Argumentation Based Negotiation in Multi-agent System

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Abstract *Negotiation is a process of reaching an agreement on the terms of a transaction such as price, quantity, for two or more parties in multi-agent systems such as E-Commerce. It tries to maximize the benefits for all parties. Argumentation-based negotiation has been proposed as an alternative to proposal-based approaches such as game theory and heuristic. The main advantage is that it allows agents to exchange additional information rather than just simple proposals. This property of argumentation protocols can lead to beneficial agreements when used for complex multi agent negotiation. This paper presents an empirical comparison of argumentation-based negotiation to proposal-based negotiation in a strategic two-player scenario. It is implemented through a well established FIPA-complaint Agent Toolkit, JADE. Our experiments show that the argumentation-based approach outperforms the proposal-based approach with respect to the quality of the agreements found and the quantity of unsuccessful negotiations.*

Keywords: *Multi-Agents Systems, Automated Negotiation, Argumentation Negotiation, Proposal-Based Negotiation*

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1. Introduction

Negotiation is generally called for when there exist common interests as well as differences among the negotiating parties. Approaches to one-to-one automated negotiation have been classified in three categories; game theoretic, heuristic and argumentation based [5]. The first two families focus on the traditional form of automated bilateral negotiation characterized by the exchange of offers between parties with conflicting positions and interests, a style commonly referred to as position-based negotiation. These approaches tend to view the object of the negotiation as fixed and reduce the negotiation process to a search problem in the space of possible deals. An incentive compatible negotiation mechanism inclusive the Protocol (Monotonic Utility-granting) and the strategy (What You Display Influences What You Get), in case time-constrained environments, can adopt automated negotiation procedure to quickly locate the best mutually beneficial deal [3]. Automated negotiation can help a consumer to obtain a best deal in the virtual retailing market, after he has determined which product to buy [7].

Bargaining consists in an exchange of offers by the agents, who try to accommodate each other's preferences until a deal is acceptable to both parties or the negotiation terminates unsuccessfully [12-16]. Argumentation-based negotiation (ABN) has been introduced to enhance automated negotiation with the exchange of richer information between negotiators, supporting or attacking their positions and potentially modifying these positions [2, 6, 9, 15]. Interest-based negotiation (IBN) is a particular type of ABN where the agents exchange information about the goals that motivate their negotiation. The intuition behind ABN is that those exchanges can change the agents' positions in a way that can increase the likelihood or the quality of potential agreements. There are three principal forms of negotiation, namely bidding, auction, and bargaining, in the decreasing order of simplicity. In bidding, the buyer specifies the product or service required and asks for bids from potential suppliers. Based on the bids, the buyer selects the supplier. In auction, a fixed auction protocol is followed, for example English auction. Auctions allow negotiation of only one issue, which is typically the "price". Bargaining is the most complex form of negotiation that requires multiple proposals and counterproposals to reach a mutual agreement or disagreement and can be bilateral or multi-lateral and involve more than one issue. An autonomous intelligent software agent is used to represent each negotiated party and conduct the negotiation process on a party's behalf. So, 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 agreement [13]. A reinforcement learning approach allows the agent to improve the argument selection effectiveness by updating the argument selection policy [10]. This paper focuses on an empirical comparison of argumentation-based negotiation to proposal-based negotiation in a strategic two-player scenario. It is implemented through a well established FIPA-complaint Agent Toolkit, JADE [1]. Experiments show the role of the argumentation in

increasing quality of the agreements. The argumentation-based approach outperforms the proposal-based approach with respect to the quality of the agreements found and the quantity of unsuccessful negotiations.

The structure of this paper is as follows. Section II offers a brief description of the negotiation framework. In section III the bargaining and ABN negotiation protocols are presented. Section IV describes implementation of the bargaining and ABN negotiation protocols through a well established FIPA-complaint Agent Toolkit, JADE and evaluation results. Finally, some conclusions are put forward in section V.

