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# Socially rational agents in spatial land use planning: A heuristic proposal based negotiation mechanism

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ABSTRACT

This paper introduces a novel heuristic based negotiation model for urban land use planning by using multi-agent systems. The model features two kinds of agents: facilitator and advocate. Facilitator agent runs the negotiation according to a certain protocol that defines the procedure. Two roles are designated for advocate agent in the negotiation process: speaker and listener roles. Advocate agents act as a speaker on a regular basis and its role is to propose a modification of land use plan for the listener agents. The role of listener agent is to express his opinion about the proposed plan.
The model also considers that the agents are socially rational in proposing and responding to the others. Social rationality is the rationality of interpersonal relations and social action; it describes that in social contexts, people do not only care about their own payoff, but also they care about others' payoff. In fact, this research also seeks to examine the link with social reasoning and use its insights to explore conflicts between individual and social concerns in an urban land use planning meeting. An illustrative example of the proposed negotiation process is performed on a real-world case study. The results of the study are presented and are compared with two other scenarios: non-collaborative scenario (purely selfish) and fully-collaborative scenario (purely altruistic). The results show that the proposed social rationality scenario is more realistic, and it has a better performance than the two other scenarios.



## 1. Introduction

Negotiation is a daily human activity and plays significant role in resolving conflicts, facilitating human social interactions and reaching a consensus. It has been received particular attention in Urban Land Use Planning (ULUP). The increased involvement of stakeholders and the multiplicity of their interests and priorities in ULUP has led to the necessity of negotiation in order to help them to reach an agreement (Haque & Asami, 2014). Negotiation commonly is a complex, time-consuming and expensive activity (Beam & Segev, 1997; Kersten & Lai, 2007). To relieve human beings from the cumbersome negotiation related efforts, save time with lower opportunity costs and also help people with limited negotiation skills, automated negotiation was established (Vahidov, Kersten, & Saade, 2014). It has root in Artificial Intelligence (AI) and it is a distributed search in the space of potential agreements, facilitated by multi-agent system (MAS) which consists of a set of intelligent elements, called agents, designed to mimic human behavior.

For performing automated negotiation, three types of approaches have been discussed in MAS literature as the authors argued in Jennings et al. (2001). These approaches are the game-theoretic approach, argumentation-based approach and the heuristic-based approach. The Game-theoretic approach utilizes a set of rules, called solution concept, to find a strategy for each actor to take the most rational action at each negotiation state (MacKenzie & DaSilva, 2006). To find the best choice of action, the agents assume that their opponents are rational (i.e. they try to optimize their outcome). The game theory literature on the topic of negotiation is vast. For an overview, readers can refer to Binmore and Vulkan (1999). The second approach is the argumentation-based approach, in which, in addition to the proposals, agents can also exchange supplementary information, called argument, which can help them in reaching a consensus. An argument is defined as a piece of information that helps an agent to justify its opinion or influence its opponents' opinion by persuading them (Rahwan et al., 2003). That is, instead of rejecting a proposal, an agent can explain which parts of the proposal are not acceptable and why. The agent can also provide arguments in the form of rewards, threats or appeals to persuade other parties to accept an offer (Eshragh, Pooyandeh, & Marceau, 2015). For an overview of argument based techniques, readers can refer to Carrera and Iglesias (2015).

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The third approach is heuristic-based, it came to cope with some limitations of the game-theoretic approach (Jennings et al., 2001). In this approach, agents try to find a satisfactory, not necessarily the optimal solution. Negotiating agents rate the points in the agreement space based on their utility function then exchange offers with other parties to find a mutually acceptable agreement. The most common strategy which is used by the negotiators during the heuristic-based negotiation process is concession strategy. The strategy consists in determining the level of concession at each step by using either a single function or a combination of functions. The most common functions for calculating the level of concession are (Faratin, Sierra, & Jennings, 1998): time-dependent, resource dependent and behavior dependent.

The current work suggests a novel negotiation model based on the third approach. In this case, it is assumed that several negotiator agents come together to reach an agreement on the underlying issue according to a specific negotiation protocol. They enable to do proposals and respond to others' proposal by saying “accept” or “reject”. The interaction and also sharing the information among the agents are coordinated by an agent who is called facilitator agent. The proposed negotiation mechanism also utilizes a time-dependent concession strategy to ensure reaching an agreement before the deadline. The proposed approach is applied to urban land use planning process and demonstrated in a case study.

