IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **April 2024**

Editor: Xiang Yin
Chair, IEEE CSS Technical Committee on DES
Associate Professor
Department of Automation, Shanghai Jiao Tong University
SEIEE Building 2-443, Dongchuan Rd 800, Shanghai, 200240, China

Phone: (+86) 021-34204022
Email: yinxiang@sjtu.edu.cn
Website: http://xiangyin.sjtu.edu.cn

Welcome to the 2024 April issue of the newsletter, also available online at
https://ieeecss.org/tc/discrete-event-systems/newsletters

Editorial

You are welcome to submit new items to the newsletter (topics including schools, workshops, sessions, conferences, journals, books, software, positions). Also please encourage relevant colleagues and students to subscribe to this newsletter.

- To **submit a new item**, please email to yinxiang@sjtu.edu.cn.
- To **subscribe**, please email to yinxiang@sjtu.edu.cn.
- To **unsubscribe**, please reply to this email with the subject line UNSUBSCRIBE.

Contents

1 Selections of Journal Publications

Contributed by: Xiang Yin (yinxiang@sjtu.edu.cn)

1.1. IEEE Transactions on Automatic Control

Volume: 69, Issue: 4, April 2024

- **Opacity Enforcement via Greedy Privately-and-Publicly Known Insertion Functions**
  Authors: Rongjian Liu ; Jianquan Lu ; Yang Liu ; Xiang Yin ; Christoforos N. Hadjicostis
  Abstract: In this article, we investigate the enforcement of (current-state) opacity, an important information-flow security property, via insertion functions. An insertion function is an obfuscation mechanism that inserts fictitious events to the outputs in order to confuse the outside observer (intruder) such that the secret of the system is not revealed. In some situations, the secret may be revealed when the insertion mechanism is (or becomes) publicly known. This leads to the problem of synthesizing private-and-public enforcing (PP-enforcing) insertion functions in the sense that opacity is still enforced even when the mechanism is discovered or published by the designer. Existing works that have investigated this synthesis problem are either only sound or have limited applicability as we show in this work. For this reason, and more importantly, to better solve the synthesis problem, a new approach is proposed upon an improved greedy criterion. We show that the proposed algorithm is both sound and complete, and can be used to completely solve the synthesis problem for the PP-enforcing insertion function. With slight modifications of our algorithm, infinite-step opacity and K-step opacity can also be enforced under publicly-known insertion mechanisms.
- **Asymptotical Controllability of Continuous-Time Probabilistic Logic Control Systems**
  Authors: Zhitao Li ; Yuqian Guo ; Weihua Gui
  Abstract: Herein, we investigate the asymptotical controllability of continuous-time probabilistic logic control systems (CT-PLCSs) under piecewise constant and right continuous controls (PCRCCs). The theory of an invariant subset for a CT-PLCS controlled by a PCRCC is developed. Based on this theory, we prove that a state is asymptotically reachable from another state under a PCRCC if and only if it is asymptotically reachable under a simple periodic PCRCC; in other words, the control values are pairwise distinct within one period. Thereafter, a verifiable, necessary and sufficient condition for the asymptotical reachability between states is obtained, based on which verifiable, necessary and sufficient conditions for the asymptotical reachability and asymptotical controllability are derived. In particular, we prove that a CT-PLCS is asymptotically controllable if and only if each state can be asymptotically stabilized by PCRCCs. In addition, the proof of the proposed results is constructive, which naturally leads to the development of methods of designing PCRCCs. Finally, the examples are provided to illustrate the theoretical results.
- **Synthesizing Control Barrier Functions With Feasible Region Iteration for Safe Reinforcement Learning**
  Authors: Yujie Yang ; Yuhang Zhang ; Wenjun Zou ; Jianyu Chen ; Yuming Yin ; Shengbo Eben Li
  Abstract: Safety is a critical concern when applying reinforcement learning to real-world control problems. A widely used method for ensuring safety is to learn a control barrier function with heuristic feasibility labels that come from expert demonstrations or constraint functions. However, their forward invariant sets fall short of the maximum feasible region because of inaccurate labels. This article proposes an algorithm called feasible region iteration (FRI) that learns the maximum feasible region to generate accurate feasibility labels. The core of FRI is a constraint decay function (CDF), which comes with a self-consistency condition and naturally leads to the constraint Bellman equation. The optimal CDF, which represents the maximum feasible region, is learned through the iteration of feasible region identification and feasible region expansion. Experiment results show that our algorithm achieves near-zero constraint violations and comparable or higher performance than the baselines.
- **Stability and Tracking Recovery of Continuous-Time Markov Jump Piecewise Affine Systems Using Virtual-Sensor-Based Reconfiguration**

