Negotiation Strategies for Combining Partials Deals in One-To-Many Negotiations

Doctoral Consortium

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ABSTRACT

Efficient automated negotiation is not trivial in one-to-many negotiations with partial deals, where a negotiation agent is challenged with a difficult task to plan and oversee multiple interconnected negotiations. A decision or deal made in one negotiation can affect subgoals in other subnegotiations, so substrategies in different subnegotiations should be well aligned to achieve a common goal. The interconnected nature of subnegotiations and the uncertain course of opponent actions makes this setting a complex challenge.

We study the challenges faced in a one-to-many context with partial deals and explore their theoretical properties in combination with experimental research. We specifically discuss the challenges for protocol design and negotiation strategies.

KEYWORDS

One-to-many negotiation; Automated negotiation; Partial deals; Optimal offers; Bidding strategy; Concessions; Negotiation

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1 INTRODUCTION

Automated negotiation is applied in many fields, including energy systems [8], supply chain management [14] and e-commerce [11], where it can save time and reduce process errors. However, efficient and accurate negotiation is non-trivial, especially when an agent has to negotiate with multiple parties at the same time. The agent is challenged with a difficult task to combine interconnected subnegotiations and optimize the bidding (sub)strategies.

As an example, imagine a hospital that needs to purchase a large quantity of face masks, disposable gloves, and soap. There are several suppliers, each of which has its own stock, price, delivery time, etc., and the hospital can collect the goods from several of them; in other words, it does not have to commit to one supplier to buy the full lists of goods. The hospital is challenged to decide which supplier to negotiate with and what to negotiate over.

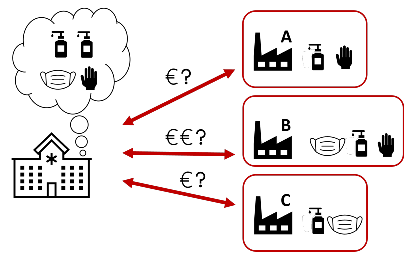

Figure 1: One-to-many negotiations with partial deals.

The given example entails several aspects of negotiation. Negotiation is making concessions toward a mutually agreeable outcome [17], assuming incomplete information about the preferences of the opponents. This problem specifically describes *one-to-many negotiation*, which means that one agent (the hospital) engages in bilateral negotiations with multiple opponents (the suppliers) concurrently, also called subnegotiations, studied before by [1, 9, 15, 19] among others. Moreover, it describes how the hospital is allowed to collect the goods in multiple *partial deals*: The negotiation will not conclude in one big agreement with all the parties together (which is multilateral negotiation [3]) nor will it end in one agreement with one party; instead, the final result will consist of multiple smaller agreements between our agent and several opponents, for instance studied before by [12].

Several challenges arise in one-to-many negotiation, because the different subnegotiations influence each other. Reviewing the running example, suppose we can obtain a fairly good deal for all the face masks that we need from supplier A. This deal allows the subnegotiators to adopt more ambitious strategies, since they certainly know that they should never accept or bid anything worse than this deal from any other supplier. However, since the setting allows partial deals, the interconnectivity between each negotiation extends even further. For example, if supplier B offers a deal with both face masks and soap, the buyer should carefully think if it can combine well with possible future deals, dependent on factors such as the expected price and availability of soap. This makes the interactions complex, since the separate negotiations do not necessarily strive for the best deal anymore; instead, an achieved deal in one negotiation greatly affects the goals that the other subnegotiators should aim for.

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2 PROTOCOL CHALLENGES

The interconnectivity of subnegotiations requires a well-adapted protocol that supports concurrent negotiations and information exchange between them and allows to evaluate and consolidate a combination of multiple deals. Here, we discuss some key protocol aspects that influence the course of negotiations with partial deals.

For instance, the specification of immediate binding offers as used in the widely known alternating offers protocol (AOP) [18] limits the flexibility, since it would force the buyer agent (the hospital) to send out offers that are mutually exclusive. Alternatively, one could implement a two-side acceptance protocol [1, 5] or a protocol that allows buyers and sellers to decommit at a cost [16], which could be extended to a partial deal setting. Further adaptation of the AOP is necessary, where agents take turns in proposing an offer, until one of them accepts or the deadline is reached. One can randomly assign an order of negotiations, synchronize the rounds of all the different subnegotiations as adopted in [12], or allow an asynchronous offering protocol as has been done in [5]. However, the specific choice can affect the generalizability, complexity and fairness of the approach. For example, when the order of negotiations is randomly assigned, the last seller in the row might have much less chance of finishing a deal in comparison with the synchronous protocol. Instead of specific amendments, recent work [13] introduces a generalized version of AOP for unmediated and mediated protocols, showcasing preliminary strategic results.

