IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **March 2021**

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Welcome to the 2021 March issue of the newsletter, also available online at
http://discrete-event-systems.ieeecss.org/tc-discrete/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: 66, Issue: 3, March 2021

- **Optimal Minimum Violation Control Synthesis of Cyber-Physical Systems Under Attacks**
  Authors: Luyao Niu ; Jie Fu ; Andrew Clark
  Abstract: Temporal logic provides a rigorous and expressive way to model specifications for cyber-physical systems (CPS). Such systems, which are playing increasingly important roles in various domains, are also subject to malicious attacks initiated by intelligent adversaries. Malicious attacks may prevent the system from satisfying the desired specification. In this article, we introduce a control synthesis method to minimize deviations from the desired specification due to adversaries. We consider the scenario where the adversary has limited capability of observing the controller's strategy. We synthesize a minimum violation control strategy for a finite-state stochastic game under cosafe linear temporal logic constraints. We formulate a mixed-integer nonlinear program for computing the optimal controller strategy and present two algorithms. First, we propose an exact algorithm that computes the optimal control strategy with probability one but without guarantees on the convergence rate. Second, we present an approximate algorithm that computes a suboptimal control strategy. The approximate algorithm converges faster compared to the exact algorithm; however, it only returns an optimal solution when the adversary has full observation over the controller's strategy. A numerical case study is presented to evaluate the proposed framework.

- **Formal Control Synthesis via Simulation Relations and Behavioral Theory for Discrete-Time Descriptor Systems**
  Authors: Sofie Haesaert ; Fei Chen ; Alessandro Abate ; Siep Weiland
  Abstract: The control and verification of industrial processes, modeled as discrete-time descriptor systems, is often computationally hard due to the presence of both algebraic couplings and difference equations. In this article, we introduce a new control synthesis method for descriptor systems which is based on formal abstractions and enables control design over related reduced-order models. We leverage notions of exact and approximate similarity relations, which hold for the algebraic couplings that are inherent to descriptor systems. Using the behavioral framework, we extend a control refinement scheme for classical dynamical systems and develop a corresponding notion for descriptor systems: We show that any given well-posed controller of the abstract (reduced-order) descriptor system can be refined to a controller for the original descriptor system. The resulting controlled system preserves the same controlled output behavior in the case of exact similarity, whereas in the case of approximate similarity, the output behavior of the controlled descriptor system is shown to have a bounded deviation from that of the abstract model where the controller is designed.

- **Strategy Synthesis for POMDPs in Robot Planning via Game-Based Abstractions**
  Authors: Leonore Winterer ; Sebastian Junges ; Ralf Wimmer ; Nils Jansen ; Ufuk Topcu ; Joost-Pieter Katoen ; Bernd Becker
  Abstract: We study synthesis problems with constraints in partially observable Markov decision processes (POMDPs), where the objective is to compute a strategy for an agent that is guaranteed to satisfy certain safety and performance specifications. Verification and strategy synthesis for POMDPs are, however, computationally intractable in general. We alleviate this difficulty by focusing on planning applications and exploiting typical structural properties of such scenarios; for instance, we assume that the agent has the ability to observe its own position inside an environment. We propose an abstraction refinement framework, which turns such a POMDP model into a (fully observable) probabilistic two-player game (PG). For the obtained PGs, efficient verification and synthesis tools allow to determine strategies with optimal safety and performance measures, which approximate optimal schedulers on the POMDP. If the approximation is too coarse to satisfy the given specifications, a refinement scheme improves the computed strategies. As a running example, we use planning problems where an agent moves inside an environment with randomly moving obstacles and restricted observability. We demonstrate that the proposed method advances the state

of the art by solving problems several orders of magnitude larger than those that can be handled by existing POMDP solvers. Furthermore, this method gives guarantees on safety constraints, which is not supported by the majority of the existing solvers.

