IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **April 2021**

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Welcome to the 2021 April 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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  or email to kai.cai@eng.osaka-cu.ac.jp.
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1 Selections of Journal Publications

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

1.1. Discrete Event Dynamic Systems Theory and Applications

Volume 31, issue 1, March 2021

- **Pathwise stability of multiclass queueing networks**
  Authors: Kan Wu ; Yichi Shen
  Abstract: It has been shown that, under some service policies, a queueing network can be unstable even if the load of every station is less than one. Although the stability of queueing systems in some special cases (e.g. under First-Buffer-First-Served policy) has been well addressed, there are still difficulties in coping with more general networks. In this paper, we study the stability problem through depicting the mutual blocking effect among different classes and generalize the concept of servers in the context of queueing networks based on the sample path analysis. We show that the general servers have similar impacts on the system stability as physical stations and a queueing network is pathwise stable if and only if the effective traffic intensity of every general server does not exceed one. Through case studies, we show that the stability of queueing networks and the structure of general servers are sensitive and depend on various factors, including the service policies. Furthermore, we prove that queueing systems operating under the Work-in-Progress-Dependent service policies are always stable if every physical station has sufficient capacity.

- **Critical subsystems in time interval models-Application to a baking process**
  Authors: P. Declerck
  Abstract: The aim of this paper is the generation of the min-critical and max-critical subsystems which determine the optimal cycle times. Considering a Time Interval Model which can describe Timed Event Graphs and P-time Event Graphs completely, each critical subsystem depends on the lower and upper bounds of the time durations. The proposed approach which is based on linear programming makes a classification of the relations which describe the system. The application to a baking process in a plant bakery shows that the min-critical and max-critical subsystems are not limited to the critical circuits of the Event Graph.

- **Long time behaviour for Markovian branching-immigration systems**
  Authors: Li, Junping ; Cheng, Lan ; Li, Liuyan
  Abstract: Let $\{X(t); t \geq 0\}$ be a continuous-time branching-immigration system with branching rates $\{b_k; k \geq 0, k \neq 1\}$ and immigration rates $\{a_k; k \geq 1\}$. We assume that $b_0 = 0, m =: \sum_{k=1}^{\infty} k b_k < \infty$ and $a =: \sum_{k=1}^{\infty} k a_k < \infty$. In this paper, we first discuss the martingale property of $W(t) = e^{-mt}X(t) - m^{-1}a(1 - e^{-mt})$ and prove that it has a limit W.Furthermore, we show that $X(t+s)/X(t)$ converges to e^{ms} in probability, $W(t)$ converges to W in probability and $X(t+s)/X(t)$ converges to e^{ms} in probability conditioned on $W \geq \alpha$ (here α is a positive constant) as $t \to \infty$. The explicit estimates of the above three convergence rates are obtained under various moment conditions on $\{b_k; k \geq 0, k \neq 1\}$. It is shown that the rate of the first one is geometric, while the other two are supergeometric.

- **Intermittent fault diagnosability of discrete event systems: an overview of automaton-based approaches**
  Authors: Abderraouf Boussif ; Mohamed Ghazel ; João Carlos Basilio
  Abstract: Real life experience has shown that intermittent faults are among the most challenging kinds of faults to detect and isolate, being present in the majority of production systems. Such a concern has made intermittent fault an active area of research in both discrete event and continuous-variable dynamic systems. In this paper, we present a review of the state-of-the art of intermittent fault diagnosability of discrete event systems modeled by finite state automata. To this end, we re-visit the main definitions of diagnosability of intermittent faults, and present comparisons between them, consider verification and analysis techniques, and discuss available complexity results. Examples are used throughout the paper to illustrate the reviewed concepts and verification algorithms. We also look ahead, by suggesting some perspectives for future research.