2. The Negotiation Framework

Abstractly negotiation framework can be viewed in terms of its negotiating agents and the environment in which these agents are interacting. In ABN framework agents need richer communication and domain languages to be able to exchange meta-level information. Therefore major distinguishing factor of ABN frameworks is in the type of information that can be expressed and exchange between agents and consequently in the specifications of the agents that generate and evaluate this information. Given a communication and domain language a negotiation framework should also specify a negotiation protocol in order to constrain the use of the language. Protocol can be view as a formal set of conventions governing the interaction among participants [5]. This includes the interaction protocol as well as rules of the dialogue. The interaction protocol specifies each stage of the negotiation process who is allowed to say what. In ABN the negotiation protocol is usually more complex than those in non-ABN, this lead to computational complexity [14]. However in many negotiation frameworks there is a need to keep externally accessible information during interaction [17 and18]. Moreover having external information stores makes it possible to perform some kind of enforcement of protocol related behaviors.

2.1. Elements of ABN agents

The interaction protocol commitment rules and communication languages represent the environment in which agents operate but often these say little about how agents are specified or how they reason about the interaction. Figure 1 shows a conceptual model of a simple classic negotiator. This model is a very abstract level for the main components needed by an agent in order to be capable of engaging in negotiation agent involved in negotiation interactions which largely depend on exchanging proposal such as auction-based and bargaining agents can be refer to an as a classical negotiating agent. The only information usually available to the agent during the interaction is:

- Proposals from the counterpart or a competitor.
- A message rejecting a proposal initially made by the agent.
- Other observations from the environment.

The agent may be able to infer certain things from this information. In contrast with a classical negotiating agent more sophisticated meta-level information can be explicitly exchange between the ABN agents as shown in figure 2, the dashed line boxes represent the additional components necessary for ABN agents. In case ABN agents negotiating agents must at least able to:

- Interpret incoming locutions
- Evaluate incoming proposals
- Generate outgoing proposals
- Generate outgoing locutions

An ABN agent needs in addition to be able

- Evaluate incoming arguments and update its mental state accordingly
- Generate candidate outgoing arguments
- Select an argument from the set of available arguments

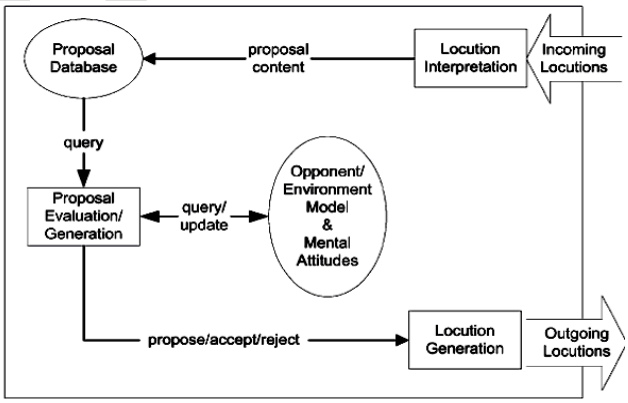

Figure 1. Conceptual elements of a classical negotiating agent.

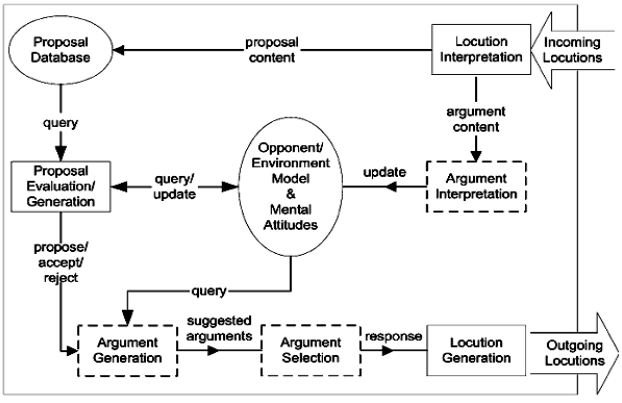

Figure 2. Conceptual elements of an ABN agent.

