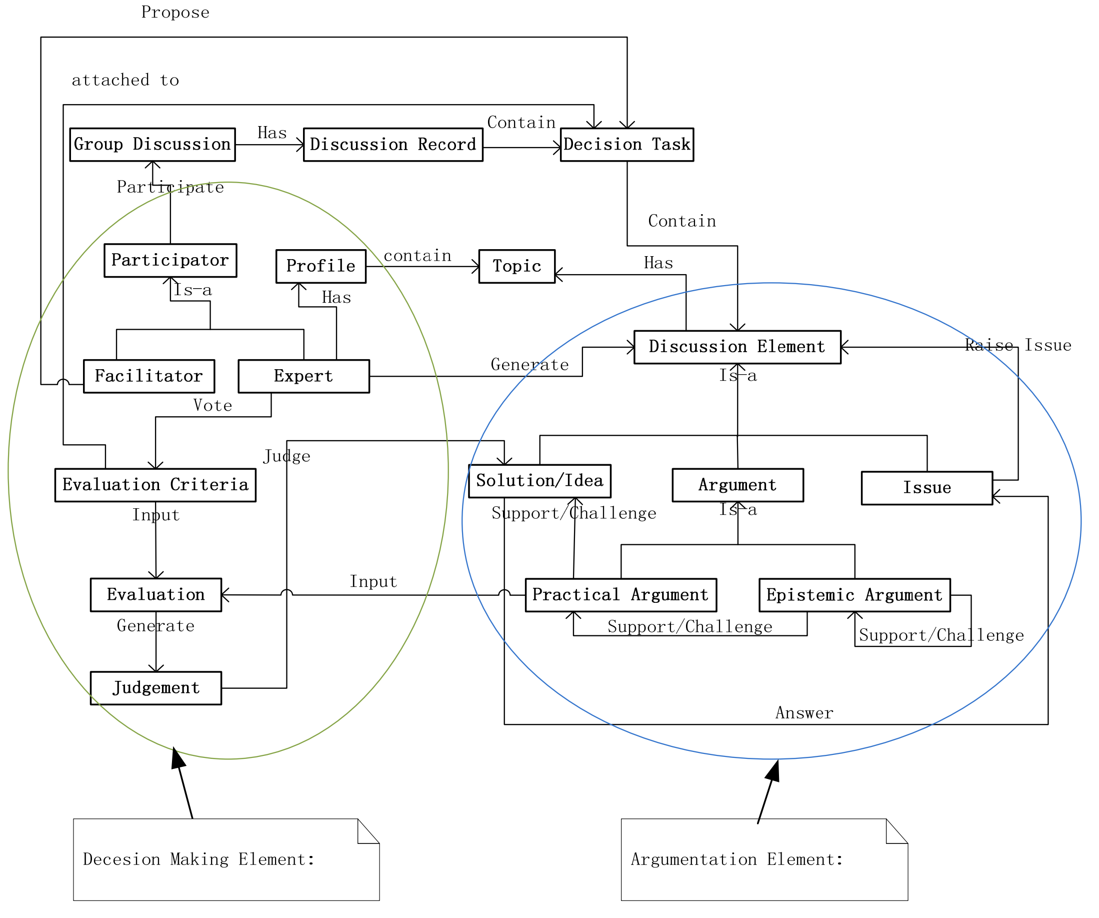

Figure 1. Data model for argumentation based group decision making

Question utterance can raise a question towards any discussion elements. Some questions will lead to further discussion for decision making. However, solution/opinion utterance only can be made towards a decision task or a question utterance.

A participator is defined as a facilitator or an expert, a multitude of which collaboratively carry out discussion tasks. A group of experts not only contribute towards the discussion element based on their knowledge and desire, but also collectively vote to generate preference of criteria for evaluating decisions. Based on the evaluation of arguments, the system can automatically produce judgement for each solution or sub-solution. Therefore, the data model records both the group discussion contents in a structured manner and the judgement on decisions and the justification of the judgement process. Furthermore, the unsolved question may discover the new underlying decision problems, and can evolve the process of group decision making to the next level.

3.2 Modelling of Argumentative Elements

3.2.1 Argumentative Elements for Decision Making

In the data model above, we have to design a new argumentation schema which can be integrated from the points of view of both argumentation process and decision making process without loss of usability in a group discussion environment. In Figure 1, utterance is the basic unit that can act as different roles. Combining IBIS model and Amgoud's argument framework for decision making, we identify various roles of utterances as follows.

(i) Specifying task,
(ii) Proposing solution (idea),
(iii) Raising issue,
(iv) Practical argument on pros/cons (i.e., support/challenge),
(v) Epistemic argument on pros/cons (i.e., support/challenge).

An argumentation can be abstracted as a triplet, i.e.,

argumentation= {utterance1, link, utterance2}, (1)

Instantiations of this abstract representation can be seen in Table 1. An utterance element comprises multiple fields as below.

```
utterance element
                    field #1:  expert_id,
                    field #2:  utterance_id,
                    field #3:  time,
                    field #4:  content,
                    field #5:  state,
                    field #6:  target_id,
                    field #7:  domain,
                    field #8:  type,
                    field #9:  semantic_link,
                    field #10:  score.
```

`field #5 (state)` may take values *"rejected"*, *"accepted"* or *"unverified"* for solution or argument utterance, which indicate the certainty of information; or values *"unsolved"*, *"solved"* or *"unverified"* for issue utterance, which indicate whether or not there is an accepted solution to address the issue. Only *"accepted"* or *"solved"* utterance will be considered for use by decision function in the evaluation process. The score of the solution utterance will set the ordering for decision making.

`field #7 (domain)` is the topic of an utterance, which may conceptualize experts' mental space and also reflect the preference for evaluating decisions.

In argumentation, a participator inputs information in the form of the above argumentation schema, and by this way an argumentation tree will be generated.

