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Automated negotiation for e-commerce decision making: A goal deliberated agent architecture for multi-strategy selection

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ABSTRACT

Automated negotiation plays an important role in dynamic trading in e-commerce. Its research largely focuses on negotiation protocol and strategy design. There is a paucity of further scientific investigation and a pressing need on the implementation of multi-strategy selection, which is crucially useful in human–computer negotiation to achieve better online negotiation outcomes. The lack of such studies has decelerated the process of applying automated negotiation to real world problems. To address the critical issue, this paper develops a multi-strategy negotiating agent system. More specifically, we formally define the agent's conceptual model, and design its abstract software architecture. Grounded on the integration of the time-dependent and behavior-dependent tactics, we also develop a multi-strategy selection theoretical model and algorithm. To demonstrate the effectiveness of this model algorithm, we implement a prototype and conduct numerous experiments. The experimental analysis not only confirms our model's effectiveness but also reveals some insights into future work about human–computer negotiation systems, which will be widely used in the future B2C e-commerce.

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1. Introduction

Negotiation is a communication process among a group of parties with conflicting interests or preferences in order to reach an agreement or compromise [1,2]. The tremendous success of the online auction [3], which is a kind of one-to-many negotiation and has been employed as the main trading mechanism in the electronic market and smart market [4], suggests that the dynamic trading based on e-negotiation has gradually become the primary paradigm of decision making in e-commerce [5–8]. In addition, e-commerce oriented negotiation is increasingly assuming a pivotal role in many organizations, and a number of prominent negotiation models have been developed over the past decades [9].

There are three forms of e-commerce oriented negotiation [2]: human–human negotiation, computer–computer negotiation, and human–computer negotiation. With the rapid growth of global e-markets, there has been a significant interest in designing Automated Negotiation System (ANS) [10] that can serve as surrogates for human business decision-makers, where software agents are designed to autonomously act on behalf of the real-world parties [11,12]. As the automated negotiation is becoming crucially important and pervasive and agents promise exciting opportunities to turn conventional transactions into an automated, cost-efficient manner, the study of ANS has piqued increasing interest in the scholarly fields of e-commerce and artificial intelligence [13].

While the e-commerce and AI literatures mirror that the ANS can be used in computer–computer and human–computer negotiations, extant studies on ANS primarily focus on the former, leaving the latter comparatively unexplored [14]. In fact, human involvement in decision-making is still required in most of present online negotiations, and with the ever mushrooming growth of e-commerce and e-markets, there is an increasing potential for the use of software agents to more effectively and efficiently negotiate with human negotiators [11,15]. The human–computer negotiation plays a paramount role in the e-commerce oriented applications, especially in the B2C context where software agents act as business provider [16]. Compared with the traditional online sales mode where customers view the basic product or service information on the website and often need to negotiate with human salespeople through a "contact us" link, a human–computer ANS can help business organizations to reduce the labor cost for negotiation and greatly increase the transaction efficiency to the optimum extent.

Prior studies have been conducted to design various human–computer negotiating agent [14,15], which demonstrate that a software agent can proficiently negotiate with and even outperform people. Owing to the randomness of the human's behavior, the human–computer negotiation context is assumedly more complicated.

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The human–computer negotiation system accordingly needs much smarter software agents to negotiate with the human negotiators effectively. In automated negotiation, people entrust the software agent to negotiate automatically online, and normally expect that the agent can try different strategies to obtain a better negotiation outcome. In such cases, the ability to quickly and autonomously select an appropriate strategy among the candidates according to negotiation situation changes is a very important perspective for evaluating the designed agent's intelligence level.

Existing research has not yet shed light on such crucial issues as such strategic choices [9], and hence has stalled the much-needed development of the real-world applications of automated negotiation system [17]. Previous models mainly focused on specific protocols (e.g., the alternating offers protocol) and libraries of negotiation strategies (e.g., various concession strategies [18] and trade-off strategies [19]), and have investigated the behaviors of these strategies to determine the most effective strategy in various negotiation situations. Notwithstanding the achievements concerning protocols and strategies, there exists a gap where the strategy selection issue has not been addressed yet. As such, this study is one of the first efforts of advancing this line of research for automated negotiation in e-commerce decision-making. The main objective of this study is to construct and validate a generic, robust decision-making model in an effort to support multi-strategy selection during a course of automated negotiation in e-commerce.

The remainder of this paper is organized as follows. Section 2 discusses related work. Section 3 proposes a conceptual architecture in mathematical form for the negotiating agent. Section 4 presents our negotiating agent's software architecture based on the conceptual model, and describes the logical structure of its main inner components. Section 5 describes a goal deliberation process, which is the core function of the software architecture. Section 6 presents our multi-strategy selection theoretical model and the corresponding algorithm. Section 7 presents the experimental evaluation for our model and algorithm, and discusses the implication of the experimental results. Section 8 elaborates the contributions and limitation of the current work, and draws the picture of the future work. Finally, Section 9 summarizes the findings of this paper and suggests future research directions.

