IEEE Control Systems Society
Technical Committee on Discrete Event Systems

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Welcome to the 2022 December issue of the newsletter, also available online at
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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. Discrete Event Dynamic Systems: Theory and Applications

Volume: 32, Issue: 4, December 2022

- **Zero-sum semi-Markov games with state-action-dependent discount factors**
  Authors: Zhihui Yu ; Xianping Guo ; Li Xia
  Abstract: Semi-Markov model is one of the most general models for stochastic dynamic systems. This paper deals with a two-person zero-sum game for semi-Markov processes. We focus on the expected discounted criterion with state-action-dependent discount factors. The state and action spaces are both Polish spaces, and the reward rate function is ω-bounded. We first construct a fairly general model of semi-Markov games under a given semi-Markov kernel and a pair of strategies. Next, based on the standard regularity condition and the continuity-compactness condition for semi-Markov games, we derive a "drift condition" on the semi-Markov kernel and suppose that the discount factors have a positive lower bound, under which the existence of the value function and an optimal pair of stationary strategies of our semi-Markov game are proved by using a general Shapley equation. Moreover, in the scenario of finite state and action spaces, a value iteration-type algorithm for approximating the value function and an optimal pair of stationary strategies is developed. The convergence and the error bound of the algorithm are also proved. Finally, we conduct numerical examples to demonstrate the main results.

- **Synthesis of winning attacks on communication protocols using supervisory control theory: two case studies**
  Authors: Shoma Matsui ; Stéphane Lafortune
  Abstract: There is an increasing need to study the vulnerability of communication protocols in distributed systems to malicious attacks that attempt to violate properties such as safety or nonblockingness. In this paper, we propose a common methodology for formal synthesis of successful attacks against two well-known protocols, the Alternating Bit Protocol (ABP) and the Transmission Control Protocol (TCP), where the attacker can always eventually win, called FOR-ALL attacks. This extends previous work on the synthesis of THERE-EXISTS attacks for TCP, where the attacker can sometimes win. We model the ABP and TCP protocols and system architecture by finite-state automata and employ the supervisory control theory of discrete event systems to pose and solve the synthesis of FOR-ALL attacks, where the attacker has partial observability and controllability of the system events. We consider several scenarios of person-in-the-middle attacks against ABP and TCP and present the results of attack synthesis using our methodology for each case.

- **Using Subobservers to Synthesize Opacity-Enforcing Supervisors**
  Authors: Richard Hugh Moulton ; Behnam Behinaein Hamgini ; Zahra Abedi Khouzani ; Rômulo Meira-Góes ; Fei Wang ; Karen Rudie
  Abstract: In discrete-event system control, the worst-case time complexity for computing a systems observer is exponential in the number of that systems states. This results in practical difficulties since some problems require calculating multiple observers for a changing system, e.g., synthesizing an opacity-enforcing supervisor. Although calculating these observers in an iterative manner allows us to synthesize an opacity-enforcing supervisor and although methods have been proposed to reduce the computational demands, room exists for a practical and intuitive solution. Here we extend the subautomaton relationship to the notion of a subobserver and demonstrate its use in reducing the computations required for iterated observer calculations. We then demonstrate the subobserver relationships power by simplifying state-of-the-art synthesis approaches for opacity-enforcing supervisors under realistic assumptions.

- **Correction to: Formal specification and verification of decentralized self-adaptive systems using symmetric nets**
  Authors: Matteo Camilli ; Lorenzo Capra

Back to the contents

1.2. IEEE Transactions on Automatic Control

Volume: 67, Issue: 12, December 2022

- **Opacity Enforcing Supervisory Control Using Nondeterministic Supervisors**
  Authors: Yifan Xie ; Xiang Yin ; Shaoyuan Li
  Abstract: In this article, we investigate the enforcement of opacity via supervisory control in the context of discrete-event systems. A system is said to be opaque if the intruder, which is modeled as a passive observer, can never infer confidently that the system is at a secret state. The design objective is to synthesize a supervisor such that the closed-loop system is opaque even when the control policy is publicly known. In this article, we propose a new approach for enforcing opacity using nondeterministic supervisors. A nondeterministic supervisor is a decision mechanism that provides a set of control decisions at each instant, and randomly picks a specific control decision from the decision set to actually control the plant. Compared with the standard deterministic control mechanism, such a nondeterministic control mechanism can enhance the plausible deniability of the controlled system as the online control decision is a random realization and cannot be implicitly inferred from the control policy. We provide a sound and complete algorithm for synthesizing a nondeterministic opacity-enforcing supervisor. Furthermore, we show that nondeterministic supervisors are strictly more powerful than deterministic supervisors in the sense that there may exist a nondeterministic opacity-enforcing supervisor even when deterministic supervisors cannot enforce opacity.
- **Finite-Memory Supervisory Control of Discrete Event Systems for LTL$[\mathcal{F}]$ Specifications**
  Authors: Ami Sakakibara ; Natsuki Urabe ; Toshimitsu Ushio
  Abstract: In this article, we study a supervisory control problem under a constraint on memory size as well as a constraint described by a class of quantitative linear temporal logic, which enables us to consider how well the specification is satisfied. Our control objective is to design a finite-memory supervisor such that the satisfaction value of the specification formula on the controlled system is larger than or equal to a given threshold. We adopt a Safraless synthesis methodology and reduce the problem to solving a safety game parameterized with the memory size of a supervisor. On the safety game, we compute a winning strategy by leveraging a ranking function. Our definition of the ranking function relies on the product automaton, which captures both the behavior of the controlled plant and that of an automaton transformed from the specification and the threshold.
- **Convex Optimization for Parameter Synthesis in MDPs**
  Authors: Murat Cubuktepe ; Nils Jansen ; Sebastian Junges ; Joost-Pieter Katoen ; Ufuk Topcu
  Abstract: Probabilistic model-checking aims to prove whether a Markov decision process (MDP) satisfies a temporal logic specification. The underlying methods rely on an often unrealistic assumption that the MDP is precisely known. Consequently, parametric MDPs (pMDPs) extend MDPs with transition probabilities that are functions over unspecified parameters. The parameter synthesis problem is to compute an instantiation of these unspecified parameters such that the resulting MDP satisfies the temporal logic specification. We formulate the parameter synthesis problem as a quadratically constrained quadratic program, which is nonconvex and is NP-hard to solve in general. We develop two approaches that iteratively obtain locally optimal solutions. The first approach exploits the so-called convexconcave procedure (CCP), and the second approach utilizes a sequential convex programming (SCP) method. The techniques improve the runtime and scalability by multiple orders of magnitude compared to black-box CCP and SCP by merging ideas from convex optimization and probabilistic model-checking. We demonstrate the approaches on a satellite collision avoidance problem with hundreds of thousands of states and tens of thousands of parameters and their scalability on a wide range of commonly used benchmarks.
- **Entropy Maximization for Partially Observable Markov Decision Processes**
  Authors: Yagiz Savas ; Michael Hibbard ; Bo Wu; Takashi Tanaka ; Ufuk Topcu
  Abstract: We study the problem of synthesizing a controller that maximizes the entropy of a partially observable Markov decision process (POMDP) subject to a constraint on the expected total reward. Such a controller minimizes the predictability of an agents trajectories to an outside observer while guaranteeing the completion of a task expressed by a reward function. Focusing on