Table 1. Triplet schema of argumentation

Preceding	**Following**	**Link**	**Semantic**
Task	Solution	resolve	Propose the solution to the specified Task
Solution	Practical Argument	support/challenge	In favour or against the solution with belief and preference
Solution	Issue	raise_issue	Raise question regarding some aspect of solution and hope to clarify or update solution
Issue	Solution	resolve	Propose the solution to the specified issue, the original solution may be updated or evolved.
Practical Argument	Epistemic Argument	support/challenge	In favour or against the practical argument with belief
Epistemic Argument	Epistemic Argument	support/challenge	In favour or against the epistemic argument with belief

3.2.2 Semantic Representation of Argumentative Elements

In the section above, argumentative elements for decision making have been identified. In GDSS, decision makers may be geographically dispersed or use different argumentation tools, and even use agent to communicate with each other. Therefore, it is necessary to use a formal way to represent argumentative information. With such a formal representation, argumentative information can be integrated, maintained (e.g., check inconsistency) and queried semantically; and also it's easy to extend the system with more enriched argumentative elements in the future.

Ontology is the formal specification of concepts and relationship among the concepts [8]. Ontology can be represented by a triplet comprised of classes C, properties P and instances i. In our research an ontological modelling approach is adopted to represent the argumentative information.

Property, domain and range are standard terminologies in Semantic Web for defining the concepts and relationships between the concepts. Generally speaking, in a triplet expression of semantics, i.e., <domain, range, property>, domain often refers to the type of subject, range refers to the type of object and property is type of relationship (predicate). For example, if there is a statement like "Peter publishes an academic article in Computer Sciencet". The domain of this should be Researcher or more generic -- Human being, of which Peter is an instance. The property of it should be "publishes". The range of it should be Publication or Research Outcome. A particular academic article should be instance of research outcome. So the conceptualized triplet pattern should be like "Researcher--- (Publish) -- Research Output". Normally when we define property we have to explicitly or implicitly declare what domain and range this property should apply to. Here "implicitly" means the property can inherit domain and range from its super property. Sometimes the range of property could be a simple data type (number, string) rather than data type defined in Ontology. In this case, we call it data range.

In a sense, these concepts in semantic web are more or less like in object oriented programming. However, in object oriented programming, we can only associate two classes by a few types of relationships (is-a, associate, aggregation, etc.), but no more semantics is given to this relationship. By use of the enriched semantic relationship in Semantic Web, we can implement different services such as inconsistency checking, semantic information pattern match and information inference, etc.

Defining argumentation concepts through classes. In the ontology of an argumentation domain, are defined through classes.

$$Utterance = \{Argument\} \cup \{Idea\} \cup \{Issue\} \cup \{Task\}\ , \tag{2}$$

$$Argument = \{\ \mathrm{Pr}atical\ \ \mathrm{arg}ument\} \cup \{Epistemic\ \ \mathrm{arg}ument\}\,. \tag{3}$$

All classes are disjoint with one other, i.e.,

$\{Argument\} \cap \{\ Issue\} = \varnothing,$

$\{Idea\} \cap \{Issue\} = \varnothing,$

…. …

where $\varnothing$ denotes null.

Defining argumentation concepts through axioms. Concepts defined by axioms are useful for inconsistency check or class inference.

$$\mathrm{Pr}actical\ \ \mathrm{arg}ument \equiv \mathrm{sup}\,port\ \ \exists\ \ (Idea\ \ \ ) \ \vee challenge\ \ \exists\ \ (Idea)\,. \tag{4}$$

$$Epistemic\ \ \mathrm{arg}ument \equiv \mathrm{sup}\,port\ \ \exists\ \ (Argumentation) \vee challenge\ \ \exists\ \ (Argumentation)\,. \tag{5}$$

$$Idea \equiv\ \ resolve\ \ \exists\ \ (Issue\ \ \vee\ \ Task)\,. \tag{6}$$

$$Issue \equiv raise\_issue\ \ \exists\ \ (Idea\ \ \vee\ \ Argumentation \vee\ \ Issue)\,. \tag{7}$$

where $\exists$ denotes *hasValue*.

Defining property through domain and range. In the ontology, a property relates to two instances of classes. Property has domain and range. Syntactically, via domain a property is linked to a class and via range a property is linked to either a class or a data range.

Table 2 lists properties versus class range used in the ontology. Properties versus other data range can be referred to from the data structure of utterance presented above.

Table 2. List of properties

Property Name	**Domain**	**Range**
resolve	Idea	Issue ∨ Task
support	Argumentation	Idea ∨ Argument
challenge	Argumentation	Idea ∨ Argument
raise_issue	Issue	Idea ∨ Argument ∨ Issue

Realizing concepts through instances. The practical utterances in argumentation are defined through the instances which belong to the classes. Figure 2 illustrates a simple snippet of realizing concepts about a discussion on traffic congestion control. There are four instances which belong to issue class, idea class and practical argument class, respectively. Each instance is semantically annotated by a formal defined topic term (domain). Semantic annotation is an approach to annotating the entities using the formal concepts with well-defined meaning and relationship. In our research, we employ DBpedia[1] based semantic annotation approach which can transform user defined keywords to the conceptual terms formally defined in DBpedia.

In the exemplar snippet in Figure 2, *expert #2* proposes the argument about economic issue (money) to challenge *expert #3*'s idea about bus service aspect. This kind of information can be easily represented by semantic web language such as OWL [14]. Argumentation systems developed with such a semantic enhanced model will enable computational agents to discover the information and then the agents will present to user the topic related utterance such as *"find all utterances (or an issue) regarding bus service"*, and can also help the agents find any similar argumentative patterns from the previous discussions, such as *"find all argumentative patterns similar to economic issue challenge (support) bus service aspect"*. There are two different types of information match, called concept match and pattern match, respectively. Pattern match is more important for group members to find other's rationale of solving the problem. Figure 3 and Figure 4 illustrate the match processes.

