ARGUMENTATION-BASED ONE-TO-MANY NEGOTIATION MODEL

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Abstract: Today, within the field of multi-agent systems, the theory of argumentation has become instrumental in designing rich interaction protocols and in providing agents with a means to manage and resolve conflicts. However, to date much of the existing literature focuses argumentation models based on two agents and tends to overlook the influence on knowledge base and the relationship between different negotiation processes. To end this, this paper presents an argumentation-based one-to-many negotiation model. The contributions are three points: First, we present an argumentation model based on knowledge set with different influence. Second, we extend a protocol based on dialogue game to govern the agent interactions and the update of knowledge bases in one-to-many negotiation. In doing so, our model can collect the knowledge from other negotiating partners and use it in the negotiation with another negotiating partner.

1 INTRODUCTION

Argumentation-based negotiation (Rahwan et al., 2004) which is gaining increasing popularity for allows agents to exchange additional information, or to challenge about their beliefs and other mental attitudes during the negotiation process has potential ability to overcome the limitations of more conventional approaches to automated negotiation. There are many frameworks of argumentation-based negotiation having been proposed by many scholars, such as Carles Sierra (Sierra et al., 1997), Amgoud (Amgoud et al., 2000a), Sarit Kraus (Kraus et al., 1998). The key elements of argumentation-based framework contain communication and domain languages, the negotiation protocol, and various information stores, argument and proposal evaluation, argument and proposal generation and argument selection (Guorui & Xiaoyu, 2009).

However, to date much of the existing literature focuses argumentation models based on two agents and tends to overlook the influence on knowledge base and the relationship between different negotiation processes. Actually, how to arrange and update the knowledge in database is an important problem in argumentation negotiation. The agent can collect the information from different negotiation processes or different opponents. So, this paper presents an one-to-many argumentation negotiation model that focuses on the arranging and updating the knowledge of agents during negotiating.

2 THE ARGUMENTATION MODEL

The agent’s reasoning model is specified using argumentation model. This work is inspired by the work of Dung (Dung, 1995) and Leila Amgoud (Amgoud et al., 2000b) but goes further in dealing with influence between arguments which come from different knowledge base in a set of knowledge bases.

An agent has many knowledge bases during one-to-many negotiation. Let $\Gamma_0$ be the private knowledge base of the agent, and $\Gamma_1, \Gamma_2, ..., \Gamma_n$ be the knowledge bases that store the knowledge comes from the negotiating agents $Ag_1, Ag_2, ..., Ag_n$ respectively. We can organize the set of knowledge bases in the form of a tree. Each base is supposed to be consistent. We assume knowledge bases contain formulas of a propositional language $\zeta$. $\equiv$ stands for classical inference and $\leftrightarrow$ for logical equivalence during negotiation.
**Definition 1** (Argument) An argument is a pair \((H, h)\) where \(h\) is a formula of \(\zeta\) and \(H\) is a subset of \(\Gamma\) such that 1) \(H\) is consistent, 2) \(H \models h\) and 3) \(H\) is minimal, so no subset of \(H\) satisfying both 1) and 2) exists. \(H\) is called the support of the argument and \(h\) is its conclusion.

We use the notation: \(H = \text{Support}(Ag, h)\) to indicate that agent \(Ag\) has a support \(H\) for the conclusion \(h\).

**Definition 2** (Attack Relation) Attack is a binary relation between two arguments. Let \((H_1, h_1)\) and \((H_2, h_2)\) be two arguments over \(\Gamma_1\) and \(\Gamma_2\) respectively. \((H_1, h_1)\) attacks \((H_2, h_2)\) is denoted by \((H_1, h_1) \rightarrow \text{attack} \rightarrow (H_2, h_2)\). \(h \in H_2\) such that \(h = \neg h_1\). In other words, an argument is attacked iff there exists an argument for the negation of an element of its support.