- **Contract-Based Design of Symbolic Controllers for Safety in Distributed Multiperiodic Sampled-Data Systems**
  Authors: Adnane Saoud ; Antoine Girard ; Laurent Fribourg
  Abstract: This article presents a symbolic control approach to the design of distributed safety controllers for a class of continuous-time nonlinear systems. More precisely, we consider systems made of components where each component is equipped with a sampled-data controller with its own sampling period, resulting globally in a distributed multiperiodic sampled-data system. Moreover, controllers receive partial information on the state of the other components. We propose a component-based approach to controller synthesis, which relies on the use of abstractions and continuous-time assume-guarantee contracts. The abstractions describe the dynamics of the system from the point of view of each component based on the information structure, whereas assume-guarantee contracts specify guarantees that a component must satisfy if assumptions on the other components are met. We show that our approach makes it possible to decompose a global safety control problem into local ones that can be solved independently. We then show how symbolic control techniques can be used to synthesize controllers that enforce the local control objectives. Illustrative applications in building automation and vehicle platooning are shown.

- **Stochastic Approximation for Risk-Aware Markov Decision Processes**
  Authors: Wenjie Huang ; William B. Haskell
  Abstract: We develop a stochastic approximation-type algorithm to solve finite state/action, infinite-horizon, risk-aware Markov decision processes. Our algorithm has two loops. The inner loop computes the risk by solving a stochastic saddle-point problem. The outer loop performs $Q-$ learning to compute an optimal risk-aware policy. Several widely investigated risk measures (e.g., conditional value-at-risk, optimized certainty equivalent, and absolute semideviation) are covered by our algorithm. Almost sure convergence and the convergence rate of the algorithm are established. For an error tolerance $\epsilon > 0$ for optimal Q-value estimation gap and learning rate $k \in (1/2, 1]$, the overall convergence rate of our algorithm is $\Omega((\ln(1/\delta\epsilon)/\epsilon^2)^{1/k} + (\ln(1/\epsilon))^{1/(1-k)})$ with probability at least $1 - \delta$.

- **Verification of Detectability for Unambiguous Weighted Automata**
  Authors: Aiwen Lai ; Sebastien Lahaye ; Alessandro Giua
  Abstract: In this article, we deal with the detectability problem for unambiguous weighted automata (UWAs). The problem is to determine if, after a finite number of observations, the set of possible states is reduced to a singleton. Four types of detectabilities, namely, strong detectability, detectability, strong periodic detectability, and periodic detectability are defined in terms of different requirements for current state estimation. We first construct a deterministic finite state automaton (called observer) over a weighted alphabet and prove that it can be used as the current-state estimator of the studied UWA. Finally, necessary and sufficient conditions based on the observer are proposed to verify detectabilities of a UWA.

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1.2. Automatica

Volume: 125, March 2021

- **Liveness enforcing supervisory policies tolerant to controllability failures for discrete-event systems modeled by Petri Nets**
  Authors: Arun Raman ; Ramavarapu S.Sreenivas
  Abstract: A Discrete Event System (DES) modeled by a Petri Net (PN) is live if it is possible to fire any transition, although not necessarily immediately, from any marking that is reachable from the initial marking. A Liveness Enforcing Supervisory Policy (LESP) for a PN enforces liveness by preventing the firing of a subset of transitions called the controllable transitions, which correspond to the preventable events in a DES. In this paper, we consider the existence and synthesis of LESPs for

arbitrary PNs in the presence of faults, where a subset of controllable transitions become temporarily uncontrollable, for a finite number of event occurrences. Following the formal specification of the fault model, we present a necessary and sufficient condition for the existence of Fault-Tolerant LESPs (FT-LESPs) for arbitrary PNs. We show that, even when an LESP is given, the existence of an FT-LESP for an arbitrary PN is undecidable. We then identify a class of PNs for which the existence of FT-LESPs is decidable. We conclude with some suggestions for future research.

- **On quotients of Boolean control networks**
  Authors: Rui Li ; Qi Zhang ; Tianguang Chu
  Abstract: In this paper, we focus on the study of quotients of Boolean control networks (BCNs) with the motivation that they might serve as smaller models that still carry enough information about the original network. Given a BCN and an equivalence relation on the state set, we consider a labeled transition system that is generated by the BCN. The resulting quotient transition system then naturally captures the quotient dynamics of the BCN concerned. We therefore develop a method for constructing a Boolean system that behaves equivalently to the resulting quotient transition system. The use of the obtained quotient system for control design is discussed and we show that for BCNs, controller synthesis can be done by first designing a controller for a quotient and subsequently lifting it to the original model. We finally demonstrate the applicability of the proposed techniques on a biological example.