Authors: Yanzheng Zhu ; Nuo Xu ; Michael V. Basin ; Donghua Zhou ; Xinkai Chen
Abstract: This technical note studies both the stability and tracking recovery problems for a class of continuous-time Markov jump piecewise-affine systems against sensor faults. A novel reconfigurable control design approach is proposed to recover the mean-square input-to-state stability of the closed-loop system and the tracking property of constant reference inputs, the key idea of this approach is to insert a reconfiguration block including a separate virtual sensor between the faulty system and the nominal controller. Then, a novel extended improved mode-region switching paths (extended-IMRSPs) algorithm is developed to overcome the state switching position mismatch between the faulty system and the reconfiguration block due to interleaving different regions. Furthermore, the S -procedure is employed to cope with the affine term, combining with the ellipsoidal outer approximation technique. Finally, the effectiveness and the advantage of both the proposed reconfigurable control strategy and the developed extended-IMRSPs algorithm are demonstrated via an illustrative example.

Back to the contents

1.2. Automatica

Volume: 162, April 2024

- **Fault-prognosability, K-step prognosis and K-step predictive diagnosis in partially observed petri nets by means of algebraic techniques**
  Authors: Amira Chouchane ; Mohamed Ghazel
  Abstract: In this paper, we explore some issues relevant to fault monitoring in discrete event systems modeled by partially observed LPNs with, possibly indistinguishable observable events and acyclic unobservable subnet. Firstly, we address the (offline) fault-prognosability analysis problem. Subsequently, we tackle the two online problems of K-step fault prognosis and K-step predictive diagnosis. We propose algebraic formulations and solutions to these problems. Namely, a necessary and sufficient condition for fault-prognosability is established based on solving an integer optimization problem. The proposed approach is applicable for bounded Petri nets. As for the K-step prognosis and K-step predictive diagnosis, algebraic approaches based on state estimation on a sliding horizon are elaborated to produce relevant verdicts. The established results for K-step prognosis and K-step predictive diagnosis are applicable for both bounded and unbounded Petri nets.
- **Distributed Nash equilibrium seeking with stochastic event-triggered mechanism**
  Authors: Wei Huo ; Kam Fai Elvis Tsang ; Yamin Yan ; Karl Henrik Johansson ; Ling Shi
  Abstract: In this paper, we study the problem of consensus-based distributed Nash equilibrium (NE) seeking in a network of players represented as a directed graph, where each player aims to minimize their own local cost functions non-cooperatively. To address bandwidth constraints and limited energy, we propose a stochastic event-triggered algorithm that triggers individual players with a probability depending on certain events, thus enhancing communication efficiency through reduced continuous communication. We prove that our developed event-triggered algorithm achieves exponential convergence to the exact NE when the underlying communication graph is strongly connected. Furthermore, we establish that our proposed event-triggered communication scheme does not exhibit Zeno behavior. Finally, through numerical simulations of a spectrum access game and comparisons with existing event-triggered methods, we demonstrate the effectiveness of our proposed algorithm.
- **Optimal control of connected automated vehicles with event/self-triggered control barrier functions**
  Authors: Ehsan Sabouni ; Christos G. Cassandras ; Wei Xiao ; Nader Meskin
  Abstract: We address the problem of controlling Connected and Automated Vehicles (CAVs) in conflict areas of a traffic network subject to hard safety constraints. It has been shown that such problems can be solved through a combination of tractable optimal control problem formulations and the use of Control Barrier Functions (CBFs) that guarantee the satisfaction of all constraints. These solutions can be reduced to a sequence of Quadratic Programs (QPs) which are efficiently solved on-line over discrete time steps. However, the feasibility of each such QP cannot be guaranteed over every time step. To overcome this limitation, we develop both an event-triggered approach

