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An experimental study of software agent negotiations with humans

Rustam Vahidov *, Gregory Kersten, Raafat Saade

Department of Supply Chain & Business Technology Management, John Molson School of Business, Concordia University, Montreal, Quebec, Canada

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ABSTRACT

Electronic negotiations allow participants to negotiate online and use analytical support tools in making their decisions. Software agents offer the possibility of automating negotiation process using these tools. This paper aims at investigating the prospects of agent-to-human negotiations using experiments with human subjects. Various types of agents have been configured using the following tactics: individualistic, neutral, yielding, yielding-then-individualistic, and absolute tit-for-tat. These agents were paired up with human counterparts for negotiating product sale. A set of hypotheses has been proposed involving the performance of agents, as well as humans in terms of objective, as well as subjective measures. Overall, the findings speak in favor of agent-managed negotiations.

1. Introduction

Negotiation is a powerful and flexible mechanism that allows two or more parties to search for acceptable agreements. While negotiations are less structured than other mechanism families, i.e., catalogs and auctions, they nonetheless allow for the parties to be actively involved in the process of exchange. Online negotiations supported by electronic negotiation systems (ENS) allow spatially separated parties exchange offers over the internet [21]. ENS can be used to structure the offer exchange to a different degree (e.g., by requiring an explicit specification of issues and options or exchanging plain text only). They may also incorporate analytical toolboxes for supporting negotiators in their preparation and conduct of negotiations, as well as post-negotiation analysis. This support can range from tools used to capture and model the negotiator's preferences, to provide active advice and critique, and even to automate the negotiation on behalf of human principals.

While a bulk of research on the design and evaluation of ENS has been produced in the recent past, in reality only few commercial sites offer such capabilities to their customers. One such commonly known website that allows customers to make (a limited number of) offers is Priceline.com. Other examples include car dealer sites with the "make us an offer" option. In B2B exchanges, a site like Alibaba lists available products with the possibility to send a message to the supplier containing offers. Yet, negotiations do not represent a dominant model of exchange in either B2C or B2B segments.

A possible explanation to the scarcity of negotiating websites is that negotiations imply a relatively high cognitive load, especially if multiple issues are involved (e.g. price, warranty, product attributes, shipment, etc.). This load may translate into a prohibitive cost when day-to-day transactions involving people who are not negotiation experts are concerned. Additionally, with multiple issues involved, because of bounded rationality of human decision makers, as well as psychological factors they may end up making less consistent decisions.

Automated negotiations as a field that was established over the past couple of decades [1,20] promise to relieve human beings from the above efforts, while taking advantages of the benefits offered by negotiation mechanism. Software agents are autonomous active software units that facilitate negotiation automation by employing various negotiation strategies and tactics. The potential role of agents in B2C and B2B transactions, negotiations in particular has long been recognized [16,18,33].

According to Lin and Kraus [28] agents can alleviate negotiation-related efforts, help people with limited negotiation skills, and also help with training successful negotiators. Yan and Singhal [53] give the following benefits of using negotiation agents as follows: time saving with lower opportunity costs; fewer negative effects, and more efficient settlements. While past work on design and study of agent-to-agent negotiations has been substantial, relatively little experimental work has been done in assessing the potential of human customer vs. software agent negotiations in terms of objective as well as subjective variables.

The purpose of this work is to investigate the prospects of human–software agent negotiations in experimental settings. This is an important question as it relates to the prospects of employing software negotiation agents in practice. To this end an electronic negotiation system incorporating software agents has been built. The system was

* Corresponding author at: Concordia University, 1455 de Maisonneuve Blvd. W, Montreal, QC H3G 1M8, Canada. Tel.: +1 514 848 2424x2974.
E-mail address: rustam.vahidov@concordia.ca (R. Vahidov).

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used in experiments with human subjects to measure such outcomes as utility of agreements and number of agreements. Additionally, such subjective variables as satisfaction and perceived usefulness were also measured.

The remainder of the paper is organized as follows. The next section reviews the relevant past work on negotiation software agents' tactics, designs, frameworks, and experimental studies. The following section discusses theoretical model for the study and puts forward hypotheses based on the past work and expectations from negotiating agents. The paper further describes the ENS and configuration of software agents used in the experiments. Next, the experimental setup is described, including the negotiation case. The paper further presents the results of the experiments, including the hypotheses tests. The paper concludes with the discussion of findings, limitations, and directions for future research.

2. Background

Yang and Singhal [53] distinguish the following three categories of agent involvement in negotiations: (1) human-to-human negotiations with agents providing active support; (2) agent-to-agent negotiations where the process is fully automated, and (3) human-to-agent negotiations, where one party is a software agent, while the other one is a human. Research in the first category concerns use of agents as advisors to help human negotiators cope with complex multi-issue negotiations and stay in line with their declared preference structures and concession-making policies. Examples include the work on Aspire agent [24] and eAgora marketplace [6]. Experimental study involving eAgora system showed that human negotiators using advise-giving agents performed better in complex (multi-issues) tasks than unaided human negotiators [46]. Research in second category, as mentioned earlier, has been extensive and is beyond the scope of the current paper. The third category is most suitable for the work presented here, and we will discuss past studies on human–agent negotiations further in the section.

