Extending Contract Net Protocol for Arguing Agents

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Abstract. Negotiation is a technique through which two agents having conflicting interests reach an agreement that is beneficial for both of them. Argumentation-based negotiation is a better form of negotiation where one negotiating agent argues with another to justify its position and influences the other agent to follow it. This increases the likelihood and quality of agreement in a negotiation process. In this paper, we present an interaction protocol to support argumentation-based negotiation in agent-based e-commerce. We extend the widely used Contract Net protocol for the purpose with a set of performatives essential for argumentation scenario.

Keywords: Contract Net Protocol, Interaction Protocol, Argumentation-Based Negotiation, Automated Negotiation, Agent-based E-Commerce

1. Introduction

Multi-agent system has been recognized as a promising technology for next generation e-commerce applications. Agent-based e-commerce automates several of the business processes and thereby reduces transaction time and cost. Negotiation is an essential requirement not only in e-commerce but also in multi-agent systems. Negotiation provides satisfactory agreement between the trading partners involved in the commerce activity. Negotiation process varies in duration and complexity depending on the business context. In a multi-agent e-commerce buyer and seller agents negotiate intelligently on behalf of their human counterparts. Considering the complexity of human negotiation process, automated negotiation has been a major research challenge. There are three primary approaches to automated negotiation found in multi-agent literature. These are Game-theoretic approach [15], Heuristic-based approach [3, 6] and Argumentation-based approach [4, 7]. As claimed in [2] game-theoretic and heuristic-based approaches have many limitations. In game-theoretic and heuristic approaches agents’ preferences are fixed, complete and correct. Agents cannot influence on other agents’ preferences or internal mental attitudes. Both the approaches allow agents to exchange proposals but do not allow the agents...
to express any meta-information. Agents in these approaches have complete information. They know the space of possible deals and also know how to evaluate such deals. However, in real-life negotiation agents often have incomplete information, which makes their preferences incorrect and incomplete. This incomplete information also limits an agent’s capability to evaluate a deal. These limitations are overcome in argumentation-based approach to negotiation. Argumentation-based approach enables flexibility in agents’ cognitive states and behavior. These rational agents exchange additional information along with their proposals and argue about it. They modify their preferences on receiving new information from their peers. Through argumentation an agent justifies its negotiation stance and influences another agent’s negotiation stance [5]. Thus it makes negotiation more efficient and is found to be more popular in agent-based negotiations.

In an open multi-agent system like e-marketplace the buyer and seller agents are inherently heterogeneous in their designs and are dispatched from different computers on the Internet [8]. Their beliefs, desires and intentions (BDI) [19] may not coincide. So they cooperate with each other and negotiate on issues. They exchange messages to seek information, persuade each other and justify their positions in a negotiation process to reach an optimal deal. Multi-agent interactions require agent communication languages (ACLs) to specify messages and interaction protocols (IPs) to sequence these messages. The most widely adopted and the leading standard FIPA specifies agent communication language FIPA ACL [9] and several interaction protocols for multi-agent interactions. Since performatives and protocols contained in the FIPA specifications are not exhaustive, they do not support argumentation scenarios. In this paper, we identify a set of performatives missing in FIPA ACL that is essential for argumentation. Then using these performatives, we propose an interaction protocol for argumentation-based negotiation in e-commerce environment. We extend the widely used Contract Net protocol (CNP) for the purpose.

In the next section, we discuss the related work and compare with our approach. Section 3 briefly describes the Contract Net protocol. Section 4 presents the extended Contract Net protocol and provides semantics to the new performatives suggested. In section 5, we illustrate the working of the extended protocol with a real world negotiation scenario and then, conclude the paper.

2. Related Work

Recent literature on multi-agent systems reveals that there is a demand for design of ACLs and IPs for argumentation-based negotiation [11, 12, 13, 14]. In [11] Leila Amgoud et al. proposed an ACL with a set of performatives to capture the different types of dialogues using a formal model of argumentation. A two-layer semantics similar to [16] is used for the performatives. The semantics combine a mentalistic approach and a social approach. The mentalistic approach is concerned with the argument generation and evaluation. The social approach deals with a private commitment store that captures the state of the dialogue in an agent. While this
approach may provide a flexible protocol as claimed, the concept of commitment store and its updation seems to be computationally complicated.