In last few years there has been rapid development and deployment of Multi-agent Systems implementation environment such as JADE, FIPA-OS, Zeus, etc. With the increasing number of these frameworks, two parallel agent development standards

have evolved: FIPA and MASIF. FIPA is standard to promote interoperable agent applications and agent systems. FIPA specifications only talk about the interfaces through which agents may communicate each other. It does not describe the implementation details. FIPA specifications are divided into five categories: Applications, Abstract architecture, Agent Communication, Agent Management and Agent Message Transport, are the five categories in which FIPA specifications are divided. The FIPA reference model considers an agent platform as a set of four components: Agents, Directory Facilitator (DF), Agent Management System (AMS), and Message Transport System (MTS). The DF and AMS support the management of the agents, while the MTS provides a message delivery service. MASIF intends to support interoperability among heterogeneous agent systems. It normally focuses on the migrations of the agents on different hosts [8].

3. Bargaining and ABN negotiation protocols

In order to enable agents to use bargaining, one needs to define appropriate communication protocols and negotiation strategies. Figure 3 presents the UML 2.0 specification of the bargaining protocol.

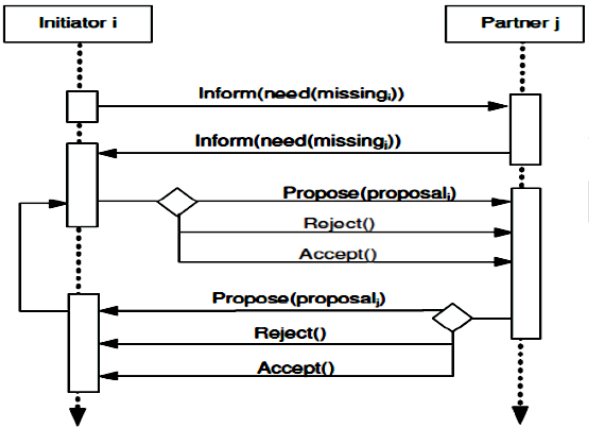

Figure 3. UML specification of the bargaining protocol..

In order to ensure that at least the initiator agent needs a negotiation dialogue to occur. Bargaining protocol initiated by agent i with agent j and it is divided in two parts as follows [14]. The bargaining protocol initiated by agent i with agent j is divided into two parts as follows:

- Part one: negotiating the resources to be exchanged, each agent discloses the set of resources that he wants.
- Part two: bargaining over the payment:
  - Agent i makes a first offer.
  - Then Agent j chooses between the three following options:
    - Accept agent i's proposal.
    - Reject agent i's proposal.
    - Make a counter proposal.

This paper employs the following bargaining process as in figure 4.

```
bargain_result = "Bargain"
Initiator I (II) start Negotiation
If Partner J (PJ) accept Negotiation
        initiator I offer first proposal
else
       bargain_result = "Reject"
endif
Do bargaining loop while (bargin_result != accept
                          or bargin_result != reject)
   If P J accept proposal from II
           bargin_result = accept, break;
   elseif (!counter proposal PJ)
           bargin_result = reject, break;
   endif
   If II accept proposal from PJ
          bargin_result = accept, break;
   elseif (!counter proposal II)
          bargin_result = reject, break;
   endif
EndDo
```

Figure 4. Pseudo code of bargaining process.

3.1. Argumentation Based Protocol

While the proposal-based negotiating agent's abilities are restricted to the exchange of proposals, the argumentation-based negotiating agent can use arguments to justify his negotiation stance and to critique proposals he has received from fellow players. The proposed protocol is shown in figure 5 which is a subset of the FIPA Contract Net Interaction Protocol [4]. The meanings of symbols are as following:

- Call-For-Proposal (CFP) is used to request an offer from the service provider.
- In response, the service provider can either send a Propose Proposal (PP) or Refuse Proposal (RP).
- Propose Proposal is also used for repeated offers and counteroffers in bargaining.
- Refuse Proposal indicates a party's unwillingness to participate in negotiation.
- The work of this paper proposed an additional message Attack proposal (TP), which is used to generate a counter-attacker argument by using the argumentation game. The content of TP is also PP.
- A successful negotiation ends with Accept Proposal (AP) while failure to reach an agreement is decided by a Reject Proposal (XP).
- Failure (F) indicates inability to receive, transmit, or interpret a message, to which the other party may reply by resending the previous message.