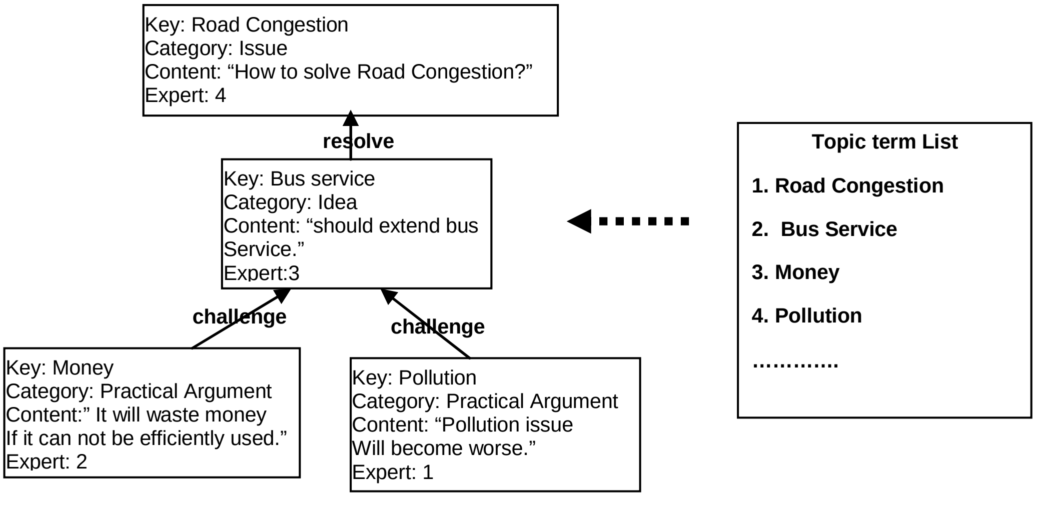

Figure 2. Instances of argumentation

[1] http://www.dbpedia.org

find all the utterance with exact topic T:

hasTopic(?X, T)

find all the utterance with topic T or its subtopic:

$\text{hasTopic\_all}(?X,T) \rightarrow \text{hasTopic}(?X,T) \vee (\text{hasTopic}(?X,?O) \wedge \text{subClassOf}(?O,T))$

$\text{subClassOf}(?A,?B) \wedge \text{subClassOf}(?B,?C) \rightarrow \text{subClassOf}(?A,?C)$

Figure 3. Snippet: concept match

find all the argumentative pattern which satisfy Topic1 challenge Topic2

$\text{Challenge}(?X,?Y) \wedge \text{hasTopic}(?X,T_1) \wedge \text{hasTopic}(?Y,T_2)$

find all the argumentative pattern which satisfy Topic1 or its subtopic challenge Topic2 or its subtopic

$\text{Challenge}(?X,?Y) \wedge \text{hasTopic\_all}(?X,T_1) \wedge \text{hasTopic\_all}(?Y,T_2)$

$\text{hasTopic\_all}(?X,T) \rightarrow \text{hasTopic}(?X,T) \vee (\text{hasTopic}(?X,?O) \wedge \text{subClassOf}(?O,T))$

$\text{subClassOf}(?A,?B) \wedge \text{subClassOf}(?B,?C) \rightarrow \text{subClassOf}(?A,?C)$

Figure 4. Snippet: pattern match

3.3 Modelling of Social Parameters

[9] points out that most of the current research in decision making has mainly addressed computational issues, but little attention is paid to social issues. However, in group activities, social issues such as trust, belief, empathy and emotions are very important. Particularly in group decision making, the credibility of a decision maker in the group will greatly affect the acceptability of her/his opinion. In our model, we define group's social parameter in terms of the decision maker's credibility, which is one of the variables forming the group profile. We consider both the decision maker's general credibility and the decision maker's domain specific credibility. The latter is a very important factor to evaluate the acceptability of a decision maker's argumentation in the particular context. The group profile can be defined as follows.

$$\text{group profile: } GP[i]=\{a_i, (D_1^{(i)},D_2^{(i)},\ldots,D_n^{(i)}), (C_1^{(i)},C_2^{(i)},\ldots,C_n^{(i)}), GR_i, (U_1^{(i)},\ldots,U_k^{(i)})\} \tag{8}$$

where a_i denotes *agent$_i$* (i-th decision maker), $D_1^{(i)}$, $D_2^{(i)}$, ….., $D_n^{(i)}$ domains of the i-th agent, $C_1^{(i)}$, $C_2^{(i)}$, ..., $C_n^{(i)}$ credibility of the i-th agent in the domains $D_1^{(i)}$, $D_2^{(i)}$, ….., $D_n^{(i)}$, respectively, GR_i general reputation of the i-th agent at the group level, $U_1^{(i)}$, …, $U_k^{(i)}$ utterance sets proposed by the i-th agent, respectively.

Credibility of $agent_i$ in domain D indicates to what degree $agent_i$'s belief in domain D is true. This credibility can be dynamically updated based on others' attitude towards $agent_i$ during the argumentation. When group members argue in favour of or against other's claims about a certain domain, $agent_i$'s credibility in this domain will be increased or decreased. The extent of increase/decrease will depend very much upon the credibility held by the one who interacts with $agent_i$, which means arguments from an agent with a higher credibility will affect more on other agent's credibility values in the domain this agent argued about. The credibility value of agent_i towards domain D_k can be updated as follows.

$$C_k^{(i)} = \begin{cases} C_k^{(i)} + \delta, & if\ C_k^{(i)} + \delta \geq 0, \\ 0, & otherwise. \end{cases}$$
$$\delta = \sum_{j \in \{j / support(a_j, a_i)\ in\ \mathrm{D_k}\}} C_k^{(j)} - \sum_{p \in \{p / challenge(a_p, a_i)\ in\ \mathrm{D_k}\}} C_k^{(p)} \tag{9}$$

3.4 Computational Modelling of Group Decision Making

In decision making, the payoff of potential action is judged by estimating how much in terms of several criteria its possible consequences fit the preference or the intention of the decision maker. In group decision making due to possible conflicts among different decision makers' preferences and knowledge, the system should have some functions to achieve group consensus.

In the context of argumentation, a group decision function should be designed which can evaluate the acceptability of arguments, calculate the strength of each argument, score the decisions by their following arguments. Acceptability of an argument may be determined by two factors. One is up to how much credibility the proposer has in the topic of this argument; another is how other group members respond to this argument. The credibility of an agent towards a certain topic will be dynamically updated based on the agent's performance and other agent's interactions within the group activities. The intention of others' response to the argument is identified as in Table 3. Acceptability of arguments can be computed as follows.

$$accepted[\arg_i] = \begin{cases} true, & if \quad ACC[\arg_i] \geq \theta, \\ false, & otherwise \end{cases} \tag{10a}$$

$$ACC[\arg_i] = C(a[\arg_i]) + \Delta_{acceptability}[\arg_i] + w * \Delta_{credibility}[\arg_i] ,$$
$$\Delta_{acceptability}[\arg_i] = \sum_{k \in \{k / support(a_k, \arg_i)\}} ACC(a_k) - \sum_{o \in \{o / challenge(a_o, \arg_i)\}} ACC(a_o) , \tag{10b}$$
$$\Delta_{credibility}[\arg_i] = \sum_{\substack{s \in \{s / raise\_issue \wedge \\ solved(a_s, \arg_i)\}}} C(a_s) - \sum_{\substack{r \in \{r / raise\_issue \wedge \\ unsolved(a_r, \arg_i)\}}} C(a_r)$$

where $\arg_i$: denotes the i-th argument, ACC[$\arg_i$] acceptability value of the i-th argument, a[$\arg_i$] agent holding the i-th argument, C(a[$\arg_i$]) credibility of the agent holding the i-th argument, θ pre-defined threshold, w relative coefficient.

