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On the use of particle swarm optimization and Kernel density estimator in concurrent negotiations

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ABSTRACT

Electronic Marketplaces (EMs) can offer a number of advantages for users searching for products. In EMs, Intelligent Agents (IAs) can undertake the responsibility of representing buyers and sellers and negotiate over the conclusion of purchases. For this purpose, a negotiation is held between IAs. The most important characteristics are the deadline and the pricing strategy. The strategy defines the proposed prices at every round of the negotiation. We focus on the buyer side. We study concurrent negotiations between a buyer and a set of sellers. In this setting, the buyer utilizes a number of threads. Each thread follows a specific strategy and adopts swarm intelligence techniques for achieving the optimal agreement. The Particle Swarm Optimization (PSO) algorithm is adopted by each thread. Our architecture requires no central coordination. In real situations, there is absolutely no knowledge for the characteristics of the involved entities. In this paper, we model such kind of uncertainty through known techniques for estimating the distribution of deadlines and strategies. One of them is the Kernel Density Estimation (KDE) technique. Our experimental results depict the time interval where the agreement is possible and the efficiency of the proposed model.

1. Introduction

Web users are confronted with a huge number of product providers. They have the opportunity to search, find and purchase the products they like. The most straightforward approach, for buyers, is to visit various online providers and search for the desirable product. However, due to the excessive number of providers, users cannot browse and process numerous resources. In order to overcome these shortcomings, 'smart' and 'autonomous' technologies should be used. Intelligent Agents (IAs) could be the solution to this problem. IAs can undertake the responsibility to act on behalf of their owners. They are software components having artificial intelligence capabilities and, thus, be capable of accomplishing tasks delegated by users. They can learn users' preferences as well as their characteristics, thus, increasing their efficiency. For example, they can undertake the responsibility of searching, finding and purchasing products through million of resources interacting with a vast number of entities. Such interactions could be held in Electronic Marketplaces (EMs). In such places, entities, not known in advance, can negotiate and agree upon the exchange of products for specific returns. In EMs, there are specific member roles: the buyers, the sellers and members that are in the middle, helping them to accomplish their tasks. Buyers aim to buy specific products while sellers have a number of products in their possession and want to sell them in the most profitable price. Middle entities mainly deal with administration or mediation tasks.

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Negotiation is the process where unknown entities try to agree upon the exchange of specific items for specific returns [27]. Buyers and sellers negotiate over product purchases. IAs can represent users in such negotiations saving time and resources for their owners. Usually, entities are selfish and try to maximize their utility. Buyers want to buy products at the lowest possible price while sellers want to sell products at the highest possible price. In EMs, a product can be provided by a number of sellers, however, with different characteristics (e.g., price, delivery time). Every buyer should decide from which seller to buy the desired product. This can be achieved through the adoption of concurrent negotiations. The buyer utilizes a number of threads in order to negotiate with every seller. However, in such cases, the buyer needs a coordination module that could probably define the strategy for each thread. Such strategy is compatible with the results obtained by applying specific strategies in the remaining threads.

In this paper, we examine the case where buyers negotiate concurrently with a number of sellers. The negotiation refers to the price of a specific product (i.e., single issue negotiation). The novelty of our work is that we provide a solution which combines an optimization and a prediction technique in a negotiated e-commerce setting. Through the concurrent negotiations, the buyer tries to reach to the best agreement (if possible). The solution involves a number of self-adapting threads that adopt the discussed techniques. We assume absolutely no knowledge on the players' characteristics. Such knowledge involves the players' deadlines, reservation prices, etc. Reservation price is the acceptable upper/lower limit of price for the buyer/seller. Moreover, in our scenario, there is no need for coordination as threads adopt Swarm Intelligence (SI) [10] in order to converge to the best agreement. When an agreement is achieved by a specific thread, the remaining threads can readjust their strategy, if needed, in order to force the respective sellers to accept lower prices. The thread provides feedback to the seller for the final agreement after a specific time interval that enables the remaining threads to achieve lower prices.

The rest of the paper is organized as follows. In Section 2, we provide an analytical review on the related work. Our negotiation scenario is described in Section 3 by giving the players' characteristics and presenting their strategies. In Section 4, we discuss how the SI theory, and more specifically the Particle Swarm Optimization (PSO), can be applied in our scenario and describe the strategy of buyer threads. In Section 5, we describe the decision process for each side. We assume no knowledge on the players' characteristics and adopt the Kernel Density Estimation (KDE) technique for deriving the distribution for the pricing strategy of the opponent. Our results are described in Section 6. Finally, in Section 7, we discuss our conclusions.

2. Related work

Finite horizon negotiations usually involve the exchange of alternating offers for a number of rounds [31]. However, one can find approaches where infinite horizon is considered [28]. The time for which the entities participate in a negotiation is important as it is used to exercise pressure on the entities. Many solutions have been proposed for the discussed problem. We can group these efforts as follows:

- approaches based on Game Theory (GT) (bargaining);
- approaches based on Machine Learning (ML) (learning or adaptation on the opponent strategy);
- approaches based on Fuzzy Logic (FL);
- approaches based on heuristic decision functions.

GT models usually study the bargaining game [5,8,13,15,30]. In many efforts, the authors assume knowledge of players' characteristics or their distributions. For instance, reservation values could be common knowledge [8]. Other parameters as the deadline, strategies or the type of entities could be also common knowledge [5,31]. At every round of the negotiation, players make a proposal to the opponent and the latter entity has the opportunity to accept or reject it and make a counter offer. Each player has a specific strategy. The strategy affects the offers or the response to the counter offers. Based on strategies, the market equilibrium can be defined and analyzed. However, determining the equilibrium assumes that players are rational and remain at the equilibrium path during negotiation.

In [13], the authors describe a negotiation model with outside options in the seller side. The seller faces an infinite number of buyers in the negotiation process. The buyers' valuation (i.e., the upper price limit) is common knowledge as well as its distribution. An important characteristic of the presented model is that buyers do not have the opportunity to make any offers to the seller. A negotiation between a seller and a buyer is also analyzed in [5]. The authors describe two players' strategies: hard and soft. Prior probabilities for reservation prices are common knowledge. The context of an infinite horizon negotiation under two sided uncertainty is examined in [8]. The authors describe how time and information affect the rational behavior of IAs when commitment is not possible. The players should exchange some private information before an agreement is reached.

A Pareto optimal algorithm for negotiation is described in [15]. The authors describe the Maximum Greedy Trade-offs algorithm that generates offers at any aspiration level in short time. In the described negotiation, IAs have limited knowledge about the opponents' deadline and utility. The generation of Pareto-optimal offer needs information about the opponent's importance weights. In [11], the authors describe functions for the definition of alternating offers and present a set of tactics based on which IAs try to conclude an agreement. They propose a formal model for negotiations and provide relevant results. They examine a large set of tactics and define the following metrics: (i) the intrinsic benefit of the agent, (ii) the cost, and, (iii)