2. Literature review

In order to develop an automated negotiating agent system that has the ability of multi-strategy selection, it is of vital importance to elucidate two necessary issues: (1) how to design a decision making model to support the multi-strategy selection, and (2) how to design an agent architecture as the runtime platform for the decision making model. This section serves to revisit previous work in respect to these issues.

2.1. Negotiating agent architecture

In light of the theoretical foundation and the number of successfully applied systems, the most interesting and widespread agent architecture is the Belief–Desire–Intention (BDI) model [20], which consists of three mental attitudes: (1) beliefs, which capture informational attitudes, (2) desires, which describe motivational attitudes, and (3) intentions, which are deliberative attitudes of agents. However, such agent architecture cannot support various agent applications. In fact, most prior studies (e.g., [21]) did not shed light on the important pre-negotiation step of selecting proper strategies for a specific negotiation situation. Also, most prior studies assumed that the strategies do not change during a course of negotiation. This crucial void was further highlighted with few attempts made to develop models that can effectively choose strategies dynamically. Moreover, most extant models do not support the strategy selection as the negotiation unfolds [9] with an exception of the model proposed by [22,23].

Nevertheless, the work of [22,23] has the potential for further improvements. Firstly, the architecture of their negotiating agents is designed from the buyer's viewpoint and so provides limited guidelines for the architecture design of seller agents. Secondly, their model merely works in one-buyer multi-seller environments. In e-commerce practice, however, other one-to-many and one-to-one negotiation situations also exist. Thus, one of the main aims of this study is to go beyond their spectrum and build a more comprehensive and robust architecture model that can cope with a plethora of negotiation situations. Thirdly, the core of their strategy selection mechanism comprises two matrices: the percentage of success matrix and the payoff matrix, which are imposed artificial subjectivity. This contrasts with the primary underlying of the agent theory. To advance this line of research, the multi-strategy selection model we are going to design based on BDI model will provide the agent with more autonomous ability to cope with the ever changing negotiation situations, without any effect from the external environment, so that the agent can decide by itself to select an appropriate negotiation strategy and complete the decision making process.

2.2. Negotiation strategy

A negotiation strategy is a decision-making model used by the participants to achieve their purposes [24]. In negotiation, one party cannot control its opponent directly, so each should employ certain strategies to persuade the opponent towards the outcome they desired. The work of [25] proposed two typical strategies: (1) Behavior-dependent one is concerned with responsiveness to a partner's behavior, and imitates its behavior in a variety of ways. (2) Time-dependent one completely ignores the reaction of the opponent, i.e. it proposes offers only according to a predetermined time-dependent sequence [26]. Based on these strategies, a negotiating agent can make offers against its opponents complying with a fixed decision function during the course of negotiation. However, to be more successful, an agent needs to adapt to the behavior of its partners and changing environment. Accordingly, effective mechanism should allow a negotiating agent to learn from the previous offers of its negotiating partner in order to predict the partner's future behavior and adapt to it [27].

Much work has been done to equip the agents with the capability of predicting their opponents' negotiation behavior (e.g., price offer, reservation price, and negotiation deadline prediction) by learning from previous negotiations, so that they can achieve more profitable results and better resource utilization [27–30]. For example, in [28], a negotiation model is equipped with feed forward artificial neural network and thus can forecast the opponent's next price proposal according to its past three price proposals. This prediction is very effective and relatively accurate when the curve of the price proposal is regular and smooth. Yet when being near to the inflection point of the curve, the prediction would be increasingly hard and unreliable. In essence, as shown in Fig. 3, the area near the inflection point is the critical place of the negotiation. In addition, in a human–computer negotiation context, predicting human's behavior could be even more difficult because the human's offers do not comply with a fixed offer function.

In theory, negotiating agents are designed to imitate human being's thinking to negotiate autonomously. However, human negotiators usually perform a behavioral game process [31], rather than surmising the opponent's next offer in real world negotiations. Normally it is required to observe the opponent's behavior, including offers, words, actions, and so on, to collect enough information before making the next decision. During this process, imitating the opponent's negotiation behavior is the most conventional method, just as [25] pointed out. In essence, we consider that an intelligent method for the agent to enhance its capability of learning is not to solely predict the opponent's behavior, but to quickly adjust its offer strategy according to the opponent's changing proposals. This lays the theoretical foundation for the multi-strategy selection, so that we can further associate the

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