IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **August 2024**

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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: 69, Issue: 8, August 2024

- **Distributed Fault Diagnosis in Discrete Event Systems With Transmission Delay Impairments**
  Authors: Jiwei Wang ; Simone Baldi ; Wenwu Yu ; Xiang Yin
  Abstract: This note studies the distributed fault diagnosis problem in partially-observed discrete event systems, where the system is monitored by a group of agents to cooperatively diagnose faults within a finite number of steps. The novelty of this work is the creation of a methodology to verify when the faults can be diagnosed even in the presence of transmission delay impairments. To address this scenario, a new distributed diagnosability condition is proposed, which extends decentralized diagnosability conditions proposed in the literature. Such distributed diagnosability condition is then verified via a novel structure named delay recorder and a new diagnosis function. Theoretical analysis shows that the verification method can successfully determine whether the faults can be diagnosed.
- **Data-Driven Models of Monotone Systems**
  Authors: Anas Makdesi ; Antoine Girard ; Laurent Fribourg
  Abstract: In this article, we consider the problem of computing from data guaranteed set-valued over-approximations of unknown monotone functions with additive disturbances. We provide a characterization of a simulating map that provably contains all monotone functions that are consistent with the data. This map is also minimal in the sense that any set-valued map containing all consistent monotone functions would also include the map we are proposing. We show that this minimal simulating map is interval-valued and admits a simple construction on a finite partition induced by the data. As the complexity of the partition increases with the amount of data, we also consider the problem of computing minimal interval-valued simulating maps defined on partitions that are fixed a priori. We present an efficient algorithm for their computation. We then use those data-driven over-approximations to build models for partially unknown systems where the unknown part is monotone. The resulting models are used to construct finite-state symbolic abstractions, paving the way for discrete controller synthesis methods to be applied. We extend our approach to handle systems with bounded derivatives and introduce an algorithm to calculate the bounds on those derivatives and on the disturbances from the data. We present several numerical experiments to test the performance of the introduced method and show that the data-driven abstractions are suitable for controller synthesis purposes.
- **Synthesis of Distributed Covert Sensor–Actuator Attackers**
  Authors: Ruochen Tai ; Liyong Lin ; Yuting Zhu ; Rong Su
  Abstract: This article investigates the synthesis of distributed attackers for distributed discrete-event systems, where the distributed attackers could implement sensor insertion/deletion/replacement attacks and actuator enablement/disablement attacks. The distributed attackers to be synthesized should fulfill the following goals: 1) Each local sensor–actuator attacker needs to remain covert against all the distributed monitors, which are used to detect the existence of attacks; and 2) the distributed sensor–actuator attackers need to cooperate to implement attacks such that the damage infliction could be realized. To solve this distributed attacker synthesis problem, our solution methodology is to first model the original problem as a distributed supervisor synthesis problem by modeling each system component as a finite-state automaton and then perform incremental synthesis with a heuristic that takes the special structure of this distributed synthesis problem into consideration. The effectiveness of the proposed approach is illustrated via an example regarding the transportation task of multiple robots.
- **Optimal Synthesis of Opacity-Enforcing Supervisors for Qualitative and Quantitative Specifications**
  Authors: Yifan Xie ; Shaoyuan Li ; Xiang Yin

Abstract: In this article, we investigate both qualitative and quantitative synthesis of optimal privacy-enforcing supervisors for partially observed discrete-event systems. We consider a dynamic system whose information flow is partially available to an intruder, which is modeled as a passive observer. We assume that the system has a "secret" that does not want to be revealed to the intruder. Our goal is to synthesize a supervisor that controls the system in a least-restrictive manner such that the closed-loop system meets the privacy requirement. For the qualitative case, we adopt the notion of infinite-step opacity as the privacy specification by requiring that the intruder can never determine for sure that the system is/was at a secret state for any specific instant. If the qualitative synthesis problem is not solvable or the synthesized solution is too restrictive, then we further investigate the quantitative synthesis problem so that the secret is revealed (if unavoidable) as late as possible within a finite security-preserving horizon. Effective algorithms are provided to solve both the qualitative and quantitative synthesis problems. Specifically, by building suitable information structures that involve information delays, we show that the optimal qualitative synthesis problem can be solved as a safety game. The optimal quantitative synthesis problem can also be solved as an optimal total-cost control problem over an augmented information structure. Our work provides a complete solution to the standard infinite-step opacity control problem, which has not been solved without an assumption on the relationship between controllable events and observable events. Furthermore, we generalize the opacity enforcement problem to the numerical setting by introducing the secret-revelation-time as a new quantitative measure.

