IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter May 2022

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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: 67, Issue: 5, May 2022

- **Local Mean Payoff Supervisory Control for Discrete Event Systems**
  Authors: Yiding Ji ; Xiang Yin ; Stephane Lafortune
  Abstract: This article investigates quantitative supervisory control with local mean payoff objectives on discrete event systems modeled as weighted automata. Weight flows are generated as new events occur, which are required to satisfy some quantitative conditions. We focus on mean weights (payoffs) over a finite number of events, which serve as a measure for the stability or robustness of weight flows. The range of events to evaluate the mean payoff is termed a window, which slides as new events occur. Qualitative requirements such as safety and liveness are also necessary along with quantitative requirements. Supervisory control is employed to manipulate the operation of the system so that the requirements are satisfied. We consider two different scenarios based on whether the window size is fixed or not. Correspondingly, we formulate two supervisory control problems, both of which are solved sequentially by first tackling the qualitative issues and then the quantitative ones. The automaton model is then transformed to a two-player game between the supervisor and the environment, where safety and liveness are enforced. Based on the intermediate results, several quantitative objectives are defined to formulate two games, which correspond to the two proposed supervisory control problems. Finally, we synthesize provably correct supervisors by solving the games and completely resolve both problems.
- **Online Supervisory Control of Networked Discrete Event Systems With Control Delays**
  Authors: Zhaocong Liu ; Xiang Yin ; Shaolong Shu ; Feng Lin ; Shaoyuan Li
  Abstract: We investigate state estimation and safe controller synthesis for networked discrete-event systems (DESs), where supervisors send control decisions to plants via communication channels subject to communication delays. Previous works on state estimation of networked DES are based on the open-loop system without utilizing the knowledge of the control policy. In this article, we propose a new approach for online estimation and control of networked DES with control delays. We first propose a new state estimation algorithm for the closed-loop system utilizing the information of control decision history. The proposed state estimation algorithm can be implemented recursively upon the occurrence of each new observable event. Then we investigate how to predict the effect of control delays in order to calculate a control decision online at each instant. We show that the proposed online supervisor can be updated effectively and the resulting closed-loop behavior is safe. Furthermore, we compare the proposed online supervisor with the predictive supervisor proposed in the literature and show that our proposed online supervisor is more permissive than predictive supervisor in the sense of language inclusion.

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1.2. Automatica

Volume: 139, May 2022

- **Formal synthesis of closed-form sampled-data controllers for nonlinear continuous-time systems under STL specifications**
  Authors: Cees Ferdinand Verdier ; Niklas Kochdumper ; Matthias Althoff ; Manuel Mazo Jr.
  Abstract: We propose a counterexample-guided inductive synthesis framework for the formal synthesis of closed-form sampled-data controllers for nonlinear systems to meet STL specifications over finite-time trajectories. Rather than stating the STL specification for a single initial condition, we consider an (infinite and bounded) set of initial conditions. Candidate solutions are proposed using genetic programming, which evolves controllers based on a finite number of simulations. Subsequently, the best candidate is verified using reachability analysis; if the candidate solution does not satisfy the specification, an initial condition violating the specification is extracted as a counterexample. Based on this counterexample, candidate solutions are refined until eventually a solution

is found (or a user-specified number of iterations is met). The resulting sampled-data controller is expressed as a closed-form expression, enabling both interpretability and the implementation in embedded hardware with limited memory and computation power. The effectiveness of our approach is demonstrated for multiple systems.

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1.3. Systems & Control Letters

Volume: 163, May 2022

- **Minimal observability of Boolean control networks**
  Authors: Yang Liu ; Lina Wang ; Yujing Yang ; Zheng-Guang Wu
  Abstract: In this paper, the minimum observability of Boolean control networks (BCNs) is investigated. An augmented system is proposed to analyze the dynamical trajectories of state pairs, followed by an effective criterion for observability of BCNs utilizing graphic tools. A minimal observability problem is formulated based on the fact that observability of the underlying network is facilitated by injecting new measurements. By introducing an indicator matrix, the solution of added measurements in vector form can be converted into dealing with the equations, by which, all the feasible measurements can be derived. Furthermore, the solution of the least added measurements can be solved by a minimum set covering problem. Meanwhile, two examples are given to illustrate the theoretical results.