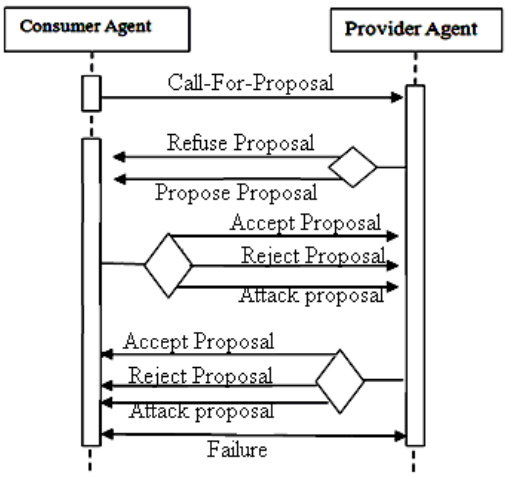

Figure 5. Argumentation based protocol.

In [11] A UML activity diagram is used to show the activities and flow of control for the protocol. Activity states are represented with rounded rectangles, a black solid circle stands for an initial node and a black in-out circle is a final node. A diamond represents a decision or merging state. A bar shows an activity that splits a flow into several concurrent flows or an activity that synchronizes several concurrent flows and joins them into one single flow.

Figure 6 shows an activity diagram for the proposed protocol where agent-based web services providers and consumers interact with each other in a negotiation setting. The activity diagram describes the behavior of agents that interact with each other. These agents perform certain actions according to the protocol they use. An agent has beliefs, goals, and intentions that are stored in a database accessible to the agent but external to the activity diagram. Activity states represent activities preformed by certain agents, such as accepting or refusing a proposal.

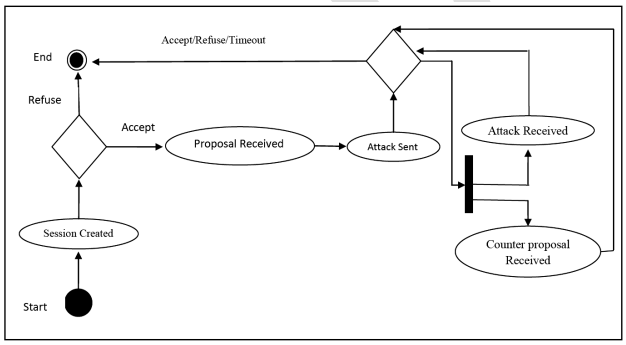

Figure 6. Activity diagram for the proposed protocol.

A transition from one state to another is trigged by a set of internal (by agent's own actions) or external (by other agents' actions) activities. The proposed protocol verified by using model checking tool, the specifications and the model map in ISPL and verified them with MCMAS. MCMAS uses BDD, Binary Decision Diagram, to verify the properties. Firstly, the interpreted system is translated into Boolean functions. BDD is an efficient mechanism to representation of Boolean functions in terms of memory and CPU. Secondly, BDD computes the set of states in which a formula holds. Finally, it compares this set with the set of reachable states. If they are Equivalent, it returns true. The system was running on Windows 7 on Inter Core 2 Duo CPU T 6600 2.20GHz with 2.0GB memory. Different properties of the protocols have been checked:

- Soundness: The protocol is correct.
- Termination: The protocol will end.
- Reachability: certain states are reachable through any possible sequence of transitions, starting from the initial state.
- Liveness: Liveness means something good will be eventually happen. An example of liveness is, if there is a negotiation, an acceptance will eventually follow in the future.

3.2. Architecture and Design

The proposed automated multi-agent negotiation system is based on FIPA Specifications. This specification has layered architecture, which consists of four layers. The proposed system is based on five major components. The negotiation system is based on FIPA Specifications. This specification has four layered architecture as shown in figure. 7. Catalog provides information about the availability of product in stock, and price related information. The system has two negotiation protocols which are compared with each other in the next section.