- **Supervisor synthesis and throughput optimization of partially-controllable manufacturing systems**
  Authors: Berend Jan Christiaan van Putten ; Bram van der Sanden ; Michel Reniers ; Jeroen Voeten ; Ramon Schiffelers
  Abstract: One of the challenges in the design of supervisors with optimal throughput for manufacturing systems is the presence of behavior outside the control of the supervisor. Uncontrollable behavior is typically encountered in the presence of (user) inputs, external disturbances, and exceptional behavior. This paper introduces an approach for the modeling and synthesis of a throughput-optimal supervisor for manufacturing systems with partially-controllable behavior on two abstraction levels. Extended finite automata are used to model the high abstraction level in terms of system activities, where uncontrollability is modeled by the presence of uncontrollable activities. In the lower abstraction level, activities are modeled as directed acyclic graphs that define the constituent actions and dependencies between them. System feedback from the lower abstraction level, including timing, is captured using variables in the extended finite automata of the higher abstraction level. For throughput optimization, game-theoretic methods are employed on the state space of the synthesized supervisor to determine a guarantee to the lower-bound system performance. This result is also used in a new method to automatically compute a throughput-optimal controller that is robust to the uncontrollable behavior.
- **Decentralized state estimation and diagnosis of p-time labeled Petri nets systems**
  Authors: Patrice Bonhomme
  Abstract: This paper proposes a state estimation technique in a decentralized context for time dependent systems. The plant of the studied system is modeled by P-time labeled Petri nets (P-TLPN) and the set of events is partitioned into a set of observable and unobservable ones, leading to a partial observation configuration. Indeed, the observation is distributed over a set of distinct sites which have their own local vision of the system. Moreover, some event are indistinguishable as the same label can be associated with the same transition adding another source of non-determinism. Thus, thanks to a global coordinator helped by the consideration of the timing factor, the local information transmitted via the different sites will be exploited to assess the set of states consistent with the current considered observation. The developed technique is an iterative procedure coupled with a time feasibility analysis (i.e., schedulability) conducted for particular firing sequences allowing to explain the considered observation, called time explanations. A diagnosis procedure aiming at evaluating the occurrence of particular faults for each behavior is also provided.
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1.2. IEEE Transactions on Automatic Control

Volume: 66, Issue: 4, April 2021

- **On Approximate Opacity of Cyber-Physical Systems**
  Authors: Xiang Yin ; Majid Zamani ; Siyuan Liu
  Abstract: Opacity is an important information-flow security property in the analysis of cyber-physical systems. It captures the plausible deniability of the system's secret behavior in the presence of an intruder that may access the information flow. Existing works on opacity only consider nonmetric systems by assuming that the intruder can always distinguish between two different outputs precisely. In this article, we extend the concept of opacity to systems whose output sets are equipped with metrics. Such systems are widely used in the modeling of many real-world systems whose measurements are physical signals. A new concept called approximate opacity is proposed in order to quantitatively evaluate the security guarantee level with respect to the measurement precision of the intruder. Then, we propose a new simulation-type relation, called approximate opacity-preserving simulation relation, which characterizes how close two systems are in terms of the satisfaction of approximate opacity. This allows us to verify approximate opacity for large-scale, or even infinite, systems using their abstractions. We also discuss how to construct approximate opacity-preserving symbolic models for a class of discrete-time control systems. Our results extend the definitions and analysis techniques for opacity from nonmetric systems to metric systems.
- **An Algorithm to Compute the Inverse Image of a Point With Respect to a Nondeterministic Max-Plus Linear System**
  Authors: Renato Markele Ferreira Cândido ; Laurent Hardouin ; Mehdi Lhommeau ; Rafael Santos Mendes
  Abstract: Max-plus linear (MPL) systems are often described by a transition function, which models the state evolution of the system, and a measurement function, which binds the measures with the system states. Methods for computing the inverse image of a point w.r.t. the measurement function are particularly interesting in applications where it is desirable to obtain information about the system states based on the output observations. The inverse image of a set w.r.t. a nondeterministic MPL system, called uncertain MPL (uMPL) system, can be computed by using the difference-bound matrices (DBM) approach. In this article, we aim to use an interval analysis to propose a method to compute the inverse image of a point w.r.t. an uMPL system. The algorithm proposed has a lower worst-case complexity compared with the DBM approach as previously proposed in the literature.
- **Analytic Expressions in Stochastic Max-Plus-Linear Algebra and their Application in Model Predictive Control**
  Authors: Ton J. J. van den Boom ; Bart De Schutter
  Abstract: The class of max-plus-linear systems can model discrete event systems with synchronization but no choice. Model mismatch and/or disturbances can be characterized as stochastic uncertainties. In stochastic max-plus-linear systems one often needs to compute the expectation of a max-plus-scaling (MPS) function or the chance constraint of a MPS function. The algorithms available in literature are either computationally too expensive or only give an approximation. In this article, we derive an analytic expression for both the expectation and the chance constraint of a MPS function. Both can be written in the form of a piecewise polynomial function in the components of the control variables. The analytic function can be derived offline and can be evaluated online in a quick and efficient way. We also show how the expressions can be used in a model predictive control setting and show the efficiency of the proposed approach with a worked example.
- **Policy Evaluation in Continuous MDPs With Efficient Kernelized Gradient Temporal Difference**
  Authors: Alec Koppel ; Garrett Warnell ; Ethan Stump ; Peter Stone ; Alejandro Ribeiro
  Abstract: We consider policy evaluation in infinite-horizon discounted Markov decision problems with continuous compact state and action spaces. We reformulate this task as a compositional stochastic program with a function-valued decision variable that belongs to a reproducing kernel Hilbert space (RKHS). We approach this problem via a new functional generalization of stochastic

