

Negotiation Coalitions in Group-Choice Multi-Agent Systems

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ABSTRACT

In Group-Choice Decision Making (GCDM) where a number of stakeholders are involved in choosing a single solution from a set of available solution options, it is common for the stakeholders to form coalitions during negotiations in order to increase their individual welfare. It is also common to use Multi-Agent Systems (MAS) to automate GCDM processes. In such MAS, agents have to form coalitions like their human counterparts. Within each coalition, the individual agents behave according to the strategies of their clients. In this paper we present a coalition formation model which can employ multiple coalition formation algorithms. The model is motivated by a real-world group-choice multi-agent system that we developed; in the system, agents can form coalitions dynamically based on the similarity between their preferences, and based on the ownership criteria. Finally, this paper presents simulation results that illustrate the operational effectiveness of our coalition formation model.

Keywords

Coalition-formation, Negotiation, Group-Choice, Game-Theory, Qualitative-Reasoning.

1. INTRODUCTION

Coalition formation has the potential of increasing the welfare of negotiating entities. Therefore, the notion of forming coalitions is normally applied in various domains, including commerce, engineering and social planning. Furthermore, coalition formation in MAS has attracted a lot of attention because agents can easily be used to represent the negotiating entities, and they are capable of finding more profitable coalitions than humans in complex environments.

Although a variety of automatic coalition formation models have been proposed in literature, they all fall under the following two distinctive categories:

1. Utility based models: These models (e.g. Game Theoretic Models) normally aim at identifying stable coalitions of negotiating agents, as well as determining appropriate models for sharing coalition benefits [1, 2, 3 and 8]. Most of these algorithms are naturally centralized; this is against the principle of decentralization which is fundamental to the concept of MAS. The computational requirements of utility based coalition formation algorithms usually make them impossible to implement [4]. Moreover, the algorithms normally assume that the agents surrender all their autonomy to their coalitions.
2. Knowledge based models: Knowledge based models for coalition formation [5, 6 and 7], depend on the skills of the individual agents to establish the most beneficial coalition structures. These models are normally computationally feasible, but they invariably have the following shortfalls:
 - They are usually feasible for small MAS.
 - They implicitly assume that there is no coalition structure that is more beneficial to all agents than the grand (coalition of all negotiating agents) coalition [4].
 - Like the utility based coalition formation algorithms, knowledge based algorithms normally assume total loyalty of agents to their coalitions.

This paper presents a coalition formation model that can employ multiple coalition formation algorithms. Besides increasing the utility of the negotiating agents and controlling the dynamics of the negotiation process, our coalition formation model has the following advantages:

- Our coalition formation model allows each agent to have different commitment levels for different coalitions to which it belongs.
- The model is not limited to any particular type of coalition structures.
- The model does not add any extra communication requirements to the MAS.

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- The model is effective for both small and large scale MAS.

The rest of this paper is arranged as follows, In Section 2, we present our coalition formation model. Section 3 deals with simulation experiments that illustrate the capabilities of the coalition formation model. Finally, conclusions are given in Section 4.

2. COALITION FORMATION MODEL

Our coalition formation model works in the context of Group-Choice Multi-Criteria Decision Making (GC-MCDM). Each agent in MAS evaluates the available solution option individually based on the preference model of its client, using a Multi-Criteria Decision Making (MCDM) model. Thereafter, the agents select the solutions with the highest score as the offers to their negotiation opponents. At the end of every negotiation round, each agent adjusts its preference value function in a way so to increase the utility associated with the solution that the agent regards to be the “best-fit” for its coalition. Figure 1 shows that the main components of our coalition formation model are the following: the Algorithm Component, the Social Component, and the Commitment Component.

The Algorithm Component of our coalition formation model can have multiple coalition formation algorithms. In view of that, the GC-DSS we developed has two coalition formation algorithms. The first algorithm is based on agent ownership. This algorithm is very simple; all it requires is for the agents to have the ability to identify the owners of their negotiation opponents. The second algorithm is based on the similarity of preferences, which is determined using the *Qualitative Reasoning* model presented in Wanyama and Far [11]. For the ownership algorithm, the input is the identification of the negotiation opponent and the offer that the opponent has made. On the other hand, the input for the similarity algorithm is the offer made by the negotiation opponent. The output of both algorithms is the preference model of the negotiation opponent (proposer).

The preference model of the proposer is sent to the Social Component, which uses a MCDM model to determine the estimated scores of all the solution options for the proposer. The estimated scores of the solution options for all coalition members which have already made their offers, together with the scores of the solution options for the concerned agents are fed into a *Game Theory* model to generate the *Social Fitness Factors* (SF_r) of the Solutions [9, 10]. These factors represent the tradeoffs associated with the solution options in respect of the coalition.