To capture the fact that some facts are more strongly believed (Guorui et al., 2009) (maybe because of different honesty and capability degree of different agents) we assume that any set of knowledge bases has an influence order over it. We suppose that this ordering derives from the fact that the knowledge bases set \(\Gamma_1, \Gamma_2, \ldots, \Gamma_n\) come from different agents \(Ag_1, Ag_2, \ldots, Ag_n\), respectively such that facts in \(\Gamma_i\) have the same influence order and have more influence than those in \(\Gamma_j\) where \(i \neq j\). The influence level of a nonempty subset \(H\) of \(\Gamma_i\), \(\text{level}(H)\).

**Definition 3** (Influence) Let \((H_1, h_1)\) and \((H_2, h_2)\) be two arguments over \(\Gamma_1\) and \(\Gamma_2\) respectively. \((H_1, h_1)\) has more influence than \((H_2, h_2)\) according to \(\text{Influ}\) if \(\text{level}(H_1) \succeq \text{level}(H_2)\).

**Definition 4** (Argumentation Model) An argumentation model (AM) is a triple \((A(\Gamma), \text{Attack}, \text{Influ})\) such that \(A(\Gamma) = A(\Gamma_0) + A(\Gamma_1) + \ldots + A(\Gamma_n)\) is a set of the arguments built from \(\Gamma_0, \Gamma_1, \ldots, \Gamma_n\), respectively. \(\text{Attack}\) is a binary relation representing defeat relationship between arguments, \(\text{Attack} \subseteq A(\Gamma) \times A(\Gamma)\), and \(\text{Influ}\) is a (partial or complete) pre-ordering on \(A(\Gamma) \times A(\Gamma)\). \(\succeq_{\text{Both}}\) stands for the strict pre-order associated with \(\text{Influ}\).

**Definition 5** (Strongly Attack) Let \(A, B\) be two arguments of \(A(\Gamma)\), \(B\) strongly attacks \(A\) iff \(B\) attacks \(A\) and it is not the case that \(A \succeq_{\text{Both}} B\).

**Definition 6** (Legal Argument Rule) An argument \(A\) from AM is legal iff there is no argument from AM which strongly attacks \(A\). And a legal argument that come from AM can be denoted as \(A \triangleleft \text{AM}(Ag)\).

### 3 DIALOGUE GAME FOR ONE-TO-MANY NEGOTIATION

#### 3.1 Dialogue Game

Formal dialogue games (Maudet et al., 1998) are games in which two or more participants “move” by uttering locutions, according to certain pre-defined rules. In recent years, they have found application as the basis for communications protocols between autonomous software agents, including for agents engaged in: persuasion dialogues, where one agent seeks to persuade another to endorse some claim; information-seeking dialogues, where one agent seeks the answer to some question from another (Amgoud et al., 2006c).

#### 3.2 Dialogue Move Rules

A social commitment \(SC\) is an engagement made by an agent that some fact is true or that something will be done. This commitment is directed to a set of agents. A commitment is an obligation in the sense that the sender must respect and behave in accordance with this commitment. The paper uses \(SC(Ag_1, Ag_2, p)\) which will be denoted in the rest of this paper \(SC(p)\) to indicate the social commitment that \(Ag_1\) sends to \(Ag_2\).

The paper uses \(SCS(Ag_i)\) storing the social commitment that presented by \(Ag_i\). When \(Ag_i\) create a new social commitment, \(SCS(Ag_i)\) will update itself by adding the new commitment, \(SCS(\text{Ag}_i) = SCS_{\text{Ag}_i}(\text{Ag}_i) \cup SC(p)\). Each Agent has access to the other Agent’s SCS to get the social commitments which are sent to it. The knowledge retrieves from the social commitments from the other Agent \(Ag_i\) constitute the new knowledge of
Agent \(Ag\). So \(Ag\) can get knowledge from the SCS of other Agents to build the knowledge set.

