Multiagent Learning in Adaptive Dynamic Systems

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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 Dynamics Learner (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 these dynamics to obtain a higher utility than any equilibrium strategy can provide. We tested our algorithms 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 equilibrium 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 tantamount 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 evolve according to some fixed rules, and what if some agents know (or are able to deduct) 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 [3], Infinitesimal Gradient Ascent (IGA)[1] [9], Policy Hill-Climbing [1] and Adaptive Play Q-learning [4] (a Q-learning based extension of the Adaptive Play algorithm [11]). The adaptive players[2] 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.

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

[2] To 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.

Adaptive Agents And Multiagent Systems Adaptation And Multiagent Learning

James L. Rash,Christopher A. Rouff,Walter Truszkowski,Diana Gordon,Michael G. Hinchey

Adaptive Agents And Multiagent Systems Adaptation And Multiagent Learning:

Adaptive Agents and Multi-Agent Systems Eduardo Alonso,Daniel Kudenko,Dimitar Kazakov,2003-08-03 Adaptive Agents and Multi Agent Systems is an emerging and exciting interdisciplinary area of research and development involving artificial intelligence computer science software engineering and developmental biology as well as cognitive and social science This book surveys the state of the art in this emerging field by drawing together thoroughly selected reviewed papers from two related workshops as well as papers by leading researchers specifically solicited for this book The articles are organized into topical sections on learning cooperation and communication emergence and evolution in multi agent systems theoretical foundations of adaptive agents *Adaptive Agents and Multi-Agent Systems II* Daniel Kudenko,Dimitar Kazakov,Eduardo Alonso,2005-02-18 Adaptive agents and multi agent systems is an emerging and exciting interdisciplinary area of research and development involving artificial intelligence software engineering and developmental biology as well as cognitive and social science This book presents 17 revised and carefully reviewed papers taken from two workshops on the topic as well as 2 invited papers by leading researchers in the area The papers deal with various aspects of machine learning adaptation and evolution in the context of agent systems and autonomous agents **Adaptive Agents and Multi-Agent Systems III. Adaptation and Multi-Agent Learning** Karl Tuyls,Ann Nowe,Zahia Guessoum,Daniel Kudenko,2008-02-08 This book contains selected and revised papers of the European Symposium on Adaptive and Learning Agents and Multi Agent Systems ALAMAS editions 2005 2006 and 2007 held in Paris Brussels and Maastricht The goal of the ALAMAS symposia and this associated book is to increase awareness and interest in adaptation and learning for single agents and mul agent systems and encourage collaboration between machine learning experts softwareengineeringexperts mathematicians biologistsandphysicists andgive a representative overviewof current state of a airs in this area It is an inclusive forum where researchers can present recent work and discuss their newest ideas for a rst time with their peers Thesymposiaseriesfocusesonallaspectsofadaptiveandlearningagentsand multi agent systems with a particular emphasis on how to modify established learning techniques and or create new learning paradigms to address the many challenges presented by complex real world problems These symposia were a great success and provided a forum for the pres tation of new ideas and results bearing on the conception of adaptation and learning for single agents and multi agent systems Over these three editions we received 51 submissions of which 17 were carefully selected including one invited paper of this year s invited speaker Simon Parsons This is a very c petitive acceptance rate of approximately 31% which together with two review cycles has led to a high quality LNAI volume We hope that our readers will be inspired by the papers included in this volume **Adaptive Agents and Multi-Agent Systems** Eduardo Alonso,Daniel Kudenko,Dimitar Kazakov,2003-04-23 Adaptive Agents and Multi Agent Systems is an emerging and exciting interdisciplinary area of research and development involving artificial intelligence computer science software engineering and developmental biology as well as cognitive and social

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KES AMSTA 2007 held in Wroclaw Poland from May 31 to 1 June 2007 and the Second KES Symposium on Agent and Multi agent Systems Technologies and Applications KES AMSTA 2008 held in Incheon Korea March 26 28 2008 KES AMSTA 2009 featured keynote talks oral and poster presentations and a number of workshops and invited sessions closely aligned to the themes of the conference The aim of the symposium was to provide an international forum for scientific search into the technologies and applications of agent and multi agent systems Agent and multi agent systems are an innovative type of modern software system and have long been recognized as a promising technology for constructing autonomous c plex and intelligent systems A key development in the field of agent and multi agent systems has been the specification of agent communication languages and formali tion of ontologies Agent communication languages are intended to provide standard declarative mechanisms for agents to communicate knowledge and make requests of each other whereas ontologies are intended for conceptualization of the knowledge domain **Cooperative Information Agents X** Matthias Klusch,Michael Rovatsos,Terry R. Payne,2006-08-30 This book constitutes the refereed proceedings of the 10th International Workshop on Cooperative Information Agents CIA 2006 held in Edinburgh UK in September 2006 The 29 revised full papers presented together with four invited papers were carefully reviewed and selected from 58 submissions The papers are organized in topical sections **Autonomous Agents and Multi-agent Systems** Jiming Liu,2001 An autonomous agent is a computational system that acquires sensory data from its environment and decides by itself how to relate the external stimulus to its behaviors in order to attain certain goals Responding to different stimuli received from its task environment the agent may select and exhibit different behavioral patterns The behavioral patterns may be carefully predefined or dynamically acquired by the agent based on some learning and adaptation mechanism s In order to achieve structural flexibility reliability through redundancy adaptability and reconfigurability in real world tasks some researchers have started to address the issue of multiagent cooperation Broadly speaking the power of autonomous agents lies in their ability to deal with unpredictable dynamically changing environments Agent based systems are becoming one of the most important computer technologies holding out many promises for solving real world problems The aims of this book are to provide a guided tour to the pioneering work and the major technical issues in agent research and to give an in depth discussion on the computational mechanisms for behavioral engineering in autonomous agents Through a systematic examination the book attempts to provide the general design principles for building autonomous agents and the analytical tools for modeling the emerged behavioral properties of a multiagent system Contents Behavioral Modeling Planning and Learning Synthetic Autonomy Dynamics of Distributed Computation Self Organized Autonomy in Multi Agent Systems Autonomy Oriented Computation Dynamics and Complexity of Autonomy Oriented Computation Readership Undergraduate and graduate students in computer science and most engineering disciplines as well as computer scientists engineers researchers and practitioners in the field of machine intelligence *Cognitive Networks* Qusay Mahmoud,2007-09-11 Cognitive networks