- **Active Fault Isolation for Discrete Event Systems**
  Authors: Lin Cao ; Shaolong Shu ; Feng Lin
  Abstract: In practice, a supervisor can often not only disable some events, but also enforce the occurrence of some events prior to the occurrence of other events. In this article, we combine these two control mechanisms to synthesize a more powerful supervisor. The control goal is to design an isolation supervisor, which ensures in the closed-loop system, faults are fault isolatable in the sense that after a fault occurs, we can determine which type the fault belongs to by observing the output of the closed-loop system. The isolation supervisor starts to work when the occurrence of faults is detected. We solve the isolation supervisor synthesis problem as follows. For a given discrete event system, we first construct a bipartite transition system which includes all feasible isolation supervisors. An isolation supervisor is feasible if it enforces only events that are physically possible. We then develop an algorithm to check whether the synthesis problem is solvable or not. The algorithm can also be used to find a valid isolation supervisor if the synthesis problem is solvable. The method of combining two control mechanisms can be used to synthesize more powerful supervisors for other supervisory control problems of discrete event systems as well.

Back to the contents

1.2. Automatica

Volume: 166, August 2024

- **Model-based control of switched linear systems under network communication**
  Authors: Jun Fu ; Tai-Fang Li ; Tao Yang ; Bin Lu
  Abstract: Model-based control strategy is introduced for improving the closed-loop performance of switched systems under network communication in this paper. In traditional networked control system, a Zero-Order Hold (ZOH) is often used at the controller side to realize continuous feedback control. However, to use a ZOH usually decreases control accuracy since the state will be held invariably during each sampling period. In order to improve control accuracy, we introduce a model-based control strategy instead of ZOH-based one and propose two analysis frameworks for switched linear systems in network communication environment with periodic sampling mechanism (PSM) and event-triggered sampling mechanism (ETSM), respectively. A model-based dynamic switching controller is set up with certain robust performance. Asynchronous switching is taken into account since the switching time sequence of the controller is determined by the network transmission time sequence which cannot coincide with the controlled system. Under switching and control gain conditions, stability criteria of the closed-loop switched system in network communication environment are derived and verified through two simulation examples.