The communication language proposed in [13] uses the negotiation system of [17] and a persuasion dialogue game protocol where an agent uses speech acts to attack or surrender. The agent only argues for the rejection of an offer it makes. It does not cooperate with the other agent to find a better proposal. The dialogue is not guaranteed to terminate, since the opponent can always continue challenging the proponent’s premises.

A protocol called Fatio is proposed in [12] where five legal locutions considered necessary for argumentation are defined. It uses both an axiomatic semantics for beliefs and desires of the agents and an operational semantics for the dialogue moves. Associated with the semantics is a publicly viewable store to record dialectical obligations of an arguing agent. It also suggests combination rules for locutions as part of the protocol. In the protocol, the agent uttering assert or justify can withdraw its statement by uttering retract when questioned or challenged by another agent. The agent, who questions only listens the justification from the proponent. The protocol does not provide specific locution for the questioning agent to accept the justification made by the asserting agent. Thus, the protocol is too generic. Since in e-commerce environment any participating agent can submit itself before the other during argumentation, we note that Fatio protocol may not be able to capture the scenario well.

Our proposal aims at a protocol, which is extended from FIPA CNP [24] to support argumentation in e-commerce environment. The protocol not only helps agents to argue for the rejection of an offer, but also allows them to cooperate with each other for a better offer. Also, the protocol can be implemented conveniently while addressing the richness of argumentation-based negotiation desired by the domain.

3. The Contract Net Protocol

The Contract Net protocol was originally proposed in [23]. It specifies problem-solving communication and control for nodes in a distributed problem solver. The CNP has been a widely used protocol in distributed artificial intelligence due to the fact that it is a flexible and low communication interaction protocol for task assignment. FIPA has adapted the CNP with minor modification by adding rejection and confirmation communicative acts [24]. Currently, the FIPA CNP is available in major agent platform implementations like [25]. Fig. 1 shows an UML diagram for this protocol.

In the Contract Net protocol one agent called initiator wishes to have some task performed by one or more other agents called participants. The initiator agent sends a \textit{cfp} (call for proposal) message that includes a task description to all the participants. For a given task, any number of participants may respond with a proposal, while the
rest must refuse. Once the deadline passes the initiator evaluates the received proposals and selects one or more agents to perform the task. The selected agents receive an *accept-proposal* message while the rest receive a *reject-proposal* message. Once the initiator accepts a proposal, the participant commits to perform the task. When the participant completes the task it sends an *inform* message to the initiator. The participant sends a *failure* message in case it fails to perform the task.

Fig. 1: UML diagram for Contract Net protocol

The protocol enables an agent to distribute a task among several other agents through a *cfp* and then accepting or rejecting proposals. However, the protocol does not permit the agents to argue for the proposal rejection. Thus, FIPA CNP is not suitable for scenario where argumentation drives the negotiation process.

4. Extended Contract Net Protocol

To extend the Contract Net protocol we identify a minimal set of performatives that essentially captures the different types of dialogues in an argumentation scenario and is missing in FIPA ACL. The performatives in the set are:

\{withdraw, claim, challenge, justify, concede, retract\}

Additionally, to facilitate cooperation and BDI exploration, we identify two performatives *query-ref* and *inform*. These performatives are available in FIPA ACL and are useful for finding a better proposal in the proposed protocol.
4.1 Semantics of Performatives

The formal semantics of the performatives follow the semantic language (SL) used in FIPA ACL specification [9]. In this formalism, α, φ, ψ are closed formula schemes which stand for any closed propositions; i, j are schematic variables which denote agents. The mental model of an agent is based on the three primitives: belief (what the agent knows or can know), intention (which is defined as a persistent goal that leads to some actions) and uncertainty. These are formalized by modal operators B, I and U respectively and can be read as:

\[ B_i \phi \text{ agent } i \text{ believes } \phi; \quad I_i \phi \text{ agent } i \text{ intends } \phi; \quad U_i \phi \text{ agent } i \text{ is uncertain about } \phi. \]

