One-day Workshop
Game Theory: Models and Applications to Networked Systems

Workshop Proposal for the 2015 American Control Conference

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1 Background and topic description

We are witnessing an extraordinary growth in a variety of networked systems, including sensory systems, power systems, communication networks, health systems, and data management systems, as well as hybrid systems arising from virtual and physical integration of such systems. A multitude of issues arise with control and optimal operations of such networked systems, including resilience, reliability and security. Game theory has emerged as a central discipline capable of providing a versatile and effective framework for addressing such issues. Furthermore, to successfully address these issues, novel game-theoretic models and algorithms have been developed that can adequately capture the dynamics of such games on networks and deal with incomplete and/or unreliable information access, as well as the issues associated with large size networks (i.e, the number of players).

The goal of this workshop is to provide an introduction into basic game-theoretic concepts and tools, and to showcase some recent applications of game theory in control of emerging large scale and distributed networked systems.

The proposed workshop is for 1 day, consisting of 4 lectures.

2 Tutorial Lectures

The lecturers and their tutorial information are as follows:

1) **Foundations of Game-Theoretic Framework for Networks and Control**,
Tamer Başar, Director of the Center for Advanced Study, Swanlund Endowed Chair and Professor of Electrical and Computer Engineering, University of Illinois at Urbana Champaign, USA
Tutorial Abstract: With its rich set of conceptual, analytical and algorithmic tools, game theory has emerged as providing a versatile and effective framework for addressing a multitude of issues in networks and control, including resilience, reliability and security in networked (control) systems. This expository talk will introduce the key elements of this modeling paradigm, and discuss various game-theoretic solution concepts, mostly within the framework of nonzero-sum games. Among these are the solution concepts of saddle point (for zero-sum games) and Nash equilibrium as well as Stackelberg equilibrium (for nonzero-sum games), for both static and dynamic games, as well as stochastic games. The talk will also cover efficiency (or inefficiency) of these solutions within a non-cooperative mode of decision-making, their sensitivity to imprecision in modeling, and ways of coping with the presence of strategic adversaries. Further, the role of incentive (or disincentive) mechanisms in mitigating or totally eliminating the adverse effects of inefficiency, sensitivity, and adversarial impact will be discussed. The presentation will conclude with some specific applications of the game-theoretic framework in networked control, sensor networks, and cyber-physical systems.
Biography: Tamer Başar has been with the University of Illinois at Urbana-Champaign since 1981, where he holds the academic positions of Swanlund Endowed Chair; Center for Advanced Study Professor of Electrical and Computer Engineering; Professor, Coordinated Science Laboratory; Professor, Information Trust Institute; and Affiliate Professor, Mechanical Sciences and Engineering. He is also the Director of the Center for Advanced Study. He is a member of the US National Academy of Engineering and the European Academy of Sciences; Fellow of IEEE, IFAC, and SIAM; a past president of the IEEE Control Systems Society (CSS), the founding president of the International Society of Dynamic Games (ISDG), and a past president of the American Automatic Control Council (AACC). He has received several awards and recognitions over the years, including the highest awards of IEEE CSS, IFAC, AACC, and ISDG, the IEEE Control Systems Technical Field Award, and a number of international honorary doctorates and professorships. Dr. Başar has over 650 publications in systems, control, communications, optimization, and dynamic games, including books on non-cooperative dynamic game theory, robust control, network security, wireless and communication networks, and stochastic networks. He is the Editor-in-Chief of Automatica and editor of several book series.

2) **Mean Field Control Theory and its Applications**,
Roland Malhamé, Electrical Engineering, University of Montreal, Canada
Tutorial Abstract: The fundamental intuitions that underline the development of so called Mean Field Games (also known as Mean Field Control Theory) will be presented, as well as some of its foundational results for continuous time systems. The results for both linear and nonlinear continuous time systems will be discussed. Mean Field Control emerges as the

natural tool for dealing with the coordination and decentralized control of systems made up of large aggregates of similar weakly interacting elements such as found in the natural world from herds, to fish schools, to beehives, to human societies. Such configurations also occur in manmade constructs such as economic systems and the Internet. We present applications of the linear quadratic versions of the theory, first to a collective navigation problem such as fish schooling; secondly, to a class of control problems in the area of smart grids, whereby large collections of energy storage capable devices such as electric water heaters, are coordinated to mitigate the variability of renewable energy sources.
Biography: Roland P. Malhamé received the Bachelors, Masters and Ph.D. degrees in Electrical Engineering from the American University of Beirut, the University of Houston, and the Georgia Institute of Technology in 1976, 1978 and 1983, respectively. After single year stays at University of Quebec, and CAE Electronics Ltd. (Montreal), he joined in 1985 École Polytechnique de Montréal, where he is Professor of Electrical Engineering. He has held visiting positions at CNRS?Supélec France, École Centrale, Politecnico de Milano, and University of Rome Tor Vergata. His current research interests are in stochastic control, and the analysis and optimization of complex networks, in particular manufacturing, communication and power system networks. From june 2005 to june 2011, he was director of GERAD (Groupe dtudes et de Recherche en Analyse des Dcisions). He is an Associate Editor of International Transactions on Operations Research.

