Stochastic Stability of Perturbed Learning Automata in Positive-Utility Games

Georgios C. Chasparis

Abstract—This paper considers a class of reinforcement-based learning (namely, *perturbed learning automata*) and provides a stochastic-stability analysis in repeatedly-played, positive-utility, finite strategic-form games. Prior work in this class of learning dynamics primarily analyzes asymptotic convergence through stochastic approximations, where convergence can be associated with the limit points of an ordinary-differential equation (ODE). However, analyzing global convergence through an ODE-approximation requires the existence of a Lyapunov or a potential function, which naturally restricts the analysis to a fine class of games. To overcome these limitations, this paper introduces an alternative framework for analyzing asymptotic convergence that is based upon an explicit characterization of the invariant probability measure of the induced Markov chain. We further provide a methodology for computing the invariant probability measure in positive-utility games, together with an illustration in the context of coordination games.

I. INTRODUCTION

Recently, multi-agent formulations have been utilized to tackle distributed optimization problems, since communication and computational complexity might be an issue under centralized schemes. In such formulations, decisions are usually taken in a *repeated* fashion, where agents select their next actions based on their *own* prior experience. In the case of finite number of actions for each agent, such multi-agent interactions can be designed as strategic-form games, where agents are repeatedly involved in a strategic interaction with a fixed *payoff* or *utility* function. Such framework finds numerous applications, including, for example, the problem of distributed overlay routing [2], distributed topology control [3] and distributed resource allocation [4].

Given the repeated fashion of the involved strategic interactions in such formulations, several questions naturally emerge, including: a) *Can agents "learn" to asymptotically select optimal actions?*, b) *What information should agents share with each other?*, and c) *What is the computational complexity of the learning process?* Under the scope of engineering applications, it is usually desirable that each agent

shares minimum amount of information with other agents, while the computational complexity of the learning process is small. Naturally, *payoff-based learning* has drawn significant attention. Under such class of learning dynamics, each agent receives *only* measurements of its own utility function, while the details of this function (i.e., its mathematical formula) are unknown. Furthermore, each agent cannot access the actions selected or utilities received by other agents.

In such repeatedly-played strategic-form games, a popular objective for payoff-based learning is to guarantee convergence (in some sense) to Nash equilibria. Convergence to Nash equilibria may be desirable, especially when the set of optimal centralized solutions belongs to the set of Nash equilibria.

Reinforcement-based learning has been utilized in strategic-form games in order for agents to gradually learn to play Nash equilibria. It may appear under alternative forms, including discrete-time replicator dynamics [5], learning automata [6], [7] and *Q*-learning [8]. In all these classes of learning dynamics, deriving conditions under which convergence to Nash equilibria is achieved may not be a trivial task, especially in the case of large number of agents (as it will be discussed in detail in the forthcoming Section II).

In the present paper, we consider a class of reinforcement-based learning introduced in [9] that is closely related to both discrete-time replicator dynamics and learning automata. We will refer to this class of dynamics as *perturbed learning automata*. The main difference with prior reinforcement-based learning schemes lies in a) the *step-size sequence*, and b) the *perturbation (or mutations)* term. The step-size sequence is assumed constant, thus introducing a fading-memory effect of past experiences in each agent's strategy. On the other hand, the perturbation term introduces errors in the selection process of each agent. Both these two features can be used for designing a desirable asymptotic behavior.

We provide an analytical framework for deriving conclusions over the asymptotic behavior of the dynamics that is based upon an explicit characterization of the invariant probability measure of the induced Markov chain. In particular, we show that in all finite strategic-form games satisfying the *Positive-Utility Property* (i.e., games with strictly positive utilities), the support of the invariant probability measure coincides with the set of pure strategy profiles. Furthermore, we provide a methodology for computing the set of stochastically stable states in all positive-utility games. We illustrate

G. C. Chasparis is with the Department of Data Analysis Systems, Software Competence Center Hagenberg GmbH, Softwarepark 21, A-4232 Hagenberg, Austria. E-mail: georgios.chasparis@scch.at.