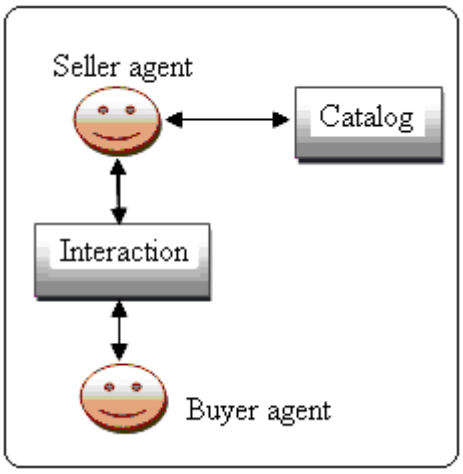

Figure 7. Negotiation system.

4. Implementation and Evaluation Results

It has been discussed earlier that MASIF only focuses on mobility while FIPA talks in detail about the communication and interaction protocols. So it is obvious that instead of using MASIF-compliant agent platform we must choose a FIPA-compliant platform. Under FIPA standardization JADE is the appropriate agent toolkit for our implementation. Because it is rich in interaction protocols, negotiations, etc. It is open

source and being updated continuously. JADE is supported by all operating systems and distributed in nature because it is developed in JAVA [1]. In future we also plan to run our application over ACENET (Agent Collaborative Environment based on .NET). Book store system has been implemented in JADE. It provides Agent Communication Language (ACL) for message passing among agents. Seller agent and buyer agent talk to each other through ACL message passing.

4.1. Results and Discussion

Table 1 contains the results of first protocol (bargaining protocol) for 12 examples. For each example our system stored (seller best price, seller worst price) and (buyer best price, buyer worst price). Also the system stored status of final decision, and the accepted value in case accept status.

Table 2 contains the results of second protocol (argumentation-based protocol) for 12 examples. By the same manner in first protocol for each example our system stored (seller best price, seller worst price) and (buyer best price, buyer worst price). Also the system stored status of final decision, and the accepted value in case accept status. Snapshots in figure 8 and figure 9 compare the two negotiation protocols for the same scenario. According to the results, argumentation based protocol outperforms the proposal based one by increasing the quantity of the agreements.

Table 1. Results of first protocol (bargaining protocol).

Example No.	seller best price	seller worst price	buyer best price	buyer worst price	status	Accepted values
1	600	480	500	600	accept by seller	550
2	600	480	450	550	accept by seller	525
3	700	560	450	550	failed by buyer	--
4	400	320	450	550	accept by buyer	400
5	50	40	30	60	accepted by seller	40
6	50	40	40	40	failed by buyer	-
7	50	40	40	45	accepted by seller	45
8	50	40	30	35	failed by buyer	-
9	50	40	20	40	failed by buyer	-
10	100	90	80	85	failed by seller	-
11	100	90	100	110	accept by buyer	100
12	100	90	80	95	accept by seller	94

Table 2. Results of second protocol (argumentation-based protocol).

Example No.	seller best price	seller worst price	buyer best price	buyer worst price	status	Accepted values
1	600	480	500	600	accept by seller	550
2	600	480	450	550	accept by seller	525
3	700	560	450	550	accept by buyer	560
4	400	320	450	550	accept by buyer	400
5	50	40	30	60	accepted by seller	40
6	50	40	40	40	accepted by seller	40
7	50	40	40	45	accepted by seller	45
8	50	40	30	35	accept by buyer	41
9	50	40	20	40	accept by buyer	40
10	100	90	80	85	accept by buyer	91
11	100	90	100	110	accept by buyer	100
12	100	90	80	95	accept by seller	90

Figure.8. Agents reached to an agreement.