Besides generating the estimated preference value functions of the offer proposers, the Algorithm Component of our GC-DSS determines the *Tradeoff Factors* (T_r) of the

solution options. These factors represent the amount of tradeoff associated with the solution options with respect to the concerned agent. The *Tradeoff Factors* and the *Social Fitness Factors* of each of the solution options are combined in the Commitment Component to generate the *Acceptance factors* (A_r) of the solution options [10]. The

Acceptance Factor of a solution option is a measure of the ability of the solution to satisfy the combined preferences of the coalition members, from the perspective of a given coalition member. The generated Acceptance factors are used to update the offer acceptance/rejection criteria in the decision making component of the agent before responding to the current offer. Furthermore, the *Acceptance factors* associated with the last offer in each negotiation round are used in the modification of the *preference value function* of the concerned agent [11].

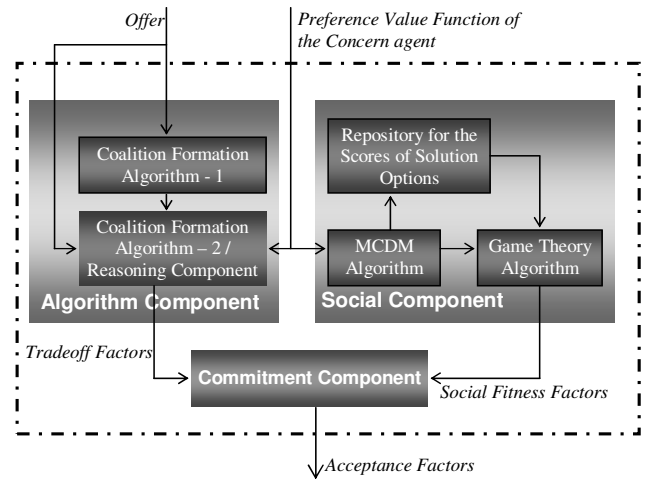


Figure 3. Coalition formation model

The proposed coalition formation model enables each agent to select individually its allies or coalition. Therefore, the model supports the formation of any coalition structure, and it does not require any extra communication or central coordination entity or agent. However, the model results in increased processing for each of the negotiating agents. The focus of this paper is the modeling of the coalition formation process, as well as the modeling of the commitment level of the agents to their coalitions. Therefore, in the following subsections, we briefly describe each of the three components on our coalition formation model.

3. EXAMPLE

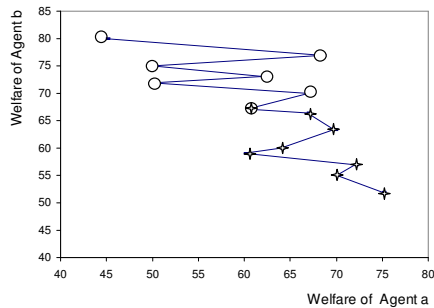
We adopted a group-choice decision making problem from Wanyama and Far [10]. In the problem, three agents were required to evaluate four COTS products based on the preference models of their individual clients, and then

negotiate to select the best-fit product. The following simulation experiments were carried out:

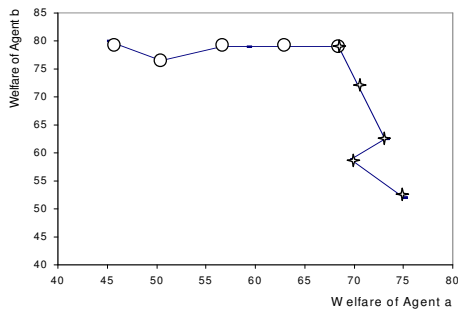
- Negotiation without coalition formation.
- Negotiation with a grand coalition by assuming that all the agents have the same owner.
- Negotiation with each of the three agents being allowed to form an alliance with any other agent based on the similarity of their preferences.

3.1 Results

The results of the first and last simulation experiments are presented in Figures 2(a) and 2(b).



5(a) No coalition formation



5(f) All the three agents are free to form alliances based on the similarity of their preferences

3.2 Discussion of Results

Generally, coalition formation creases the utility (payoff) of the coalition members. That is, the utility of the agreement offer for no coalition formation negotiation (Figure 2(a)) is smaller then the utility of agreement offers for any of the negotiations with coalition formation (Figure 2(b)). Furthermore, Figure 2 illustrates that coalition formation controls the dynamics of the negotiation process, and that coalition formation expedites the negotiation process (forming coalitions resulted in few negotiation rounds).

4. CONCLUSIONS AND FUTURE WORK

This paper presents a coalition formation model that is capable of employing multiple coalition formation algorithms. Currently, the model has two coalition formation algorithms, one based of the ownership of the agents, and the other based on the similarities between the

preferences of the agents. Finally, the paper presents an example that illustrates the capabilities of our coalition formation model.

For the future, we would like to model coalition membership such that agents that belong to multiple coalitions can exhibit different levels of commitment to the different coalitions.

5. ACKNOWLEDGMENTS

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