

# Multi-Agent Automatic Negotiation and Argumentation for Courses Scheduling

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**Abstract**—this paper proposes an argumentation and negotiation mechanism for multi-agent systems. Through argumentations and negotiations, agents obtain more information on the topics of common interests or on those they have odds with. At the inception of the negotiation, agents can hardly understand completely the goals and beliefs other agents have toward related issues. Through argumentations and negotiations, the beliefs evolve, and agents will have better understanding about each other's target needs and preferences. During negotiations, agents can select the proposal that better suits other agents, further improving the chances for the agents to reach a consensus. Lastly, this paper illustrates our proposed methods through a simple course-scheduling negotiating system.

**Keywords**—agent; Negotiation; argumentation

## I. INTRODUCTION

In a multi-agent system, agents, in order to complete tasks with others through various forms of interaction, negotiation is the most commonly used method. Negotiation is a form of interaction in which a group of agents, with conflicting interests and a desire to cooperate try to come to a mutually acceptable agreement on the division of scarce resources. Resources are scarce in the sense that not all demands can be simultaneously satisfied [7][8]. For the information in the surroundings, agents can hardly obtain complete information about them. Therefore, agents often have to make decisions based on incomplete information, or to use a different way trying to obtain more information on the subject in order to make the decision making more precise. In traditional negotiations, an agent can only refute or submit another proposal when it doesn't agree with it. Recently, it has been proposed that argumentation mechanisms can be used to facilitate negotiation among computational agents. These mechanisms attempt to overcome some of the limitations of bargaining-based frameworks by allowing agents to exchange additional information or to argue about their beliefs and other

internal characteristics during the negotiation process. This process of argumentation allows an agent to justify its negotiation stance and/or influence that of another agent [10][14][15]. Adding in the argumentation mechanism allows agents to understand the reasons and considerations behind these rejections of other's. In the end of the Negotiation and Argumentation System [1][13], agents can understand the reason behind other agents' decisions in favor of or against the proposal.

In a general course scheduling problem, a set of courses need to be arranged into a certain number of time slot under a set of constraints. This often makes the problem very hard to solve in real world circumstances [5]. It consists of efficiently arranging a set of courses into class periods. Scheduling consists of assigning offered courses to available time periods so that the teachers' satisfaction factor is maximized while preserving the unbreakable academic rules such as two distinct courses cannot be scheduled during the same period of time.

It is practically impossible to exhaustively consider and evaluate all possible schedules. The number of such schedules is exponential in the number of courses and time periods. Many papers proposed different approaches to solve this tough problem, such as genetic algorithm, case-based reasoning and fuzzy reasoning [4][6][9]. The present work applied negotiation and argumentation approaches for the courses scheduling problem. Each teacher is regarded as an agent called *course negotiation agent*. Through the negotiation and argumentation process of multi-agent, a suitable course timetable is scheduled. The paper is organized as follows. In the next section, we provide a conceptual framework of the negotiation and argumentation mechanism. Section 3 presents the processes of the negotiation and argumentation. Section 4 shows the results of the experiment. Section 5 is the conclusions of this work.

## II. THE FRAMEWORK OF NEGOTIATION AND ARGUMENTATION

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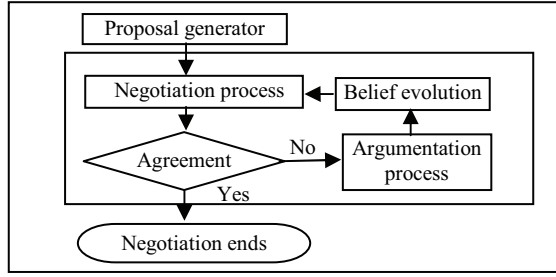


Figure 1 the System Pcess

The System Process is shown in Figure 1. The System obtains the User Belief from each agent, then generates numbers of different proposals through the Proposal Generator according to agents' various preferences and enters the Negotiation Process phase. During the negotiation process, each agent will select the acceptable proposal from all the proposals. The agents then submit this proposal and make efforts to reach a consensus with other agents. If there is a consensus among all the agents on a specific proposal, this proposal becomes the final agreement proposal and the Negotiation ends. If the attempt to reach a consensus has been unsuccessful, the System goes to Argumentation process where agents create arguments according to their own beliefs, and proceed with Argumentation with other agents. After the Argumentation phase comes the Belief Evolution, where beliefs are updated and intensified according to the outcome of Argumentation. The system then goes back to the start and proceeds with the next negotiation, re-evaluating proposals until a general consensus is reached.

