Coalition Structure Generation and Multi-Agent Planning: Centralized and Distributed Approaches

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A key feature of a multi-agent system is that the agents that form it could have different skills and capabilities. Moreover, each agent may be limited in terms of capabilities. To perform complex tasks, agents may need to group together within coalitions. The grouping of agents into such multiple subsets is called coalition structure generation (CSG) [6,7]. Some of the reasons why agents join coalitions are because they cannot accomplish tasks that are beyond the capabilities of individual agents alone or because they ambition to perform such tasks more efficiently and improve their performance. Coalition structure generation became thus central for multi-agent coordination, which has been an active research topic in artificial intelligence over the past three decades. This is a major problem in artificial intelligence and game theory that is fundamental to many practical applications [3, 5].

Planning in multi-agent systems [9, 10, 11] determines how agents (or coalitions) execute actions to achieve their assigned tasks. Planning can be centralized, where a global planner computes a complete plan for all agents with full knowledge of the system, or distributed, where agents plan locally and coordinate with each other. Both approaches have strengths and trade-offs: centralized planning often yields more optimal results but is less scalable, while distributed planning is more scalable and adaptable to dynamic environments but may be suboptimal.

This project investigates how coalition formation affects planning quality and how planning constraints influence coalition structures. The project aims to design algorithms that jointly address CSG and planning and focuses on two main tasks:

Task 1: Develop a centralized version, where a global planner generates coalitions and task plans to maximize total utility.

Task 2: Develop a distributed version, where agents negotiate, form coalitions locally, and coordinate their plans dynamically.

The expected outcomes include algorithms for both approaches, an analysis and an evaluation of their performance in terms of optimality and scalability.

The proposed work plan is as follows:

1. The student will begin by reviewing the state of the art in coalition formation and familiarizing himself with the most recent algorithms developed on this problem [1, 2, 3].
2. Attention will then be directed towards the study of planning methods, starting with centralized approaches and subsequently extending to decentralized ones.
3. An appropriate application scenario will be selected and analyzed in order to provide a concrete framework for illustrating the algorithms to be proposed in the next step.
4. The existing relationships between planning methods and the execution of collective tasks through coalition formation mechanisms will be examined.
5. Building upon this foundation, a novel coalition formation algorithm tailored to a planning context will be designed, implemented, and evaluated within the chosen application scenario.
6. Finally, both a theoretical analysis and an empirical study will be carried out to assess the proposed approach.

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