IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **April 2025**

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https://ieeecss.org/tc/discrete-event-systems/newsletters

Editorial

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Contents

1 Selections of Journal Publications

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

1.1. IEEE Transactions on Automatic Control

Volume: 70, Issue: 4, April 2025

- **Barrier-Based Test Synthesis for Safety-Critical Systems Subject to Timed Reach-Avoid Specifications**
  Authors: Prithvi Akella ; Mohamadreza Ahmadi ; Richard M. Murray ; Aaron D. Ames
  Abstract: We propose an adversarial, time-varying test-synthesis procedure for safety-critical systems without requiring specific knowledge of the underlying controller steering the system. Specifically, our approach codifies the system objective as a timed reach-avoid specification. Then, by coupling control barrier functions with this class of specifications, we construct an instantaneous difficulty metric whose minimizer corresponds to the most difficult test at that system state. By defining tests as the minimizer of this difficulty metric over the space of allowable tests, we provably identify realizable and maximally difficult tests of system behavior. Finally, we develop this test-synthesis procedure for both continuous and discrete-time systems and showcase our test-synthesis procedure on simulated and hardware examples.
- **Secret Protection in Discrete-Event Systems With Generalized Confidentiality Requirements**
  Authors: Ziyue Ma ; Kai Cai
  Abstract: In this article, we propose a general framework to design optimal secret protection policies in discrete-event systems. The system is modeled by an automaton in which several states are secret and assigned with different confidentiality requirement. Events in the system can be protected to verify the identity of the user, and a user who successfully executes/passes a protected event gains some authorization. Our purpose is to design an event-protecting policy such that any user, either legal or unauthorized, who visits a secret state must have an authorization that satisfies the requirement of confidentiality of the state. We consider the criteria of optimality on protecting policies as to protecting policies with a minimum degree of disturbance to legal users' normal operations. To this aim, we use Moore machines to model the dynamics of the clearance level of users when using the system. Then, we develop an auxiliary data structure called the generalized secret automaton, based on which we propose a method to design a protecting policy using the classical supervisory control theory. The minimally disruptive protecting policy is then represented by an automaton called the secret enforcer whose state size is polynomial both in the number of the plant states and the number of secret states in the plant.
- **Switching Model Predictive Control for Perturbed Max-Plus Linear Systems via Minimum Dwell-Time**
  Authors: Jin Wang ; Hongjiu Yang ; Zhiqiang Zuo ; Chaoxu Mu
  Abstract: In this article, switching model predictive control (MPC) is proposed for a perturbed max-plus linear system with a reference signal. The lack of stability guarantee for MPC brings difficulties in reducing tracking errors caused by perturbations in the perturbed max-plus linear system. To reduce tracking errors, the perturbed max-plus linear system is partitioned into a switching max-plus linear system by a permutation matrix. Based on a local maximum terminal set, each mode of the switching max-plus linear system is assigned with an optimal control problem to track the reference signal. Minimum dwell-time is designed to ensure the feasibility of the switching MPC and the stability of the switching max-plus linear system via Hausdorff metric analyses and ∞-norm hypercube invariance. Numerical simulations show the effectiveness and superiority of the switching MPC for a perturbed max-plus linear system.
- **Optimal Control of Switched Dynamical Systems Under Dwell Time Constraints—Theory and Computation**
  Authors: Usman Ali ; Magnus Egerstedt
  Abstract: This article addresses the problem of optimal mode scheduling subject to dwell time constraints, which is the minimum amount of time a system has to spend in one mode before it

can transition to another. The constraint is important since most physical systems cannot switch rapidly between different modes and its presence also eliminates the problem of chattering solutions by construction. We investigate the topology of the optimization space and show that it lacks structure to define local minima. A framework is developed for defining optimal solutions as stationary points of optimality functions and an optimality function is proposed for characterizing the necessary conditions for optimality. The challenges posed by dwell time constraints to algorithmic implementation are addressed by exploring the geometric properties of the so-called mode insertion gradient, and a technique is developed for rapidly updating of the mode sequence. The algorithm's convergence to an optimal solution is proved and simulation results are provided to demonstrate the algorithm's efficacy.

