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A systematic model of stable multilateral automated negotiation in e-market environment

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ABSTRACT

In e-market environment, the participants are usually bilateral such as in Consumer-to-Business or Customer-to-Customer business models. The participant on each side prefers the counterpart from which the concerned issues or profits can be pursued. Hence, the effective matching from a global point of view and the stable matching from an individual point of view become the critical function of the business models. In this paper, a systematic model of Stable Multilateral Automated Negotiation (*SMAN*) is proposed to facilitate the involved parties' matching process in two-sided e-market, where confidential mediator agent as well as party agents communicate and make decisions on behalf of their principal parties. To make the matching effective and stable, two optimization models are designed. One is matching points model which makes an effective balance among the proposal value of issues for each possible pair of matching, such that the joint weighted profit measure is optimized with feature rescaling. The other one is matching scheme model which optimizes Social Welfare (*SW*) subject to the stable constraints, and ensures the engaged individual party satisfies the matching result from its viewpoint. And the optimality of stable matching is proved by mathematical deduction. Finally, numerical experiments are illustrated and show that the designed systematic models can generate effective matchings with individually stable advantages over the traditional Multilateral Automated Negotiation of Two Sides (*MANTS*).

1. Introduction

Electronic market (e-market) means using Internet and digital technologies to help selling/buying goods or services (Louta et al., 2008), in which all members can join or exit dynamically and all market information is open and dynamic (Ren and Zhang, 2014a). In recent years, the incredible growth of e-market has profoundly changed business models of enterprises, human life and consumption patterns (Kurbel and Loutchko, 2005; Li et al., 2013; Louta et al., 2008), where merchants can conduct business such as commodity trading or various operations of *SCM* (Supply Chain Management), and even communicating worldwide with partners on Internet throughout the day etc. (Bakos, 1998; Ren and Zhang, 2014a). The budgets or costs on business maintenance of merchants can be significantly saved by avoiding or reducing the physical shops and shop assistants as well (Louta et al., 2008). Moreover, consumers in e-market can enhance their ability of visiting a great diversity of shops and getting much more information about merchants or commodities, and they may negotiate with the desired trading partners as needed such that both the time and traffic costs are saved (Bakos, 1998; Kurbel and Loutchko, 2005; Li et al., 2013; Ren and Zhang, 2014a). In e-market, two-sided business is a common market form and has been employed by many well-known firms such as *eBay* and *Taobao*, where generally there exist two distinct participant groups sellers and buyers (Economides and Katsamakas, 2006; Parker and Van Alstyne, 2005). It is straightforward to consider a bilateral environment where two or more agents belong to the two distinct sides and each agent on one side may negotiate with the counterpart on the other side, such that their principals may find desired trading or service partner. With competition intensified and cooperative communication increased, the participants in two-sided market often

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cope with various benefit conflicts complicated and time consuming. Moreover, as e-market business model becomes popular in commercial society, these conflicts often emerge in trading in terms of warranty, logistics service or quality, etc., and become diversified, complex and distributed (Chen and Weiss, 2013; Li et al., 2013; Louta et al., 2008; Ren and Zhang, 2009; Wong and Fang, 2010). Without doubt, in common sense a variety of negotiations are constructive to mitigate or cope with the conflicts. Particularly, by means of information technology, the negotiation process can be automated where the participants can rely on autonomous agents to cope with the conflicts and guaranteeing their benefits (Cheng et al., 2006; Kurbel and Loutchko, 2005; Louta et al., 2008; Ren and Zhang, 2014a). Autonomous agent based automated negotiation takes place when the negotiating function is performed by (networked) computers on behalf of participants or principals (Beam and Segev, 1997), which is central for establishing contracts about goods or services between agents that have conflicting interests (Chen and Weiss, 2013) and has attracted much attentions (Dasgupta et al., 1999; Li et al., 2013; Park and Yang, 2008; Ren and Zhang, 2014a; Lopes et al., 2008). In automated negotiation, an agent can be designated by its principal to take part in multiple negotiations concurrently with specific negotiation protocols (Jennings et al., 2011; Li et al., 2013). *A negotiation protocol* is defined as a set of rules that govern the interaction and specify the types and valid actions of agents and the events related to negotiation states (Jennings et al., 2011; Kurbel and Loutchko, 2005; Wong and Fang, 2010). In order to reconcile the benefit conflicts in two-sided e-market efficiently, the Multilateral Automated Negotiation of Two Sides (*MANTS*) has drawn much attention of scholars and professionals interested in seller–buyer market (Byde et al., 2003; Park and Yang, 2008; Rahwan et al., 2002; Wang et al., 2013; Yoo and Sim, 2010), job market (Kurbel and Loutchko, 2005) and as well as personnel/job shop scheduling (Hsu et al., 2016; Sabar et al., 2009) or partner(s) selection (Wang and Zhang, 2015).