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1.3. Systems & Control Letters

Volume: 149, March 2021

- **Logical matrix factorization towards topological structure and stability of probabilistic Boolean networks**
  Authors: Yuna Liu ; Haitao Li
  Abstract: The study of logical matrix factorization provides a new insight into the matrix dimension reduction problems of biological systems. This paper develops the logical matrix factorization technique for exploring the topological structure and stability of probabilistic Boolean networks (PBNs). Firstly, the union set of distinct indices in factorized structural matrices for different modes is obtained, based on which, a size-reduced system is constructed for the original PBN. Secondly, it is proved that the topological structure of original PBN is equivalent to that of the size-reduced system. Thirdly, the equivalence of finite-time stability and stability in distribution between the original PBN and the size-reduced system is further revealed. Finally, the effectiveness of the obtained new results are verified via several Boolean models of genetic regulatory networks (GRNs).

- **Event-triggered attitude synchronization of multiple rigid-body systems**
  Authors: Shimin Wang ; Zhan Shu ; Tongwen Chen
  Abstract: In this paper, an attitude synchronization problem of multiple rigid-body systems is investigated by using an event-based approach. The leader and followers are described by unit quaternions. A nonlinear distributed observer with event-triggered observations is proposed to estimate the attitude and angular velocity of the leader without continuous information exchange. The triggering mechanism is intermittent and asynchronous; and a positive lower bound of inter-event triggering times is given to show that Zeno behavior can be excluded in the intermittent communication sequence for any agent. Based on the estimated attitude and angular velocity of the leader, a distributed controller is synthesized for each follower to achieve attitude synchronization with the leader via intermittent communication. Finally, an example is provided to illustrate the effectiveness of the theoretical results.

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

Volume: 51, Issue: 3, March 2021

- **Efficient Approach to Failure Response of Process Module in Dual-Arm Cluster Tools With Wafer Residency Time Constraints**
  Authors: Yan Qiao ; SiWei Zhang ; NaiQi Wu ; MengChu Zhou ; ZhiWu Li ; Ting Qu
  Abstract: In semiconductor manufacturing, a process module (PM) failure in cluster tools (CTs) happens from time to time. To effectively operate a CT, such a failure should be handled in a proper and timely manner. This issue becomes much more complicated because wafer residency time constraints (WRTCs) must be met to ensure the quality for some wafer fabrication processes. With such constraints, if a tool is operated under a periodic schedule and a PM fails, it is desired that the tool can still operate under a periodic schedule if it is possible. Nevertheless, the periodic schedule after a PM failure must be different from that before its failure since in this case the tool is degraded. Thus, there must be a transient process between them. It is a great challenge to operate a tool such that it can go through such a transient process with WRTCs being always satisfied. This paper aims to solve this problem by proposing PM failure response policies which can successfully transfer a CT to the feasible schedule after failure from the one before a failure. Then, efficient algorithms are developed to improve these response policies. The proposed policies are composed of simple control laws such that they can be realized in real time and online. Illustrative examples are presented to show their applications.
- **Stabilization and Finite-Time Stabilization of Probabilistic Boolean Control Networks**
  Authors: Liqing Wang ; Yang Liu ; Zheng-Guang Wu ; Jianquan Lu ; Li Yu
  Abstract: In this paper, we study the stabilization and finite-time stabilization of probabilistic Boolean control networks (PBCNs). A complete family of reachable sets is defined first, based on which, feedback stabilization conditions are obtained. Then a way to find all possible state feedback controllers are presented for the stabilization of PBCNs accordingly. Moreover, it has been stated that the approach in this paper can also be applied to finite-time stabilization via some changes in the construction of set sequence. Finally, an evolutionary networked game is given as an example to illustrate the efficiency of the obtained results.