Back to the contents

1.3. IEEE Control Systems Letter

Volume: 8, Issue: 7, August 2024

- **Computing the Maximal Positive Invariant Set for the Constrained Zonotopic Case**
  Authors: Bogdan Gheorghe ; Daniel-Mihail Ioan ; Florin Stoican ; Ionela Prodan
  Abstract: The maximal positive invariant (MPI) set results from a finite set recurrence instantiated by the intersection of input and state bounds (e.g., the stage constraints of the linear model predictive control problem). When these constraints take the form of hyper-rectangles, zonotopes or constrained zonotopes, the resulting polyhedral MPI set may be succinctly described as a constrained zonotope, eliminating the need for explicit enumeration of its halfspaces. In this letter we discuss the various MPI computation algorithms (with both exact and sufficient stop conditions), recasted in the framework of constrained zonotopes. We analyze one of these variations over a dynamical system whose dimension can be arbitrarily increased in order to asses changes in computation time and storage requirements with respect to the polyhedral case (under the simplifying assumption of closed-loop invertibility of the state matrix).
- **Decentralized Control of Networks of Nondeterministic and Metric Finite State Systems**
  Authors: Giordano Pola ; Elena De Santis ; Maria Domenica Di Benedetto
  Abstract: In this letter, we consider a network of nondeterministic and metric finite state systems and address a control problem where local controllers are designed for enforcing local specifications expressed in terms of regular languages up to desired accuracies. The control architecture considered is decentralized, that is each controller can only communicate with the corresponding plant. Necessary and sufficient conditions are found and control strategies derived. Checkable sufficient conditions are also proposed. An illustrative example is presented.
- **Layered Control Systems Operating on Multiple Clocks**
  Authors: Inigo Incer ; Noel Csomay-Shanklin ; Aaron D. Ames ; Richard M. Murray
  Abstract: Autonomous systems typically leverage layered control architectures, created by interconnecting components that operate at multiple timescales, i.e., evolve under various clocks. To formalize this typically heuristic procedure, we introduce a new logic, Multiclock Logic (MCL), that can express the requirements of components from the point of view of their local clocks, promoting independent design and component reuse. We then use assume-guarantee contracts expressed in MCL to prove global stability properties of a system using the stability properties of its components. In particular, we consider the classic layered architecture consisting of model predictive control (MPC) layered on top of feedback linearization, and prove overall stability of the systems.
- **Markov Chain Monte Carlo for Koopman-Based Optimal Control**
  Authors: João Hespanha ; Kerem Çamsarı
  Abstract: We propose a Markov Chain Monte Carlo (MCMC) algorithm based on Gibbs sampling with parallel tempering to solve nonlinear optimal control problems. The algorithm is applicable to nonlinear systems with dynamics that can be approximately represented by a finite dimensional Koopman model, potentially with high dimension. This algorithm exploits linearity of the Koopman representation to achieve significant computational saving for large lifted states. We use a videogame to illustrate the use of the method.

Back to the contents

1.4. Nonlinear Analysis: Hybrid Systems

Volume: 53, August 2024

- **Output-feedback stabilization of probabilistic Boolean control networks**
  Authors: Shuting Zhang ; Xueying Ding ; Jianquan Lu ; Jungang Lou ; Yang Liu
  Abstract: To simulate a more realistic and uncertain system model, this paper innovatively studies the output feedback control strategy to stabilize probabilistic Boolean control networks (PBCNs). This is the first time that output feedback method is used to solve stability problems in PBCNs.

Compared with the traditional state feedback, observing output states is more direct and efficient. Firstly, a condition for the output-feedback stabilization in the sense of minimum time is explored. A sufficient and necessary condition is then provided to determine time-invariant output-feedback stabilizers. Afterwards, two constructive algorithms for design time-invariant output-feedback controllers are proposed. To comprehensively solve the output feedback stabilization problems, this paper explores two sufficient conditions for obtaining stabilizers under time-varying feedback control inputs, which provides more feasibility and significance for solving biomedical problems.

- **Fully automated verification of linear time-invariant systems against signal temporal logic specifications via reachability analysis**
  Authors: Niklas Kochdumper ; Stanley Bak
  Abstract: While reachability analysis is one of the most promising approaches for formal verification of dynamic systems, a major disadvantage preventing a more widespread application is the requirement to manually tune algorithm parameters such as the time step size. Manual tuning is especially problematic if one aims to verify that the system satisfies complicated specifications described by signal temporal logic formulas since the effect the tightness of the reachable set has on the satisfaction of the specification is often non-trivial to see for humans. We address this problem with a fully-automated verifier for linear systems, which automatically refines all parameters for reachability analysis until it can either prove or disprove that the system satisfies a signal temporal logic formula for all initial states and all uncertain inputs. Our verifier combines reachset temporal logic with dependency preservation to obtain a model checking approach whose over-approximation error converges to zero for adequately tuned parameters. While we in this work focus on linear systems for simplicity, the general concept we present can equivalently be applied for nonlinear and hybrid systems.