Stochastic Automata Stability Nondetermi

V. V. KOLASHNIKOV

Stochastic Automata Stability Nondetermi:

Stochastic Automata: Stability, Nondeterminism and Prediction E.-E. Doberkat,1981-06   **Stochastic Automata** Ernst-Erich Doberkat,1981 Provides a general mathematical framework for the analytical aspects of stochastic automata Shows that under certain topological conditions non deterministic automata are generated which in some cases are produced by stochastic automata   **Stochastic Automata** E. E. Doberkat,2014-01-15   Physics Briefs ,1991   **Science Citation Index** ,1993 Vols for 1964 have guides and journal lists   **Design and Analysis of Novel Fixed Structure Stochastic Automata in Non-stationary Environments** Chenhui Liu,2006   *STOCHASTIC AUTOMATA* Ernst-Erich Doberkat,1981

State-Dependent Stochastic Stability and the Non-Existence of Conventions Sebastian Ille,2015 Arising from criticism in the literature and focusing on 2x2 coordination games the concept of stochastic stability is extended to take account of state dependent error and sample sizes Both error and sample size are expected to be correlated with the loss that occurred if a player chooses a non best response strategy The state independent and state dependent predictions determine the same Stochastically Stable State SSS if the game s pay off matrix exhibits a form of symmetry or if only the relative potential loss from idiosyncratic play defines the state dependent variable Predictions may differ if neither of these conditions is met In addition the paper raises a second crucial point Even if these conditions are met the minimum stochastic potential is only a necessary but not a sufficient condition for the evolution of an SSS The SSS must further be sufficiently risk dominant otherwise no convention will evolve   **Stability Problems for Stochastic Models** Vladimir V. Kalashnikov,Vladimir M. Zolotarev,2014-01-15   **Nondeterminism of stochastic automata** Ernst-Erich Doberkat,1981

Stochastic Stability and Control Kushner,1967-01-01 Stochastic Stability and Control   *Stability Problems for Stochastic Models* Vladimir V. Kalashnikov,Vladimir M. Zolotarev,2014-09-01   **Simulation and Chaotic Behavior of Alpha-stable Stochastic Processes** Aleksand Janicki,A. Weron,1993-11-16 Presents new computer methods in approximation simulation and visualization for a host of alpha stable stochastic processes   **The Evolution of Stochastic Automata** David Eric Probert,University of Cambridge. Department of Pure Mathematics and Mathematical Statistics,1976

The Decomposition of Stochastic Automata Dudley Columbus Edgemon,1968   *Learning Automata and Stochastic Optimization* A.S. Poznyak,K. Najim,1997-03-12 In the last decade there has been a steadily growing need for and interest in computational methods for solving stochastic optimization problems with or wihout constraints Optimization techniques have been gaining greater acceptance in many industrial applications and learning systems have made a significant impact on engineering problems in many areas including modelling control optimization pattern recognition signal processing and diagnosis Learning automata have an advantage over other methods in being applicable across a wide range of functions Featuring new and efficient learning techniques for stochastic optimization and with examples illustrating the practical application of these techniques this volume will be of benefit to practicing control engineers and to graduate students taking

courses in optimization control theory or statistics **STABILITY PROBLEMS FOR STOCHASTIC MODELS** V. V. KOLASHNIKOV,1983 **Robust Stability Theory for Stochastic Dynamical Systems** Anantharaman Subbaraman,2015 In this work we focus on developing analysis tools related to stability theory for certain classes of stochastic dynamical systems that permit non unique solutions The non unique nature of solutions arise primarily due to the system dynamics that are modeled by set valued mappings There are two main motivations for studying such classes of systems Firstly understanding such systems is crucial to developing a robust stability theory Secondly such system models allow flexibility in control design problems **Product of Random Stochastic Matrices and Distributed Averaging** Behrouz Touri,2012-03-02 Exploring averaging dynamics in multiagent networked systems this book offers an in depth study of stability and other phenomena characterizing the limiting behavior of both deterministic and random averaging dynamics Includes numerous illustrative examples Learning algorithms for stochastic automata S. Lakshmi Varahan,1973