- **Schrödinger's Control and Estimation Paradigm With Spatio-Temporal Distributions on Graphs**
  Authors: Asmaa Eldesoukey ; Tryphon T. Georgiou
  Abstract: The problem of reconciling a prior probability law on paths with data was introduced by Schrödinger in 1931 and 1932. It represents an early formulation of a maximum likelihood problem. This specific formulation can also be seen as the control problem to modify the law of a diffusion process so as to match specifications on marginal distributions at given times. Thereby, in recent years, this so-called Schrödinger's bridge problem has been at the center of the uncertainty control development. However, an understudied facet of this program has been to address uncertainty in space (state) and time, modeling the effect of tasks being completed contingent on meeting a certain condition at some random time instead of imposing specifications at fixed times. The present work is a study to extend Schrödinger's paradigm on such an issue, and herein, it is tackled in the context of random walks on directed graphs. Specifically, we study the case where one marginal is the initial probability distribution on a Markov chain, while others are marginals of stopping (first-arrival) times at absorbing states, signifying completion of tasks. We show when the prior law on paths is Markov, a Markov policy is once again optimal to satisfy those marginal constraints with respect to a likelihood cost following Schrödinger's dictum. Based on this, we present the mathematical formulation involving a Sinkhorn-type iteration to construct the optimal probability law on paths matching the spatio-temporal marginals.

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1.2. Automatica

Volume: 174, April 2025

- **On algorithms verifying initial-and-final-state opacity: Complexity, special cases, and comparison**
  Authors: Tomáš Masopust ; Petr Osička
  Abstract: Opacity is a general framework modeling security properties of systems interacting with a passive attacker. Initial-and-final-state opacity (IFO) generalizes the classical notions of opacity, such as current-state opacity and initial-state opacity. In IFO, the secret is whether the system evolved from a given initial state to a given final state or not. There are two algorithms for IFO verification. One arises from a trellis-based state estimator, which builds a semigroup of binary relations generated by the events of the automaton, and the other is based on the reduction to language inclusion. The time complexity of both algorithms is bounded by a super-exponential function, and it is a challenging open problem to find a faster algorithm or to show that no faster algorithm exists. We discuss the lower-bound time complexity for both general and special cases, and use extensive benchmarks to compare the existing algorithms.

- **A neural network-based approach to hybrid systems identification for control**
  Authors: Filippo Fabiani ; Bartolomeo Stellato ; Daniele Masti ; Paul J. Goulart
  Abstract: Opacity is a security property of discrete-event systems that specifies whether the secret can be concealed from an external intruder. In this paper, we proposed two advanced variants of initial-and-final-state opacity, namely partially strong initial-and-final-state opacity (PSIFO) and strong initial-and-final-state opacity (SIFO), which impose more stringent security requirements, for discrete-event systems modeled by nondeterministic finite-state automata. SIFO (resp. PSIFO)

is a property that for each path between a given secret state pair, there exists a strongly non-secret-pair path (resp. non-secret-pair path), with the same observation as that path. In other words, the strong version of initial-and-final-state opacity requires the existence of at least one path always guarding the secret. Furthermore, we conduct an analysis of the reductions from strong current-state opacity and initial-state opacity to PSIFO. Finally, two concurrent composition-based information structures are proposed to verify these two properties, the size of which grows exponentially with the number of states of the original system.

