IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **September 2022**

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Welcome to the 2022 September issue of the newsletter, also available online at
http://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.

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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: 9, September 2022

- **From Dissipativity Theory to Compositional Synthesis of Large-Scale Stochastic Switched Systems**
  Authors: Abolfazl Lavaei ; Majid Zamani
  Abstract: This work is concerned with a compositional technique for the construction of finite abstractions (a.k.a., finite Markov decision processes (MDPs)) for networks of discrete-time stochastic switched systems. We propose a framework based on a notion of stochastic simulation functions, using which one can quantify the probabilistic distance between original interconnected stochastic switched systems and their finite MDPs by leveraging dissipativity-type compositional conditions. We show that the proposed compositionality conditions can enjoy the structure of the interconnection topology and be potentially fulfilled independently of the number or gains of subsystems. We also propose an approach to construct finite MDPs together with their corresponding stochastic simulation functions for nonlinear stochastic switched systems satisfying some incremental passivity property. We show that for a particular class of nonlinear stochastic switched systems whose nonlinearities satisfy an incremental quadratic inequality, the aforementioned property can be readily checked by some linear matrix inequalities. To demonstrate the effectiveness of the proposed results, we apply our approaches to the following two different case studies: a road traffic network, and a fully interconnected network of nonlinear switched systems accepting different dissipativity properties.

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1.2. Automatica

Volume: 143, September 2022

- **Functional sets with typed symbols: Mixed zonotopes and Polynotopes for hybrid nonlinear reachability and filtering**
  Authors: Christophe Combastel
  Abstract: Verification and synthesis of CyberPhysical Systems (CPS) are challenging and still raise numerous issues so far. In this paper, based on a new concept of mixed sets defined as function images of symbol type domains, a compositional approach combining eager and lazy evaluations is proposed. Syntax and semantics are explicitly distinguished. Both continuous (interval) and discrete (signed, boolean) symbol types are used to model dependencies through linear and polynomial functions, so leading to mixed zonotopic and polynotopic sets. Polynotopes extend sparse polynomial zonotopes with typed symbols. Polynotopes can both propagate a mixed encoding of intervals and describe the behavior of logic gates. A functional completeness result is given, as well as an inclusion method for elementary nonlinear and switching functions. A Polynotopic Kalman Filter (PKF) is then proposed as a hybrid nonlinear extension of Zonotopic Kalman Filters (ZKF). Bridges with a stochastic uncertainty paradigm are briefly outlined. Finally, several discrete, continuous and hybrid numerical examples including comparisons illustrate the effectiveness of the theoretical results.

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1.3. IEEE Transactions on Cybernetics

Volume: 52, Issue: 9, September 2022

- **Parameterized MDPs and Reinforcement Learning ProblemsA Maximum Entropy Principle-Based Framework**
  Authors: Amber Srivastava ; Srinivasa M. Salapaka
  Abstract: We present a framework to address a class of sequential decision-making problems. Our framework features learning the optimal control policy with robustness to noisy data, determining

the unknown state and action parameters, and performing sensitivity analysis with respect to problem parameters. We consider two broad categories of sequential decision-making problems modeled as infinite horizon Markov decision processes (MDPs) with (and without) an absorbing state. The central idea underlying our framework is to quantify exploration in terms of the Shannon entropy of the trajectories under the MDP and determine the stochastic policy that maximizes it while guaranteeing a low value of the expected cost along a trajectory. This resulting policy enhances the quality of exploration early on in the learning process, and consequently allows faster convergence rates and robust solutions even in the presence of noisy data as demonstrated in our comparisons to popular algorithms, such as Q-learning, Double Q-learning, and entropy regularized Soft Q-learning. The framework extends to the class of parameterized MDP and RL problems, where states and actions are parameter dependent, and the objective is to determine the optimal parameters along with the corresponding optimal policy. Here, the associated cost function can possibly be nonconvex with multiple poor local minima. Simulation results applied to a 5G small cell network problem demonstrate the successful determination of communication routes and the small cell locations. We also obtain sensitivity measures to problem parameters and robustness to noisy environment data.

