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 at., 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 Γ_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 ζ. $\mapsto$ stands for classical inference and $\equiv$ for logical equivalence during negotiation.

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Definition 1(Argument) An argument is a pair (H,h) where h is a formula of ζ and H is a subset of Γ such that 1) H is consistent, 2) $H \mapsto h$ 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: $H = Support(Ag, h)$ 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 Γ_1 and Γ_2 respectively. (H_1, h_1) attacks (H_2, h_2) is denoted by $(H_1, h_1) \xrightarrow{attack} (H_2, h_2)$. $(H_1, h_1) \xrightarrow{attack} (H_2, h_2)$ *iff* $\exists h \in H_2$ such that $h \equiv \neg h_1$ .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 $\Gamma_1, \Gamma_2, ..., \Gamma_n$ come from different agents $Ag_1, Ag_2, ..., Ag_n$ respectively such that facts in Γ_i have the same influence order and have more influence than those in Γ_j where $i \neq j$ .The influence level of a nonempty subset H of Γ_i, $level(H)$.

Definition 3 (Influence) Let (H_1, h_1) and (H_2, h_2) be two arguments over Γ_1 and Γ_2 respectively. (H_1, h_1) has more influence than (H_2, h_2) according to *Influ* *iff* $level(H_1) \geq level(H_2)$.

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

Definition 6 (Legal Argument Rule) An argument A from AM is legal *iff* there is not any argument from AM which strongly attacks A . And a legal argument that come from AM can be denoted as $A \lhd AM(Ag)$.

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, $SCS_i(Ag_i) = SCS_{i-1}(Ag_i) \cup SC(p)$. 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: $Accept, Refuse, Challenge, Defend, Attack, Justfiy$.

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 $p \lhd Arg\_Sys(Ag)$ to denote the fact that a propositional formula p can be generated from the argumentation system of Ag ($AM(Ag)$).

The paper uses $S = Create\_Support(Ag, SC(Ag_1, Ag_2, p))$ which will be denoted in the rest of this paper $S = Support(Ag, SC(p))$ to indicate the set of commitments S created by agent to support the content of $SC(Ag_1, Ag_2, p)$. 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 Agent 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

$$Create(Ag_1, SC(p)) \quad (1)$$

Rationality: $p \lhd Arg\_Sys(Ag_1)$
Dialogue: the other player can respond with
1. $Accept(Ag_2, [S_1], SC(p)), a_1 = p \lhd Arg\_Sys(Ag_2)$, $S_1 = Support(Ag_2, SC(p))$, a_1 is the condition to accept $SC(p)$, S_1 is the support of $SC(p)$ in the argumentation model of Ag_2 .
2. $Refuse(Ag_2, SC(p)), b_1 = \neg p \lhd Arg\_Sys(Ag_2)$, b_1 is the condition.
3. $Challenge(Ag_2, SC(p)), c_1 = \neg(p \lhd Arg\_Sys(Ag_2)) \wedge \neg(\neg p \lhd Arg\_Sys(Ag_2))$, c_1 is the condition.

Update: $SCS_i(Ag_1) = SCS_{i-1}(Ag_1) \cup \{SC(p)\}$, Ag_1 will update its social commitment store by adding the new commitment $SC(p)$.
$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S_1\}$,when Ag_2 respond by $Accept(Ag_2, [S_1], SC(p))$, Ag_2 will update its commitment store by adding S_1 .
$SCS_i(Ag_2) = SCS_{i-1}(Ag_2)$,when Ag_2 respond by $Refuse$ or $Challenge$.

3.2.2 Defence Game

$$Defend(Ag_1, [S], SC(p)) \quad (2)$$

Rationality: receive $Refuse(Ag_2, SC(p))$ from other player
Dialogue:
1. $Accept(Ag_2, [S_0], S_1), a_2 = \forall i, SC(p_i) \in S_1 \Rightarrow p_i \lhd Arg\_Sys(Ag_2)$, $S_0 = Support(S_1)$ As for every propositional formula in S_1, the AM of Ag_2 has a support of it. And the support set is S_0 .
2. $Challenge(Ag_2, S_2), b_2 = \forall i, SC(p_i) \in S_2 \Rightarrow (\neg(p_i \lhd Arg\_Sys(Ag_2)) \wedge \neg(\neg p_i \lhd Arg\_Sys(Ag_2)))$.
3. $Attack(Ag_2, [S'], S_3), c_2 = \forall i, SC(p_i) \in S_3 \Rightarrow \exists S'_j \subseteq S'$, $S'_j = Support(Ag_2, \neg p_i)$ As for every propositional formula in S_3, the AM of Ag_2 has a support of the opposition of it. And the support set is S'.

