

Forming Dynamic Coalitions of Rational Agents by use of the DCF-S Scheme

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1. INTRODUCTION

Self-interested, autonomous software agents on the Internet may negotiate rationally to gain and share benefits in stable (temporary) coalitions. For this purpose, each agent determines the utility of its actions and productions in a given environment by an individual utility function. The value of a coalition among agents is computed by a commonly known characteristic function which determines the guaranteed utility the coalition is able to obtain in any case. In a characteristic function game the agents may use imposed individual strategies to achieve a desired type of economically rational.

In any case, the distribution of the coalition's profit to its members is de-coupled from its obtainment but is supposed to ensure individual rational payoffs to provide a minimum of incentive to the agents to collaborate, also in scenarios in which dynamically occurring events may interfere with the running coalition.

Due to its nature dynamic coalition formation (DCF) methods promise to be particularly well suited for applications of ubiquitous and mobile computing. In m-commerce settings, for example, personalized information agents each representing a potential business partner may dynamically form temporary profit-oriented coalitions on demand at any time. That may increase customers' benefits of purchasing and negotiating sets of items at multiple electronic market places world wide in reasonable time. First research towards appropriate economic models for agent-based applications in this domain includes, for example, [4] [5].

2. Traditional Methods to Coalition Forming and Limits

According to [1] models of coalition formation may be classified into two main approaches: utility-based and complementary-based models dividing the societies of actors into ones following either the principle of 'bellum omnium contra omnes' as it is largely favoured, for example, by game theory [2], or ones which rely on the collaborative use of complementary individual

skills to enhance the power of each agent to accomplish its goals, respectively.

Up to now, most classic methods and protocols for a formation of stable coalitions among rational agents follow the utility-based approach that covers two main activities: a) the generation of coalition structures and b) the distribution of gained benefit. These activities may be interleaved and are not independent.

All traditional approaches to coalition formation remain static in the sense that they do not allow for any type of (non-deterministic) interference with the running coalition formation process. In addition, many results known today only hold for super-additive coalition formation environments. Regarding results achieved, further basic research on appropriate concepts and criterions of "vague" stability and corresponding coalition algorithms remains to be performed.

3. The DCF Problem

The research domain of *dynamic coalition formation* (DCF) can be defined by the set of co-operation methods, schemes, and key enabling technologies to cope with the problem of dynamically building beneficial coalitions among agents in open, distributed, and heterogeneous environments. This DCF problem has to be solved in any collaboration environment and scenario in which a) agents may enter or leave coalition formation processes, b) the set of tasks may change dynamically, and c) the information, network, and environment may change dynamically as well.

Co-operation scenarios inducing uncertain, time-limited, context-based utilities and coalition values may exacerbate the DCF problem. In dynamic coalition formation environments the following classes of events occur non-deterministically: a) *tasks* may change for each individual agent at any time, b) *agents* may leave or enter the agent society and c) *information* may change, or become corrupt.

One hard challenge for agents to negotiate stable coalitions in such dynamic settings is how to flexibly react on different kind of changes preferably in real-time without having to restart the complete negotiation process. This in particular requires the agents to individually handle uncertain environment knowledge via appropriate adaptation mechanisms.

4. DCF-S: A Simulation-Based DCF Scheme

The simulation-based dynamic coalition formation scheme DCF-S is designed to enable agents for effectively reacting on changes of their set of goals and agent society. This DCF-S scheme may be instantiated by, for example, the utilization of different computational methods and negotiation protocols with respect to the application and the stability criterion.

4.1 The DCF-S Scheme

In the DCF-S scheme each coalition leading agent concurrently simulates, adaptively selects, and negotiates coalitions each of which is able to accomplish one of its goals with an acceptable ratio between estimated risk of failure and individual profit to gain in the coalition. The main steps of the DCF-S scheme are executed by each coalition leading agent (CLA).

Preparation: The CLA determines the set of goals to be accomplished in co-operation with other agents. It periodically updates its knowledge on the environment. The local knowledge base includes information on (partially) known problem-solving capabilities of other agents as well as individual evaluations of past collaborations. Since this environment knowledge may be incomplete or vague the agent is assumed to utilize appropriate learning mechanisms for approximating the needed information.

Simulation: The CLA simulates the formation of coalitions each of which may be able to accomplish a given goal with an acceptable ratio between the estimated individual profit and risk of forming the coalition. This simulation consists of the following steps.

- The agent performs a capability-based matching to determine the set of possible candidates.
- For each goal and corresponding set of candidates the agent then randomly simulates coalitions of limited size until it finds a coalition which appears to be significantly better than the currently valid coalition. The individual decision on whether a candidate will be added to or removed from the currently valid coalition is made by the CLA themselves. The estimation of the other agents' values may be derived from information available in the updated local knowledge base of the CLA.
- If no events did occur so far this may endanger the formation of at least one of the simulated coalitions the CLA proceeds with the following negotiation step to realise these coalitions. Otherwise it continues the simulation deliberately taking the detected changes in the environment into account trying to avoid a complete restart. This is achieved by keeping the already committed agents in the initial hypothetical coalition for the new simulation.

Negotiation: The CLA negotiates all coalitions it has determined in the previous simulation step. Each goal-oriented coalition is bilaterally negotiated by the CLA with each potential member of the coalition in sequence; the complete set of negotiation sequences may be performed concurrently. The result of a successful negotiation is a binding agreement between agents on the constraints and attributes of their co-operation in the new coalition. In case one bilateral negotiation fails or an event changing the value or structure of the considered coalition is detected the negotiation process for that coalition is immediately halted.

Evaluation: The CLA may evaluate its recent negotiations and report these evaluations to the nearest world-utility agent for distribution. Concurrently, it controls the distribution of payoffs

and resources to members of the newly formed coalitions according to the successfully negotiated contracts and then restarts the simulation.

Note: For the restart it keeps those agents in its coalitions with which it has already successfully negotiated.

4.2 Discussion of the DCF-S Scheme

In the DCF-S scheme each agent concurrently simulates, adaptively selects, and negotiates coalitions each of which is able to accomplish one of its goals. In other words, the agents strive to concurrently solve a set of single goal-oriented co-operative games $(A, v)|G$ by forming potentially overlapping coalitions with stable payoff distributions regarding their local planning criteria. The problem of assigning tasks and goals to coalitions of agents has been approached in [3].

According to the DCF-S scheme each coalition leading agent reacts on these changes during negotiation via a partial rather than complete restart of necessary simulation and negotiation of alternative size-bounded coalitions. The agent tries to keep those agents in the affected coalitions with which it has already successfully reached a coalition agreement. However, the DCF-S scheme does not guarantee in general that an optimal solution of these games will be found. Rather the agents are supposed to continuously approximate best solutions given their current knowledge on the dynamic environment by simulation and adaptation. One problem is that changes in the environments may occur that rapidly that it is not possible to realize any of the continuously simulated coalitions. However, that is a general problem for any type of DCF algorithm.

The DCF-S scheme assumes the existence of a set of networked world-utility agents, which each agent in the society is free to contact for obtaining needed information on the environment. In addition, the quality of the local knowledge base of an agent improve the quality of its decision and reduce the overall complexity in computation and communication.

5. REFERENCES

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