A speech act \(SA\) is an act performed on a commitment or its content. The action that an agent can perform on a commitment is Create and Withdraw. Create means that making an offer. When the agent (speaker) accept the other agent’s SC and the content of other agent’s SC is the opposition of speaker’s SC, the speaker will withdraw the SC that its sent. And the actions that an agent can perform on commitment content are: Act-Arg: Accept, Re fuse, Challenge, Defend, Attack, Justify.

A propositional formula \(p\), which is accord with legal argument rule, can be generated from an agent’s argumentation system, if this Agent can find an argument supporting \(p\). The paper uses the notation \(p \in \text{Arg}_\text{Sys}(Ag)\) to denote the fact that a propositional formula \(p\) can be generated from the argumentation system of \(Ag\) (AM \((Ag)\)).

The paper uses \(S=\text{Create Support}(Ag,SC(Ag,SC(p)))\) which will be denoted in the rest of this paper \(S=\text{Support}(Ag,SC(p))\) to indicate the set of commitments \(S\) created by agent to support the content of \(SC(Ag,Ag,p)\). Act-Arg \((Ag,[S],SC(p))\) means the argumentation-related action that \(Ag\) performs on the content of \(SC(p)\) using the contents of \(S\) as support. Act-Arg \((Ag,[S],S)\) indicates that \(Ag\) performs an argumentation-related action on the content of a set of commitment \(S\) using the content of \(S\) as support.

As the dialogue move rules presented by Jamal Bentahar and Jihad Labban (Bentahar & Labban, 2009) he paper distinguish five types of dialogue games: entry, defense, challenge, justification and attack. Based on the five types of dialogue games, this paper extends the protocol by adding the rules of updating knowledge database of each agent.

### 3.2.1 A Entry Game

\[\text{Create}(Ag,SC(p))\] (1)

**Rationality:** \(p \in \text{Arg}_\text{Sys}(Ag)\)

**Dialogue:** the other player can respond with
1. \(\text{Accept}(Ag,[S],SC(p)),a_i = p \in \text{Arg}_\text{Sys}(Ag)\), \(S_i = \text{Support}(Ag,SC(p))\), \(a_i\) is the condition to accept \(SC(p)\), \(S_i\) is the support of \(SC(p)\) in the argumentation model of \(Ag\).
2. \(\text{Re fuse}(Ag,SC(p)),b_i = \neg p \in \text{Arg}_\text{Sys}(Ag)\), \(b_i\) is the condition.
3. \(\text{Challenge}(Ag,SC(p)),c_i = (\neg (p \in \text{Arg}_\text{Sys}(Ag)) \land \neg (\neg p \in \text{Arg}_\text{Sys}(Ag)))\), \(c_i\) is the condition.

**Update:** \(SC_i(Ag) = SCS_{i-1}(Ag) \cup \{SC(p)\}\), \(Ag\) will update its social commitment store by adding the new commitment \(SC(p)\).

\(SC_i(Ag) = SCS_{i-1}(Ag) \cup \{S\}\), when \(Ag\) respond by \(\text{Accept}(Ag,SC(p))\), \(Ag\) will update its commitment store by adding \(S\).

**3.2.2 Defence Game**

\[\text{Defend}(Ag,SC(p))\] (2)

**Rationality:** receive \(\text{Re fuse}(Ag,SC(p))\) from other player

**Dialogue:**
1. \(\text{Accept}(Ag,[S],SC(p)),a_0 = \forall \in SC(p)\in S \Rightarrow p \in \text{Arg}_\text{Sys}(Ag)\), \(S_0 = \text{Support}(S)\) As for every propositional formula in \(S\), the AM of \(Ag\) has a support of it. And the support set is \(S_0\).
2. \(\text{Challenge}(Ag,[S],S),b_0 = \forall \in SC(p)\in S \Rightarrow (p \in \text{Arg}_\text{Sys}(Ag)) \land \neg (\neg p \in \text{Arg}_\text{Sys}(Ag))\).
3. \(\text{Attack}(Ag,[S],S),c_0 = \forall \in SC(p)\in S \Rightarrow \exists S_j \subseteq S\), \(S_j = \text{Support}(Ag,\neg p)\) As for every propositional formula in \(S_j\), the AM of \(Ag\) has a support of the opposition of it. And the support set is \(S_j\).