Where $S = \{SC(p_i) \mid i = 0, ..., n\}$, p_i are propositional formulas.
$U_{i=1}^{3} S_i = S \cup SC(p), S_i \cap S_j = \Phi, i, j = 1, ..., 3 \& i \neq j$
Update: $SCS_i(Ag_1) = SCS_{i-1}(Ag_1) \cup \{S\}$, Ag_1 will update its social commitment store by adding the new commitment $SC(p)$.
$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S_0\}$,when Ag_2 respond by $Accept$.
$SCS_i(Ag_2) = SCS_{i-1}(Ag_2)$,when Ag_2 respond by $Challenge$.
$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S_3\}$, when Ag_2 respond by $Attack$.

By definition, $Defend(Ag_1, [S], SC(p))$ means that Ag_1 creates S in order to defend the content of $SC(p)$ .Formally: $[S] = Create\_Support(Ag_0, SC(p))$.

3.2.3 Challenge Game

$$Challenge(Ag_1, SC(p)) \quad (3)$$

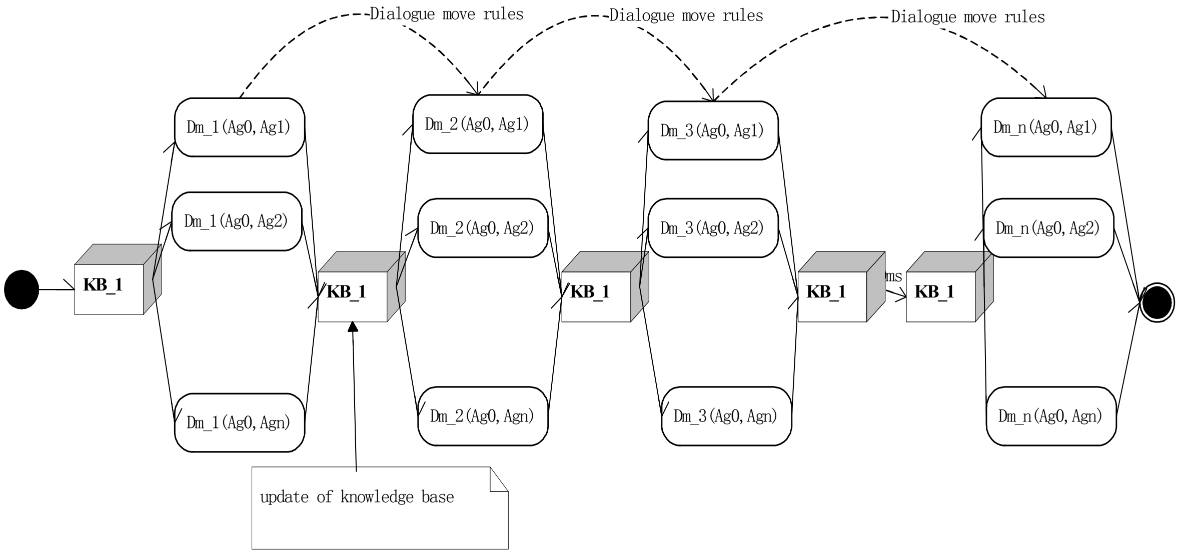

Figure 1: The protocol of one-to-many negotiation.

Rationality: $b_2 = \forall i, SC(p_i) \in S_2 \Rightarrow (\neg(p_i \lhd Arg\_Sys(Ag_1)) \wedge \neg(\neg p_i \lhd Arg\_Sys(Ag_1)))$ means Ag_1 does not has knowledge about propositional formula p.

Dialogue: $Justify(Ag_2, [S], SC(p))$

Update: $SCS_i(Ag_1) = SCS_{i-1}(Ag_1)$

$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S\}$,when Ag_2 respond by *Justify* .

3.2.4 Justification Game

Case1($SC(p) \notin S$)

$$Justify(Ag_1, [S], SC(p)) \qquad (4)$$

Rationality: receive *Challenge* from other player, then Agent should use *Justify* to answer the question.