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1.3. IEEE Control Systems Letter

Volume: 9, Issue: 1, April 2025

- **ISC-POMDPs: Partially Observed Markov Decision Processes With Initial-State Dependent Costs**
  Authors: Timothy L. Molloy
  Abstract: We introduce a class of partially observed Markov decision processes (POMDPs) with costs that can depend on both the value and (future) uncertainty associated with the initial state. These Initial-State Cost POMDPs (ISC-POMDPs) enable the specification of objectives relative to a priori unknown initial states, which is useful in applications such as robot navigation, controlled sensing, and active perception, that can involve controlling systems to revisit, remain near, or actively infer their initial states. By developing a recursive Bayesian fixed-point smoother to estimate the initial state that resembles the standard recursive Bayesian filter, we show that ISC-POMDPs can be treated as POMDPs with (potentially) belief-dependent costs. We demonstrate the utility of ISC-POMDPs, including their ability to select controls that resolve (future) uncertainty about (past) initial states, in simulation.
- **A Weighted Smooth Q-Learning Algorithm**
  Authors: V. Antony Vijesh ; S. R. Shreyas
  Abstract: Q-learning and double Q-learning are well-known sample-based, off-policy reinforcement learning algorithms. However, Q-learning suffers from overestimation bias, while double Q-learning suffers from underestimation bias. To address these issues, this letter proposes a weighted smooth Q-learning (WSQL) algorithm. The proposed algorithm employs a weighted combination of the mellowmax operator and the log-sum-exp operator in place of the maximum operator. Firstly, a new stochastic approximation based result is derived and as a consequence the almost sure convergence of the proposed WSQL is presented. Further, a sufficient condition for the boundedness of WSQL algorithm is obtained. Numerical experiments are conducted on benchmark examples to validate the effectiveness of the proposed weighted smooth Q-learning algorithm.

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1.4. IEEE Transactions on Cybernetics

Volume: 55, Issue: 4, April 2025

- **High-Level Decision Making in a Hierarchical Control Framework: Integrating HMDP and MPC for Autonomous Systems**
  Authors: Xue-Fang Wang ; Jingjing Jiang ; Wen-Hua Chen
  Abstract: This article addresses challenges of autonomous decisions making influenced by discrete system states, underlying continuous dynamics, and evolving operational environments. A comprehensive framework is proposed, encompassing new modeling, problem formulation, control design, and stability analysis. The framework integrates continuous system dynamics, used for low-level control, with discrete Markov decision processes (MDP) for high-level decision making. To capture the interactions between these domains, the decision-making system is modeled as a hybrid system consisting of a controlled MDP and autonomous (uncontrolled) continuous dynamics, collectively referred to as the hybrid Markov decision process (HMDP). The design focuses on ensuring safety and optimality by accounting for both discrete and continuous state variables across different levels. With the help of the model predictive control (MPC) concept, a decision-making scheme is

developed for the hybrid model, with guarantees for recursive feasibility and stability. The proposed framework is applied to the autonomous lane changing system for intelligent vehicles, and simulation shows its capability to handle diverse behaviors in dynamic and complex environments.

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2 Conferences

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

2.1 **2025 ACM International Conference on Hybrid Systems: Computation and Control (HSCC)**
Irvine, California, USA, May 6-9, 2025.
https://hscc.acm.org/2025/

2.2 **2025 IEEE International Conference on Robotics and Automation (ICRA)**
Atlanta, USA, May 19-23, 2025.
https://2025.ieee-icra.org/

2.3 **2025 Annual Learning for Dynamics & Control Conference (L4DC)**
Ann Arbor, Michigan, USA, June 4-6, 2025.
https://sites.google.com/umich.edu/l4dc2025/

2.4 **2025 IFAC Workshop on Smart Energy Systems for Efficient and Sustainable Smart Grids and Smart Cities (SENSYS 2025)**
Bari, Italy, June 18-20, 2025.
https://conferences.ifac-control.org/sensys2025/

2.5 **2025 European Control Conference (ECC)**
Thessaloniki, Greece, June 24-27, 2025.
https://ecc25.euca-ecc.org/

2.6 **2025 American Control Conference (ACC)**
Denver, Colorado, USA, July 8-10, 2025.
https://acc2025.a2c2.org/

2.7 **2025 International Conference on Automation Science and Engineering (CASE)**
Los Angeles, California, USA, August 17-21, 2025.
https://2025.ieeecase.org/