quasi-gradient methods operating in tandem with stochastic sparse subspace projections. The result is an extension of gradient temporal difference learning that yields nonlinearly parameterized value function estimates of the solution to the Bellman evaluation equation. We call this method parsimonious kernel gradient temporal difference learning. Our main contribution is a memory-efficient nonparametric stochastic method guaranteed to converge exactly to the Bellman fixed point with probability 1 with attenuating step-sizes under the hypothesis that it belongs to the RKHS. Further, with constant step-sizes and compression budget, we establish mean convergence to a neighborhood and that the value function estimates have finite complexity. In the Mountain Car domain, we observe faster convergence to lower Bellman error solutions than existing approaches with a fraction of the required memory.

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1.3. IEEE Control Systems Letter

Volume: 5, Issue: 2, April 2021

- **Stochastic Safety for Markov Chains**
  Authors: Manuela L. Bujorianu ; Rafael Wisniewski ; Evangelos Boulougouris
  Abstract: In this letter, we study the so-called p-safety of a Markov chain. We say that a state is p-safe in a state space S with respect to an unsafe set U if the process stays in the state space and hits the set U with the probability less than p. We show several ways of computing p-safety: by means the Dirichlet problem, the evolution equation, the barrier certificates, and the Martin kernel. The set of barrier certificates forms a cone. We show how to generate barrier certificates from the set of extreme points of a cone base.

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1.4. IEEE/CAA Journal of Automatica Sinica

Volume: 8, Issue: 1, April 2021

- **Property Preservation of Petri Synthesis Net Based Representation for Embedded Systems**
  Authors: Chuanliang Xia ; Chengdong Li
  Abstract: Embedded systems have numerous applications in everyday life. Petri-net-based representation for embedded systems (PRES+) is an important methodology for the modeling and analysis of these embedded systems. For a large complex embedded system, the state space explosion is a difficult problem for PRES+ to model and analyze. The Petri net synthesis method allows one to bypass the state space explosion issue. To solve this problem, as well as model and analyze large complex systems, two synthesis methods for PRES+ are presented in this paper. First, the property preservation of the synthesis shared transition set method is investigated. The property preservation of the synthesis shared transition subnet set method is then studied. An abstraction-synthesis-refinement representation method is proposed. Through this representation method, the synthesis shared transition set approach is used to investigate the property preservation of the synthesis shared transition subnet set operation. Under certain conditions, several important properties of these synthetic nets are preserved, namely reachability, timing, functionality, and liveness. An embedded control system model is used as an example to illustrate the effectiveness of these synthesis methods for PRES+.

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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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