Efficient Agent Negotiations in a Realistic Context

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1 Introduction

In practice, many problems can be modeled by resource allocation problems. However, even if their aim is often to identify a resource distribution maximizing a given objective, different approaches exist. Many solving techniques only focus on the best resource distribution. Such approaches consider resources from one side and agents on the other side. It is the case for all centralized techniques, like with combinatorial auctions and the so-called winner determination problems [5]. However, in many applications, resources are initially already distributed between agents of the population. In such cases, the aim is to identify a sequence of transactions leading from the initial resource allocation to an optimal solution. Then, centralized techniques are not suitable to solve allocation problems in such conditions. In this purpose, methods based on agent negotiations have been developed, where autonomous agents negotiate by pair to identify acceptable transactions. Studies in this field are most of the time theoretical. Some studies established the existence or not of transaction sequence to optimal solutions [4]. Classes of utility functions and payment functions are also studied to design convergent negotiation processes [1]. They also study different scenarios corresponding to different preference representation and to different acceptability criteria [2]. However, these studies did not focus on the mechanism to use in order to get an optimal solution, they characterize properties that may favor the achievement of optimal allocations and design abstract frameworks. However, none of them is able to exhibit acceptable transaction sequences or provide the agent behavior to implement in order to negotiate efficiently in practice.

More importantly, these studies are not always based on realistic assumptions. Most of the time, agents are omniscient: they know everything about other agents , their resources as well as their preferences. Most of the time, communication abilities of the agents are always assumed complete. An agent is always able to negotiate with all agents in the system. These assumptions are not realistic. For instance, in networks, a node is only linked with a very restricted number of neighbors, like in peer-to-peer networks, and is not aware of the whole system. As well, in routing problems, all servers are not interconnected. Solutions provided by methods that do not consider restricted communications may not be achievable in practice.

In this paper, we choose to focus on distributed methods to solve resource reallocation problems in a realistic context. The aim is to design negotiation settings leading agent negotiations to optimal solutions using local negotiations. Any restriction on the agents' communication abilities can be considered and information privacy can be handled. Agents should only have a local perception of the system. The efficiency of a negotiation setting must be guaranteed, even when communication abilities of the agents are restricted. Thus, the impact of the communication restrictions should also be evaluated and features favoring or penalizing the negotiation efficiency must be identified.

2 Issues on agent negotiations

Since agents communication abilities are usually not restricted to negotiation problems, it is legitimate to investigate the importance of such a parameter. Negotiation processes, which lead to optimal solutions according to complete communication abilities (i.e. based on complete social graphs), may only lead to solutions far from the optimum, when communications are restricted.

Proposition 1 (Social graph impact)**.** *Independently of the objective function considered, the achievement of optimal resource allocations cannot be guaranteed if a restricted social graph is considered.*

Proof. Let us prove this proposition using a counter-example, based on a population of 3 agents $\mathcal{P} = \{0, 1, 2\}$ and a set of 3 resources $\mathcal{R} = \{r_1, r_2, r_3\}$, where the aim is to maximize the utilitarian welfare. The agents preferences and the social graph with the initial resource allocation are described in Figure .

Agents only perform transactions increasing their own utility. According to such conditions and to the social graph, no transaction can be performed. Only two exchanges are possible, but both lead to a decrease of the individual welfare

Population $\mathcal{P}$	Resource Set $\mathcal{R}$		
	r_1	r_2	r_3
0	3	1	9
1	1	4	1
2	10	2	3

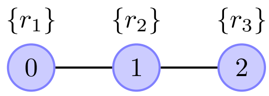

Figure 1: Example of agents preferences and social graph

of at least one participant. The exchange of r_1 and r_2, or the exchange of r_2 and r_3 penalizes both participants.

However, the current allocation is suboptimal. The exchange of r_1 and r_3, which leads to an increase of both participants' utility, is not possible since agent 0 and agent 2 cannot communicate. Hence, restrictions on agents communication abilities may prevent the achievement of optimal solutions. □

Restricted social graphs also have an indirect influence on the negotiation process. The order according to which agents negotiate is not important when complete social graphs are considered. Indeed, resources can always be traded with all other agents. However, this order becomes an important parameter to consider in the case of a restricted social graph.

Proposition 2 (Negotiation order)**.** *Independently to the objective function which is considered, the order in which agents negotiate with each other can prevent the achievement of optimal resource allocations.*

Proof. Let us prove this proposition using a counter-example, based on a population of 3 agents $\mathcal{P} = \{0, 1, 2\}$ and a set of 3 resources $\mathcal{R} = \{r_1, r_2, r_3\}$, where the aim is to maximize the utilitarian welfare. The agents preferences and the social graph with the initial resource allocation are described in Figure .

Population $\mathcal{P}$	Resource Set $\mathcal{R}$		
	r_1	r_2	r_3
0	2	10	4
1	5	3	9
2	2	7	1

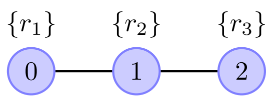

Figure 2: Example of agents preferences and social graph

Let us assume that agent 1 initiates a negotiation. Depending on which neighbor it selects to negotiate first, the negotiation process may end with suboptimal allocations instead of optimal ones. If agent 1 first chooses agent 0 as partner, the exchange leads to a sub-optimal allocation from which the negotiation process cannot leave. However, if agent 2 is selected first, the negotiation process ends on a socially optimal allocation. Hence, the optimum can only be achieved using a specific order of negotiation. □

Thus, the social graph represents an important issue since its topology may prevent the achievement of an optimal resource allocation in practice. Its influence on the efficiency of negotiation processes must be considered and should not be omitted as it has been done in former studies.

3 Conclusion

Many applications can be represented by an allocation problem where resources are initially distributed to the agents. The aim is to find a transaction sequence leading from the initial allocation to an optimal solution. Centralized techniques are not efficient due to the problem complexity, and moreover are based on an ideal context, as well as former agent-based studies. Indeed, agents are omniscient and can negotiate with all agents of the population. However, such assumptions are not realistic compared to real life applications.

We show in this paper the importance of considering realistic environment, i.e. restrictions on agent communication abilities. Thus, it is essential to provide mechanisms able to handle such restrictions and ensure as well the achievement of interesting results. Agents should have limited perception of the whole system, starting to negotiate with their resource bundle, their own preferences and a list of possible partners [3].

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