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An adaptive prediction-regret driven strategy for one-shot bilateral bargaining software agents

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ABSTRACT

Bargaining is a popular paradigm to solve the problem of resource allocation. Factors such as complexity of dynamic environment, bounded rationality of negotiators, time constraints and incomplete information, make the design of optimal automated bargaining strategies difficult. Currently, most bargaining strategies are designed under the assumption that opponents offer according to specific models. Therefore, most of them focus on modeling opponents or predict opponents' private information such as reservation price, deadline, or the probabilities of different behaviors. Without model opponents, this paper presents an adaptive prediction-regret driven negotiation strategy for bilateral one-shot price bargaining, which extends the existing heuristic method of "looking forward" into "looking forward and reviewing the past" pattern by the regret principle in psychology. Four sets of experiments are designed and implemented to verify the general performance of this strategy. Results show that this strategy outperforms the strategies that model opponents and existing adaptive strategy when bargaining with multifarious opponents who offer according to pure consecutive concession strategies, sit-and-wait strategy, fixed mixture strategies, random mixture strategies, or even intelligent strategies.

1. Introduction

Bargaining denotes the process of two or more agents who have disparate interests searching for an agreement on some issues, and the search process involves exchange of offers, relaxation of initial offers, and mutual concessions (Rosenschein, 1994; Sim, 2009). It can also be viewed as a form of decision-making among actively interacting agents who cannot make decisions independently (or achieve their goals unilaterally), and therefore must make concessions to achieve a compromise (Kersten, Michalowski, Szpakowicz, & Koperczak, 1991; Sim, 2010). Automated bargaining among software agents is required in many different contexts such as e-commerce (Lomuscio, Wooldridge, & Jennings, 2003), supply chain management (Wu, Baron, & Berman, 2009), and resource co-allocation in Cloud computing (Sim, 2012, 2013; Son & Sim, 2012) and Grid computing (Sim, 2006, 2010; Sim, Guo, & Shi, 2009; Sim & Shi, 2010), in which conflicts and differences need to be resolved.

According to the relationship between bargainers, automated bargaining can be divided into two categories, namely, repeated bargaining and one-shot bargaining. In one-shot bargaining scenarios, bargainers encounter each other only once, i.e., each pair of seller and buyer are expected not to meet each other again after the bargaining process, whether an agreement is reached or not. There are many cases of one-shot bargaining in real-life, especially when you bargain with the shopkeeper of a shop not in your neighborhood, or you bargain with the salesperson in a souvenir shop as a tourist. This is different from the scenarios of repeated bargaining, in which both parties might be able to obtain (through learning from experience) some private information such as the preference and bargaining characteristics of the counterpart. Besides, in order to keep a long and friendly relationship between the bargainers, they might be willing to cooperatively making concessions. In contrast, if it is the first time two bargainers meet each other, and there is not any clue that they may trade in the future (i.e., the bargaining is one-shot), then it is more difficult for them to infer each other's private information because there is not any historical data for reference. Besides, a bargainer can act more

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aggressive than what he behaves in repeated bargaining, because he does not expect to keep long term relationship with the other party.

A research of eBay (Resnick & Zeckhauser, 2002) showed that 89% of all seller-buyer pairs conducted just one transaction during the research time period, and 98.9% conducted no more than four. In the vast majority of cases, multiple transactions between a seller and buyer occurred within a few days of each other (sellers often offer reduced shipping costs to buyers who buy several items that can be shipped together). In most cases, even these multiple transactions are best thought of as single interactions. Thus, performance in the current transaction will rarely be directly remembered by future buyers who are, after all, different from the current buyer. Therefore, in most cases bargainers do not have historical interaction experience for reference and do not consider the possibility of long term cooperation in the bargaining process. This paper focuses on the design of strategy for software agents to deal with multifarious opponents in one-shot price bargaining environment.

1.1. Motivations

In a one-shot price bargaining process, the unavailability of historical interaction makes it is difficult to obtain private information of opponents (e.g., strategy, tactics, reservation price, deadline, etc) according to off-line learning methods that are typically based on historical interactions. Thus, to improve agent's bargaining capability in maximizing their owners' benefits in one-shot price bargaining and adaptability in dealing with multifarious kinds of opponents, researchers have to explore alternative strategies.