Where \(S = \{SC(p)\} \forall i = 0,\ldots,n\), \(p\) are propositional formulas.

**Update:** \(SC_i(Ag) = SCS_{i-1}(Ag) \cup \{S\}\), \(Ag\) will update its social commitment store by adding the new commitment \(SC(p)\).

\(SC_i(Ag) = SCS_{i-1}(Ag) \cup \{S\}\), when \(Ag\) respond by \(\text{Accept}\).

**3.2.3 Challenge Game**

\[\text{Challenge}(Ag,SC(p))\] (3)

**By definition,** \(\text{Defend}(Ag,SC(p))\) means that \(Ag\) creates \(S\) in order to defend the content of \(SC(p)\). Formally: \(\{S\} = \text{Create Support}(Ag,SC(p))\).
Rationality: $b_1 = \forall i, SC(p_i) \in S_i \Rightarrow \neg(p_i < Arg_{_Sys}(Ag))$
\[\neg(p_i < Arg_{_Sys}(Ag))\] means $Ag$ does not have knowledge about propositional formula $p$.

Dialogue: Justify$(Ag,[S],SC(p))$ (4)

Dialogue: the respond rule is the same with Defend rules.

1. Accept$(Ag,[S],SC(p))$, $a_i = \forall i, SC(p_i) \in S_i \Rightarrow p_i < Arg_{_Sys}(Ag)$, $S_0 = Support(S_i)$.
2. Challenge$(Ag,[S],b_j = \forall i, SC(i) \in S_i \Rightarrow \neg(p_i < Arg_{_Sys}(Ag)))$
\[\neg(p_i < Arg_{_Sys}(Ag))\] means $Ag$ does not have any other knowledge to justify $p$. At this situation, $Ag$ only can accept or reject it, because $Ag$ has challenged it and it does not have any argument about $p$.

3.2.5 Attack Game

\[Attack(Ag,[S],SC(p))\] (6)

Rationality: receive Challenge from other player,

Dialogue:

1. Accept$(Ag,[S],SC(p))$, (Acceptence) , when $Ag$ trusts $Ag$ or the influence of $Ag$ is higher than $Ag$.
2. Re fuse$(Ag,[S],SC(p))(Ter min ate)$, when $Ag$ does not trust $Ag$ or the influence of $Ag$ is higher than $Ag$.

Update: $SCS(Ag) = SCS^{+}(Ag)$ and $SCS(Ag) = SCS^{−}(Ag)$

\[\{SC(p)\} = S\] means that Agent justify $p$ by itself and Agent does not have any other knowledge to justify $p$. At this situation, $Ag$ only can accept or reject it, because $Ag$ has challenged it and it does not have any argument about $p$.

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\[ S'_i = \text{Support}(Ag_j, \neg p) \] where \( S = \{SC(p)\}_{i=0, \ldots, n} \), \( p \) is a propositional formula.

\[ \bigcup_{i \neq j} S_i = S \cup SC(p), S_i \cap S_j = \emptyset, \quad i, j = 1, \ldots, 4 \text{ and } i \neq j. \]

**Update:** \( SCS(Ag_i) = SCS_{i-1}(Ag_i) \cup \{S_i\} \), \( Ag_i \) will update its social commitment store by adding the new commitment set \( S_i \).

\( SCS(Ag_2) = SCS_{i-1}(Ag_2) \), if \( Ag_2 \) responds with Re fuse or Challenge .

\( SCS(Ag_0) = SCS_{i-1}(Ag_j) \cup \{S_j\} \), when \( Ag_0 \) respond by Accept .

\( SCS(Ag_2) = SCS_{i-1}(Ag_z) \cup \{S_z\} \), when \( Ag_2 \) respond by Attack .