and a self-triggered approach such that the next QP is triggered by properly defined events. We show that both approaches, each in a different way, eliminate infeasible cases due to time-driven inter-sampling effects, thus also eliminating the need for selecting the size of time steps. Simulation examples are included to compare the two new schemes and to illustrate how overall infeasibilities can be significantly reduced while at the same time reducing the need for communication among CAVs without compromising performance.

Back to the contents

1.3. Annual Reviews in Control

Volume: 56, August 2023

- **Formal synthesis of controllers for safety-critical autonomous systems: Developments and challenges**
  Authors: Xiang Yin ; Bingzhao Gao ; Xiao Yu
  Abstract: In recent years, formal methods have been extensively used in the design of autonomous systems. By employing mathematically rigorous techniques, formal methods can provide fully automated reasoning processes with provable safety guarantees for complex dynamic systems with intricate interactions between continuous dynamics and discrete logics. This paper provides a comprehensive review of formal controller synthesis techniques for safety-critical autonomous systems. Specifically, we categorize the formal control synthesis problem based on diverse system models, encompassing deterministic, non-deterministic, and stochastic, and various formal safety-critical specifications involving logic, real-time, and real-valued domains. The review covers fundamental formal control synthesis techniques, including abstraction-based approaches and abstraction-free methods. We explore the integration of data-driven synthesis approaches in formal control synthesis. Furthermore, we review formal techniques tailored for multi-agent systems (MAS), with a specific focus on various approaches to address the scalability challenges in large-scale systems. Finally, we discuss some recent trends and highlight research challenges in this area.
- **Advances in the Theory of Control Barrier Functions: Addressing practical challenges in safe control synthesis for autonomous and robotic systems**
  Authors: Kunal Garg ; James Usevitch ; Joseph Breeden ; Mitchell Black ; Devansh Agrawal ; Hardik Parwana ; Dimitra Panagou
  Abstract: This tutorial paper presents recent work of the authors that extends the theory of Control Barrier Functions (CBFs) to address practical challenges in the synthesis of safe controllers for autonomous systems and robots. We present novel CBFs and methods that handle safety constraints (i) with time and input constraints under disturbances, (ii) with high-relative degree under disturbances and input constraints, and (iii) that are affected by adversarial inputs and sampled-data effects. We then present novel CBFs and adaptation methods that prevent loss of validity of the CBF, as well as methods to tune the parameters of the CBF online to reduce conservatism in the system response. We also address the pointwise-only optimal character of CBF-induced control inputs by introducing a CBF formulation that accounts for future trajectories, as well as implementation challenges such as how to preserve safety when using output feedback control and zero-order-hold control. Finally we consider how to synthesize non-smooth CBFs when discontinuous inputs and multiple constraints are present.
- **Safety-critical control for autonomous systems: Control barrier functions via reduced-order models**
  Authors: Max H. Cohen ; Tamas G. Molnar ; Aaron D. Ames
  Abstract: Modern autonomous systems, such as flying, legged, and wheeled robots, are generally characterized by high-dimensional nonlinear dynamics, which presents challenges for model-based safety-critical control design. Motivated by the success of reduced-order models in robotics, this paper presents a tutorial on constructive safety-critical control via reduced-order models and control barrier functions (CBFs). To this end, we provide a unified formulation of techniques in the literature that share a common foundation of constructing CBFs for complex systems from CBFs for much simpler systems. Such ideas are illustrated through formal results, simple numerical examples, and case studies of real-world systems to which these techniques have been experimentally

applied.

