Guest Editorial
Special Issue on Game-Theoretic Analysis and Stochastic Simulation of Negotiation Agents

DESIGNING agents that can negotiate deals on behalf of humans is essential for developing the next generation of e-commerce systems (e.g., dynamic pricing systems) and for developing tools for resolving conflicts in distributed resource allocation. Although there are researchers that focus on the game-theoretic analyses of negotiation agents, empirical approaches concentrate on studying the properties of negotiation and trading agents through simulations and experiments.

Game-theoretic analyses for automated negotiation are based on well-founded theories and models, and there is an enormous volume of work on game-theoretic models of bargaining. Some famous examples include the seminar work of Nash's axiomatic approach to bargaining [1] and Rubinstein's alternating offer model [2]. Game theory has been used as a mathematical tool for analyzing and evaluating the design of the mechanisms and interaction protocols of rational and utility maximizing agents. Through game-theoretic analyses, desirable properties such as system stability (equilibrium) and efficiency (pareto-optimality) can be proven.

However, classical game theory assumes that players are optimizing against one another and that every player knows this (i.e., it is based on the assumptions of perfect rationality and the common knowledge of this rationality) [3], [4]. Research in experimental economics [5] seems to suggest that perfect rationality may not necessarily apply to human negotiators, and that binding social constraints may effectively determine bargainers' behaviors.

In bargaining games, when agents are not endowed with complete information about their opponents (e.g., their preferences), an agent can only deduce the private information of its opponents by studying their moves. Although there are many promising models of game of incomplete information, it may still be difficult to derive pareto-optimal solutions using these models.

Nevertheless, game theory provides the best available set of tools for analyzing automated negotiation systems, and it is emphasized that this editorial is not intended to scrutinize game-theoretic approaches, nor is it debating the merits and weaknesses of game-theoretic approaches versus empirical approaches of automated negotiation. Rather, this special issue serves as a forum for researchers to present alternative approaches when game-theoretic analysis of bargaining and negotiation systems may be difficult. For instance, when the space of possible strategies is very large, analyzing the interactions among agents may be complex, and a heuristics approach may be used to approximate game-theoretic solutions. In other situations, stochastic simulations may provide an alterative means for studying the behaviors and characteristics of negotiation agents, as well as the dynamics and trends of changing market situations in agent-based electronic markets that may not be easily analyzed using game theory.

This special issue brings collections of papers in both game-theoretic approaches (that are not necessarily in the tradition of von Neumann–Morgenstern) and empirical approaches of automated negotiation together into the same forum. It presents recent research achievements and studies on understanding, analyzing, and developing (societies of) agents for negotiation, conflict resolution, and e-commerce systems.

In this special issue, eight papers were accepted as full papers and one paper as technical correspondence. Some of the issues addressed in the nine papers include.

- Providing theoretical alternatives to game-theoretic models that are in the tradition of von Neumann–Morgenstern.
- Considering negotiation agents that can be partially cooperative rather than fully self-interested or completely cooperative.
- Analyzing and studying the impact of both competitive environments and alternative trading opportunities (or outside options).
- Studying and understanding the complexities of the interactions between human traders and artificial agents.
- Considering a framework for negotiation of contracts.
- Developing agents for resolving conflicts in distributed resource allocations and for dynamic pricing.

1) Satisficing Negotiation: Many of the existing negotiation approaches that are based on Von Neumann–Morgenstern game theory are founded on the principle of individual rationality, whereby agents are committed to optimizing their own satisfactions. Based on their previous work on satisficing game theory, the paper by J. Archibald, J. Hill, F. Johnson, and W. Stirling presents an interesting alternative by enabling negotiation agents to lower their "aspiration levels" in search of "satisficing" or "good enough" solutions according to some protocol. Another interesting concept discussed in this paper is "situational altruism" in which an agent conditionally moderates its preference and choice only if other agents would benefit from its sacrifice. The authors also provide a negotiation protocol that is based on satisficing game theory in which a satisficing agent can identify all options that are good enough as defined by its criteria. In addition, the paper also provides examples to demonstrate negotiation under the satisficing approach. In

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summary, this paper provides a new tool for analyzing and designing negotiation agents.

2) Partially Cooperative Negotiation Agents: To date, negotiation agents are generally classified as self-interested agents operating in a market-like setting or cooperative agents operating in a distributed problem-solving environment. The impetus of the paper by X. Zhang, V. Lesser, and T. Wagner is addressing the negotiation problem in the context of complex organizations by considering partially cooperative agents between the two extreme cases. They propose an integrative negotiation mechanism in which agents dynamically select a negotiation attitude characterized by the degree of consideration for other agents' outcomes as well as its own (which the authors call "externally directedness"). The selection is based on an agent's organizational goals, the current environmental circumstances, the opposite parties that the agent is negotiating with, and the issue(s) for deliberation. Their empirical results show that in situations when other agents' attitudes are unknown, it may be more appropriate for both individual agents and the agent society to be partially externally directed rather than completely externally directed.