#### A. Negotiation Mechanism

TABLE 1 DEFINITION OF NEGOTIATION SYMBOL

| Symbol                 | Definition                                                             |
|------------------------|------------------------------------------------------------------------|
| $bp_i$                 | The most suitable proposal for agent <sub><i>i</i></sub> .             |
| $bp_i'$                | The most personally effective proposal for agent <sub><i>i</i></sub> . |
| $P$                    | Negotiation proposal.                                                  |
| $NS$ (Negotiation set) | The set of available proposals.                                        |
| $T_i$                  | The proposed proposal by agent.                                        |
| $Utility_i$            | The utility of the agent for the proposal.                             |
| $Risk_i$               | The risk of the agent.                                                 |

The so called Negotiation is a series of interactions performed by a group of conflicting agents when they need to work together, finding a way they all agree to allocate limited resources within an environment. The complete definition of Negotiation Symbol is shown in Table 1. During the process of Negotiation, agents select a proposal for the agent negotiation from existing proposals through a specific evaluating method. The purpose of Negotiation is to reach a consensus, and different negotiating proposal may have different value for the objects within the negotiation. The entire agent proposal can be defined by the equation (1).

$$P = \{ (issue.name, issue.value) \mid issue, issue \in NO \} \quad (1)$$

The NO represents the entire Negotiation object; where issue is an issue within the Negotiation object. Agents select the best proposal by evaluating the best utility as a whole from those that have the highest utility. The expression for evaluating the utility of a proposal is presented in expression (2).

$$Utility_k(P) = \frac{\sum_{i=1}^N \sum_{j=1}^M f_j(issue_i)}{\max(LevelPriority_k \mid K \in M) * N} \quad (2)$$

The system obtains the agent's preference on  $issue_i$  based on  $f_j(issue_i)$ .  $issue_i$  represents the  $i$ th issues of the agent; where  $f_j$  represents the level of  $j$ th preference time of the  $issue_i$ . In the equation (2),  $k$ ,  $N$ ,  $M$ , and  $LevelPriority$  are used to represent the agent number, the number of issues agent  $k$  has, the number of time level of the agent  $k$ 's preference and assign weighting values according to its Level respectively.  $\max$  and  $\Sigma$  are used to present the maximum value within a group and its summation. Evaluating with equation (2), the agent can then evaluate which proposal has the highest utility for itself.

The raising of a proposal is based on an agent's individual preference. The utility degree the agent evaluates on in this proposal is the preference this proposal has for this agent. We can divide the level of preference into different levels according to how strong it is, and average them evenly as a general utility of the proposal.

$$bpi = \{P \mid P \in bpi' \text{ and } Utility(P) = \max \{ Utility(P') \mid P' \in bpi' \} \} \quad (3)$$

Equation (3) evaluates the proposal that is most suitable for agent  $i$ . Agents decide whether to join  $bp_i$  based on the utility of each proposal. The proposal of  $bp_i$  will be submitted as a negotiating proposal during the negotiation and then be joined into  $T_i$ , which records every proposal agent submitted. The Negotiation Set is a set of all the available proposals. If the set is not empty, it means there is at least one proposal on which there exists a general consensus among all the agents.

To select which agent to concede during the negotiation, it is often decided by figuring out which agent has the lowest risk value. The risk value is evaluated by how much utility an agent will lose during the concession, as shown in equation (4). The equation calculates the maximum cost of giving in to other agent's proposal and the utility of its own proposal in order to obtain how much the agent will lose. This is the risk value for concession.

$$Risk_k = \frac{(Utility_k(SP_k) - \min(Utility_k(SP_j) \mid K \in N))}{Utility_k(SP_k)} \quad (4)$$

The *priority* is the calculation of *priority* value according to the teacher's teaching years and its job title;  $N$  is the number of selected proposals submitted by other agents.  $SP_k$  (Selected Proposal) is the negotiation proposal submitted by the  $k$ th agent during this round of negotiation. If there are many agents that share the same lowest risk value, the selection of which agent to concede will take turns in fair. In that case, the agent that has conceded for the least times in history will be selected.

### B. Argumentation Mechanism

In order to pass on additional information between agents, the Negotiation system relies on the argumentation system to generate arguments and to evaluate them. [1][2][3][11][12].