According to the information interaction mode of automated negotiation, there are two main negotiation mechanisms to distinguish *MANTS*: the trade-off mechanism based on agents' direct communication and the centralized mechanism based on Confidential Mediator Agent (*CMA*) (Aydoğan et al., 2014; Beam and Segev, 1997; Jennings et al., 2011). As the trade-off mechanism makes negotiation space too complex to explore (Jennings et al., 2011), lots of time and computing resources are spent on finding counter-offers and exchanging offers (Park and Yang, 2008). In contrast, the centralized mechanism and the concept of *CMA* are broadly studied and customized to improve the efficiency and effectiveness of *MANTS* (Aydoğan et al., 2014; Jennings et al., 2011; Lin et al., 2011). The *CMA* may be considered as a benevolent and omniscient external observer which is neutral (unbiased) and objective and. In *MANTS*, *CMA* can get perfect information of all negotiations and derive an outcome for each negotiation (Fatima et al., 2014), *i.e.*, controlling the process of *MANTS* and finding a suitable matching scheme such that each matched pair of agents obtains optimal benefits based on *CMA*'s negotiation proposals (Aydoğan et al., 2014; Jennings et al., 2011; Lin et al., 2011; Park and Yang, 2008). The *negotiation proposal* for an agent pair is defined as a set of all issue values in a reciprocal trading agreement calculated by *CMA* according to the negotiation information of two paired agents. A *matching scheme* of *MANTS* is a final matching result of all agent pairs in *MANTS* in the forms of *CMA* negotiation proposals for each pair, and the matching of agent pairs in *MANTS* is a typical two-sided matching problem (Fatima et al., 2014; Gale and Shapley, 1962; Teo and Sethuraman, 1998). Each matched pair consists of two agents with different roles, such as a buyer and a seller in a trading market of used cars. It is the agents who help their principals to draw up the trading agreement about a used car through negotiation processes (Park and Yang, 2008). The stability of a matching scheme is very significant to guarantee the efficiency and effectiveness of *MANTS* (Fatima et al., 2014; Ren and Zhang, 2014b; Sheu, 2011). When a matching scheme of agent pairs is stable, no two agents in distinct pairs prefer each other to their current pairs (Teo and Sethuraman, 1998; Teo et al., 2001), *i.e.*, no agent can find any incentive to reject the matching scheme (Fatima et al., 2014). Although some matching scheme of agent pairs without stability consideration can be obtained by maximizing the objective of *SW* in *MANTS*, the agent might give up its matched pair to seek more benefits when the matched pair was found unstable, *i.e.*, there were better pairs for it than the current matched pair in *MANTS*. The abandon of agents in unstable pairs will lead to negotiation failures, which may reduce both the *SW* value and the number of matched agent pairs in *MANTS*. Hence, it is obvious that the stability constraints should play an important role in the *MANTS*, which is considered little in the existing studies (Beam and Segev, 1997; Fatima et al., 2014; Jennings et al., 2011).

In this paper, considering the characteristics of many-to-many structural *MANTS* with multiple issues, a novel systematic model with the centralized mechanism based on *CMA*, called *SMAN*, is proposed. Not only is it designed for facilitating the negotiation processes in an open and dynamic two-sided e-market, but also aims to derive a stable matching scheme adaptively for each *MANTS* round, so as to maximize the *SW* value subject to the constraints of fairness and stability. A round of *MANTS* denotes an information interaction process between agents and *CMA*, *i.e.* agents send their negotiation information to *CMA*, then *CMA* generates an optimal matching scheme and returns to the corresponding agents. Finally, agents make negotiation decision according to the matching scheme and their own negotiation strategies. The *SMAN* consists of a set of seller agents, a set of buyer agents, a set of issues, *CMA* and negotiation protocol. During negotiation, a concerned attribute of some goods is denoted as an issue in trading negotiation, each seller or buyer agent may negotiate on all the issues with its goods trading partner. In *SMAN* the role of *CMA* is to control the negotiation process and to find a stable matching scheme of agent pairs for *MANTS*. The decision-making model of *CMA* consists of two sub-models: matching points model and matching scheme model. ***The matching point model*** *is to find all possible matching points in MANTS, in terms of profit matrices of buyer and seller agents and joint profit matrices of matching points*. ***The matching scheme model*** *is to generate a stable matching scheme of agent pairs in each MANTS round to maximize SW value subject to the constraints of stability and the profit matrices.* The main contribution of this paper can be summarized as follows: a systematic model of *SMAN* concerning the stability of agents matching is proposed and it is proved that the matching scheme model in *SMAN* can ensure the matching stability as well as effectively solving *MANTS* problem in e-market. The systematic model of *SMAN* and the designed *MANTS* platform can be applied to many supply–demand matching business platform environments, such as second-hand goods sale, marriage service, house renting, labor recruitment, teaching assistant and so on.

The rest of this paper is organized as follows. In Section 2, the literature review is presented about the existing related researches, including automated negotiation and stable matching. In Section 3, the definition of *SMAN* is given in detail and two optimization models are designed. Section 4 describes the simulation environment and presents the numerical studies, to validate the significant effect of stability in the agent pair matching problem of *MANTS*. Finally, in Section 5 the conclusion is drawn and the future researches are discussed.

2. Literature review

2.1. Negotiation in e-market

Since *Baekeland*'s negotiation with *Eastman Kodak* for the price of selling his invention rights in 1899 (Beam and Segev, 1997), negotiation has become an important research topic and is more active in recent years (Ren and Zhang, 2014a). The aim of negotiation is to settle benefit conflicts and reach a mutually acceptable agreement between distinct parties concerning some problem domain (Fatima et al., 2014). In a negotiation, each person or party often has a set of negotiation ranges over all issues (an issue is a key attribute in negotiation Baek and Kim,