3) **Games, Information, and Networked Control**,
Jason Marden, Department of Electrical, Computer, and Energy Engineering, the University of Colorado, USA
Tutorial Abstract: Game theory is a well-established discipline in the social sciences that is primarily used for modeling social behavior. Traditionally, the preferences of the individual agents are modeled as utility functions and the resulting behavior is assumed to be an equilibrium concept associated with these modeled utility functions, e.g., Nash equilibrium. This is in stark contrast to the role of game theory in engineering systems where the goal is to design both the agents utility functions and an adaptation rule such that the resulting global behavior is desirable. The transition of game theory from a modeling tool for social systems to a design tool for engineering systems promotes several new research directions that we will discuss in this talk. In particular, this talk will focus on the following questions: (i) How to design admissible agent utility functions such that the resulting game possesses desirable properties, e.g., the existence and efficiency of pure Nash equilibria? (ii) How to design adaptation rules that lead to desirable system-wide behavior? and (iii) How does the information available to the agents impact achievable performance guarantees in distributed engineering systems?
Biography: Jason Marden is an Assistant Professor in the Department of Electrical, Computer, and Energy Engineering at the University of Colorado. Jason received a BS in Mechanical Engineering in 2001 from UCLA, and a PhD in Mechanical Engineering in 2007, also from UCLA, under the supervision of Jeff S. Shamma, where he was awarded the Outstanding Graduating PhD Student in Mechanical Engineering. After graduating from UCLA, he served as a junior fellow in the Social and Information Sciences Laboratory at the California Institute of Technology until 2010 when he joined the University of Colorado. Jason is a recipient of the NSF Career Award (2014), the AFOSR Young Investigator Award (2012),

and the American Automatic Control Council Donald P. Eckman Award (2012). Jason's research interests focus on game theoretic methods for the control of distributed multi-agent systems.

4) **Games on Time-varying Networks**,
Angelia Nedić, Industrial and Enterprise Systems Engineering, University of Illinois at Urbana Champaign,USA
Abstract: This talk will present some special games arising in networked systems with dynamically changing connectivity structure and with limited access to the whole system information. Some examples of such games that will be discussed include Transferable Utility (TU) games, aggregative games and monotone Nash games on graphs, where the players can use the local neighborhoods to learn/estimate network wide quantities that affect their payoff/cost functions. We will discuss distributed strategies such as decentralized gradient-play strategies that can result in a Nash equilibrium in the presence of imperfect information such as gradient noise and other forms of uncertainties. Also, the complexity estimates for such strategies will be discussed in terms of their scaling properties with the time and with the number of players.
Biography: Angelia Nedić received her B.S. degree from the University of Montenegro (1987) and M.S. degree from the University of Belgrade (1990), both in Mathematics. She received her Ph.D. degrees from Moscow State University (1994) in Mathematics and Mathematical Physics, and from Massachusetts Institute of Technology in Electrical Engineering and Computer Science (2002). She has been at the BAE Systems Advanced Information Technology from 2002–2006. In Fall 2006, she has joined the Department of Industrial and Enterprise Systems Engineering at the University of Illinois at Urbana-Champaign (UIUC), USA. She is a recipient of the NSF CAREER Award 2007 in Operations Research, and a Donald Biggar Willett Scholar of Engineering award in 2013 from the UIUC College of Engineering. Her general interest is in optimization and dynamics including fundamental theory, models, algorithms, and applications. Her current research interest is focused on large-scale convex optimization, distributed multi-agent optimization and equilibrium problems, stochastic approximations, and network aggregation-dynamics with applications in signal processing, machine learning, and decentralized control.

3 Workshop Schedule

Tentative schedule including breaks is as follows:

- 8:00–10:00
  Foundations of Game-Theoretic Framework for Networks and Control,
  Tamer Başar, University of Illinois at Urbana-Champaign

- 10:20 am–12:20
  Mean Field Control Theory and its Applications,
  Roland Malhamé, University of Montreal, Canada

- 14:00-16:00
  Games, Information, and Networked Control,
  Jason Marden, University of Colorado, USA

- 16:20–18:20
  Games on Time-varying Networks
  Angelia Nedić, University of Illinois at Urbana-Champaign (USA)

4 Targeted Audience

The targeted audience are the professionals and young researchers (including graduate and post-graduate students) who are interested in learning the basics of the game theory and, also, getting an exposure to some of the currently active research topics in networked systems centered around the game-theoretic models. If properly advertised, this worksop is anticipated to have enrollment in the order of 30-40 participants.