- **Cooperative control of heterogeneous multi-agent systems under spatiotemporal constraints**
  Authors: Fei Chen ; Mayank Sewlia ; Dimos V. Dimarogonas
  Abstract: A current trend in research on multi-agent control systems is to consider high-level task specifications that go beyond traditional control objectives and take into account the heterogeneity of each agent in the system, i.e., the different capabilities of the agents in terms of actuation, sensing, communication and computation. This article provides an overview of our work on the problem of control of heterogeneous multi-agent systems under both spatial and temporal constraints as well as our perspective on the challenges and open problems associated with the consideration of such spatiotemporal constraints. Initially, we review a set of control strategies introduced by the authors addressing the satisfaction of cooperative tasks such as formation control as well as individual objectives such as reference tracking. The satisfaction of those objectives is ensured using prescribed performance control. Building upon these approaches we then review recent results on control under high-level spatiotemporal objectives expressed in Signal Temporal Logic, a formal language that allows to express complex spatial tasks that must be satisfied within pre-defined deadlines. Theoretical results considering multi-agent systems with various capabilities under spatiotemporal constraints are presented.

- **Learning safe control for multi-robot systems: Methods, verification, and open challenges**
  Authors: Kunal Garg ; Songyuan Zhang ; Oswin So ; Charles Dawson ; Chuchu Fan
  Abstract: In this survey, we review the recent advances in control design methods for robotic multi-agent systems (MAS), focusing on learning-based methods with safety considerations. We start by reviewing various notions of safety and liveness properties, and modeling frameworks used for problem formulation of MAS. Then we provide a comprehensive review of learning-based methods for safe control design for multi-robot systems. We start with various shielding-based methods, such as safety certificates, predictive filters, and reachability tools. Then, we review the current state of control barrier certificate learning in both a centralized and distributed manner, followed by a comprehensive review of multi-agent reinforcement learning with a particular focus on safety. Next, we discuss the state-of-the-art verification tools for the correctness of learning-based methods. Based on the capabilities and the limitations of the state-of-the-art methods in learning and verification for MAS, we identify various broad themes for open challenges: how to design methods that can achieve good performance along with safety guarantees; how to decompose single-agent-based centralized methods for MAS; how to account for communication-related practical issues; and how to assess transfer of theoretical guarantees to practice.

Back to the contents

1.4. IEEE Control Systems Letter

Volume: 8, Issue: 3, March 2024

- **Minimal Sensor Activation for Detectable Networked Discrete Event Systems**
  Authors: Anjie Mao ; Yuchen Zhang ; Zheming Wang ; Bo Chen
  Abstract: This letter is concerned with the minimal sensor activation problem for a class of networked discrete event systems (DESs) with channel delays. A new concept called networked detectability is proposed to characterize the detectability of networked DESs in minimal sensor activation problem. Then, an observer-based approach is proposed to verify the networked detectability. Under verified networked detectability, the feasible sensor activation policies for networked DESs are investigated. By searching for the maximum feasible sub-policy of a given activation policy, a minimal sensor activation policy for networked DESs is designed as an algorithm. Several examples are used to illustrative the proposed methods.

Back to the contents

2 Conferences

Contributed by: Xiang Yin (yinxiang@sjtu.edu.cn)

2.1 **2024 IFAC Workshop on Discrete Event Systems (WODES)**
Rio de Janeiro, Brazil, April 29-May 1, 2024.
https://wodes2024.eventos.ufrj.br

2.2 **2024 IFAC Conference on Analysis and Design of Hybrid Systems (ADHS)**
Boulder, Colorado, July 1-3, 2024.
https://www.colorado.edu/conference/adhs2024/

2.3 **2024 American Control Conference (ACC)**
Toronto, Canada, July 8-12, 2024.
https://acc2024.a2c2.org/

2.4 **The IEEE Conference on Control Technology and Applications (CCTA)**
Newcastle upon Tyne, UK, August 21-24, 2024.
https://ccta2024.ieeecss.org/