For the architecture in this paper, the purpose behind the agents submitting argument contents is to persuade others in the negotiation. The content of the submitted argument by the agent is a series of reasoning principles intended to praise the benefits of its own argument. The argumentation content  $A$  is represented by formula (5).

$$A = (H, h) \quad (5)$$

The purpose of the argumentation system is to provide agents with the ability to evaluate and generate arguments. Our research extended the argumentation system in [3] to generate suitable arguments using reasoning principles according to agents' beliefs, and to provide conflicts between beliefs in order for the agents' beliefs to evolve after argumentation. It also assigns priorities to beliefs that help the agents to compare them more easily.

$A$  represents the argument content.  $H$  is the knowledge set that the reasoning is based on.  $h$  is the reasoning-formed conclusion. The knowledge includes the reasoning principle knowledge base available for the agents; the argumentation content is the set of used reasoning principles. When the arguments submitted by different agents in the system clash with each other, use *Undercut* to resolve the conflict, as shown in equation (6) and (7). Assume  $(H1, h1)$ ,  $(H2, h2)$  to be two arguments.

$(H1, h1)$  undercuts  $(H2, h2)$ :

$$(1) \text{ If } h1 \equiv h2 \text{ or If } \exists h \in H2 \text{ such that } h \equiv h1, \quad (6)$$

Using Rule of Inference.

$$(2) \text{ Undercut} = \{(A_i, A_j) \mid A_i, A_j \in \text{Arguments}\} \quad (7)$$

For example,  $A_i$  and  $A_j$  represents two arguments respectively, where  $A_i$  undercuts  $A_j$  as in equation (7).  $A_i$  is  $(H1, h1)$ , and  $A_j$  is  $(H2, h2)$ . The two arguments, based on (6):

$h1 \wedge h2 \Rightarrow \text{False}$ , If  $h \in H2$ ,  $h \wedge h1 \Rightarrow \text{False}$ ,  
 $(H1, h1)$  can then refute  $(H2, h2)$ .

For example, in equation (7),  $A_i$  and  $A_j$  represents proposal by agent  $i$  and  $j$ , respectively. The  $A_i$  submitted by agent  $i$  is  $P$ . By using the *Modus ponens*:  $\{P, PQ\} \vdash Q$  in (6), agent  $j$  can submit  $A_i$  as  $Q$ , and  $A_i$  undercuts  $A_j$ .

This ordering is considered the priority of *Knowledge Preference*. The definition of argumentation symbol is shown in Table 2.

TABLE 2 DEFINITION OF ARGUMENTATION SYMBOL

| $\langle A(\Sigma), \text{Undercut}, \text{Knowledge Preference} \rangle$ |                                                                               |
|---------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| $\Sigma$                                                                  | The knowledge base.                                                           |
| $A(\Sigma)$                                                               | Output the suitable arguments for the agent according to the given $\Sigma$ . |
| <i>Undercut</i>                                                           | Describes the conflicts between arguments.                                    |
| <i>Knowledge_Preference</i>                                               | Divide the available knowledge into several prioritized levels.               |

During the process of argumentation, agents can submit, query, and accept proposal by other agents. Agent submits a new proposal  $P$  by *assert*( $p$ ); query other agents' proposal by *question*( $p$ ), and accept other's proposal using *accept*( $p$ ).

In the agent argumentation process, each argumentation is preceded with two agents, submitting proposal in turns. For those conflicting items, both agents are required to explain the reason of their own once. The proposal of both agents and other's that passes the argumentation wins. For the agent that loses, its belief needs to be updated and intensified.

### III. NEGOTIATION AND ARGUMENTATION PROCESS

Negotiation process uses the conceding policy shown in Figure 2. If the negotiation fails, the system will enter argumentation process shown in Figure 3. Upon the completion of the argumentation, the beliefs are updated and the next round of negotiation begins.

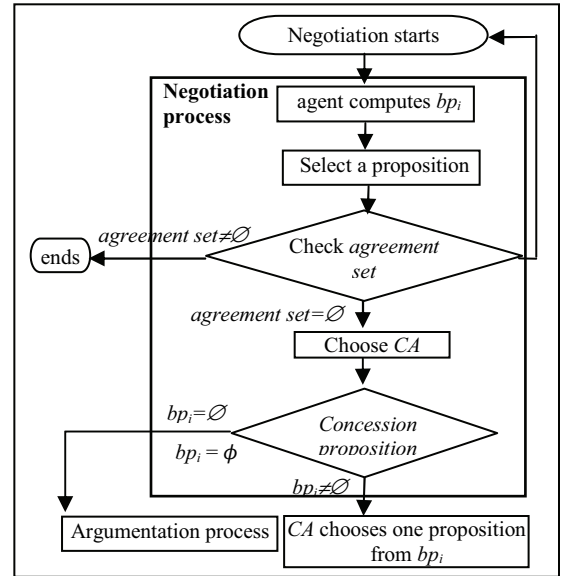


Figure 2 Negotiation process

#### A. Negotiation Process

This research proposes the negotiation process as follows:

- The agent calculates the utility value of the proposal. Select the proposal that best meets the agent requirement standards based on the utility value to form  $bp_i$ .
- Each agent chooses a proposal from  $bp_i$  to submit. The submitted proposal is then removed from  $bp_i$  and added to  $T_i$ .
- Evaluate whether the Negotiation Set is empty; if it is not empty, then at least one consensus has been reached, and the negotiation ends.
- Calculate the risk value of each agent. The agent with the least risk value will concede in the next turn. If numerous agents share the same minimum risk value,

the system chooses the agent who has conceded for the least times in the past to concede.

- The conceding agent then checks if  $bp_i$  is empty. If it is, which means that the agent does not have any other proposals that meet the requirements during this negotiation, it enters the argumentation process.
- On the other hand, if  $bp_i$  is not empty, choose a proposal from it. The chosen one should be the proposal that hasn't been submitted before, and goes back to step 1 to continue the negotiation.

### B. Argumentation Process

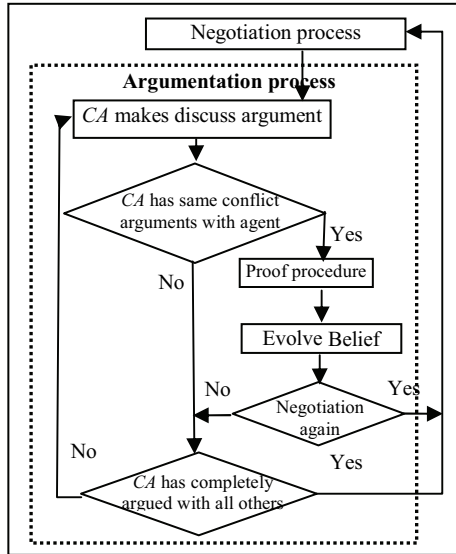


Figure 3 Argumentation process

The proposed argumentation process is specified as follows: (1) The conceding agent picks agent<sub>i</sub> who has the minimum risk value during negotiations, and compare the value for any conflicting issues. (2) The two agents search for any conflicting issue between them. If there is a conflicting issue, proceed with argumentation on this conflicting issue; if there is not, the conceding agent checks whether it has completed argumentations with all the other agents. (3) If the arguments conflict each other, use the argumentation reasoning. (4) The agents that fail the argumentation must evolve their beliefs. (5) After evolving, the failed agents re-check whether the negotiation can be carried on again. (6) Checking whether the conceding agents have completed argumentations with all the others. If they all have, the process goes back to the negotiation process and proceeds with the next negotiation; otherwise, it goes back to negotiation process step 1 and continues with argumentations.

### C. Belief Evolvment

During the argumentation process, the agents pass on the argument to each other. The failed agents in the argumentation process get persuaded, and their beliefs must be evolved. The process includes: (1) Acquire the conflicting relations between beliefs through argumentation system. (2) Evolve the agent's

belief according to the conflicting relations and the obtained results. (3) Remove the conflicting relation from the agent's belief. (4) Adjust and evolve the agent's belief.

## IV. CASE STUDY

This paper uses a simple course-scheduling system to illustrate our negotiation and argumentation architecture written by Java and Jade (Java Agent Development Framework). A teacher represents the equivalence of a negotiation agent in this system, and each teacher obtains a suitable school timetable scheduling through negotiations.

A central coordinator obtains the preference time of each teacher agent, and with the help of the general school timetable generator, it submits a general school timetable proposal. For each teacher agent involved in the negotiation, according to this general timetable, each of them forms their own set of proposals. Based on the timetable set, the teacher agent submits proposal to the central coordinator, who then checks if any consensus can be reached within all the submitted proposals submitted by fellow agents. If there is no consensus, the conceding generator will decide which agent to concede. The conceding agent will carry on with the next round of negotiation later on, until a consensus has been reached.

