Learning and System Identification for Safety and Control Design in Dynamical Processes

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Thursday, November 20
10:30 A.M. • MSEE 112

Abstract

AI-based methods have tremendous potential for impacting the performance of autonomous and robotic systems. Such systems include drones, ground- and water-based vehicles, and limbed robots for instance. A barrier to the wide deployment of AI-powered methods in such applications is the risk or unpredictability of algorithm performance. In this presentation we consider the development of safe machine learning (ML) methods for control that provide guarantees about their convergence and performance. First: we present an algorithm and a tool for statistical model checking (SMC) of continuous state space Markov chains initialized to a prescribed set of states. We observe that it can be formulated as an X-armed bandit problem, and therefore, can be solved using hierarchical optimistic optimization. Our experiments, using our tool HooVer, suggest that the approach scales to realistic-sized problems and is often more sample-efficient compared to other existing tools. Second: We address system identification of a new important class of nonlinear systems: nonlinear systems whose vector fields are real-analytic functions of the state variables and linearly parametrized. Such models are relevant in a wide range of engineered systems. We consider two system identification methods: least-squares estimation (LSE), which is a point estimation method; and set-membership estimation (SME), which estimates an uncertainty set that contains the true parameters. We provide new non-asymptotic convergence rates for LSE and SME under i.i.d. control inputs and control policies with i.i.d. random perturbations, both of which are considered as non-active-exploration inputs. We also illustrate these theory results empirically on some well-known examples. Third: We will explore the convergence of large language models (LLMs) and machine reasoning, with an emphasis on their applications in control engineering. In particular we will discuss our recent investigations on the capabilities of state-of-the-art large language models (LLMs), such as GPT, Claude 3 Opus, and Gemini Ultra, o2, and o4 in solving control design problems. In particular, we introduce ControlBench, ControlAgent and EngDesign. These studies serves as an initial step towards the broader goal of employing artificial general intelligence in control engineering. Hardware: presented will be the HoTDeC multi- vehicle testbed, which consists of indoor airborne and groundbased vehicles.

Bio

Geir E. Dullerud is a Professor in Electrical and Computer Engineering at the University of Minnesota, where he is Head of the Department and the Centennial Chair in Electrical Engineering. Prior to this he was at the University of Illinois at Urbana-Champaign where as a member of the Coordinated Science Laboratory he served as the Director of the Decision and Control Laboratory, and subsequently the Director of the Illinois Center for Autonomy. He has held visiting positions in Electrical Engineering KTH, Stockholm (2013), and Aeronautics and Astronautics, Stanford University (2005-2006). Earlier he was on faculty in Applied Mathematics at the University of Waterloo (1996-1998), after being a Research Fellow at the California Institute of Technology (1994-1995), in the Electrical Engineering Department. He holds a PhD in Engineering from Cambridge University. He has published two books: "A Course in Robust Control Theory", Texts in Applied Mathematics, Springer, and "Control of Uncertain Sampled-data Systems", Birkhauser. His areas of current research interest include autonomy and cooperative robotics, convex optimization in control, cyber-physical system security, stochastic simulation, and hybrid dynamical systems. In 1999 he received the CAREER Award from the National Science Foundation, and in 2005 the Xerox Faculty Research Award at UIUC. In 2018 he was awarded the UIUC Engineering Council Award for Excellence in Advising. He is a Fellow of both IEEE (2008) and ASME (2011). He was the General Chair of the IFAC workshop Distributed Estimation and Control in Networked Systems (NECSYS2019). He is currently a Senior Editor for the IEEE Transactions on Automatic Control.

Host

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