Table 3. Decision oriented argumentation act

Argumentation Act	**Intention**	**Level**
support	prefer	High
challenge	not_prefer	High
raise_issue (solved)	prefer	Low
raise_issue(unsolved)	not_prefer	Low

If *accepted[arg$_i$]* is true, the state of the corresponding argument will be assigned as *"accepted"*, otherwise it will be *"rejected"*. Only accepted argument will be used to evaluate other relevant arguments and candidate decisions targeted by it. As shown in Table 3 the "unsolved" issue will decrease the acceptability of argument, while the "solved" issue is the opposite. If there is an accepted solution for an issue, the state of issue will be set as "solved", otherwise its state will be "unsolved". The state of issue can be computed as follows.

$$solved(issue_i) = \begin{cases} true, if \ \{j | is\_solution(S_j) \wedge resolve(S_j, issue_i) \wedge accepted(S_j)\} \neq \phi, \\ false, otherwsie, i.e., \{j | is\_solution(S_j) \wedge resolve(S_j, issue_i) \wedge \neg accepted(S_j)\} \neq \phi \end{cases} \quad (11)$$

"true" value of *solved(issue$_i$)* represents the *"solved"* state, while *"false"* value of *solved(issue$_i$)* the *"unsolved"* state.

Practical arguments, which are directly connected to the candidate decisions and highlight their positive or negative features, take a significant role in comparing different candidate decisions. So the score of a decision will be evaluated by the aggregation of the strength of the accepted practical arguments and related raised issue. The strength of practical arguments can be determined by the agent's belief and preference as follows.

$$strength[\arg_i] = ACC[\arg_i] \ * \ preference(domain[\arg_i]) \quad (12)$$

where *strength[arg$_i$]* denotes the strength of argument i, ACC[arg$_i$] the acceptability of argument i, *domain[arg$_i$]* the domain which argument i belongs to.

Here preference means the importance of the aspect related with the argument toward achieving task which is equivalent to the criteria with the degree in the traditional decision making approach. As to epistemic argument, it only proves the certainty of information (belief) in the related practical/epistemic argument. So the strength of epistemic argument is equal to the acceptability of it. Scoring the candidate decision is quite straightforward, and only needs to aggregate all the strength of following accepted arguments from both positive and negative aspects. The scoring function can be defined as follows.

$$score(Dec_i) = \sum_{\substack{prefer \ \wedge \\ accepted[\arg_l] \\ w.r.t. \ Dec_i}} strength[\arg_l] - \sum_{\substack{not\_prefer \ \wedge \\ accepted[\arg_j] \\ w.r.t. \ Dec_i}} strength[\arg_j] \quad (13)$$

where *Dec$_i$* denotes candidate decision i (solution in argumentation schema), *w.r.t.* is abbreviation of *"with regard to"*.

4. Prototyping and Experiment

Based on the semantic model of argumentative information and evaluation model of group decision making as defined above, a prototype of GDSS has been developed on JADE ---- a Java based agent middleware platform. The system provides the interface for the participants (decision makers) and the facilitator, which are normally located in different machines. In this section, the functions of the prototype system are discussed and a group decision making experiment using this prototype system is designed and carried out to demonstrate the effectiveness of our proposed model.

About the terminologies used in our paper, decision maker and expert appear in different situations but may mean the same. Expert is mainly used in the group argumentation context, while decision maker is mainly used in the decision making related context. However, participator can refer to expert or facilitator.

Agent is a term broad sense, and means an entity, which may be a computational entity or a non-computational one. In this paper, agent is used in the computational modelling of decision making, agent oriented programming and agent based system modelling. Conceptually it is not the same as decision maker or participator.

4.1 Prototype System

The prototype system consists of participant module, facilitator module, decision making module and data storage, as depicted in Figure 5.

In the framework of the prototype system, participant module provides an argumentation environment for participants to communicate. The design of the interface is driven by the argumentative information model, as depicted in Figure 6. The icon preceding each utterance symbolizes its semantic link towards the top utterance (argument object), as exemplified in Table 4.