### A. Agent Belief

In this paper, agent's preference, and their thoughts on the available proposals affect how agents choose the negotiating proposal. We classify agent's preference into their beliefs. The agent can provide others with how it thinks about each proposal, making others' proposals more suitable to itself. The teacher agents' beliefs can be set by themselves; the beliefs are represented in XML, which includes the following elements: (1) Course: The courses name. (2) Degree: Agent's preference over the course timetable scheduling. Smaller value means higher preference; Degree = 1 represents the favorite time schedule. (3) Time\_Preference: The preferred time schedule of the teacher. Each Time\_Preference includes the ArgumentDep of the related arguments. (4) ArgumentDep: The arguments related to teachers' preferred time schedule, associated with the arguments in argumentation. (5) Argumentation: The argument that the agent (teacher) holds, which is classified into "Arguments" and "Counter-Arguments". (6) Arguments: The argument of the agent (teacher) its own. (7) Counter-Argument: Refute the argument of other agents.

TABLE 3 CANDIDATES PROPOSALS

| Proposal Number<br>Course Name | 1                   | 2                   | 3                   | 4                  | 5                   |
|--------------------------------|---------------------|---------------------|---------------------|--------------------|---------------------|
| Web 2.0                        | Monday, afternoon   | Tuesday, afternoon  | Thursday, morning   | Monday, afternoon  | Monday, afternoon   |
| Network Fundamental            | Tuesday, afternoon  | Friday, morning     | Friday, afternoon   | Thursday, morning  | Friday, morning     |
| Algorithm                      | Monday, morning     | Monday, morning     | Monday, morning     | Monday, morning    | Monday, morning     |
| Linear Algebra                 | Wednesday, morning  | Thursday, morning   | Friday, morning     | Friday, afternoon  | Tuesday, afternoon  |
| Java                           | Thursday, afternoon | Thursday, afternoon | Thursday, afternoon | Tuesday, morning   | Thursday, afternoon |
| AI                             | Tuesday, morning    | Wednesday, morning  | Monday, afternoon   | Wednesday, morning | Friday, afternoon   |

The agent belief includes its preferred time and the school timetable. The time format includes the day of the week and whether it's in the morning or afternoon. The purpose of negotiation is to arrange the course timetable for each teacher agent, therefore the issue contained in the proposal of the agent is the course schedule. The complete proposal candidates are listed in Table 3, where five course schedules are designated with the day of the week, and the time during the day.

The argumentation system allows the agents to generate suitable arguments. With specific information, agents can predict the arguments, conflicting knowledge relations, and knowledge usage level. The course schedule is the focus of argumentation among teacher agents in this experiment, which begins after negotiation fails to reach consensus. If two teachers have same preference over certain schedules, they must provide with the reasons behind their choices. This paper designs the possible reasons behind teacher's preference over the schedule and assigns priority according to these reasons' characteristics. This priority is the *Knowledge\_Preference*. The process of assigning priorities can be discussed in public, or be decided by an unbiased third-party. Next we design possible preference reasons and their *Knowledge\_Preference*. The reasons why having lower *Knowledge\_Preference* value is better are: (1) Having regular executive meetings: ExecutiveCouncil (Agent, Time), Knowledge\_Preference: 1. (2) Agent having courses from other department: HasCourse(Agent, Time), Knowledge\_Preference: 2. (3) Single family: SingleFamily (Agent), Knowledge\_Preference: 3. (4) Picking up kids from and to school: SendChildToSchool(Agent, Status), Knowledge\_Preference: 4. (5) Preference over a schedule: Prefer(AgentName, (day, time)). (day, time) is the time the agent wishes others to concede, Knowledge\_Preference: 5. (6) How intense the agent wishes the schedule to be: DaysOfCourse(Agent, Density), Knowledge\_Preference: 6.

### B. Negotiation and Argumentation Process

During the negotiation process, agent needs first to select the target proposal and then proceed with the argumentation in order to evolve its beliefs. Finally, it obtains the negotiation-argumentation result. Using the utility equation below, we can calculate the utility value that each agent can obtain for all the proposals in this round. They are listed in Table 12. We assume that the agent will set the proposal with the highest utility value as the most suitable proposal ( $bp_i$ ), as Table 13 illustrates.