The Top Books of the Year Stochastic Automata Stability Nondetermi The year 2023 has witnessed a noteworthy surge in literary brilliance, with numerous engrossing novels captivating the hearts of readers worldwide. Lets delve into the realm of popular books, exploring the captivating narratives that have enthralled audiences this year. The Must-Read : Colleen Hoovers "It Ends with Us" This heartfelt tale of love, loss, and resilience has gripped readers with its raw and emotional exploration of domestic abuse. Hoover skillfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can succeed. Stochastic Automata Stability Nondetermi : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This intriguing historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids captivating storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Stochastic Automata Stability Nondetermi : Delia Owens "Where the Crawdads Sing" This evocative coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens crafts a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of engaging stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a exceptional and thrilling novel that will keep you guessing until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

Table of Contents Stochastic Automata Stability Nondetermi

Stochastic Automata Stability Nondetermi Introduction

In this digital age, the convenience of accessing information at our fingertips has become a necessity. Whether its research papers, eBooks, or user manuals, PDF files have become the preferred format for sharing and reading documents. However, the cost associated with purchasing PDF files can sometimes be a barrier for many individuals and organizations. Thankfully, there are numerous websites and platforms that allow users to download free PDF files legally. In this article, we will explore some of the best platforms to download free PDFs. One of the most popular platforms to download free PDF files is Project Gutenberg. This online library offers over 60,000 free eBooks that are in the public domain. From classic literature to

historical documents, Project Gutenberg provides a wide range of PDF files that can be downloaded and enjoyed on various devices. The website is user-friendly and allows users to search for specific titles or browse through different categories. Another reliable platform for downloading Stochastic Automata Stability Nondetermi free PDF files is Open Library. With its vast collection of over 1 million eBooks, Open Library has something for every reader. The website offers a seamless experience by providing options to borrow or download PDF files. Users simply need to create a free account to access this treasure trove of knowledge. Open Library also allows users to contribute by uploading and sharing their own PDF files, making it a collaborative platform for book enthusiasts. For those interested in academic resources, there are websites dedicated to providing free PDFs of research papers and scientific articles. One such website is Academia.edu, which allows researchers and scholars to share their work with a global audience. Users can download PDF files of research papers, theses, and dissertations covering a wide range of subjects. Academia.edu also provides a platform for discussions and networking within the academic community. When it comes to downloading Stochastic Automata Stability Nondetermi free PDF files of magazines, brochures, and catalogs, Issuu is a popular choice. This digital publishing platform hosts a vast collection of publications from around the world. Users can search for specific titles or explore various categories and genres. Issuu offers a seamless reading experience with its user-friendly interface and allows users to download PDF files for offline reading. Apart from dedicated platforms, search engines also play a crucial role in finding free PDF files. Google, for instance, has an advanced search feature that allows users to filter results by file type. By specifying the file type as "PDF," users can find websites that offer free PDF downloads on a specific topic. While downloading Stochastic Automata Stability Nondetermi free PDF files is convenient, its important to note that copyright laws must be respected. Always ensure that the PDF files you download are legally available for free. Many authors and publishers voluntarily provide free PDF versions of their work, but its essential to be cautious and verify the authenticity of the source before downloading Stochastic Automata Stability Nondetermi. In conclusion, the internet offers numerous platforms and websites that allow users to download free PDF files legally. Whether its classic literature, research papers, or magazines, there is something for everyone. The platforms mentioned in this article, such as Project Gutenberg, Open Library, Academia.edu, and Issuu, provide access to a vast collection of PDF files. However, users should always be cautious and verify the legality of the source before downloading Stochastic Automata Stability Nondetermi any PDF files. With these platforms, the world of PDF downloads is just a click away.