2.8 **2025 IEEE Conference on Control Technology and Applications (CCTA)**
San Diego, California, USA, August 25-27, 2025.
https://ccta2025.ieeecss.org/

2.9 **2025 IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)**
Porto, Portugal, September 9-12, 2025.
https://etfa2025.ieee-ies.org/

2.10 **2025 International Conference on Systems, Man, and Cybernetics (SMC)**
Vienna, Austria, October 5-8, 2025.
https://www.ieeesmc2025.org/

2.11 **2025 IEEE Conference on Decision and Control (CDC)**
Rio de Janeiro, Brazil December 9-12, 2025.
https://cdc2025.ieeecss.org/

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3 Books

3.1 Invitation to Supervisory Control of Discrete-Event Systems with Hands-On Python Software Tool

Author: Kai Cai, Osaka Metropolitan University.

Publish Information: Kindle Direct Publishing, 2024, ISBN: 9798373331449

Book website:
https://www.caikai.org/invitation-scdes

About the book:
This book is for anyone who is interested in getting a quick start with the supervisory control theory of discrete-event systems. A companion software package PyTCT (python-based TCT) is available for the reader to get hands-on experience with the theory.
Your feedback comments on how the book materials may be improved are highly appreciated and please send them to: cai@omu.ac.jp

3.2 Cybersecurity of Discrete Event Systems—From Smart Attacks to Resilient Defence

Author: Rong Su, Nanyang Technological University.

Description: This book describes analysis and control against smart cyberattacks in discrete event systems (DES), modelled by regular languages or finite-state automata. "Smart attacks" cannot be detected by the supervisor until an irreversible process towards ensured damage occurs. An attack may be conducted either in the observation channel (i.e., the input of the supervisor) or in the command channel (i.e., the output of the supervisor), or both simultaneously. Therefore, defense strategies against these attacks are urgently needed. This book provides an overview of the latest theories and includes empirical examples to illustrate concepts and methods. By centering on what information is available and how such information is used, the readers are provided with methods to evaluate the cyber vulnerability of a given system and to design a resilient supervisor against relevant smart attacks. By focusing on a conceptual introduction and systematic analysis, this book provides a solid theoretical foundation for future exploration by researchers and graduate students who are interested in cybersecurity research, not necessarily limited to those in the DES community. Readers are recommended to have a background in formal language theory.

Additional information on the book can be found at
https://www.routledge.com/Cybersecurity-of-Discrete-Event-Systems-From-Smart-Attacks-to-Resilient
Su/p/book/9781032368108?srsltid=AfmBOor9fqjhOR7YfMgGE8coz0rHXF6YyKhoucc7UzqYlY9GhcWpQBg3,
where an inspection copy is possible for educational institutions.

3.3 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

3.4 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).

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4 Software Tools

4.1 Eclipse ESCET™ version 7.0 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.dev/escet/.

In March 2025, ESCET version 7.0 has been released and can be downloaded from https://www.eclipse.dev/escet/download.html. The main changes in this version are

- The data-based synthesis tool may internally produce simpler predicates, such as 'true or X' now becoming 'true', in the conversion of the specification to BDDs. This may lead to differences in conversion performance, variable ordering, and debug output. The benchmarks shown only minimal changes (less than 0.1% change in memory/time). However, for the wafer_scanner_n1 benchmark, synthesis requires about 12% less BDD operations.
- The CIF language now features input parameters, a new kind of parameters for component definitions (automaton and group definitions). For such parameters, only input variables and input parameters can be used as arguments in component instantiations. A primary use case for using input parameters instead of algebraic parameters, is that input parameters can be assigned by SVG input mappings within component definitions.
- A new Eliminate state invariants CIF to CIF transformation has been added. It comes in three variants: one that eliminates all state invariants, one that only eliminates plant state invariants, and one that only eliminates supervisor state invariants.
- Several improvements to the HTML code generator, including a new HTML frequencies.
- The Developers section of the documentation now contains a page about how to reliably extract information from a CIF specification, by converting the CIF specification to XML and using XML queries.

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.dev/escet/release-notes.html.

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