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

1. $Accept(Ag_2, [S_0], S_1), a_2 = \forall i, SC(p_i) \in S_1 \Rightarrow p_i \lhd Arg\_Sys(Ag_2), S_0 = Support(S_1)$.

2. $Challenge(Ag_2, S_2), b_2 = \forall i, SC(p_i) \in S_2 \Rightarrow (\neg(p_i \lhd Arg\_Sys(Ag_2)) \wedge \neg(\neg p_i \lhd Arg\_Sys(Ag_2)))$.

3. $Attack(Ag_2, [S'], S_3), c_2 = \forall i, SC(p_i) \in S_3 \Rightarrow \exists S_j^{'} \subseteq S^{'}, S_j^{'} = Support(Ag_2, \neg p_i)$.

Update: the updating rules are the same with *Defend* rules.

Case2($\{SC(p)\} = S$)

$$Justify(Ag_1, [S], SC(p)) \qquad (5)$$

Rationality: receive *Challenge* from other player,

Dialogue:

1. $Accept(Ag_2, SC(p)), (Acceptence)$,when Ag_2 trusts Ag_1 or the influence of Ag_1 is higher than Ag_2 .

2. $Refuse(Ag_2, SC(p))(Terminate)$,when Ag_2 does not trust Ag_1 or the influence of Ag_2 is higher than Ag_1 .

Update: $SCS_i(Ag_1) = SCS_{i-1}(Ag_1)$ and $SCS_i(Ag_2) = SCS_{i-1}(Ag_2)$

$\{SC(p)\} = S$ means that Agent justify p by itself and Agent does not have any other knowledge to justify p. At this situation, Ag_2 only can accept or reject it, because Ag_2 has challenged it and it does not has any argument about p.

3.2.5 Attack Game

$$Attack(Ag_1, [S], SC(p)) \qquad (6)$$

Rationality: $S = Support(Ag_1, \neg p)$

Dialogue:

1. $Refuse(Ag_2, S_1), a_5 = \exists i, SC(p_i) \in Support(Ag_2, SC(\neg q))$ Where $S_1 = \{SC(q)\}$.

2. $Accept(Ag_2, [S_0], S_2), b_5 = \forall i, SC(p_i) \in S_2 \Rightarrow p_i \lhd Arg\_Sys(Ag_2)$.

3. $Challenge(Ag_2, S_3), c_5 = \forall i, SC(p_i) \in S_3 \Rightarrow (\neg(p_i \lhd Arg\_Sys(Ag_2)) \wedge \neg(\neg p_i \lhd Arg\_Sys(Ag_2)))$.

4. $Attack(Ag_2, [S'], S_4), d_5 = \forall i, SC(p_i) \in S_4 \Rightarrow \exists S_j^{'} \subseteq S^{'}$,