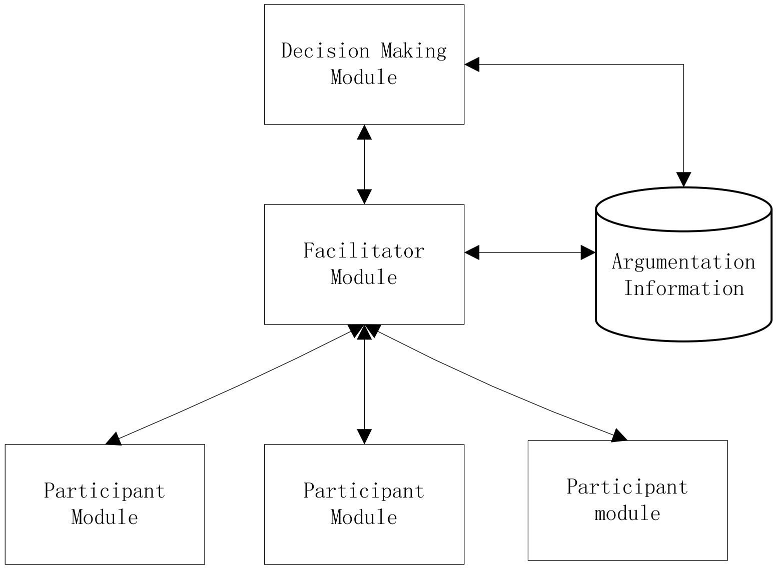

Figure 5. Framework of the prototype system

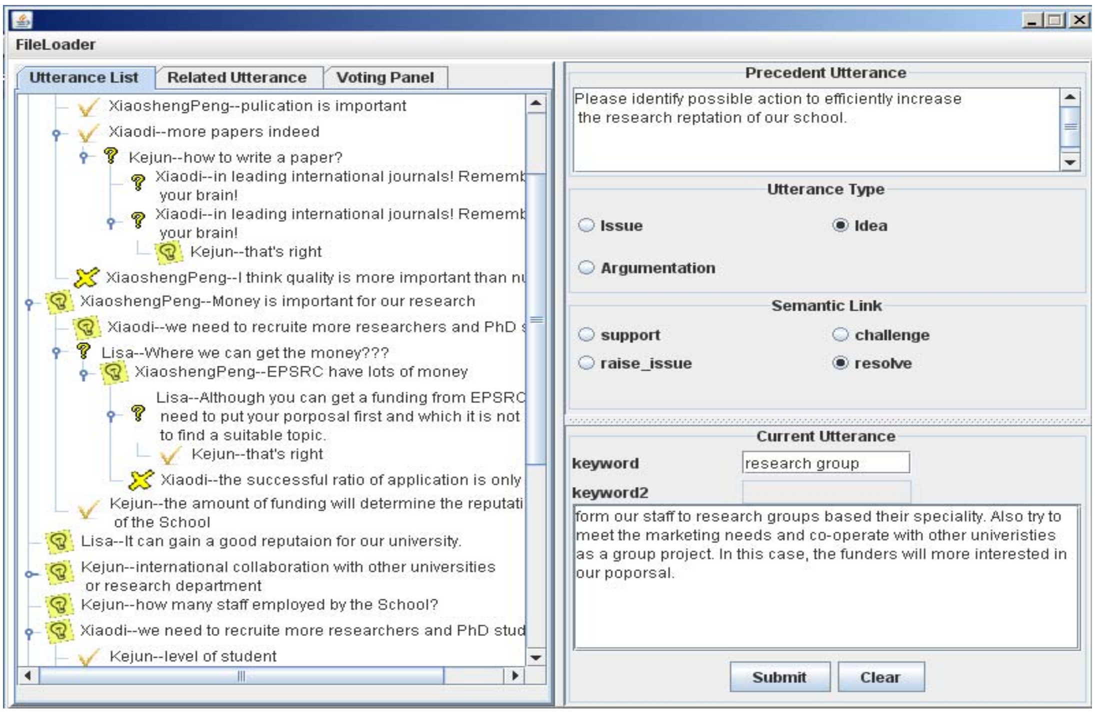

Figure 6. Argumentation interface

Facilitator Module provides different tools to assist the facilitator to control the workflow of group decision making, such as assigning task, monitoring group discussion, calling for group voting to generate criteria with group preference, triggering evaluation process and displaying decision making result. The facilitator itself is not involved in the task based discussion and decision making. Decision making module receives the preferences of participants to the criteria and the credibility of participants in certain domain from facilitator module. These factors together with the structured argumentative information are inputted into Decision Function Module to generate a solution space and unsolved issues space. The score of recommended alternatives are automatically generated by our computational model. The unsolved issues identify the decision problems which have not received the accepted solution during the argumentation. Those problems could be the guidance for the next round discussion. In a certain sense, the mechanism of identifying the unsolved decision problem could help the evolution of decision process.

Table 4. Icons preceding utterances

Word	Icon	Semantic Link Symbolized
Bulb		“resolve”
Tick		“support”
Deletion		“challenge”
Question		“raise_issue”

4.2 Experiment

In order to demonstrate the effectiveness of the prototype system, an experiment of group decision making was carried out. We used one quantitative and two cognitive indicators to evaluate the system performance, namely, number and quality of criteria the system generates; participants’ acceptability about the solution the system recommends and possible sub-tasks the system proposes for a next round discussion.

4.2.1 Undertaking of the Experiment

Four subjects were recruited from the then School of Engineering and Computing at Glasgow Caledonian University to attend a computer supported group discussion. At the time they were PhD students or post-doctoral researchers. Based on the profile of subjects, we devised a group decision task as follows.

> *"Please identify possible actions to efficiently increase the research excellence in the School of Engineering & Computing in Glasgow Caledonian University."*

The task was given to the participants a few days before the experiment, allowing them enough time to individually consider the most important facts of the problem to be solved. Individual consideration was compared with group consideration afterwards. The process of the experiment was conducted as follows.

(1) Training Session. In this session, the function and operation of the system are described by the facilitator; the predefined argumentation structure is introduced. And also participants are given an opportunity to practise the system using an example task.

(2) Argumentation Session. In this session, the group were given 30 minutes to use our argumentation tool to propose their own opinions towards the assigned task and others’ utterance. At this step, all the posted utterances were stored in the server.