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1.5. IEEE/CAA Journal of Automatica Sinica

Volume: 8, Issue: 3, March 2021

- **Deadlock-free Supervisor Design for Robotic Manufacturing Cells With Uncontrollable and Unobservable Events**
  Authors: Bo Huang ; MengChu Zhou ; Cong Wang ; Abdullah Abusorrah ; Yusuf Al-Turki
  Abstract: In this paper, a deadlock prevention policy for robotic manufacturing cells with uncontrollable and unobservable events is proposed based on a Petri net formalism. First, a Petri net for the deadlock control of such systems is defined. Its admissible markings and first-met inadmissible markings (FIMs) are introduced. Next, place invariants are designed via an integer linear program (ILP) to survive all admissible markings and prohibit all FIMs, keeping the underlying system from reaching deadlocks, livelocks, bad markings, and the markings that may evolve into them by firing uncontrollable transitions. ILP also ensures that the obtained deadlock-free supervisor does not observe any unobservable transition. In addition, the supervisor is guaranteed to be admissible and structurally minimal in terms of both control places and added arcs. The condition under which the supervisor is maximally permissive in behavior is given. Finally, experimental results with the proposed method and existing ones are given to show its effectiveness.

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2 Conferences

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

2.1 **2021 ACM International Conference on Hybrid Systems: Computation and Control**
Nashville, USA, May 19-21, 2021 (Virtual)
https://hscc.acm.org/2021/

2.2 **2021 American Control Conference**
New Orleans, Louisiana, USA, May 26-28, 2021 (Virtual)
http://acc2021.a2c2.org/

2.3 **2021 Learning for Dynamics and Control**
ETH Zurich, Switzerland, June 7-8, 2021
https://l4dc.ethz.ch/

2.4 **2021 Mediterranean Conference on Control and Automation**
Bari, Italy, June 22-25, 2021 (Hybrid)
http://med2021.poliba.it/

2.5 **2021 Chinese Control Conference**
Shanghai, China, July 26-28, 2021
https://conf2021.shu.edu.cn/index.htm

2.6 **2021 IEEE Conference on Control Technology and Applications**
San Diego, August 8-11, 2021
https://ccta2021.ieeecss.org/

2.7 **2021 IEEE International Conference on Automation Science and Engineering**
Lyon Centre de Congres, Lyon, France, August 23-27, 2021
https://www.ieee-ras.org/component/rseventspro/event/1935-case-2021

2.8 **2021 IEEE International Conference on Systems, Man, and Cybernetics**
South Wharf, Victoria, Australia, October 17-20, 2021
http://ieeesmc2021.org/

2.9 **2021 IEEE Conference on Decision and Control**
Austin, Texas, USA. December 13-15, 2021
https://cdc2021.ieeecss.org

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3 Books

3.1 **Foundations of Average-Cost Nonhomogeneous Controlled Markov Chains**
Authors: Xi-Ren Cao
Description: This Springer brief addresses the challenges encountered in the study of the optimization of time-nonhomogeneous Markov chains. It develops new insights and new methodologies for systems in which concepts such as stationarity, ergodicity, periodicity and connectivity do not apply.

This brief introduces the novel concept of confluencity and applies a relative optimization approach. It develops a comprehensive theory for optimization of the long-run average of time-nonhomogeneous Markov chains. The book shows that confluencity is the most fundamental concept in optimization, and that relative optimization is more suitable for treating the systems under consideration than standard ideas of dynamic programming. Using confluencity and relative optimization, the author classifies states as confluent or branching and shows how the under-selectivity issue of the long-run average can be easily addressed, multi-class optimization implemented, and Nth biases and Blackwell optimality conditions derived. These results are presented in a book for the first time and so may enhance the understanding of optimization and motivate new research ideas in the area.

ISBN: 978-3-030-56678-4
https://www.springer.com/gp/book/9783030566777

3.2 **Discrete-Time and Discrete-Space Dynamical Systems**
Authors: Kuize Zhang, Lijun Zhang, Lihua Xie
ISBN: 978-3-030-25971-6, Springer
https://link.springer.com/book/10.1007/978-3-030-25972-3

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4 Software Tool

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 2.6, New Version

The development team has just released a new version of Supremica, Waters/Supremica IDE 2.6.

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:

- Scaling of the GUI
- Revamped configuration dialog
- New analyzer user interface
- Logging can now be done directly to file, in addition to the log output pane
- Automaton variables have been introduced, so that guards and actions can refer to the state of an automaton
- The normalizing compiler is now the default
- Plenty of bug fixes, including more graceful termination when out of memory

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 coobservability.

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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