Lomuscio et al. [31] propose a classification scheme for automated negotiations. Part of this classification includes cardinality of negotiations as consisting of two parts: negotiation domain: single vs. multiple issues; and number of participants: one-to-one, one-to-many, and many-to-many. The latter category includes complex scenarios involving simultaneous interactions of many buyers with many sellers. Continuous double auctions come closest to theses setups among the widely used exchange mechanisms. One-to-many scenarios involve multi-bilateral negotiations with one side (buyer or seller) interacting with multiple counter-parts at the same time. Examples of relevant work include: [35,45,48,49,51]. In this work we are primarily interested in one-to-one negotiations where one party is an agent, while the other is a human.

Another component of the classification scheme according to Ref. [31] is agent characteristics, with bidding strategy being one of the components. The latter relates to the negotiation strategy/tactics and it has considerable implications for the negotiation performance. In Ref. [32] the following set of tactics for agents was introduced: stalemate (no concession), tough (small concessions), moderate (moderate concessions), soft (large concessions) and compromise (complete concession). Faratin et al. [12] have introduced families of tactics that could be flexibly defined for software agents. According to the authors, the tactics are used to decide on what offer to make at a given point in the negotiation process. Negotiation strategies, on the other hand, refer to the choice of tactics based on history, context, and other variables.

The tactics were divided into three categories: behavior-dependent, time-dependent, and resource-dependent. The first family bases its choice of offer on the moves made by the parties. Various forms of tit-for-tat tactics had been presented in this category. Time-dependent tactics model concession-making as a function of time elapsed between the beginning of negotiation and the estimated ending point. Functions that dictated small concessions in the beginning (negative second derivative over time) corresponded to tougher competitive behavior, and were named (perhaps, somewhat controversially) boulware tactics. Those that implied early large concessions were named conceder tactics. Time-dependent strategies were employed in early experiments using Kasbah marketplace [4,5]. Resource-dependent tactics aimed at adjusting concession levels based on a given resource scarcity. In Ref. [34] an idea of evolving agent strategies using the above set of tactics in genetic algorithms has been advanced, along with simulation results. Recently, a model for a negotiation agent taking into account the dynamics of the market (including the number of participants and changing objectives) has been proposed [41]. The model, however, was limited to single-issue negotiations.

The weakness of time-and resource-dependent tactics is lack of accounting for the counterpart's actions, which has a strong influence in human-to-human negotiations. Tit-for-tat family of tactics considers the counterpart's moves and one such tactic has been proposed in Ref. [42]. Here, agents exchange their concession priority vectors, with the negotiators attempting to meet their counterpart's priority, while using their utility gain from a previous offer by the opponent as an upper limit for their concessions.

In Ref. [26] simulation studies involving two-issue negotiations were performed for comparing the performance of a range of tactics. The findings imply that absolute tit-for-tat and boulware tactics performed better than most others. Filzmoser [14] has compared a set of negotiation strategies in a simulation environment using agents, which incorporated preferences of human subjects from the dataset of past negotiation experiments. He compared the performance of agents with the outcomes obtained by human negotiators in those past experiments. No direct agent–human negotiations were performed. The offer generation strategies included monotonic, strictly monotonic, least cost issue, and lexicographic ones. These were combined with concession strategies, and with the aforementioned tit-for-tat strategy by Shakun for a total of nine strategies. The comparison of agents performance with human performance in the past had produced mixed results [14].

Lin and Kraus [28] have discussed the possibility of designing agents that could proficiently negotiate with human counter-parts. The challenge of designing such agents, according to the authors includes bounded rationality and incomplete information [28]. The authors proposed several guidelines for agent designers, including randomization (to prevent manipulation of an agent by an opponent), having concession strategy, and maintaining a database of past interactions (for modeling the opponents). In Ref. [53] a set of propositions that could serve as guidelines for designing negotiation agents has been advanced. The authors stated that better outcomes can be achieved by: making a tough initial offer; making simultaneous equivalent (to an agent) offers; making monotonously decreasing concessions (based on Raiffa's [39] suggestion on signaling “approaching the limit”); making large concession in the final offer; and using strategic delays.

There also have been a number of publications describing design of negotiation systems incorporating agent and human participants. Shaman is a framework that envisages integration of heterogeneous market mechanisms and platforms with decision support tools and agents for facilitating negotiations among agents, as well as human participants [23]. An architecture for a coordination and negotiation platform that incorporates agents and may incorporate humans has been proposed in Ref. [10] and further elaborated in Ref. [11]. Based on Belief–Desire–Intention philosophy the agents negotiate over plans bilaterally and simultaneously, and their actions lead to the evolving environment. An illustration is presented using the Diplomacy game. In Ref. [38] a methodology called STRATUM has been presented to facilitate practical construction of agent-enhanced negotiation systems. Its purpose, according to the authors was to bridge the gap between automated negotiation theory and practice. Use of agent to human negotiations has also been proposed for the purposes of training [27].