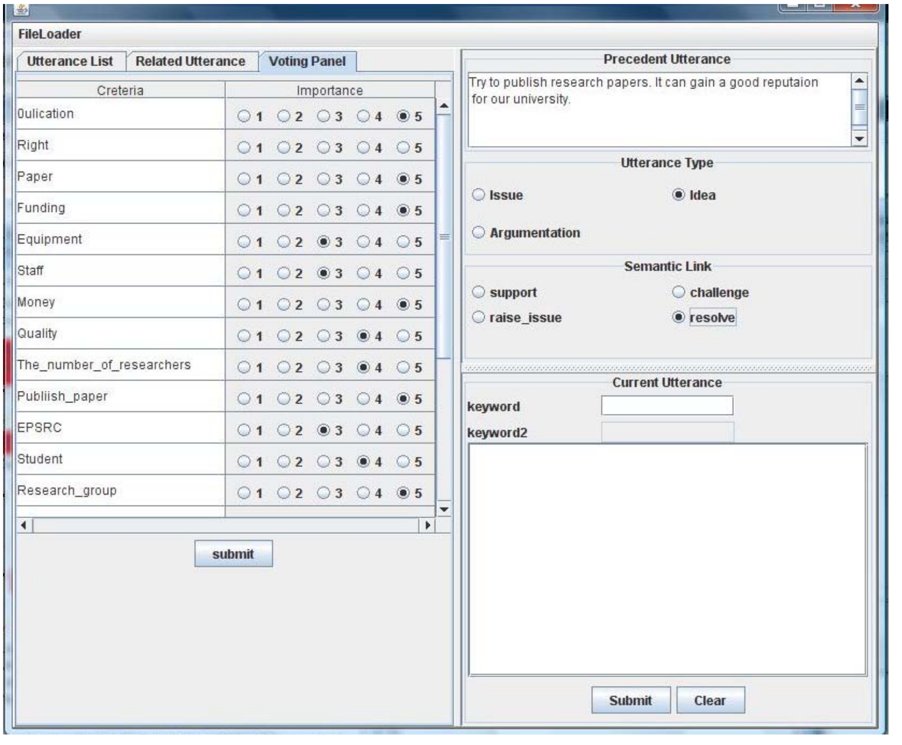

Figure 7. Group voting tool

(3) Group Voting Session. In this session, the facilitator instructs all participants to enter the group voting step. All aspects of the task discussed in the argumentation session are conceptualized and presented by the group voting tool (Figure 7). Participators are asked to give the score for each presented concept according to its significance in the context of the assigned task. The scored concepts by each participant are aggregated by the facilitator module on the server side (Figure 8). In the argumentation session, the credibility of the participant about a certain topic is dynamically updated along with the following argument. The initial credibility of all the domains for each participator is pre-set as “1”. As the social parameter, those credibility values are also sent to facilitator module in the group voting session (Figure 9).

(4) Decision Making Session. In this session, the aggregated score of the different aspects about decision task and participants’ social parameter are used by decision making module to analyse all the utterances in the discussion space. The computational modelling of group decision making has been described in the above section. The resulted solution space with suggested score and unsolved issue space are presented to the group members (Figure 10 and Figure 11).

(5) User Experience Feedback Session. In this session, participants were required to answer a few questions respectively about usability of software, familiarity of the task, functionality of argumentation support, the degree of acceptability of decision result and goodness of cognitive support for further decision problem. The result of questionnaire were analysed to evaluate the performance of the prototype system.

4.2.2 Results of the Experiment

In 30 minutes, using our system 16 distinct criteria has been identified. 4 criteria on average come from each participant as shown in Table 5. By contrast, only 12 distinct criteria were generated by