2.5 **2024 International Conference on Automation Science and Engineering (CASE)**
Bari, Italy, August 28-September 1, 2024.
https://www.ieeesmc2024.org/

2.6 **2024 International Conference on Systems, Man, and Cybernetics (SMC)**
Sarawak, Malaysia, October 7-10, 2024.
https://www.ieeesmc2024.org/

2.7 **2023 IEEE Conference on Decision and Control (CDC)**
Milan, Italy, December 16-19, 2024.
https://cdc2024.ieeecss.org/

Back to the contents

3 Books

3.1 Graph-Theoretical Methods in Systems Theory and Control

Author: Jan Lunze, Ruhr-University, Germany

Description: The book describes for numerous scenarios how to use the structural properties of a system represented by a graph to simplify modelling, analysis, and design tasks. For example, block diagrams and coupling graphs can be used to decompose systems, automata graphs to analyse discrete-event systems and Markov chains, structure graphs to find generic properties of linear systems or communication graphs to design networked control systems. The book includes many examples derived from diverse fields of application, exercises with solutions and MATLAB scripts to implement graph-theoretical methods for systems analysis

Additional information on the book can be found at
www.editionmora.de/gmsc

The book is produced as "print-on-demand" and can be ordered directly at the printer:
https://publish.bookmundo.de/books/349971

3.2 Safe Autonomy with Control Barrier Functions: Theory and Applications

Authors: Wei Xiao, Christos G. Cassandras, and Calin Belta

Description: The book presents the concept of Control Barrier Function (CBF), which captures the evolution of safety requirements during the execution of a system and can be used to enforce safety. Safety is central to autonomous systems since they are intended to operate with minimal or no human supervision. The book includes both theoretical and application perspectives on how safety can be guaranteed. It explains how the CBF approach is computationally efficient and can easily deal with nonlinear models and complex constraints used in a wide spectrum of applications, including autonomous driving, robotics, and traffic control. Safety guarantees can be integrated into the operation of such autonomous systems, including typical safety requirements that involve collision avoidance, technological system limitations, and bounds on real-time executions. Adaptive and event-driven approaches for safety are also discussed for time-varying execution bounds and noisy dynamics, as well as for systems with unknown dynamics.

Additional information on the book can be found at
https://link.springer.com/book/10.1007/978-3-031-27576-0
where an eBook version can also be downloaded (free for some educational institutions).

Back to the contents

4 Software Tools

4.1 Eclipse ESCET™ version 3.0 release

The Eclipse Supervisory Control Engineering Toolkit (Eclipse ESCET) project provides a model-based approach and toolkit for the development of supervisory controllers. It includes the languages CIF, Chi and ToolDef. ESCET, initially developed by Eindhoven University of Technology, is since January 2020 an Eclipse Foundation open-source project. More information can be found on the toolkit's website at https://www.eclipse.org/escet/.

In March 2024, ESCET version 3.0 has been released and can be downloaded from https://www.eclipse.org/escet/download.html. The main changes in this version are

- ESCET now has a logo. So the appearance of the application might be different from what you are used to (only Windows for now, macOS and Linux will follow soon).
- Several improvements to the (still experimental) new CIF PLC code generator have been included.
- The CIF code generator for HTML files and JavaScript code has received several (performance) improvements and bug-fixes.
- SVG input mappings can now either assign values to input variables (new feature), or map to an event to take (existing feature). This new feature is currently an experimental work-in-progress language feature, and is not yet supported by all CIF tools.
- All CIF tools now support reading .cifx files, CIF files in an XML format. CIF tools that write CIF specifications also support writing .cifx files. See the CIF reference manual for more information. Similarly, the ToolDef interpreter now supports reading .tooldefx files, ToolDef files in an XML format.
- The CIF benchmark models have been extended with the mri_event, mri_state and wafer_scanner benchmark models.

The full ESCET release notes, including links to the language specific release notes and release notes from previous versions, are available from https://www.eclipse.org/escet/release-notes.html.

Back to the contents