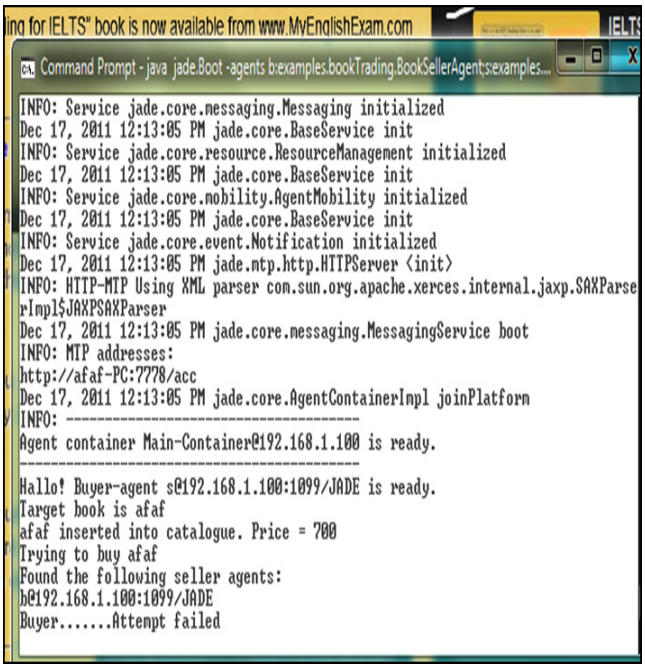

Figure. 9. Agents failed to reach to an agreement.

Figure 9 summarizes the scenario in which buyer fails to reach to an agreement with proposal based protocol, but it reaches to an agreement by using argumentation as shown in figure. 8. Also, snapshots in figure 10 and figure 11 show the role of the argumentation in increasing quality of the agreements. The buyer reaches to a cheaper deal, as shown in figure 10, than the one it gets by using the proposal protocol.

By comparing table 1 with table 2 we can notice that in the second protocol all failed examples in first protocol become accepted in argumentation based protocol. Figure 12 shows statistical results in cases first and second protocols. Where the negotiation results are accepted for 7 examples with first protocol (4 examples accepted by seller and 3 examples accepted by buyer), also by the same protocol the negotiation results are rejected for 5 examples (1 example rejected by seller and 4 examples rejected by buyer). In case second protocol the negotiation results are accepted for 12 examples (6 examples accepted by seller and 6 examples accepted by buyer), also by the same protocol the negotiation results are rejected for zero examples.

Figure 13 shows the accepted price for each example, where zero price means reject result. With using first protocol the examples no. 3, 6, 8, 9 and 10 are rejected. With using the second protocol all rejected examples with the first protocol become accepted. In the same time there is some improvement with respect to the quality of accepted result as in case of example no. 12. Where the accepted value with first protocol was 94, as with second protocol was 90.

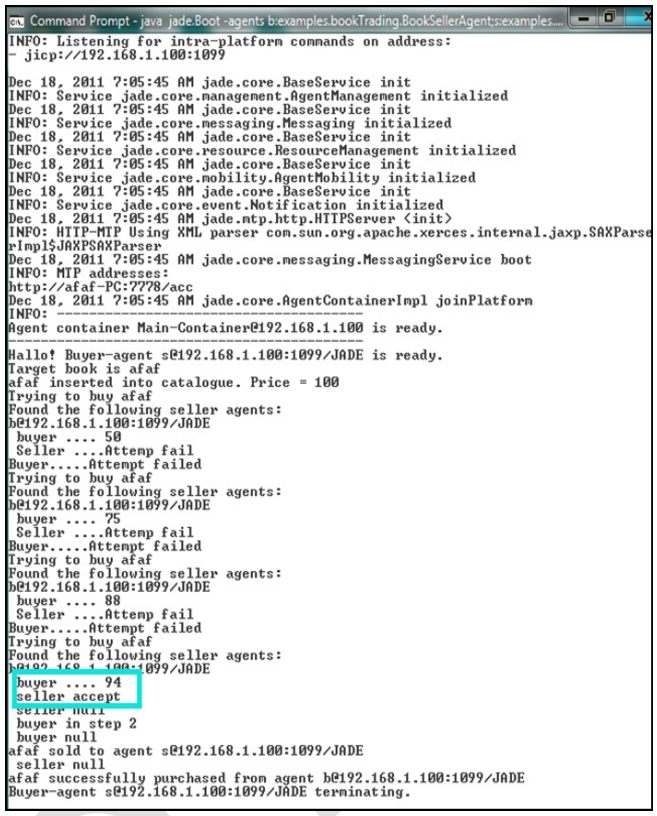

Figure 10. Both agents reached to an expensive agreement.

