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Exploiting Structure in Coordinating Multiple Decision Makers

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Abstract

This thesis is concerned with sequential decision making by multiple agents, whether they are acting cooperatively to maximize team reward or selfishly trying to maximize their individual rewards. The practical intractability of this general problem led to efforts in identifying special cases that admit efficient computation, yet still represent a wide enough range of problems. In our work, we identify the class of problems with structured interactions, where actions of one agent can have non-local effects on the transitions and/or rewards of another agent. We addressed the following research questions: 1) How can we compactly represent this class of problems? 2) How can we efficiently calculate agent policies that maximize team reward (for cooperative agents) or achieve equilibrium (selfinterested agents)? 3) How can we exploit structured interactions to make reasoning about communication offline tractable? For representing our class of problems, we developed a new decision-theoretic model, Event-Driven Interactions with Complex Rewards (EDI-CR), that explicitly represents structured interactions. EDI-CR is a compact yet general representation capable of capturing problems where the degree of coupling among agents ranges from complete independence to complete dependence. For calculating agent policies, we draw on several techniques from the field of mathematical optimization and adapt them to exploit the special structure in EDI-CR. We developed a Mixed Integer Linear Program formulation of EDI-CR with cooperative agents that results in programs much more compact and faster to solve than formulations ignoring structure. We also investigated the use of homotopy methods as an optimization technique, as well as formulation of self-interested EDI-CR as a system of non-linear equations. We looked at the issue of communication in both cooperative and self-interested settings. For the cooperative setting, we developed heuristics that assess the impact of potential communication points and add the ones with highest impact to the agents' decision problems. Our heuristics successfully pick communication points that improve team reward while keeping problem size manageable. Also, by controlling the amount of communication introduced by a heuristic, our approach allows us to control the tradeoff between solution quality and problem size. For self-interested agents, we look at an example setting where communication is an integral part of problem solving, but where the self-interested agents have a reason to be reticent (e.g. privacy concerns). We formulate this problem as a game of incomplete information and present a general algorithm for calculating approximate equilibrium profile in this class of games.

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