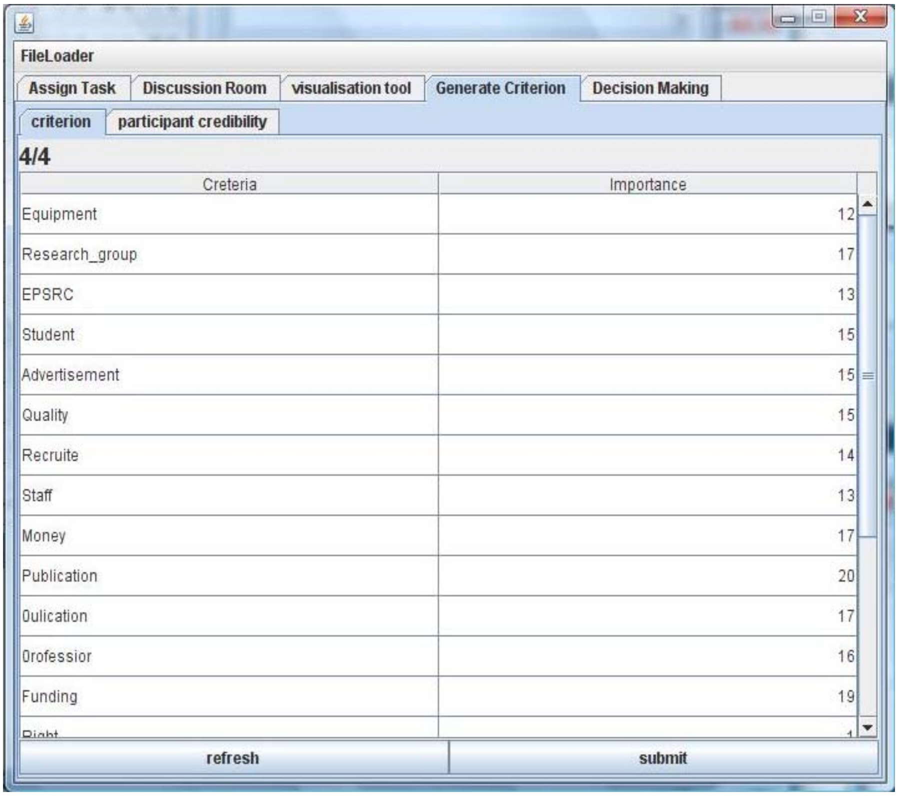

Figure 8. Criteria generator

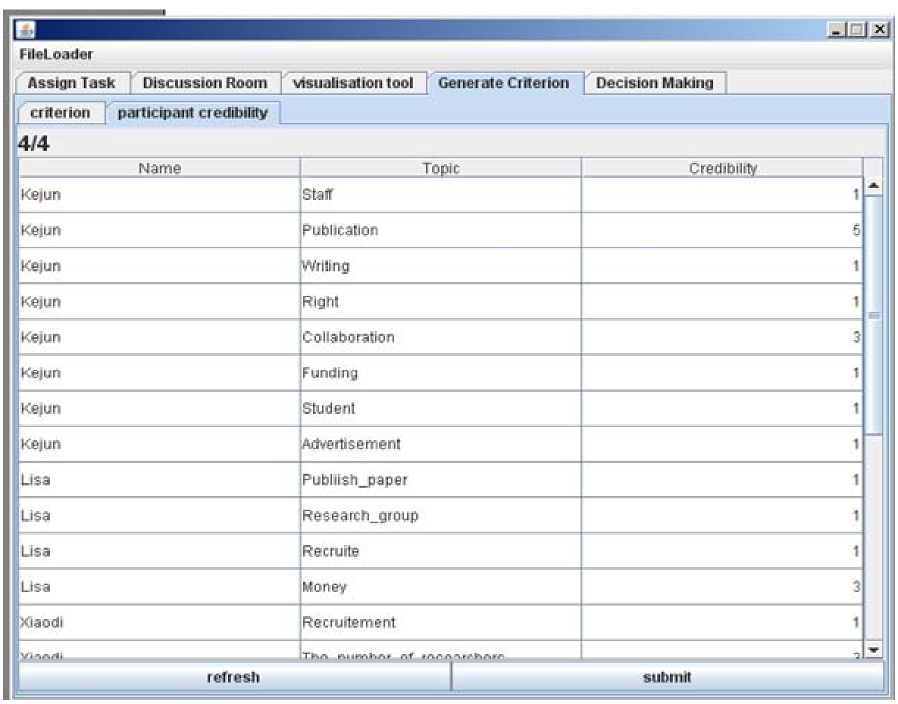

Figure 9. Participant credibility generator

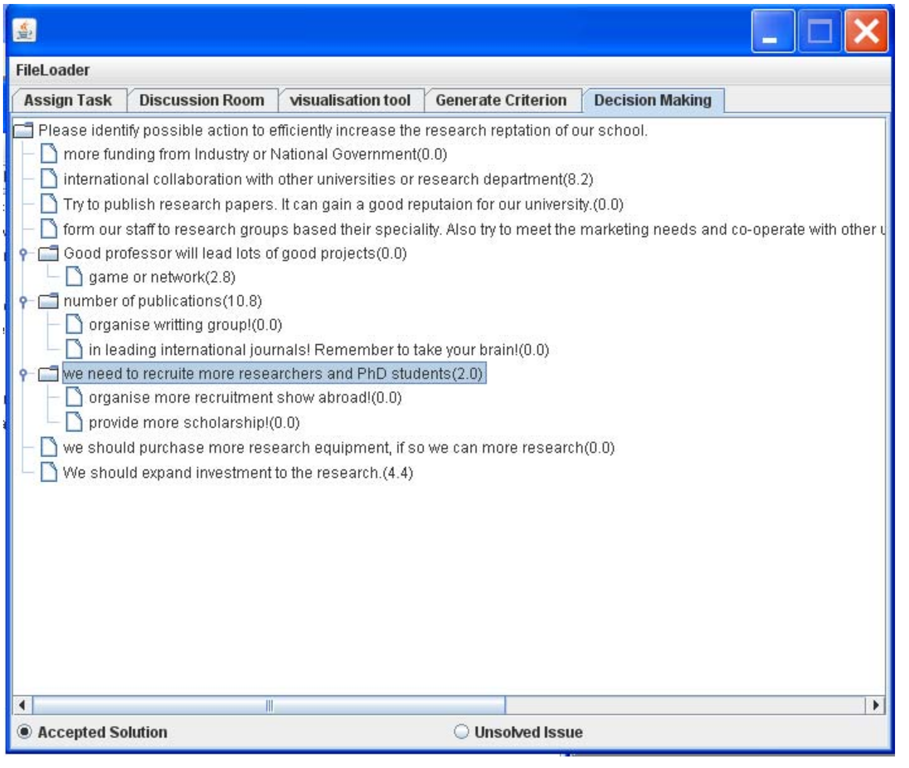

Figure 10. Solution space

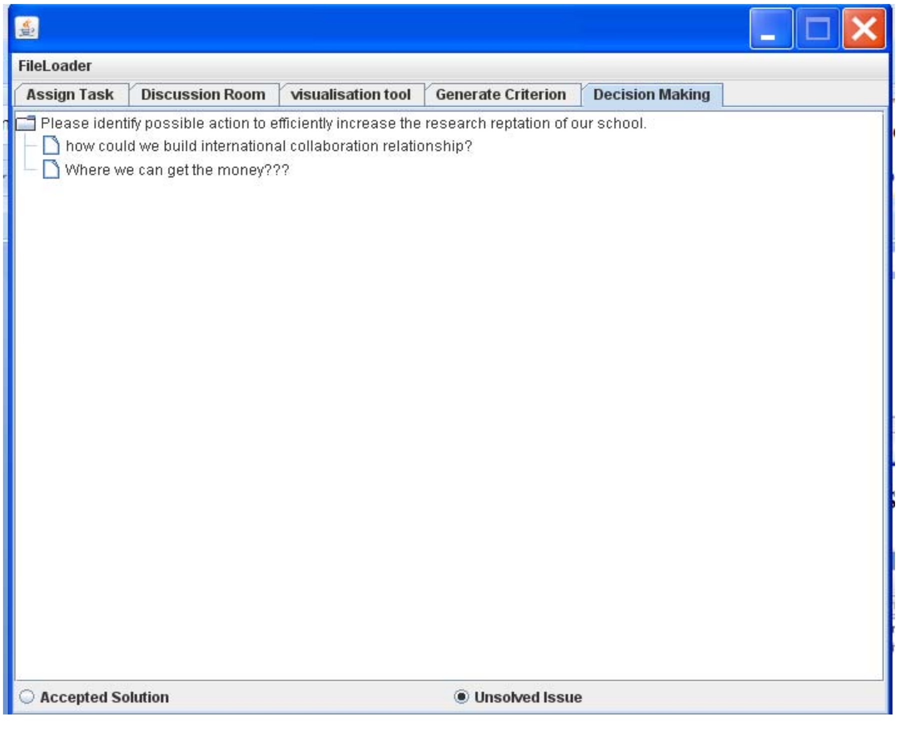

Figure 11. Issue space

participants individually before experiment without using our system. Not only are more criteria identified in the argumentation, but also better quality they have. For example, "*marketing*" is one criteria generated in the individual consideration. Comparably "*advertisement*" and "*recruitment*" are identified in the argumentation. Obviously, the latter ones are more concrete and reflect the different aspects of the "*marketing activity*". Furthermore, "*EPSRC*" as a particular research funding resource is identified as a criteria in the argumentation, however only "*funding*" is proposed as criteria in the individual consideration. Interestingly some same criteria in these two groups have been given prominent different importance. In the individual consideration, "*research group*" has the least importance among all the criteria. But in the argumentation, it is identified as the top 5 important criteria. These show our system can stimulate group members to further think in detail and in different ways.

Table 5. Number of criteria

Item	Total	Mean	Standard Deviation
The number of criteria proposed by participants before experiment	12	3	1.8
The number of criteria identified by the system in the experiment	16	4	0.75

During the argumentation, 18 solutions/ideas are proposed. In the decision making section, 13 out of them are accepted by the system based on the evaluating the related argumentation and 6 unsolved decision problem are identified as well. The recommendation score of the each solution are also presented by the system. From our experiment,

– *"increase the number of publication"*,
– *"enhance collaboration with other university"*,
– *"recruit more researcher and PhD student"* and
– *"apply for more research funding"*

are the solutions with higher recommendation value. Furthermore, some of solutions/ideas have sub-solutions which answer the question under a certain high level solution. For example,

"cooperate with industry to get more funding"	may complement	*"apply for more research funding"*	and
"university should fund more international student"	provides more detailed scheme for	*"recruit more researcher and PhD student"*.	