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1.4. Nonlinear Analysis: Hybrid Systems

Volume: 44, May 2022

- **Robust decentralized diagnosability of networked discrete event systems against DoS and deception attacks**
  Authors: Marcos V.S. Alves ; Raphael J. Barcelos ; Lilian K. Carvalho ; Joao C. Basilio
  Abstract: Denial-of-Service (DoS) are attacks conducted by malicious agents that consists in disrupting, temporally or indefinitely, the services provided by a communication network. When a malicious agent gets access to some network node, it may also perform deception attacks by inserting valid packets with fake information into vulnerable channels. We address, in this paper, DoS and deception attacks (DoS-D attack) that flood some communication channels with fake packets causing delays, loss of observations and insertion of fake observations, and their implications in decentralized fault diagnosability of networked discrete event systems (NDES). To this end, we propose an automaton model for NDES subject to DoS-D attacks that represents the adverse effects of DoS-D attacks on the observations of local diagnosers. We introduce a new codiagnosability definition called DoS-D-robust codiagnosability, and present a necessary and sufficient condition for a language to be DoS-D-robustly codiagnosable. We also propose a verification algorithm for regular languages to check DoS-D-robust codiagnosability.
- **An optimization-based approach to assess non-interference in labeled and bounded Petri net systems**
  Authors: Francesco Basile ; Maurizio Boccia ; Gianmaria De Tommasi ; Carlo Motta ; Claudio Sterle
  Abstract: An optimization-based approach to assess both strong non-deterministic non- interference (SNNI) and bisimulation SNNI (BSNNI) in discrete event systems modeled as labeled Petri nets is presented in this paper. The assessment of SNNI requires the solution of feasibility problems with integer variables and linear constraints, which is derived by extending a previous result given in the case of unlabeled net systems. Moreover, the BSNNI case can be addressed in two different ways. First, similarly to the case of SNNI, a condition to assess BSNNI, which is necessary and sufficient, can be derived from the one given in the unlabeled framework, requiring the solution of feasibility problems with integer variables and linear constraints. Then, a novel necessary and sufficient condition to assess BSNNI is given, which requires the solution of integer feasibility problems with nonlinear constraints. Furthermore, we show how to recast these problems into equivalent

mixed-integer linear programming (MILP) ones. The effectiveness of the proposed approaches is shown by means of several examples. It turns out that there are relevant cases where the new condition to assess BSNNI that requires the solution of MILP problems is computationally more efficient, when compared to the one that requires the solution of feasibility problems.

- **Compositional construction of abstractions for infinite networks of discrete-time switched systems**
  Authors: Maryam Sharifi ; Abdalla Swikir ; Navid Noroozi ; Majid Zamani
  Abstract: In this paper, we develop a compositional scheme for the construction of continuous abstractions for networks of infinitely many discrete-time switched systems. In particular, the constructed abstractions are themselves also continuous-space systems with potentially lower dimensions, which can be used as replacements of the original (also known as concrete) systems in the controller design process. Having designed a controller for the abstract system, it is refined to a more detailed one for the concrete system. We use the notion of so-called simulation functions to quantify the mismatch between the original system and its approximation. Each subsystem in the concrete network and its corresponding one in the abstract network are related through a notion of local simulation functions. We show that if the local simulation functions satisfy a spectral small-gain condition, then the aggregation of the individual simulation functions provides an overall simulation function quantifying the error between the overall abstract network and the concrete one. In addition, we show that our methodology results in a scale-free compositional approach for any finite-but-arbitrarily large networks obtained from truncation of an infinite network. We provide a systematic approach to construct local abstractions and simulation functions for networks of linear switched systems. In this case, the conditions are expressed in terms of linear matrix inequalities that can be efficiently computed. We illustrate the effectiveness of our approach through an application to AC islanded microgrids.

