

Multiagent Learning in Adaptive Dynamic Systems

Andriy Burkov
DAMAS Laboratory
Laval University
G1K 7P4, Quebec, Canada
burkov@damas.ift.ulaval.ca

Brahim Chaib-draa
DAMAS Laboratory
Laval University
G1K 7P4, Quebec, Canada
chaib@damas.ift.ulaval.ca

ABSTRACT

Classically, an approach to the multiagent policy learning supposed that the agents, via interactions and/or by using preliminary knowledge about the reward functions of all players, would find an interdependent solution called "equilibrium". Recently, however, certain researchers question the necessity and the validity of the concept of equilibrium as the most important multiagent solution concept. They argue that a "good" learning algorithm is one that is efficient with respect to a certain class of counterparts. Adaptive players is an important class of agents that learn their policies separately from the maintenance of the beliefs about their counterparts' future actions and make their decisions based on that policy and the current belief. In this paper, we propose an efficient learning algorithm in presence of the adaptive counterparts called Adaptive Dynamic Learning (ADL), which is able to learn an efficient policy over the opponents' adaptive dynamics rather than over the simple actions and beliefs and, by so doing, to exploit those dynamics to obtain a higher utility than any equilibrium strategy can provide. We tested our algorithm on a substantial representative set of the most known and demonstrative matrix games and observed that ADL agent is highly efficient against Adaptive Play Q-learning (APQ) agent and Infinitesimal Gradient Ascent (IGA) agent. In self-play, when possible, ADL is able to converge to a Pareto-optimal strategy maximizing the welfare of all players.

General Terms

Algorithms, Performance, Experimentation

Keywords

Multiagent learning, Matrix games, Adaptation

1. INTRODUCTION

Classically, an approach to the multiagent policy learning supposed that the agents, by means of interactions and/or

by using preliminary knowledge about the reward functions of all players, would find an interdependent solution called "equilibrium". One of the most used concepts of equilibria is the Nash equilibrium where each agent in a multiagent system (MAS) plays its best response to the other players' strategies and a unilateral deviation of a player from the equilibrium strategy decreases its own utility. There are two basic approaches to finding a Nash equilibrium. The first one is a game theoretic approach, which supposes the complete knowledge of the reward structure of the underlying game by all agents. In such an approach, each agent calculates an equilibrium by using mathematical programming, and all agents play on it. But a problem arises when there are several simultaneous equilibria in a game and the agents have calculated the different ones. Another problem is that the agents, by calculating an equilibrium, suppose that the other agents are rational and, thus, they will also follow this solution. But what if certain agents are not rational, or play a fixed strategy, or switch according to some fixed rules, and what if some agents know (or are able to detect) this and could exploit this knowledge to augment their utilities? As yet, there is no equilibrium concept which can answer this question.

The second approach to finding an equilibrium is the adaptive one, which supposes that the agents learn by adapting to each other in self-play (i.e., all agents use the same learning algorithm), do not know the reward structure of the game and are only able to make actions and observe their own rewards and, in some approaches, the actions made by the others. It was shown that certain algorithms of this class converge to a Nash equilibrium (or to a utility that is equivalent to the utility of a Nash equilibrium). Among these algorithms the most outstanding are Joint-Action Learning [2], Infinitesimal Gradient Ascent (IGA)¹ [9], Policy Hill-Climbing [1] and Adaptive Play Q-learning [11] (a Q-learning based extension of the Adaptive Play algorithm [11]). The adaptive players² learn their policies separately from the maintenance of the beliefs about their counterparts' future actions and make their decisions based on that policy and the current belief. These decisions can be in pure or in mixed strategies depending on the algorithm in question.

¹IGA is the only algorithm among those listed, which requires a complete knowledge of the reward structure of the game to calculate the gradient.

²To discriminate between adaptive player as a member of a class of learning agents and Young's Adaptive Player, we will write "adaptive player" or "adaptive algorithm" (in lower case) to denote the former and Adaptive Player (with a capital letter) for the latter.

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