MAS have substantially been used for land use studies and a relatively comprehensive review of works have been provided by An (2012), Filatova, Verburg, Parker, and Stannard (2013) and Parker, Manson, Janssen, Hoffmann, and Deadman (2003). MAS specifically developed for assisting participatory land use planning processes by some researchers such as (Becu, Neef, Schreinemachers, & Sangkapitux, 2008; Bousquet et al., 2002; Castella, Trung, & Boissau, 2005). Despite the numerous studies of applying MAS for land use planning, there is a lack of effective methods to reflect the stakeholders' role in the process of ULUP and the negotiation process among various actors (Long & Zhang, 2015). There are several studies related to highlighting the role of stakeholders and their negotiations in ULUP process by means of MAS. An early example is the work of Ferrand (1996), who suggested the use of simple agents representing actors to simulate the negotiation process in spatial planning. This study still lacks elaboration and a practical implementation. Ligtenberg, Wachowicz, Bregt, Beulens, and Kettenis (2004) explored the use of MAS in order to simulate spatial scenarios based on modeling multi-actor decision-making in a land use planning process. They only studied a limited form of actor communication. Therefore, negotiation and cooperation were missing in their model. Ligtenberg, Beulens, Kettenis, Bregt, and Wachowicz (2009) extended the previous work by designing a specific mechanism for sharing knowledge among participating actors. They applied the model for resolving conflicts in a three-actor and single-issue land use planning problem (a site selection problem).

Saarloos (2006) presented a combination of MAS and a probabilistic approach in order to enable decision makers to generate alternative land use plans under conditions of uncertainty. The work was concentrated on the question of how to deal with uncertainty in a plan generation phase rather than on negotiation among the agents. This plan generation phase is part of their prepared Planning Support Systems (PSS). In that context, three types of agents are distinguished: a group of interface agents to monitor user's behavior, a group of tool agents to help users or other agents with selecting and using specific tools and a group of domain agents representing the variety of land use experts involved in planning (Saarloos, Arentze, Borgers, & Timmermans, 2008). As an extension of their work, Arentze, Borgers, Ma, and Timmermans (2010) and Ma, Arentze, Borgers, and Timmermans (2007) addressed the problem of how to incorporate the uncertainty about the future spatial distribution of competitive and synergetic land uses. For this purpose, they used the Bayesian decision network to represent agents' expert knowledge.

Pooyandeh and Marceau (2013) developed a spatial web based development support system by integrating MAS and fuzzy set theory to acquire fuzzy preferences of stockholders about the alternatives. The purpose of the system was to aid stakeholders in reaching an agreement about a site selection problem. In an application, they examined the impact of incorporating a learning technique to improve the achievement of agreement in agent-based negotiation regarding land development in southern Alberta. The agents were equipped with Bayesian learning capability to predict the evaluation functions of other agents (Pooyandeh & Marceau, 2014). Kamps (2013) developed a MAS based simulation model that links the form of residential developments to actor's bargain and negotiation power. The housing development process was simulated through the negotiation between a local planning authority agent and a private housing developer agent.

In this paper, a new agent-based model of multi-actor decision-making for ULUP is developed. Several agents attend in a land use planning meeting; they apply different spatial metrics to evaluate the spatial configuration of land uses from their own viewpoints. In addition to introducing a specific negotiation mechanism, it also is considered that agents are socially rational. In almost all of the recent works, the dominant decision-making philosophy in agent design has been to equate rationality with the notion of an individual maximizing a self-biased utility function. Thus, an agent's motivation is the maximization of benefits with regards to his own goals. Therefore, they have missed the role of social parameters in negotiations. Potentially, social parameters such as altruism and selfishness play an important role in group decision-making process (e.g., Arentze, 2015). Altruism refers to a willingness to benefit others, even at one's own expense. Selfishness, the opposite of altruism, refers to prioritizing one's own interests, with a concomitant lack of consideration for others (Saito, 2015). Following Arentze (2015), it is considered that the agents use a social utility concept for evaluating other agents' proposal. A social utility function describes how individuals deal with their and other agents' preferences. It is assumed that agents act like selfish agents in earlier rounds of meeting and by passing the time, they become more willing to assign higher weights to other agents' preferences (altruism) in order to reach an agreement.

The rest of the paper is organized as follows: some preliminaries which are necessary to provide for a better description of the approach are established in Section 2. Section 3 describes the proposed negotiation model. Section 4 is devoted to introduce some spatial metrics along with steps of suitability map generation. An illustrative example is explained in Section 5. Different scenarios of group negotiations are compared and are discussed in Section 6. The paper ends with some conclusions and discussion of possible directions for future research.

## 2. Spatial urban land use planning

Spatial urban land use planning is a complex human endeavor (Couclelis, 2005) in which different stakeholders (planners) come together in order to resolve conflicts and reach an agreement about the spatial configuration of land uses. Taking account the view of Davidoff on land use planning (Davidoff, 1965), the current study assumes that several advocate planners (interested in a particular land use type) participate in a ULUP and act as advocates articulating the interests of their own and other related group much as a lawyer represents a client. Therefore, for example, a planner might develop and advocate for a plan which would be interest of residential developers and another planner might have a different plan representing the point of view of commercial developers in the same area and so on. In addition, to model USUP decision processes, the following assumptions are made:

- The environment (study area) is represented by a raster data model. The environment consists of a lattice of cells ($C_{ij}$) where $i$, $j$ are indexes that determine the location of the cell in the lattice. Therefore, land use plans, metrics, and suitability maps are also represented by a raster data model.