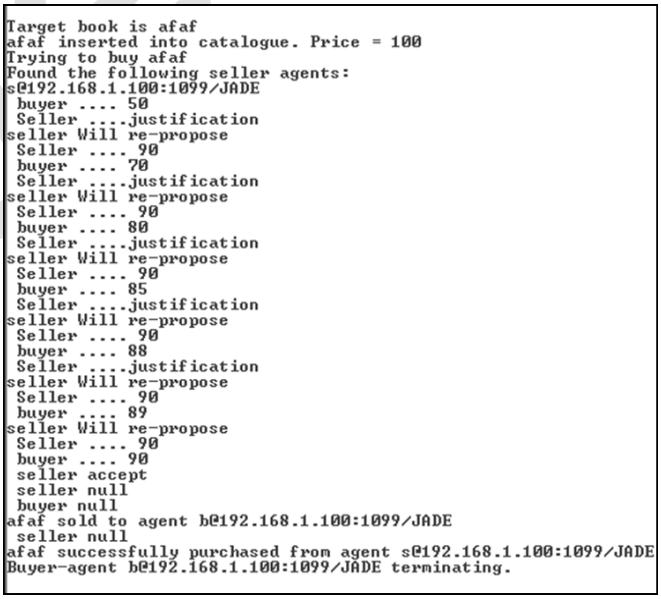

Figure11. Both agents reached to a cheaper agreement.

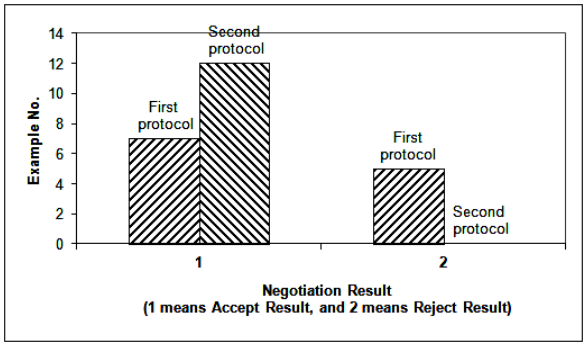

Figure 12. Comparison negotiation result for first protocol and second protocol .

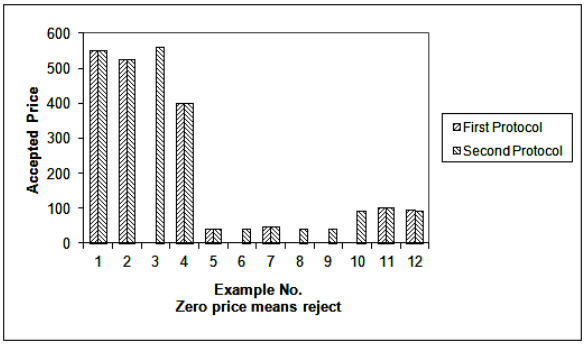

Figure 13. Comparison accepted price result for first protocol and second protocol .

5. Conclusion

Argumentation-based negotiation has been introduced to enhance automated negotiation with the exchange of richer information between negotiators, supporting their positions and potentially modifying these positions. The intuition behind Argumentation-based negotiation is that those exchanges can change the agents' positions in a way that can increase the likelihood or the quality of potential agreements. In this paper presents an empirical comparison of argumentation-based negotiation to proposal-based negotiation in a strategic two-player scenario. It is implemented through a well established FIPA-complaint Agent Toolkit, JADE. Our experiments show the role of the argumentation in increasing quality of the agreements. The buyer reaches to a cheaper deal than the one it gets by using the proposal protocol. By comparing two protocols we can notice that in the second protocol all failed examples in first protocol become accepted in argumentation based protocol. The argumentation-based approach outperforms the proposal-based approach with respect to the quality of the agreements found and the quantity of unsuccessful negotiations. In future we plan to run our application over (Agent Collaborative Environment based on .NET) and study the performance.

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