Back to the contents

1.5. IEEE Transactions on Cybernetics

Volume: 54, Issue: 8, August 2024

- **Design and Implementation of a Reconfigurable Corrective Control System Subject to Permanent Faults in the Controller**
  Authors: Jung-Min Yang ; Seong Woo Kwak
  Abstract: This article presents a reconfiguration strategy for the corrective controller achieving model matching control of an input/state asynchronous sequential machine (ASM). The considered controller is vulnerable to permanent faults that degenerate a subset of the controller's states. If the controller has a certain amount of redundancy in terms of its states, one can build a reconfiguration scheme in which the functionality of degenerated states is taken over by supplementary states. The proposed reconfiguration scheme is superior to conventional methods of fault tolerance with hardware redundancy since the required number of redundant states is much smaller. Hardware experiments on field-programmable gate array (FPGA) circuits are provided to validate the applicability of the proposed scheme. The present study serves as the first research report on the reconfigurable corrective controller.

- **Strong Non-Zeno Mixed Adaptive Dynamic Event-Triggered Control for Distributed Consensus**
  Authors: Shuo Yuan ; Chengpu Yu ; Jian Sun
  Abstract: This article studies the distributed adaptive event-triggered consensus control problem of linear multiagent systems. A strong non-Zeno mixed adaptive dynamic event-triggering scheme is proposed, which guarantees a strictly positive minimum interevent time (MIET) between any two consecutive events. A model-based event-triggered fully distributed adaptive control law is presented without using prior global information about the communication topology. Moreover, a hybrid system model is constructed to facilitate the stability analysis of the closed-loop system. It is shown that the proposed control strategy can achieve asymptotic consensus of all agents via intermittent communication in a fully distributed way, while guaranteeing the strictly positive MIET property. Finally, the effectiveness of the designed control method is illustrated by a simulation example.

Back to the contents

2 Conferences

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

2.1 **2024 IEEE Conference on Control Technology and Applications (CCTA)**
Newcastle upon Tyne, UK, August 21-24, 2024.
https://ccta2024.ieeecss.org/

2.2 **2024 International Conference on Automation Science and Engineering (CASE)**
Bari, Italy, August 28-September 1, 2024.
https://2024.ieeecase.org/

2.3 **2024 International Conference on Systems, Man, and Cybernetics (SMC)**
Sarawak, Malaysia, October 7-10, 2024.
https://www.ieeesmc2024.org/

2.4 **2024 IEEE Conference on Decision and Control (CDC)**
Milan, Italy, December 16-19, 2024.
https://cdc2024.ieeecss.org/

2.5 **2025 IEEE International Conference on Robotics and Automation (ICRA)**
Atlanta, USA, May 19-23, 2025.
https://2025.ieee-icra.org/

2.6 **2025 European Control Conference (ECC)**
Thessaloniki, Greece, June 24-27, 2025.
https://ecc25.euca-ecc.org/

2.7 **2025 American Control Conference (ACC)**
Denver, Colorado, USA, July 8-10, 2025.
https://acc2025.a2c2.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 4.0 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 June 2024, ESCET version 4.0 has been released and can be downloaded from https://www.eclipse.dev/escet/download.html. he main changes in this version are

- Several improvements to model annotations, including a new annotation 'controller:properties'. Furthermore, annotations can be added to wider range of elements of the CIF language.
- The CIF controller properties checker now has an additional check, the bounded response check. The bounded response check improves upon the finite response check by checking for finite response also for uncontrollable events, not just for controllable events. Additionally, for both controllable and uncontrollable events, the new check also computes the bounds on the number of transitions that can be executed. Furthermore, the new check does not suffer from false negatives. The bounded response check is now recommended instead of the finite response check.
- The CIF controller properties checker now has an additional check, the non-blocking under control check, that should hold for all supervisor models before controller code is generated from them.
- Several improvements to the (still experimental) new CIF PLC code generator have been included.
- The CIF data-based synthesis tool has improved performance by using compounded operations for applying edges, using partial transition relations, and taking runtime errors into account once before the main synthesis fixed point computations, rather than repeatedly during synthesis. On average it is about 3.4 times faster, and it also uses less memory. However, the gain depends on the model being synthesized.

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.

Back to the contents