can dynamically adapt their operational parameters in response to user needs or changing environmental conditions They can learn from these adaptations and exploit knowledge to make future decisions Cognitive networks are the future and they are needed simply because they enable users to focus on things other than configuring and managing networks Without cognitive networks the pervasive computing vision calls for every consumer to be a network technician The applications of cognitive networks enable the vision of pervasive computing seamless mobility ad hoc networks and dynamic spectrum allocation among others In detail the authors describe the main features of cognitive networks clearly indicating that cognitive network design can be applied to any type of network being fixed or wireless They explain why cognitive networks promise better protection against security attacks and network intruders and how such networks will benefit the service operator as well as the consumer Cognitive Networks Explores the state of the art in cognitive networks compiling a roadmap to future research Covers the topic of cognitive radio including semantic aspects Presents hot topics such as biologically inspired networking autonomic networking and adaptive networking Introduces the applications of machine learning and distributed reasoning to cognitive networks Addresses cross layer design and optimization Discusses security and intrusion detection in cognitive networks Cognitive Networks is essential reading for advanced students researchers as well as practitioners interested in cognitive wireless networks pervasive computing distributed learning seamless mobility and self governed networks With forewords by Joseph Mitola III as well as Sudhir Dixit __Formal Approaches to Agent-Based Systems__ James L. Rash,Christopher A. Rouff,Walter Truszkowski,Diana Gordon,Michael G. Hinchey,2003-06-29 This book constitutes the thoroughly refereed post proceedings of the First International Workshop on Formal Approaches to Agent Based Systems FAABS 2000 held in Greenbelt MD USA in April 2000 The 22 revised full papers presented together with 13 posters and two panel discussion reports were carefully reviewed and improved for inclusion in the book The papers are organized in topical sections on verifying agents mental states synthesizing agents initially frameworks and formalizations modeling and execution inter agent communication and adaptive agents __Adaption and Learning in Multi-agent Systems__ Gerhard Weiss,Sandip Sen,1996 This book is based on the workshop on Adaptation and Learning in Multi Agent Systems held in conjunction with the International Joint Conference on Artificial Intelligence IJCAI 95 in Montreal Canada in August 1995 The 14 thoroughly reviewed revised papers reflect the whole scope of current aspects in the field they describe and analyze both experimentally and theoretically new learning and adaption approaches for situations in which several agents have to cooperate or compete Also included and aimed at the novice reader are a comprehensive introductory survey on the area with 154 references listed and a subject index As the first book solely devoted to this area this volume documents the state of the art and is thus indispensable for anyone active or interested in the field PUBLISHER S WEBSITE **Proceedings** ,2000 **Multi-agent Systems and Applications ...** ,2005 **Multi-agent Systems** Jacques Ferber,1999 In this book Jacques Ferber has brought together all the recent developments in the field of

multi agent systems an area that has seen increasing interest and major developments over the last few years The author draws on work carried out in various disciplines including information technology sociology and cognitive psychology to provide a coherent and instructive picture of the current state of the art The book introduces and defines the fundamental concepts that need to be understood clearly describes the work that has been done and invites readers to reflect upon the possibilities of the future   IUI ... Conference Proceedings ,2006   **IJCAI Proceedings 1997** Martha E. Pollack,International Joint Conferences on Artificial Intelligence,1998-07-22

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web in this lesson plan they will add black to blue paint to create a darker shade of blue and white to blue paint to create a lighter tint of blue this process will be applied to the paintings that they will create an effect similar to that in vincent van

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web course 13k views how did he compose the starry night ironically if vincent had never gone to the asylum he might never have created one of his most famous works in 1889 he painted the

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web jul 1 2013   scissors need these materials visit blick procedure day one 1 teach van gogh history tell of his beginning job tries etc 2 show van gogh self portrait discuss why he has a greenish color to his skin bring this discussion into impressionism

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web apr 29 2020   in this lesson plan we move beyond the most recognizable and much done starry night and sunflowers images and delve into creating an original piece of art using oil pastels students will experience drawing from an actual still life set up and learn van gogh s exciting and unique mark making technique that he called color gymnastics

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