- **Self-Triggered Scheduling for Boolean Control Networks**
  Authors: Min Meng ; Gaoxi Xiao ; Daizhan Cheng
  Abstract: It has been shown that self-triggered control has the ability to deal with cases with constrained resources by properly setting up the rules for updating the system control when necessary. In this article, self-triggered stabilization of the Boolean control networks (BCNs), including the deterministic BCNs, probabilistic BCNs, and Markovian switching BCNs, is first investigated via the semitensor product of matrices and the Lyapunov theory of the Boolean networks. The self-triggered mechanism with the aim to determine when the controller should be updated is provided by the decrease of the corresponding Lyapunov functions between two consecutive samplings. Rigorous theoretical analysis is presented to prove that the designed self-triggered control strategy for BCNs is well defined and can make the controlled BCNs be stabilized at the equilibrium point.

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

Volume: 52, Issue: 9, September 2022

- **An Algorithm for Mining Indirect Dependencies From Loop-Choice-Driven Loop Structure via Petri Nets**
  Authors: Hongwei Sun ; Wei Liu ; Liang Qi ; Xiaojun Ren ; Yuyue Du
  Abstract: Process mining is an emerging technology used to extract, detect, and improve actual processes by extracting knowledge from event logs generated from information systems. In the production process, we can obtain the optimal process based on practical experience. Indirect dependencies may exist among different structures in the optimal process model discovered from the event log of the executions that perform better. However, the existing process mining algorithms cannot effectively mine the indirect dependencies among different structures. To compensate for this deficiency, an algorithm named AlphaID is proposed in this article, and it can mine the indirect dependencies in a loop-choice-driven loop structure. First, two algorithms are proposed to efficiently identify loop sequences and choice sequences from event logs. Then, the concept of association rules is proposed to describe indirect dependencies among different structures. Next, we expand the ordinary Petri net and redefine the new transition firing rules to represent the process model obtained by AlphaID . Finally, the correctness and effectiveness of the algorithm are verified by an artificial case and a real case. AlphaID is integrated into the ProM which is an open-source process mining tool platform as a plug-in.

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2 Conferences

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

2.1 **2022 IEEE International Conference on Systems, Man, and Cybernetics (SMC)**
Prague, Czech Republic, October 9-12, 2022
https://ieeesmc2022.org/

2.2 **2022 IEEE Conference on Decision and Control (CDC)**
Cancun, Mexico, December 6-9, 2022
https://cdc2022.ieeecss.org/

2.3 **2023 ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS)**
San Antonio, USA, May 9-12 2023
https://iccps.acm.org/2023/

2.4 **2023 American Control Conference (ACC)**
San Diego, USA, May 31 - June 2, 2023
https://acc2023.a2c2.org/

2.5 **2023 IFAC World Congress (IFAC)**
Yokohama, Japan, July 9-14, 2023
https://www.ifac2023.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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https://doi.org/10.1007/978-3-030-72274-6

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 Call for Papers & Participation

4.1 CFP: IFAC 2023 Invited Session on "DES Tools and Application"

At next year's IFAC 2023, Rômulo Meira Go, João Carlos Basilio, Kai Cai, and Michel Reniers are going to organize an invited session on "DES tools and applications". If you have relevant results that fit the timeline of IFAC'23, please do consider contributing to this invited session. We consider discrete-event systems broadly and it may include timing and probabilistic aspects.

The submission deadline for Invited Session proposals is mid-Oct 2022 and paper submission end-Oct. So if you would like to join us in this invited session, please let us know so by the end of Sep 2022 (m.a.reniers@tue.nl). We will need a tentative title, author list, and abstract. Note that there are different types of submission (https://www.ifac2023.org/submission/cfp/) .

4.2 CDC 2022 Workshop on "Control Software Synthesis for Cyber-Physical Systems – On Harvesting Structural and Information-Flow Properties"

At this year's CDC, Kai Cai, Anne-Kathrin Schmuck and Xiang Yin organize a workshop on "Control Software Synthesis for Cyber-Physical Systems". Please consider registering and encouraging your students to register for this workshop if you attend CDC'22. The information of the workshop can be found below. Interested colleagues are encouraged to register now.