Sandholm and Vulkan (1999) explored strategies of one-shot price bargaining under the assumption that all bargainers are absolutely rational. They pointed out that "sit-and-wait" is the unique sequential equilibrium strategy for bargainers in one-shot price bargaining even if reservation price and tolerance deadline are private to them. "Sit-and-wait" means that the assumed absolutely rational seller and buyer insist on their initial prices until the earlier of the buyer's deadline and the seller's one (which one is earlier is unknown to the bargainers) is reached, at which point the agent whose deadline is earlier accepts the opponent's offer if that price is within its acceptance range. Otherwise, no agreement can be reached.

However, lots of bargainers are willing to deviate from this "equilibrium strategy" due to a lot of factors, such as fear of business loss due to competition, reciprocity heuristics (Malhotra & Bazerman, 2008), sense of fairness (Sun, 2009), self-satisfaction (Tauber, 1972), bounded rationality, the belief that parties are likely to benefit from working together, the faith in one's own problem solving ability (Lewicki, Minton, & Saunders, 1999), or to gather more information about their opponents (Baumeister, Zhang, & Vohs, 2004). Based on the belief that agents are prone to make concessions in bargaining, a lot of automated heuristic bargaining strategies (Brzostowski & Kowalczyk, 2006; Faratin, Sierra, & Jennings, 1998; Hou, 2004; Jonker & Treur, 2001; Lee, Li, & Chen, 2005; Sim et al., 2009) are proposed. These strategies can be divided into two categories, i.e., opponent modeling ones and adaptive ones.

(1) The strategies given by Hou (2004), Lee et al. (2005), Brzostowski and Kowalczyk (2006), and Sim et al. (2009) are opponent modeling strategies. These strategies first predict private information (tactics, reservation price, deadline, etc.) of opponent based on the assumption that opponents offer according to the models defined by Faratin et al. (1998), and then make appropriated counter-proposal according to the predicted information. The agent who adopts an opponent modeling strategy must possess a large knowledgebase of offering models about opponent, which take up space and make bargaining agent heavy. Besides, the opponent modeling strategies is ineffective for two reasons. One is that it is impossible to enumerate all the offering patterns (models) of opponent, and the other is that lots of bargainers do not follow any pattern in bargaining process.

(2) The strategy presented by Jonker and Treur (2001) belongs to an adaptive one. Without modeling opponents, the agent who adopt this strategy adapts its concession according to utility difference between an opponent's recent offer and its own recent offer, its own bargaining speed and concession factor. Therefore, this kind of agents does not need any knowledgebase about opponents. Moreover, the bargaining speed and concession factor in Jonker and Treur (2001)'s strategy are pre-determined before the beginning of bargain process. However, which values are appropriate for these factors cannot be assigned before bargaining process by agent's human owner. That is because the bargaining agent may deal with various kinds of opponents and which kind of opponent it will bargain with cannot be predicted before bargaining.

1.2. Objectives

According to the analysis of above literatures, in one-shot price bargaining environment, it is needed to design a self-adaptive bargaining strategy for improving intelligent agents' bargaining capabilities in maximizing their owners' benefits as well as their adaptabilities in dealing with multifarious kinds of opponent. The aim of this paper is to gives an adaptive prediction-regret driven one-shot price bargaining strategy. In each round of bargaining after the second round of offer, the agent who adopts this strategy will first predict opponent's sincerity (see Section 3.1) in next round. From the third round of bargaining, except for predicting opponent's sincerity in next round, the agent will also summarize the accuracy of its last prediction. If its opponent's concession sincerity is smaller than it have predicted, then the agent will think that the opponent is not as sincere as it has hoped. Therefore, it will feel regret about having made too much concession according to its previous prediction. Thus, it will not concede in this round. If its opponent's sincerity is equal to or larger than it have predicted, this agent will think that its opponent has enough sincerity to reach an agreement, and it concedes $\eta(t)$ times of its opponent's latest concession. The value of concession factor $\eta(t)$ can be adapted by the rules given in Fig. 3. Therefore, the agent who adopts the adaptive prediction-regret driven strategy can actively adapt its concession speed according to multifarious opponents in bargaining process.

1.3. Contributions and significance

In contrast to existing opponent modeling strategies and existing adaptive strategy, the novel features of this adaptive prediction-regret driven bargaining strategy are as follows. Practically, the agents who adopt this strategy do not need to possess any model about opponents. Moreover, they can actively adapt their concession speeds according to various opponents in bargaining process. Therefore, the adaptive prediction-regret driven strategy given in this paper is a real self-adaptive price bargaining strategy. Theoretically, this strategy does not try to maximize the agents' benefits using game-theory methods, but using a heuristic method. And this strategy improves the existing heuristic bargaining strategies from a "looking forward" approach into a "looking forward and reviewing the past" approach by the prediction-regret