- **Robustly complete synthesis of sampled-data control for continuous-time nonlinear systems with reach-and-stay objectives**
  Authors: Yinan Li ; Jun Liu
  Abstract: Formal methods are becoming favorable for control and verification of safety-critical systems because of the rigorous model-based computation. Relying on an over-approximated model of the original system behaviors, formal control synthesis algorithms are not often complete, which means that a controller cannot necessarily be synthesized even if there exists one. The main result of this paper shows that, for continuous-time nonlinear systems, a sample-and-hold control strategy for a reach-and-stay specification can be synthesized whenever such a strategy exists for the same system with its dynamics perturbed by small disturbances. Control synthesis is carried out by a fixed-point algorithm that adaptively partitions the system state space into a finite number of cells. In each iteration, the reachable set from each cell after one sampling time is over-approximated within a precision determined by the bound of the disturbances. To meet such a requirement, we integrate validated high-order Taylor expansion of the system solution over one sampling period into every fixed-point iteration and provide a criterion for choosing the Taylor order and the partition precision. Two nonlinear system examples are given to illustrate the effectiveness of the proposed method.

- **Synchronization of drive-response singular Boolean networks**
  Authors: Rong Zhao ; Biao Wang ; Jun-e Feng
  Abstract: Network synchronization, explicating typical collective behaviors of coupled systems, plays a crucial role in social production and life. This paper addresses the synchronization problem of driveresponse singular Boolean networks (SBNs). The solvability of driveresponse SBNs is investigated based on the matrix representation. In view of the existence and uniqueness of the solutions to driveresponse SBNs, three types of concepts, synchronization, strong synchronization and weak synchronization, are put forward for the first time. By two new systems, a restricted BN and a switched restricted BN, which are constructed from the considered systems, several synchronization conditions are provided to deal with the circumstances of unique solutions and multiple solutions, respectively. Besides, the synchronous ratio is defined to characterize the synchronization capability of driveresponse SBNs for the case of multiple solutions. Finally, several examples are

given to illustrate the effectiveness of the obtained results.

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1.5. IEEE Transactions on Cybernetics

Volume: 52, Issue: 4, May 2021

- **Intelligent Knowledge Distribution: Constrained-Action POMDPs for Resource-Aware Multiagent Communication**
  Authors: Michael C. Fowler ; T. Charles Clancy ; Ryan K. Williams
  Abstract: This article addresses a fundamental question of multiagent knowledge distribution: what information should be sent to whom and when with the limited resources available to each agent? Communication requirements for multiagent systems can be rather high when an accurate picture of the environment and the state of other agents must be maintained. To reduce the impact of multiagent coordination on networked systems, for example, power and bandwidth, this article introduces two concepts for the partially observable Markov decision processes (POMDPs): 1) action-based constraints that yield constrained-action POMDPs (CA-POMDPs) and 2) soft probabilistic constraint satisfaction for the resulting infinite-horizon controllers. To enable constraint analysis over an infinite horizon, an unconstrained policy is first represented as a finite-state controller (FSC) and optimized with policy iteration. The FSC representation then allows for a combination of the Markov chain Monte Carlo and discrete optimization to improve the probabilistic constraint satisfaction of the controller while minimizing the impact on the value function. Within the CA-POMDP framework, we then propose intelligent knowledge distribution (IKD) which yields per-agent policies for distributing knowledge between agents subject to interaction constraints. Finally, the CA-POMDP and IKD concepts are validated using an asset tracking problem where multiple unmanned aerial vehicles (UAVs) with heterogeneous sensors collaborate to localize a ground asset to assist in avoiding unseen obstacles in a disaster area. The IKD model was able to maintain asset tracking through multiagent communications while only violating soft power and bandwidth constraints 3% of the time, while greedy and naive approaches violated constraints more than 60