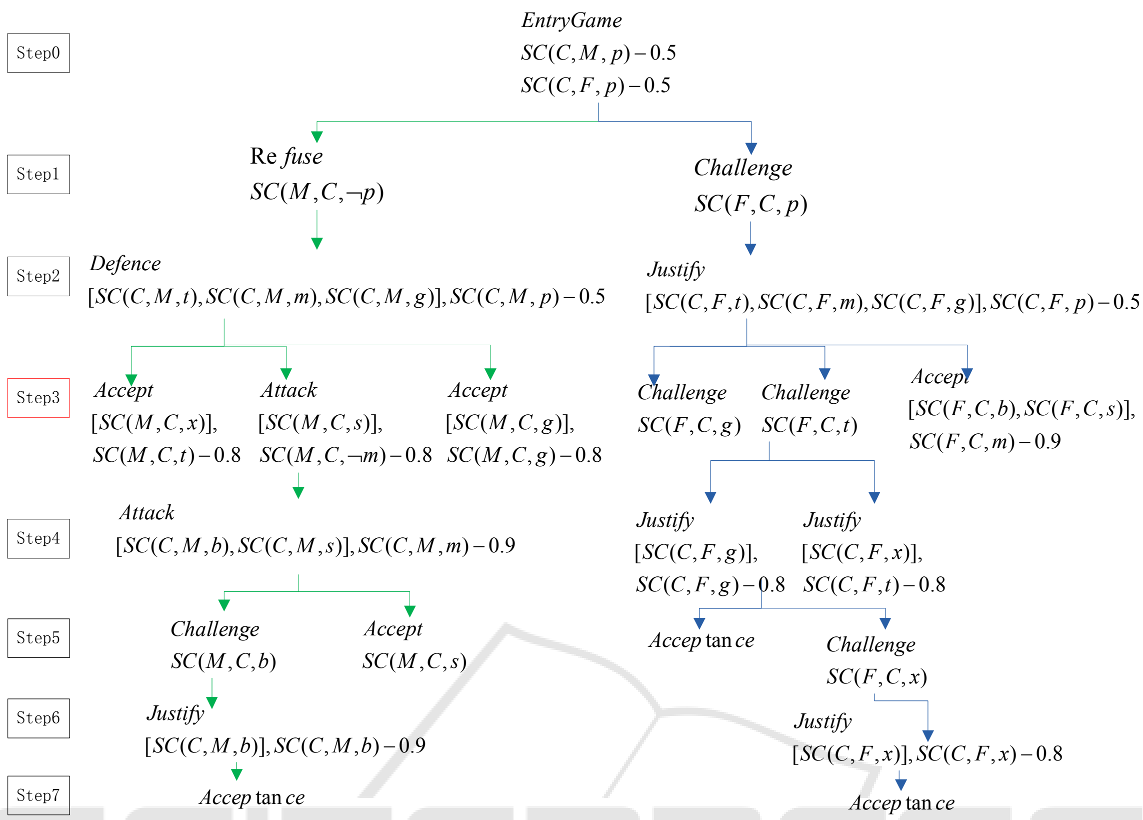

Figure 2: The process of negotiation.

$S_j^{'} = Support(Ag_2, \neg p_i)$ where $S = \{SC(p_i) \mid i = 0,...,n\}$, p_i is a propositional formula.

$\bigcup_{i=1}^{4} S_i = S \cup SC(p), S_i \cap S_j = \varnothing$, $i, j = 1,...,4$ and $i \neq j$.

Update: $SCS_i(Ag_1) = SCS_{i-1}(Ag_1) \cup \{S\}$, Ag_1 will update its social commitment store by adding the new commitment set S.

$SCS_i(Ag_2) = SCS_{i-1}(Ag_2)$, if Ag_2 responds with *Refuse* or *Challenge*.

$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S_0\}$,when Ag_2 respond by *Accept*.

$SCS_i(Ag_2) = SCS_{i-1}(Ag_2) \cup \{S^{'}\}$,when Ag_2 respond by *Attack*.

3.3 One-to-Many Protocol

In one-to-one negotiation, a negotiation process between Ag_1, 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 Γ 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 $\Gamma_1, \Gamma_2, ..., \Gamma_n$ respectively.

In the process of negotiation (Figure 1), Ag_0 negotiates with $Ag_1, Ag_2, ..., Ag_n$ respectively in synchronization. Before the negotiation started, Ag_0 only has private knowledge base Γ .When Ag_0 starts negotiation with $Ag_1, Ag_2, ..., Ag_k$ respectively in synchronization, Ag_0 can retrieve knowledge from social commitment that sent by $Ag_1, Ag_2, ..., Ag_k$ and store it in $\Gamma_1, \Gamma_2, ..., \Gamma_n$ respectively. Γ_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 want to have a 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 suggest 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 $(\{b,s\},m)$, b indicates bonus that father receives yet, s indicate the deposit of the family. Agent Mather's KB contains $(\{x\},t)$, $(\{g\},g)$, $(\{s\},\neg m)$, $(\{\neg m\},\neg p)$,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 step3 because of the luck of knowledge. Similarly, if the child negotiate with his mother, the process will stop at step3 because of the luck of knowledge.

But in one-to-many negotiation, the child can have access to his father' social commitment store(SCS) and get the new knowledge $(\{b,s\},m)$ at step3.Then child can use it to persuade mother in step4. Similarly, the child can have access to his mother's SCS and get the new knowledge $(\{x\},t)$ and $(\{g\},g)$ at step3. Because the father's influence is bigger than his mother, mother accept the knowledge $(\{b,s\},m)$ in the step5 and step7 . Because father and mother trust each other, father accept the knowledge $(\{x\},t)$ and $(\{g\},g)$ 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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