An Extended Alternating-Offers Bargaining Protocol for Automated Negotiation in Multi-agent Systems

Pinata Winoto, Gordon McCalla and Julita Vassileva

Department of Computer Science
University of Saskatchewan
57 Campus Drive, Saskatoon, SK S7N 5A9 CANADA
{piw410@mail.usask.ca; mccalla@cs.usask.ca; jiv@cs.usask.ca}

Introduction

Depending on the protocol type, a negotiation can be categorized as an auction, a contract-net protocol, or a voting or bargaining scheme. While most research focuses on auctions because the strategy is simple, bargaining is still an important way of negotiation. This is because

- auctions only allow negotiation for price, not other attributes (delivery time, payment method, delivery method, etc.);
- auctions usually are scheduled in advance and with time restrictions, but some buyers/sellers may not want to wait until an auction opens or finalizes;
- in some cases, many social factors are important, e.g., trusteeships, friendships, etc., which auctions cannot easily accommodate;
- most auctions extract the surplus for the benefit of the auctioneer, especially if there is a significant number of bidders.

Generally, the bargaining model in Multi-Agent Systems (MAS) adopts the classical alternating-offers model. Currently, there are many variants of this model, such as a model with time deadline (Krauss, Wilkenfeld and Zlotkin 1995; Sandholm and Vulkan 1999), with various information levels (complete/incomplete, symmetric/ asymmetric), with risk of breakdown (one party walks out before negotiation ends), etc. Most of the theoretical foundations have been studied by game theorists (Nash 1950; Rubinstein 1982). However, there is one important limitation of the game-theoretic approach, i.e., searching the solution in exhaustive fashion. Considering the limitation of computational power, many heuristic techniques are adopted to develop new models, namely heuristic-based negotiation models, characterized by learning mechanisms such as Bayesian learning (Zeng and Sycara 1998), influence diagrams (Mudgal and Vassileva 2000), evolutionary algorithm (van Bragt, Gerding and LaPoutre 2000). Using these models, the negotiators can make decisions faster to find a *good* solution, although not necessarily the *best* one. In addition, some researchers have proposed an argumentation-based model that focuses on natural-language-like negotiation (Hulstijn, Dastani and van der Torre 2001; Jennings et al. 2001; Sycara 1989). The main idea of this work is to provide more flexibility in the negotiation process, such as to allow a negotiator to persuade their opponents to change their perceptions.

Proposed Approach

This project is motivated by similar goals as the research above, that is, to modify the traditional alternating-offer model and then to study its advantages/ disadvantages. The proposed modifications include:

- Allowing bargaining without revealing the negotiators' preferences. For example, in the bargaining between seller *S* and buyer *B*, the following negotiations would be allowed:
  - (1) *S*: I offer you $500 per unit.
    B: Give me a lower price.
  - (2) *S*: I will not sell for less than $500.
    B: I cannot afford more than $400.

In case (1), *S* sets the upper bound, and *B* asks for a reduction without revealing a minimum willingness to pay. In case (2), neither side reveals their exact valuations, but a range of them.

- Allowing bargaining using *strategic delay*. A strategic delay is especially important at the beginning of the bargaining since it could serve as a signal of the negotiators' valuation. The less gain a negotiator expects from the bargaining, the more patient she or he is (Crampton 1992).
- Allowing arbitrary revisions of the proposal before agreement is reached. Intuitively, during negotiations, agents may revise their valuation dynamically due to external factors (e.g. the average price increases, or the demand for the same good increases, etc.).
- Allowing negotiators to try to stimulate changes in each other's beliefs. In almost all literature, it is assumed that bargaining is only in regard to the price. However, many real bargaining situations do not involve price, and in fact often implicitly or explicitly involve trying to change attitudes of the other bargainer.

In this extended proposal, eight actions are considered: offer, counter-offer, re-offer, argue, counter-argue,

strategic delay, accept and reject. And many factors influencing an agent's decision may be considered, such as private valuation, discount rate, bargaining time, unresolved disagreements, convergence rate, the likelihood of breakdown, etc.

Current and Future Work

In order to evaluate the performance of the new protocols, an agent-based simulation will be designed. The experiments will consist of two conditions: a conventional alternating-offer model (control) and a modified model designed using some or all of the modifications described earlier. There are three criteria used in the measurement of the protocol's efficiency: percentage of failure, length of bargaining, and computational costs. And there are also two metrics that are used to assess the protocol's effectiveness: fairness and participation rate.

The measurement of these five criteria is as follows:

- Ratio of failure = number of failures (walkouts)/ number of bargaining sessions.
- Length of bargaining = number of alterations until negotiation concluded.
- Computational costs = time needed for each decision.
- Fairness = % difference between buyer and seller's surplus, i.e. how much they had to concede relative to their expectations.
- Participation rate = proportion of participants in extended alternating-offer bargaining compared to participants in classical alternating-offer bargaining.

Agents used in the experiments are assumed to be bounded rational and learning agents. For instance, buyer agents will maximize their utility U_B based on the following parameters: their private valuation, time deadline, belief about market price, belief about a seller's time deadline, belief about the probability of a seller to walkout, probability to find other sellers, the price offered/counter offered by a seller, perceived probability that a seller will accept their offer, the weight (importance) assigned to the market price, and their belief about the trustworthiness of a seller's statement. Moreover, agents choose the action that yields a higher expected return in their view. For example, by indicating that the market price will be very low in the near future, a buyer can persuade a seller to sell with a lower price today, since if the buyer walks out, the seller will get less from the market.

Up to now, two steps in the research have been carried out:

- The characteristics of the bargaining protocols have been analytically studied to find the answer to some basic questions such as: will the bargaining always converge? in what conditions do bargaining solutions exist? what happens if two agents use different criteria to update their beliefs? There are, of course, many other questions which need to be studied.
- The experimental design of an agent-based simulation has been proposed, which could serve as a test-bed of the protocol design. However, there are still many unsolved problems, such as what kind of learning mechanism is appropriate? should agents trust the arguments made by their opponent? should every agent maintain a history of interactions and a model of other agents?

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