To enable reasoning about actions the operator \( \text{Done}(a, \phi) \) means that the action \( a \) takes place when \( \phi \) is true. The symbol \( \text{Bif } \phi \) means that either agent \( i \) believe \( \phi \) or that it believes \( \neg \phi \). The symbol \( \text{Ref } x \delta (x) \) is a definite descriptor. Generally, the components of a communicative act (CA) model are involved in a planning process. It contains a feasibility precondition (FP) and a rational effect (RE). The FP has to be satisfied for the act to be planned by the sender agent of the CA. The RE has an effect on the receiver agent and is termed as the post condition of the CA.

Thus, a CA model is represented as follows:

\[ < i, \text{act} (j, C) > \]
\[ \text{FP: } \varphi_1 \]
\[ \text{RE: } \varphi_2 \]

Where \( i \) is the sender agent of the act, \( j \) is the receiver agent, \( \text{act} \) the name of the act, \( C \) stands for the semantic contents and \( \varphi_1 \) and \( \varphi_2 \) are propositions.

I. Withdraw

**Description**: Withdraw allows an agent to withdraw from the interaction and explain the reason thereof. A sender agent \( i \) informs the receiver \( j \) that it no longer has the intention for an act once the precondition is true. The proposition given as a part of withdraw indicates the precondition that the agent is attaching to the withdraw (for example, so much time expires).

**Formal Model**:

\[ <i, \text{withdraw} (j, <i, \text{act}>, \varphi) > = \]
\[ < i, \text{disconfirm} (j, I, \text{Done}(<i, \text{act}>, \varphi)) > \]
\[ \text{FP: } \neg I_i \text{Done}(<i, \text{act}>, \varphi) \]
\[ \text{RE: } B_i \neg I_i \text{Done}(<i, \text{act}>, \varphi) \]

II. Claim

**Description**: An agent does this to support some previously submitted proposal and justifies it if challenged. Claim indicates that the sending agent believes that some proposition is true that corresponds to a descriptor; intends that the receiving agent
believes the proposition; believes that the receiver is uncertain of the truth of the proposition.

Formal Model:

\[ \langle i, \text{claim} ( j, \text{Ref} x \delta (x) ) \rangle = \]
\[ \langle i, \text{inform} ( j, \text{Ref} x \delta (x)=r_1 ) \rangle | \ldots | \]
\[ \langle i, \text{inform} ( j, \text{Ref} x \delta (x)=r_k ) \rangle \]

FP: \( B_i \varphi \land B_j \varphi \)
RE: \( B_j \varphi \)

Where \( \varphi = \text{Ref} x \delta (x) \)

III. challenge

Description: It is the act of attacking another agent on a proposition. Challenge indicates that the sending agent does not believe some proposition, which the receiver believes and informs that another proposition is true; intends that the receiving agent believes this proposition is either true or false; believes that the receiver is uncertain of the truth of this proposition.

Formal Model:

\[ \langle i, \text{challenge} ( j, \alpha, \varphi ) \rangle = \]
\[ \langle i, \text{inform} ( j, \neg \alpha, \text{Ref} x \delta (x)=r_1 ) \rangle | \ldots | \]
\[ \langle i, \text{inform} ( j, \neg \alpha, \text{Ref} x \delta (x)=r_k ) \rangle \]

FP: \( B_i \neg \alpha \land B_j \varphi \land B_j U_j \varphi \)
RE: \( B_j \varphi \)

IV. justify

Description: It is the act of supporting a claim made earlier. Justify indicates that the sending agent believes some proposition is true with respect to some previous claim; intends that the receiving agent believes the proposition is either true or false; believes that the receiver is uncertain of the truth of the proposition.