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1.6. IEEE Transactions on Systems, Man, and Cybernetics: Systems

Volume: 52, Issue: 5, May 2022

- **Critical Observability of Discrete-Event Systems in a Petri Net Framework**
  Authors: Xuya Cong ; Maria Pia Fanti ; Agostino Marcello Mangini ; Zhiwu Li
  Abstract: This article focuses on the issue of checking critical observability for labeled Petri nets. Critical observability is a property related to the safety concern of cyber-physical systems. With the aim of checking this property of a net system, it is required to detect whether a set of markings consistent with any observed word of the net system is a subset of a set of critical states representing undesirable operations or a set of noncritical states. In this work, we prove a necessary and sufficient condition to check critical observability when the critical state set is described by an arbitrary subset of reachable markings. Then, the result is extended to the case when a critical state set is modeled by all the reachable markings that satisfy disjunctions of generalized mutual exclusion constraints. The proposed method is derived from the solutions of integer linear programming problems and is applicable to net systems with liveness and boundness. Several case studies show the performance of the presented methodology for discrete-event systems.
- **Adaptive Deadlock Control for a Class of Petri Nets With Unreliable Resources**
  Authors: Ziliang Zhang ; Gaiyun Liu ; Kamel Barkaoui ; Zhiwu Li
  Abstract: In an automated manufacturing system (AMS), resources are, in general, subject to unpredictable failures, which invalidate many existing deadlock control strategies. In this article, we propose an adaptive deadlock control policy for an AMS with multiple types of unreliable resources. The considered AMS is modeled with a system of simple sequential processes with resources. First, based on an elementary siphon control method, monitors are added for elementary siphons and some particular dependent siphons to ensure the liveness of a system if there are no resource failures. By

considering the fact that an unreliable resource may fail in a system, recovery subnets are added to describe the resource failures and recoveries. Since a monitor added for a siphon may not be able to guarantee that the corresponding siphon is always marked if the failure of a resource in the siphon occurs, the concept of switch controllers is presented so as to make the siphon always remarked if it is emptied by resource failures. It is verified that the adaptive controller proposed in this article can guarantee the liveness of the controlled system no matter whether unreliable resources break down or not. More importantly, if there is no resource failure, the system can maintain predefined production without degrading planned system performance. Finally, examples are presented to illustrate the validity of the proposed method.

2 Conferences

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

2.1 **2022 ACM International Conference on Hybrid Systems: Computation and Control (HSCC)**
Milan, Italy, May 4-6, 2022
https://hscc.acm.org/2022/

2.2 **2022 IEEE Conference on Robotics and Automation (ICRA)**
Philadelphia, USA, May 23-27, 2022
https://www.icra2022.org/

2.3 **2022 American Control Conference (ACC)**
Atlanta, Georgia, USA, June 8-10, 2022
https://acc2022.a2c2.org/

2.4 **2022 IEEE Conference on Control Technology and Applications (CCTA)**
Stazione Marittima, Trieste, Italy, August 23-25, 2022
https://acc2022.a2c2.org/

2.5 **2022 IEEE International Conference on Automation Science and Engineering (CASE)**
Mexico City, Mexico, August 20-24, 2022
http://www.case2022.org/

2.6 **2022 International Workshop on Discrete Event Systems (WODES)**
Prague, Czechia, September 7-9, 2022
https://wodes2022.math.cas.cz

2.7 **2022 IEEE International Conference on Systems, Man, and Cybernetics (SMC)**
Prague, Czech Republic, October 9-12, 2022
https://ieeesmc2022.org/

2.8 **2022 IEEE Conference on Decision and Control (CDC)**
Cancun, Mexico, December 6-9, 2022
https://cdc2022.ieeecss.org/