FAQs About Stochastic Automata Stability Nondetermi Books

How do I know which eBook platform is the best for me? Finding the best eBook platform depends on your reading

preferences and device compatibility. Research different platforms, read user reviews, and explore their features before making a choice. Are free eBooks of good quality? Yes, many reputable platforms offer high-quality free eBooks, including classics and public domain works. However, make sure to verify the source to ensure the eBook credibility. Can I read eBooks without an eReader? Absolutely! Most eBook platforms offer web-based readers or mobile apps that allow you to read eBooks on your computer, tablet, or smartphone. How do I avoid digital eye strain while reading eBooks? To prevent digital eye strain, take regular breaks, adjust the font size and background color, and ensure proper lighting while reading eBooks. What the advantage of interactive eBooks? Interactive eBooks incorporate multimedia elements, quizzes, and activities, enhancing the reader engagement and providing a more immersive learning experience. Stochastic Automata Stability Nondetermi is one of the best book in our library for free trial. We provide copy of Stochastic Automata Stability Nondetermi in digital format, so the resources that you find are reliable. There are also many Ebooks of related with Stochastic Automata Stability Nondetermi. Where to download Stochastic Automata Stability Nondetermi online for free? Are you looking for Stochastic Automata Stability Nondetermi PDF? This is definitely going to save you time and cash in something you should think about.

Find Stochastic Automata Stability Nondetermi :

taylors 50 best roses easy plants for more beautiful gardens
teachers guide for surprises
teachers thinking teachers knowing reflections on literacy and language education
teach yourself windows me visually tm
tax planning for real estate investors how to take advantage of real estate...
teachers as agents of change a new look at school improvement
teacher creature
teach yourself latin grammar
~~tay son rebellion in 18th century vietnam.~~
tax savvy for small business year-round tax strategies to save you money 4th ed.
teacher reads aloud level 4 open court reading
teacher development and the struggle for authenticity
teachers plan plus 4 parents on your side
teach yourself violin step one
teach yourself ukranian complete course

Stochastic Automata Stability Nondetermi :

What is an IBM IPAT Test – Key Facts An IPAT Test (Information Processing Aptitude Test) is designed to assess an individual's ability to reason numerically with information under time pressure ... IBM Cognitive Ability (IPAT) Tests: Free Practice Questions Applying to IBM? Prepare for the 2023 IBM cognitive ability assessment (IPAT) with 19 practice tests and 245 questions & answers, written by experts. IBM IPAT Test – Aptitude Test Preparation Learn more about IBM IPAT Practice with a sample aptitude test, detailed answer explanations, and score reports. Prepare today and ensure success. What kinds of questions should I expect on the IBM IPAT? Oct 12, 2016 — The Information Processing Aptitude test, as I recall, has simple mathematics (no calculus) and logic questions. Applicants don't have to be a superstar on the ... IBM IPAT | AssessmentDay Sep 28, 2022 — The IPAT test will be assessing your speed and accuracy. The answers are multiple choice and you should try to work quickly within the time ... Free IBM IPAT Practice Test Questions - 2023 Learn about IBM's Information Processing Aptitude Test (IPAT) with free practice questions. IBM IPAT / Cognitive Ability Test (2022): A Guide - YouTube IBM Assessment Test: Free Practice Questions [2023] The IPAT is a notoriously difficult numerical reasoning and numerical series test that covers topics including measurement and weight conversions, understanding ... Why is IBM's IPAT so difficult? Does anyone have practice ... Structure of exam : Two sections - Numeric Series and Math problems. 18 questions in each section. About 2 mins 15 secs per question. Number Series Practice: Sample Questions, Tips & Strategies Master your number series skills with practice questions & solving tips. Great for candidates taking cognitive ability tests (Wonderlic, PLI, CCAT, ... Traditions and Encounters, AP Edition (Bentley), 5th Edition Traditions and Encounters, AP Edition (Bentley), 5th Edition · AP World History Essay Writer's Handbook · Primary Source Investigator: PSI. Chapter Activities. Traditions & Encounters: A Global Perspective on the Past ... Book details ; ISBN-10. 0073385646 ; ISBN-13. 978-0073385648 ; Edition. 5th ; Publisher. McGraw-Hill Education ; Publication date. October 7, 2010. Traditions and Encounters, AP Edition (Bentley), 5th Edition Welcome to the Traditions and Encounters (Bentley) 5th Edition Online Learning Center for students! Chapter Activities Use the Chapter pull-down menus to ... Traditions & Encounters: A Brief Global History (5th Edition) ... Traditions & Encounters: A Brief Global History presents a streamlined account of the development of the world's cultures and encounters that is meaningful ... 1T Connect Online Access for Traditions & Encounters ... 1T Connect Online Access for Traditions & Encounters, Brief 5th Edition is written by BENTLEY and published by McGraw-Hill Higher Education. Traditions and Encounters 5th Edition PDF download Traditions and Encounters 5th Edition PDF download. Does anybody have a pdf copy of Traditions and Encounters 5th Edition and will be open to ... A Global Perspective on the Past, 5th Edition ... 5th Edition. - Everything is perfectly intact, with a little wear and tear on the back. AP* World History: Traditions and Encounters# 5th ed. ... This independently made series challenges students to apply