Formal Model:

\[ \langle i, \text{justify} ( j, \alpha, \varphi ) \rangle = \]
\[ \langle i, \text{inform} ( j, \alpha, \text{Ref} x \delta (x)=r_1 ) \rangle | \ldots | \]
\[ \langle i, \text{inform} ( j, \alpha, \text{Ref} x \delta (x)=r_k ) \rangle \]

FP: \( B_i \alpha \land B_j \varphi \land B_j U_j \varphi \)
RE: \( B_j \varphi \)

V. concede

Description: It is the act of accepting a previously rejected proposal. Concede indicates that the sending agent believes some proposition is true. It informs the receiving agent that it intends that the receiving agent will perform the action once the given precondition is true.
Formal Model:
\[ i, \text{concede} (j, \alpha, <j, act>, \varphi) \equiv i, \text{inform}(j, \alpha, I_i \text{Done} (<j, act>, \varphi)) \]
FP: \( B_i \alpha \land B_j \psi \)
RE: \( B_j \psi \)
Where \( \psi = I_i \text{Done}(<j, act>, \varphi) \)

VI. retract

Description: It is the act of taking back a proposal previously made. Retract indicates that the sending agent believes some proposition is true and due to this fact it informs the receiving agent that it intends not to perform an action.

Formal Model:
\[ i, \text{retract} (j, \alpha, <i, act>) \equiv i, \text{inform}(j, \alpha, \neg I_i \text{Done}(<i, act>)) \]
FP: \( B_i \alpha \land B_j \psi \)
RE: \( B_j \psi \)
Where \( \psi = \neg I_i \text{Done}(<i, act>) \)

4.2 Protocol Specification

We specify the protocol in UML following [22]. The negotiation process starts with an initiator agent uttering a \textit{cfp} performative. The protocol may terminate with either the initiator agent or the participant agent uttering \textit{withdraw} performative during the negotiation. Withdrawal from the negotiation may happen either when a specified time elapses or due to some mental state of the agent is met. The protocol also terminates when a participant utters \textit{retract} or \textit{refuse} performative. When the initiator agent accepts a proposal or concede to it after some arguments, a participant agent utters either \textit{inform} or \textit{failure} performative to end the negotiation process. Thus, the protocol is guaranteed to terminate that avoids deadlock and may lead to a negotiation that is either successful or unsuccessful. To facilitate a successful negotiation, the protocol provides provision for BDI exploration. If the initiator agent rejects a proposal, the participant agent explores the BDI of the initiator agent through \textit{query-ref} performative and seeks information. This enables the participant agent to offer a better proposal similar to real world negotiations. The UML diagram for the protocol is given in Fig. 2. To ensure that the arguments exchanged during the negotiation process are coherent and consistent [20], necessary negotiation mechanisms have to be in place to evaluate the arguments. However, this thread of the research is beyond the scope of the paper.
4.3 Discussions

Our approach is novel as it neither produces a complete new protocol nor a new ACL. It simply makes use of the existing standard FIPA to support argumentation. Since FIPA CNP is available in many FIPA compliant agent development platforms, implementation of our protocol is relatively easier than other protocols discussed in section 2. Although, we have taken an example from e-commerce to explain the working of the protocol, we believe that the protocol is not limited to this domain only. Considering the generic nature of the FIPA CNP, the protocol can be used to tackle general negotiation scenarios in other domains also. Another significant aspect of our protocol is that it includes performatives such as `query-ref` and `inform`. These performatives allow the participant agent to understand the mental state of the initiator agent so that the participant agent can provide better proposals towards a satisfactory negotiation. These performatives along with others such as `claim`, `challenge` and `justify` handle the diversity of individual preferences and conflicts thereof, to help the agents maximize their individual utility in the negotiation outcome.
5. Working of the protocol

We present an example of a dialogue game between a buyer agent (B) and a seller agent (S) those are engaged in a car-trading scenario to illustrate how argumentation-based approach to negotiation works in practice following our protocol.

1. B: cfp (car=new ∧ model=Maruti800 ∧ price=?)
(I want to buy a new Maruti 800 car. How much is the price?)

2. S: propose (car=new ∧ model=Maruti800AC ∧ price=2.5 lakhs)
(I can provide a new car of Maruti 800AC at price Rs.2.5 lakhs.)