3) Dynamic Outside Options: The paper by C. Li, J. Giampapa, and K. Sycara studies the influence of alternative trading opportunities by considering the impact of uncertain and dynamic outside options to (concurrent) bilateral negotiations. Three models of bilateral negotiations that consider outside options with varying degrees of sophistication and complexity were studied. In their simplest single-threaded negotiation model, agents adopt time-dependent negotiation strategies without considering outside options. In their synchronized multithreaded negotiation model, negotiation agents consider the presence of concurrent existing outside options, and hence, each pair of negotiators is influenced by the current available options. Finally, the dynamic multithreaded negotiation model augments the multithreaded negotiation model by considering uncertain outside options that may arrive sequentially in the future. This paper employs several heuristic approaches, for instance, heuristics to learn the distribution of agreements that is based on previous negotiations to estimate the expected utility in a multithreaded negotiation. Their empirical results show that agents' utilities increased when outside options were considered, and agents adopting the dynamic multithreaded negotiation model record the highest average utilities among the three models.

4) Ultimatum Game and Competitive Market: The paper by E. Gerding and L. Poutre discusses a bilateral bargaining problem in a competitive environment motivated by the well-known Ultimatum game. Their Ultimatum-like game models a competitive market by considering multiple opportunities in which an agent can negotiate with other opponent(s) in the case of a disagreement. Studies conducted by the authors suggest that in their setting, bargaining outcomes largely depend on the information available to the negotiation agents. Although a game-theoretic analysis is difficult when their negotiation agents have incomplete information, they develop a standard subgame perfect equilibrium of their Ultimatum-like game when the bargaining positions (e.g., remaining bargaining opportunities) of the agents are common knowledge. The paper also suggests that when agents do not know the bargaining positions of their opponents, one alternative may be to use evolutionary algorithms to simulate the complex interactions involving a large number of agents.

5) Markets of Humans and Artificial Agents: The novel feature of the paper by J. Grossklags and C. Schmidt is studying the psychological impact and influence of artificial agents on the market behaviors of human traders. The paper reports empirical results of several experiments on trading in markets involving both humans and software agents in a controlled laboratory environment. The experimental setting implements an American futures market in which trading can occur either directly with the bank, as well as among traders in a continuous double auction. One of the questions that the authors attempt to answer is how common knowledge on the presence of software agents affects the behaviors and outcomes of human traders. Their experiments were carried out with 1) human traders being informed about the presence of artificial agents in the market; 2) human traders not knowing the presence of artificial agents; and 3) with only human participants (which the authors term as baseline treatment). The empirical results show that market efficiency decreased in comparison to the baseline treatment when artificial agents were introduced to the market but human traders were not informed of their presence. When human traders were informed of the presence of artificial agents, the market efficiency was much higher. Their results seem to indicate that common knowledge on the presence of artificial agents has a positive effect on human traders.

6) Game and Negotiation of Contracts: The paper by G. Boella and L. Torre presents a game-theoretic model for negotiation of contracts. The games in this paper deviate from the tradition of von Neumann–Morgenstern, and their model rests on the foundation of the work of sociologist Goffman's game-theoretic interpretation of obligations. This paper addresses the problem of how artificial agents acting on behalf of users reason about contracts inside virtual organizations. The authors demonstrate how agents modify behaviors of organizations through constitutive rules that alter the normative systems. In this paper, contracts are viewed as legal institutions (or systems of regulative and constitutive norms). Through recursive modeling, the authors develop a game theory in which agents negotiate contracts to alter their normative positions by adding new norms to the normative systems.

7) Cooperative Mediation-Based Protocol: The paper by R. Mailler and V. Lesser views negotiation as a cooperative, iterated search for solving distributed resource allocation problems in dynamic environments. The contribution of this paper is the design, implementation, and evaluation of a distributed cooperative mediation-based protocol (called *SPAM* (scalable, periodic, anytime mediation)) for efficient allocations of distributed sensing resources to the task of tracking targets in dynamic environments. In *SPAM*, agents act as mediators when resource conflicts are identified and the protocol exploits the cooperative nature of agents in the environment to optimize their social utility. An interesting feature of the protocol is *utility concessioning* in which small changes in an agent's local utility may remove conflicts in resource assignment and improve the global utility

without having to enter the mediation stage. Results from their simulations seem to show that the protocol is scalable; with increasing number of targets, the percentage of targets being effectively tracked remains constant.

8) Pricebot and Reinforcement Learning: The paper by C. Raju, Y. Narahari, and K. Kumar studies the problem for competing sellers to dynamically determine the right price for charging purchasers of a product/service. In this paper, sellers offering identical products/services use automated pricing agents (or *pricebots*) that employ reinforcement learning to determine price levels based on factors such as customer (purchaser) queue level, inventory level, and prices of competing sellers. Adjusting price levels at minimal cost requires information about the purchasers (e.g., their purchasing behaviors) and competing sellers (e.g., their pricing strategies). The authors consider the dynamic pricing problem in two scenarios: 1) *no information*—where each seller does not know about the inventory levels, customer queue levels, or pricing strategies of other competitors; and 2) *partial information*—where each seller has some information about the customer queue levels and inventory levels of other competitors. It is interesting to note that when sellers have partial information, the authors model the problem as a Markov game and adopt reinforcement learning to learn dynamic prices.

9) Market Simulator and Pricing Strategy: The final paper by M. Viamonte, C. Ramos, F. Rodrigues, and J. Cardoso is a technical correspondence. This short paper presents a multiagent market strategy simulator for modeling different pricing strategies of buyers and sellers. Both buyers and sellers select and adjust their pricing strategies by considering factors such as risk preferences, user preferences, and available market information acquired through data mining.

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