In round 1, teacher A chooses proposal 2, teacher B chooses proposal 1, 2, and teacher C chooses proposal 1. Obviously, in the first round, there are no proposals that can satisfy all the agents. Risk values of agents in round 1 are A: 0.17, B: 0 and C: 0.17. B has the lowest risk of all, so B has to concede in the first round. B submits another proposal for the next round, and other agents propose the same proposal on the next round. There is still no consensus in this round. Risk values of agents on round 2 are A: 0.17, B: 0 and C: 0.17. B has the lowest risk of all, and B has to concede in the second round. B's  $bp_i$  is empty, which means there is no proposal, so the negotiation process enters the argumentation process. B in the argumentation continues to concede. B argues with A.

Based on the teacher's beliefs, both of them prefer Monday morning. B cast out reasons why it loves this particular time.

- B asserts SendChildToSchool(B, AfterClass).
- A asserts  $\neg$ SendChildToSchool(B, AfterClass).
- B Supposes  $P=\text{SendChildToSchool}(B, \text{AfterClass})$ . P asserted by A,  $P=\neg\text{SendChildToSchool}(B, \text{AfterClass})$ . Teacher B according to Modus ponens  $\{\{-P, P\vee Q\} \vdash Q\}$ , inference  $Q=\text{SingleFamily}(B)$ , then asserts SingleFamily (B).
- A accepts SingleFamily (B).

TABLE 4 THE EFFECTIVENESS OF AN AGENT TO RE-CALCULATE THE VALUE OBTAINED

| Teacher \ Proposal Number | 1 | 2    | 3    | 4    | 5    |
|---------------------------|---|------|------|------|------|
| A                         | 1 | 1    | 0.67 | 0.83 | 0.83 |
| B                         | 1 | 1    | 0.83 | 0.83 | 0.83 |
| C                         | 1 | 0.83 | 0.83 | 0.83 | 0.67 |

Finally, agent A won the argumentation. B evolves its beliefs, and makes a concession on the Monday morning time and removes it from its belief. Next, B selects from the preference of session degree two which is the closest to Monday. After teacher B updated its beliefs, the perceptions of the environment are changed, and the assessment of the proposal on the curriculum will be different. All agents recalculate *Utility* value and the  $bp_i$  for the curriculum proposal in Table 4, and check whether to continue with the negotiations.

Return to the negotiation process. During round 3, teacher A chooses proposal 1, teacher B chooses proposal 1 and teacher C chooses proposal 1. The negotiation focuses on a proposal to find an agreement, and the agent concludes the negotiations. Proposal is a schedule that can be used as a school curriculum and is acceptable to all the teachers. All agents make their own proposals for the most desired curriculum at the beginning of the negotiation. After a few concessions, if it is still unable to reach consensus on the proposal, the negotiations breaks down. So that agents can use the argument mutual understanding of each other's needs and then update the agent's beliefs. The proposals will close other agent's demands in next round of consultations.

We compared method [15] with this study. In research [15], if the proposal set is empty, the agent withdraws from negotiation. Because conventional trading negotiation will not change agent's beliefs, an agent will not interact with other agents of change in spite of understanding the environment. In our method, agents interact with other agents. This allows a better understanding of the needs of others, further changing the perceptions of the environment and updates their beliefs. For example, after the teacher argumentation, B is persuaded by A, and B will change its beliefs. The curriculum for the proposal in Table 1 candidate proposals will have a different assessment.

TABLE 5 THE FINAL PROPOSALS

| Teacher \ Approach | Negotiation | Negotiation and Argumentation |
|--------------------|-------------|-------------------------------|
| A                  | 1           | 1                             |
| B                  | 1           | 1                             |
| C                  | 0.83        | 1                             |

Table 5 shows the argumentation and negotiation of the final proposal with their values for comparison. In the traditional negotiation method, if there is no more proposal that can be chosen, the negotiation process would be withdrew. In this experiment, the final outcome of the negotiations is proposal 2. However, C is not very satisfied with proposal 2. A evolves its beliefs through argumentation; the proposal 2 may be accepted. Proposal 1, which satisfies all the agents, is the best result of the negotiation. After adding the argumentation method in negotiation, agents can interact with other agents and obtain more information and evolve their beliefs and then cause the perceptions of the environment to change. The agent who withdraws from the negotiation can re-evaluate the proposal, and goes back to the negotiation process once again to put forward a new proposal. Conceding agents can put forward new proposals more in line with all the agents.

## V. CONCLUSION

Many research papers have addressed to the problem of agents' decision making accuracy being affected by the incomplete environment information in multi-agent systems. Through negotiation and argumentation, this paper makes agents understand others in the environment better, further achieving the evolvement of their beliefs.

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