Workshop Website: https://wp.mpi-sws.org/cdc22-workshop

Organizers: Kai Cai, Anne-Kathrin Schmuck, Xiang Yin

Abstract: Engineering systems that involve physical elements controlled by computational infrastructure are called Cyber-Physical Systems (CPS). CPS are present in almost every modern automated system, ranging from manufacturing and transportation systems over telecommunication networks to large-scale computer clusters. The ever-increasing demand for safety, security, performance, and certification of these often safety-critical CPS put stringent constraints on their design. This necessitates the use of formal, model-based approaches to analyze and design secure, reliable and performant systems.

In the past decades, formal, model-based approaches to control software synthesis for CPS have gained more and more attention both in the Control Engineering and in the Computer Science Community. While these approaches are applicable to the entire control stack, this workshop focuses mostly on the top layer of the control hierarchy. Here, supervisory control and coordination software orchestrates the interplay of different system components and needs to ensure their safe and reliable behavior.

This workshop will bring researches from control and computer science together to discus recent results and open problems in this research area. In particular, this workshop will focus on two specific recent topics in the verification and synthesis of CPS.

Topic A: Structural Properties in Controller Synthesis
Scalability is one of the major challenges when applying formal methodologies to large-scale CPS due to the extremely large state-space. One way to address the inherent difficulty in analyzing or controlling complex, large-scale, interconnected systems, is to apply a divide and conquer strategy, namely, compositional approaches. Such approaches, in general, leverage the structural properties of CPS by taking well-defined sub-system interactions into account. In addition, a high degree of decentralization is only achieved if control software is permissiveness - i.e., allows for local adaptations and specializations, especially when humans are in the feedback loop. In past years, many structural properties such as compositionality and permissiveness have been investigated extensively by different researchers from different angles. This workshop aims to gather recently developed novel approaches for synthesis of CPS leveraging structural properties.

Topic B: Information-Flow Properties in Dynamic Systems
In correct-by-construction synthesis of safety-critical CPS, existing works mainly focus on the correctness of the internal behavior of the system. However, in many practical scenarios, CPS are usually partially-observed either from the system-users point of view due to the limited sensing capabilities, or from the outsiders point of view due to the partial information release. In this case, the design objective can

also be related to the information-flow of the dynamic systems. In the control community, researchers have investigated many different notions of information-flow properties such as diagnosability, observability, detectability and opacity. Recently, a new temporal logic in the computer science literature called HyperLTL has been studied very actively, which has been shown as a very suitable tool for expressing information-flow properties. This workshop also aims to discuss the recent developments in correct-by-construction synthesis of CPS for information-flow properties, which is the key in ensuring security for CPS.

5 Software Tools

5.1 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.

5.2 Eclipse ESCET™ version 0.6 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 toolkits website at https://www.eclipse.org/escet/.

In July 2022, ESCET version 0.6 has been released and can be downloaded from https://www.eclipse.org/escet/download.html. The main changes in this version are

- A new Design Structure Matrix (DSM) clustering tool is added.
- In CIF invariants can be given a name. This can improve traceability with external requirement management systems.
- A CIF benchmark models import wizard is added, including several benchmarking models, similar to the CIF examples import wizard.
- The CIF data-based synthesis tool now warns about input models where plants refer to requirement state. The new functionality is enabled by default, but can be disabled using an option.
- The CIF data-based synthesis tool features the DCSH (DSM-based Cuthill-McKee-Sloan variable ordering Heuristic) algorithm as a new additional variable ordering algorithm. It is considered experimental for now, and therefore disabled by default, but can be enabled using an option.

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.

5.3 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.

5.4 MDESops

MDESops is an open-source tool written in Python for analysis and control of discrete event systems modeled as finite-state automata. It includes a growing set of operations on automata, including: (i) manipulation of models (e.g., parallel composition, observer); (ii) diagnosis and opacity verification; (iii) common supervisory control functions (e.g., computation of supremal controllable and normal sublanguages); and (iv) more advanced functions on synthesis of attackers and of resilient supervisors in the presence of sensor deception attacks. The repository is a Git server maintained by the EECS Department at the University of Michigan, USA. Download from https://gitlab.eecs.umich.edu/M-DES-tools/desops.

5.5 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.

5.6 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.

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