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3 Books

3.1 Analysis and Control for Resilience of Discrete Event Systems

Authors: Joao Carlos Basilio, Christoforos N. Hadjicostis and Rong Su

Description: System resilience captures the ability of the system to withstand a major disruption within acceptable performance degradation and to recover within an acceptable time frame. In this monograph we consider two possible sources of major disruptions, i.e., component faults and cyber intrusions. A component fault is an indigenous activity that renders unavailability or inaccessibility of certain functions within a component, either permanently or temporarily. It typically generates safety and performance concerns. Cyber intrusion on the other hand is an exogenous activity that tampers privacy, confidentiality, availability, or integrity of the system. These two sources are not always independent from each other. For example, a cyber intrusion may trigger a component fault, whereas a component fault may open a door for cyber intrusion, e.g., by keeping it undetected. For cyber intrusion, we will focus on opacity, which describes the systems ability to hide certain secrets from an external observer (or eavesdropper), and sensor and actuator attacks that exploit the systems existing controller to generate undesirable behaviours.

In this monograph, we provide a detailed account of most recent research outcomes on fault diagnosis, opacity analysis and enhancement, and cyber security analysis and enforcement, within suitable discrete event system modelling frameworks. In each case, we describe basic problem statements and key concepts, and then point out the key challenges in each research area. After that, we present a thorough review of state-of-the-art techniques, and discuss their advantages and disadvantages. Finally, we highlight key research directions for further exploration.

ISBN: 978-1-68083-856-5
https://www.nowpublishers.com/article/Details/SYS-024

3.2 Introduction to Discrete Event Systems

Authors: Christos Cassandras and Stéphane Lafortune

Description: Christos Cassandras and Stéphane Lafortune are happy to announce the publication of the third edition of their textbook, Introduction to Discrete Event Systems, by Springer in November 2021. The first two editions of this popular textbook were published in 1999 (Kluwer Academic Publishers) and 2008 (Springer), respectively. This unique textbook comprehensively introduces the field of discrete event systems, offering a breadth of coverage that makes the material accessible to readers of varied backgrounds. The book emphasizes a unified modeling framework that transcends specific application areas, linking the following topics in a coherent manner: language and automata theory, supervisory control, Petri net theory, Markov chains and queueing theory, discrete-event simulation, and perturbation analysis and concurrent estimation techniques. The third edition is a superset of the second one, with new material added based on our teaching of discrete event systems courses at Boston University and at the University of Michigan, and they reflect active research trends in discrete event systems since the publication of the second edition.

Topics and features:
- detailed treatment of automata and language theory in the context of discrete event systems, including application to state estimation and diagnosis
- comprehensive coverage of centralized and decentralized supervisory control
- timed models, including timed automata and hybrid automata - stochastic models for discrete event systems and controlled Markov chains
- discrete event simulation - an introduction to stochastic hybrid systems
- sensitivity analysis and optimization of discrete event and hybrid systems
- new in the third edition: opacity properties, enhanced coverage of event diagnosis and of supervisory control under partial observation, overview of latest software tools, updated treatment of Infinitesimal Perturbation Analysis and of concurrent estimation

This proven textbook is essential to students and researchers in a variety of disciplines where the study of discrete event systems is relevant: control, communications, computer engineering, computer science, manufacturing engineering, transportation networks, operations research, and industrial engineering. This book is available through SpringerLink as an e-book (PDF and EPUB formats) or as a print-on-demand hard cover at https://link.springer.com/book/10.1007/978-3-030-72274-6 The e-book is available for free download at Springer subscribing institutions.

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3.3 Hybrid Dynamical Systems – Fundamentals and Methods

Authors: Hai Lin and Panos Antsaklis

Description: This book is based on courses on hybrid systems, cyber-physical systems, and formal methods taught by the authors in the past years. It is a graduate level textbook and provides an accessible and comprehensive introduction to the theory of hybrid systems with a balanced treatment on fundamentals and methods from both control theory and computer science. It also serves as a reference book for researchers in the fields of hybrid dynamical systems, cyber-physical systems, formal methods and robotics.