the concepts and give examples. Easily collectible, this item may also be used as a student ... Traditions and Encounters : A Global Perspective on the ... The fifth edition ofTraditions & Encountersis a result of this. Traditions & Encountersalso has a rich history of firsts: the first world history text to ... Traditions and Encounters 5th Edition MMW 11-15 - Jerry ... Traditions and Encounters 5th Edition MMW 11-15 by Jerry Bentley; Herbert Ziegler - ISBN 10: 1259249417 - ISBN 13: 9781259249419 - McGraw-Hill Education ... Vertebrate Life (9th Edition) Widely praised for its comprehensive coverage and exceptionally clear writing style, this best-selling text explores how the anatomy, physiology, ecology, and ... Vertebrate Life (9th Edition) - Hardcover Widely praised for its comprehensive coverage and exceptionally clear writing style, this best-selling text explores how the anatomy, physiology, ecology, and ... Vertebrate Life, Books a la Carte Edition (9th Edition) Widely praised for its comprehensive coverage and exceptionally clear writing style, this best-selling book explores how the anatomy, physiology, ecology, and ... Vertebrate Life - F. Harvey Pough, Christine M. Janis, John ... The Ninth Edition features dozens of new figures and photos, updated information from molecular data and evolutionary development, and expanded discussions on ... Vertebrate Life by F. Harvey Pough; ... The Ninth Edition features dozens of new figures and photos, new end-of-chapter discussion questions, thoroughly updated information from molecular data and ... Vertebrate Life (9th Edition) | Wonder Book Vertebrate Life (8th Edition). By Heiser, John B. Hardcover. Price $7.52. Free Shipping. Vertebrate Life. Vertebrate life | WorldCat.org Vertebrate life ; Authors: F. Harvey Pough (Author), Christine M. Janis, John B. Heiser ; Edition: 9th ed View all formats and editions ; Publisher: Pearson, ... Vertebrate Life (9th Edition) by Pough, F. Harvey, Janis ... Vertebrate Life (9th Edition) by Pough, F. Harvey, Janis, Christine M., Heiser, ; Item Number. 194876291663 ; Book Title. Vertebrate Life (9th Edition) ; ISBN. 9780321773364 - Vertebrate Life by F. Harvey Pough The Ninth Editionfeatures dozens of new figures and photos, updated information from molecular data and evolutionary development, and expanded discussions on ... 9780321773364: Vertebrate Life (9th Edition) Vertebrate Life (9th Edition) ISBN 9780321773364 by Pough, F. Harvey; Ja... See the book Sell/Buy/Rent prices, more formats, FAQ & related books on ...