Due to unfamiliarity with the system, sometimes participants do not use the proper argumentation type to describe their utterance. For this reason, some issue utterances are presented in the solution space and solution/idea are presented in the unsolved issue space unexpectedly. Despite all this, all the participants agree the solution space consisting of the solutions and their sub-solutions give them clear route to solve the problem. And also they strongly agree the unsolved issue space help them easily to find what should be concerned in the next round discussion if needed.

4.3 Comments

This paper is seeking to provide a new decision support mechanism rather than automated decision making. The result which the system generates is a list of candidate solutions with scores and new issues to be addressed in the next iteration of the process. The decision making module in the system offers such decision support services. However, how final decision making is to be made and what final decision is to be achieved are not concerned with in this paper. We think these can be done in various ways, for example, the final decision may simply be choosing the high score solution, or picking the high score solution and undertaking the next round iteration based on the unsolved issues.

The actual decision mechanism may depend upon the type of issue and the type of organisation. In this paper, we didn't particularly emphasize the final actions of the decision maker.

Based on the experience from the experiment, we find our prototype system is useful to support the group decision making in the following aspects:

(i) Our system can structure the rough defined decision task and stimulate users to further consideration.

(ii) The system can advise alternative solution routes which include different detail level and those solution routes are helpful for decision maker to exploit solution space.

(iii) The system can easily identify the unsolved task which will be the possible to lead next round discussions, so it can iterate the argumentation and decision process.

However, some limitations in the current implementation are also identified:

(i) No mechanism to check semantic conflict to prevent participants from selecting improper utterance type and link type due to their careless, which will affect the result from decision module. For example, it's not valid to use "Issue" to resolve another "Issue".

(ii) No mechanism to integrate the external knowledge base with the argumentation support environment, so the process of decision making is solely upon the argumentative content in the discussion session rather than reusing other knowledge from the similar problem solving process.

As to the coefficient w in Eq. (10), it indicates how much the solved/unsolved issue will influence the acceptability of the utterance. In our experiment, w was simply set as 0.2, because we want to reduce the influence the issue type has upon the argumentation. In theory, this parameter can be configured by users and may be refined based on multiple experiments.

5. Summary and Outlook

In this paper, we have proposed a semantic enhanced framework for argumentation based group decision support. In this framework, we consider both argumentation support and evaluation support. The argumentative elements are formally represented using ontological approach. An argumentation oriented decision model is proposed, in which the decision makers' social parameter and strength of argumentation are investigated. Furthermore, we have developed a prototype system of group decision making to realize the proposed framework. A preliminary experiment based on a small group is carried out. The experiment results demonstrate the effectiveness of the system.

A future work can be studying more semantic support in our framework to prevent semantic inconsistent argument and to synthesize similar concepts. Another work can be undertaking experiments with large group and more rounds of group decision making experiments to further validate our approach.

Reference

[1] L. Amgoud and H. Prade, Using arguments for making and explaining decision, Artificial Intelligence, Vol. 173, 2009, pp. 413-436.

[2] R. M. D. Araujo and H. Fuks, QUORUM-W: A group decision support tool for the internet environment, CYTED-RITOS International Workshop on Groupware, Lisbon, Portugal, 1995, pp. 39-52.

[3] J. Conklin and M. L. Begeman, gIBIS: A hypertext tool for exploratory policy discussion, ACM Transactions on Information Systems, Vol. 6, 1988, pp. 303-331.

[4] J. F. Courtney, Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS, Decision Support Systems, Vol. 31, 2001, pp. 17-38.

[5] A. P. de Mederios and D. Schwabe, Ontology driven design rationale reuse, Monografias em Ciência da Computação, Departamento de Informática, Pontifícia Universidade Católica, Brasil, No. 14/06 April, 2006.

[6] R. F. Dyer and E. Forman, Group decision support with the analytic hierarchy process, Decision Support Systems, Vol. 8, 1992, pp. 99-124.
[7] K. Freeman and A. M. Farley, A model of argumentation and its application to legal reasoning, Artificial Intelligence and the Law, Vol. 4, 1996, pp. 163-197.
[8] T. R. Gruber, Towards principles for the design of ontologies used for knowledge sharing, International Journal of Human-Computer Studies, Vol. 43, 1993, pp. 907-928.
[9] M. Indiamma and K. R. Anandakumar, Collaborative decision making framework for multi-agent system, Proceedings of the International Conference on Computer and Communication Engineering (ICCCE’08), 13-15 May 2008, pp. 1140-1146.
[10] N. Karacapilidis, Integrating new information and communication technologies in a group decision support system, International Transactions in Operational Research, Vol. 7, 2000, pp. 487-507.
[11] N. Maudet, W. Ouerdane and A. Tsoukis, Argumentation theory and decision aiding, In: J. Figueira, S. Greco, and M. Ehrgott (eds.), New Trends in Multiple Criteria Decision Analysis, Chapter 1, Springer Verlag, Berlin, 2010, pp. 1-41.
[12] H. W. J. Rittel and M. M. Webber, Dilemmas in a general theory of planning, Policy Sciences, Vol. 4, 1973, pp. 155-169.
[13] S. B. Shum, V. Uren, G. Li, J. Domingue and E. Motta, Visualizing internetworked argumentation, In: P. A. Kirschner, et al. (eds.), Visualizing Argumentation ---- Software Tools for Collaborative and Educational Sense-Making, Springer, 2003, pp. 185-204.
[14] M. K. Smith, C. Welty and D. L. McGuinness, OWL web ontology language guide, W3C Recommendation, 2004.
[15] S. E. Toulmin, The Uses of Argument, New York: Cambridge University, 1958.
[16] C. Tweed, Support argumentation practices in urban planning and design, Computer, Environment and Urban Study, Vol. 22, 1998, pp. 351-363.
[17] C. Xiong, Y. Pan and D. Li, A discussion information-structuring model based on the Toulmin formalism, Proceedings of First International Workshop on Knowledge Discovery and Data Mining (WKDD’08), Adelaide, Australia, 23-24 Jan. 2008, pp. 268-273.
[18] P. Zhang, J. Sun and H. Chen, Frame-based argumentation for group decision task generation and identification, Decision Support Systems, Vol. 39, 2005, pp. 634-659.