More information may be found at the books Springer webpage:

https://link.springer.com/book/10.1007/978-3-030-78731-8

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4 Software Tools

4.1 IDES: An Open-Source Software Tool

IDES, the discrete-event systems software tool in Karen Rudie's lab is now available as open-source software at https://github.com/krudie/IDES. More information on IDES can also be found at https://www.ece.queensu.ca/people/K-Rudie/qdes.html#fndtn-software.

4.2 Supremica 2.7, New Version

The development team has just released a new version of Supremica, Waters/Supremica IDE 2.7.

Supremica is a DES and SCT drawing and calculation tool, that includes a multitude of efficient algorithms for modeling, verification, and synthesis of maximally permissive supervisors. In addition there are general algorithms for standard operations like synchronization, minimization, determinization, etc. Supremica also handles finite automata extended with bounded discrete variables. A feature-full simulation tool is also included.

New in this version:

- Conditional blocks or IF statements can now be created in the components list or on label blocks to allow conditional compilation of automata or events. They can also be used as an alternative to guard/action blocks.
- Update to Log4j 2.17.1 to avoid the Log4shell vulnerability.

Supremica is free to use for education and research; for commercial use, please contact fabian@chalmers.se. Download from www.supremica.org.

4.3 UltraDES 2.2 Release

UltraDES is an open-source library to the modeling, analysis and control of DES, written using C# in .NET Standard 2.0, which allows its use in multiple platforms, such as Windows, Linux, Mac, IOS, Android, so on. The library is under development at LACSED (Laboratory of Analysis and Control of Discrete Event Systems, at the Universidade Federal de Minas Gerais, Brazil) and has basic operations with automata as long as the monolithic, modular and local modular supervisory control (Alves et. al., 2017).

The main improvements of the UltraDES 2.2 version are:

- Supervisor Reduction Algorithm (Su and Wonham, 2004)
- Supervisor Localization (Cai and Wonham, 2010)
- Basic Petri Nets Functions (incidence matrix, coverability/reachability graph, Petri Net marking simulation, etc.)

Knowing that many researchers/students are not familiar with the C# language, we created an experimental python wrapper, that is less object oriented and easier to use.

Another initiative to improve the usability of UltraDES was the creation of a Web Application, developed using Blazor/WebAssembly, that allows the use of UltraDES online. This version is more limited in processing power and memory but it is useful for small examples and teaching.

We invite the community to download and contribute. Algorithms implemented may be integrated to the main distribution. Just let us know. Contact Lucas Alves lucasvra@ufmg.br or Patricia Pena ppena@ufmg.br for more information. Bugs should be informed using the UltraDES GitHub page.
Link: https://github.com/lacsed/UltraDES.

4.4 DESpot 1.10.0 Released

DESpot is a discrete-event system (DES) software, research tool. It supports both flat projects (collection of plant and supervisor DES), and Hierarchical Interface-Based Supervisory Control (HISC) projects.

DESpot 1.10.0 supports a number of new Features:

- DESpot now targets version 4.8.7 of the Qt libraries, RedHat Enterprise Linux 7.x, and MS Windows 10 with MS Visual Studios 2019.
- Support for defining template DES, and then instantiating multiple copies for flat or HISC projects.
- Now includes curved transition arrows for DES diagrams, and the ability to export DES diagrams to EPS.
- Support for verification of timed controllability, including BDD-based algorithms.
- Support for Fault-Tolerant (FT) Supervisory Control, including both timed and untimed controllability and nonblocking BDD-based algorithms, for several fault scenarios.
- Support for specifying decentralized supervisory control structure for a project, and verifying co-observability.

To find out more information and to download a copy, see: http://www.cas.mcmaster.ca/~leduc/DESpot.html

DESpot is open source software, released under the GNU General Public license (GPL), version 2.

DESpot is written in C++ and uses the QT GUI libraries. At the moment, DESpot is available as source code and as a Windows' installer. It runs under Linux, and Windows.

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