### 3.3 One-to-Many Protocol

In one-to-one negotiation, a negotiation process between \( Ag_i, Ag_2 \) constitutes by a sequence of dialogue moves one after another and the update of knowledge set between every two dialogue moves.

In one-to-many negotiation, every players are equipped with an argumentation model of the kind discussed above. Each has access to their own private knowledge base \( \Gamma \) and social commitment stores. The Agent can access to the social commitment stores to search the social commitments that sent to it. According the Agent which the social commitment comes from, The Agent can store the knowledge which is retrieved from social commitment in the knowledge base set \( \Gamma_1, \Gamma_2, \ldots, \Gamma_n \) respectively.

In the process of negotiation (Figure 1), \( Ag_0 \) negotiates with \( Ag_1, Ag_2, \ldots, Ag_n \) respectively in synchronization. Before the negotiation started, \( Ag_0 \) only has private knowledge base \( \Gamma \). When \( Ag_0 \) starts negotiation with \( Ag_1, Ag_2, \ldots, Ag_n \) respectively in synchronization, \( Ag_0 \) can retrieve knowledge from social commitment that sent by \( Ag_1, Ag_2, \ldots, Ag_n \) and store it in \( \Gamma_1, \Gamma_2, \ldots, \Gamma_n \) respectively. \( \Gamma_i \) denotes the knowledge that come from \( Ag_i \) during negotiation. Each knowledge base will grow with the process of negotiation. \( Ag_0 \) can use the opponents’ knowledge to negotiate with the other opponents. Within the process of the negotiation, the knowledge of \( Ag_0 \) will grow quickly.
4 AN DIALOGUE PROCESS

Let us consider the following dialogue to illustrate the process of one-to-many argumentation negotiation presented in this paper.

In the family, the child wants to travel to Sanya in Hainan province. The child should persuade mother and father to travel to Sanya. Only if father and mother all agree with child, the family can go to have a travel to Sanya. Agent Child’s KB contains \{t, m, g, p\}, where t means the family has enough time to have a travel, m means the family has enough money to travel to Sanya, g is a brief that Sanya is a good place to have a travel, p is the suggestion to travel to Sanya. And the expression mean that p will be true if t, m and g are true. Agent Father’s KB contains \{b, s\}, b indicates bonus that father receives yet, s indicate the deposit of the family. Agent Mother’s KB contains \{x, t\}, \{g, g\}, \{s, s\}, \{m, m\}, where x means the family has a plan to have a travel. Besides, Father has the biggest influence and the child has the smallest influence and father and mother trust each other. If they can make an argument that is the opposition of the brief, they should accept the brief of each other. And the process of the dialogue is presented as Figure 2. C indicates child, M indicates mother, and F indicates father.

If the child negotiate with his father in one-to-one negotiation, the process will stop at step 3 because of the luck of knowledge. Similarly, if the child negotiate with his mother, the process will stop at step 3 because of the luck of knowledge.

But in one-to-many negotiation, the child can have access to his father’s social commitment store (SCS) and get the new knowledge \{b, s\} at step 3. Then child can use it to persuade mother in step 4. Similarly, the child can have access to his mother’s SCS and get the new knowledge \{x\} at step 3. Because the father’s influence is bigger than his mother, mother accept the knowledge \{b, s\} in the step 5 and step 7. Because father and mother trust each other, father accept the knowledge \{x\} of mother.

5 CONCLUSIONS

This paper presents an argumentation model based on agent’s society influence and extends a protocol based on dialogue game which makes agents can collect and update the knowledge base in one-to-many negotiation’s process. Much of the existing literature overlooks the influence between different negotiation processes, especially in the field of one-to-many and many-to-many negotiation. Knowledge is the basic element for argumentation systems to build an argument supporting a conclusion. So an interesting direction for future work is how to make agents be equipped with capacity enabling them to collect, update, manage and apply knowledge during negotiating processes, especially in one-to-many and many-to-many negotiation.

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