Furthermore, the selection of a particular utility function in the protocol impacts the complexity of the negotiation task. If the buyer's utility function is simply the sum of the individual utilities from the subnegotiations, this one-to-many negotiation protocol resembles a multi-issue bilateral negotiation. Using a utility function that is based on the maximum utility in the collection of achieved deals, this resembles a one-deal one-to-many negotiation with (penalty free) decommitments, which limits the applicability. Regardless of the exact utility function, the protocol should allow the buyer to evaluate the combinations of partials deals efficiently.

An alternative to a negotiation protocol is a centralized approach, where a central body can allocate the resources and evaluate the fairness, which transforms the problem into an optimization challenge. However, a central approach brings forth some disadvantages. First, we should respect the privacy of the participating agents. Sharing the exact preferences could display sensitive information, for example on their financial situation. Second, the running example involves self-interested agents, as do many realistic applications. Even though a central approach could result in an optimal solution for fairness and sustainability, it does not guarantee the best solution for each individual agent. Specifically, hiding true preferences could be beneficial for individual outcomes. Lastly, assuming an omniscient central body is not realistic in many applications. Given the chaotic and dynamic nature of the buying and selling process, even a central authority may struggle to identify the optimal solution. Therefore, we will focus on decentralized negotiation approaches.

3 STRATEGY CHALLENGES

Given the adapted protocol design aspects as we described before, we also encounter new challenges for the design of agent strategies. We distinguish three components: the bidding strategy, acceptance strategy and opponent modeling [7].

Since the protocol allows for multiple interconnected smaller deals, the agent needs to decide what sellers to negotiate with and what to negotiate over. At the same time, the agent needs to keep track of all the different subnegotiations and handle the great number of possible sets of partial deals. A first step in combining all the subnegotiations is designing the algorithm for one specific subnegotiator. From the perspective of one subnegotiator, other negotiations can function as *backup plan*: If one deal is already agreed upon, other subnegotiators can fallback on that option if their negotiation fails. A backup plan, also called *outside option*, can often be modeled abstractly using a *reservation value*, which is the utility value that an agent gains if the negotiation fails.

In our recent work [10], we study the influence of reservation values on bidding strategies. If an agent has a high reservation value, it can seek more risks when accepting and offering bids, since it is less problematic when a negotiation ends in disagreement. The paper builds on this intuition to develop an optimal bidding strategy called MIA-RVelous for bilateral negotiations with private reservation values, and provides theoretical proofs of optimality for this setting. As an extension, we currently work on probabilistic reservation values to model concurrent negotiations. Since concurrent negotiations may not always produce a consolidated deal, probabilistic reservation values can model these subnegotiator's backup plans, and can be used to redirect the course of negotiation. In this way, our work serves as a basis to inform the bidding (sub)strategies in a multi-deal one-to-many setting.

The interplay between subnegotiators extends even further when considering the strategies from a coordinating point of view. In a police interrogation, the attitude of "good cop" and "bad cop" are strategically combined to get the best result. A similar combination of risky and conceding behavior could be beneficial in one-to-many negotiation as well. Since the subgoals change continuously, the subnegotiators should be able to deal with dynamic goals and utility functions, and align well with the strategies other subnegotiators adopt, which brings forth new coordination challenges.

Furthermore, many opponent modeling techniques have been designed in recent years [2, 6]. Assuming that the different subnegotiators negotiate over the same domain in concurrent negotiations, it might be possible to learn real-time across subnegotiators. Research in opponent modeling for repeated encounters for bilateral negotiation could serve as an inspiration here, e.g. [4].

4 CONCLUSION

We encounter many challenges in one-to-many settings with partial deals. When modeling a hospital that purchases goods from multiple suppliers, the interconnectedness of the different subnegotiations makes the problem complex. Our main challenge is combining different subnegotiations, and we aim to provide new algorithms and theoretical guarantees in this ongoing research in protocol design and negotiation strategies.

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