3. B: reject-proposal ((car=new ∧ model=Maruti800AC ∧ price=2.5 lakhs); (price=high))
(No, the price is high for me.)

4. S: query-ref (budget=?)
(What is your budget?)

5. B: inform (budget <= 2.1)
(The budget is within Rs.2.1 lakhs)

6. S: propose (car=new ∧ model=Maruti800NonAC ∧ price=2.1 lakhs)
(I can provide a new car of Maruti 800 Non-AC at price Rs.2.1 lakhs.)

7. B: reject-proposal ((car=new ∧ model=Maruti800NonAC ∧ price=2.1 lakhs); (model=Maruti800AC))
(No, I want Maruti800AC only)

8. S: query-ref (car-usage=?)
(How will you use the car?)

9. B: inform (car-usage = go-to-office ∧ distance = 7 km)
(I shall use the car to go to office that is 7 km away from my residence)

10. S: propose (car = used-car ∧ old=2 years ∧ model=Maruti800AC ∧ price=2.0 lakhs)
(I can provide a 2-year old used-car of Maruti800AC at price Rs.2.0 lakhs)

11. B: reject-proposal ((car = used-car ∧ old=2years ∧ model=Maruti800AC ∧ price=2.0 lakhs); (quality=bad))
(No, used-cars are not good)

12. S: claim (car= Maruti-certified ∧ quality=good)
( Maruti-true-value certifies good quality used-cars)
(I do not agree with your claim. Ramu’s car is not a good quality car.)

14. S: *justify* ((car-no=AP13E1927 ∧ old=5years ∧ problem=maintenance); 
(guarantee=yes))  
(That car is 5 years old and has maintenance problem. Don’t bother, the company provides guarantee for quality)

15. B: *concede* (car=Maruti-certified ∧ old=2 years ∧ model=Maruti800AC ∧ price=2.0 lakhs ∧ guarantee=yes)  
(Okay, I accept the Maruti certified used-car of 2 years old; model Maruti800AC, at price Rs.2.0 lakhs with guaranteed quality)

In the 4th and 8th dialogues the seller agent seeks information to provide a better proposal after understanding the mental attitudes of the buyer agent. In the 12th, 13th, and 14th dialogues the agents persuade each other to accept each one’s position. Let us consider the 13th dialogue of the buyer as follows:

13. B: *challenge* (car= Maruti-certified ∧ survey=AutoCar ∧ quality=bad)  
(I do not agree with your claim. The AutoCar magazine published a customer survey, which reveals that 70% of the customers are not satisfied with the used-cars delivered by Maruti.)

Since AutoCar is a popular magazine, hearing this, the seller might utter:

14. S: *retract* (car=Maruti-certified ∧ old=2 years ∧ model=Maruti800AC ∧ price=2.0 lakhs)  
(Okay, I take back the offer. May be the used-cars are not of good quality.)

In this case the protocol terminates with an unsuccessful negotiation. However, in an iterative version of the protocol *retract* performative may lead to the utterance of *cfp* performative to continue the process again, in search of an agreement that may lead to a successful negotiation.

### 6. Conclusions

Humans form their BDI based on the information available with them. This BDI is modified through social interactions among them. The interactions enable them to jointly discover possible ways to satisfy mutual interests. It increases both the likelihood and quality of agreement in a negotiation process. Thus, the benefits of argumentation are apparent in human negotiations.

Similarly, argumentation-based negotiation is an essential requirement for agent-based e-commerce due to the fact that it is a way to enable one agent to influence the
BDI of another agent through rational dialogues. Since buyer and seller agents are heterogeneous in their designs in an open multi-agent system like e-marketplace, standard ACL and public IPs are extremely important for achieving efficient interactions.

In this paper we have presented an IP for argumentation-based negotiation extending FIPA CNP and introducing some new performatives in FIPA ACL. It satisfies most of the important criteria of an interaction protocol for argumentation as proposed in [10]. We have specified the protocol in an UML diagram and illustrated its working with an example from real world. The protocol can be conveniently implemented in FIPA compliant agent platforms like JADE [21] similar to other interaction protocols as suggested in [18].

References