finite-state controllers (FSCs) with deterministic memory transitions, we show that the maximum entropy of a POMDP is lower bounded by the maximum entropy of the parameteric Markov chain (pMC) induced by such FSCs. This relationship allows us to recast the entropy maximization problem as a so-called parameter synthesis problem for the induced pMC. We then present an algorithm to synthesize an FSC that locally maximizes the entropy of a POMDP over FSCs with the same number of memory states. In a numerical example, we highlight the benefit of using an entropy-maximizing FSC compared with an FSC that simply finds a feasible policy for accomplishing a task.

Back to the contents

1.3. Automatica

Volume: 146, December 2022

- **Automated verification and synthesis of stochastic hybrid systems: A survey**
  Authors: Abolfazl Lavaei ; Sadegh Soudjani ; Alessandro Abate ; Majid Zamani
  Abstract: Stochastic hybrid systems have received significant attentions as a relevant modeling framework describing many systems, from engineering to the life sciences: they enable the study of numerous applications, including transportation networks, biological systems and chemical reaction networks, smart energy and power grids, and beyond. Automated verification and policy synthesis for stochastic hybrid systems can be inherently challenging: this is due to the heterogeneity of their dynamics (presence of continuous and discrete components), the presence of uncertainty, and in some applications the large dimension of state and input sets. Over the past few years, a few hundred articles have investigated these models, and developed diverse and powerful approaches to mitigate difficulties encountered in the analysis and synthesis of such complex stochastic systems. In this survey, we overview the most recent results in the literature and discuss different approaches, including (in)finite abstractions, verification and synthesis for temporal logic specifications, stochastic similarity relations, (control) barrier certificates, compositional techniques, and a selection of results on continuous-time stochastic systems; we finally survey recently developed software tools that implement the discussed approaches. Throughout the manuscript we discuss a few open topics to be considered as potential future research directions: we hope that this survey will guide younger researchers through a comprehensive understanding of the various challenges, tools, and solutions in this enticing and rich scientific area.
- **Learning-based symbolic abstractions for nonlinear control systems**
  Authors: Kazumune Hashimoto ; Adnane Saoud ; Masako Kishida ; Toshimitsu Ushio ; Dimos V.Dimarogonas
  Abstract: Symbolic models or abstractions are known to be powerful tools for the control design of cyberphysical systems (CPSs) with logic specifications. In this paper, we investigate a novel learning-based approach to the construction of symbolic models for nonlinear control systems. In particular, the symbolic model is constructed based on learning the un-modeled part of the dynamics from training data based on state-space exploration, and the concept of an alternating simulation relation that represents behavioral relationships with respect to the original control system. Moreover, we aim at achieving safe exploration, meaning that the trajectory of the system is guaranteed to be in a safe region for all times while collecting the training data. In addition, we provide some techniques to reduce the computational load, in terms of memory and computation time,of constructing the symbolic models and the safety controller synthesis, so as to make our approach practical. Finally, a numerical simulation illustrates the effectiveness of the proposed approach.
- **Reduced-order observer design for fault diagnosis of Boolean control networks**
  Authors: Zhihua Zhang ; Ping Zhang ; Thomas Leifeld
  Abstract: In this paper, we propose an approach to design reduced-order observer of Boolean control networks (BCNs) for fault diagnosis by applying the semi-tensor product (STP) of matrices. At first, for observability analysis a computationally efficient approach based on the relational coarsest partition problem (RCP) is proposed. Then a necessary and sufficient condition for fault detectability analysis is introduced. After that an approach is introduced to design a reduced-

order observer for fault detection. If fault occurrence has been detected, then an approach is proposed to solve fault isolation problem of BCNs. The basic idea is to separate dynamics of the faults into different independent subsystems by using graph theory. For each subsystem a residual generator is constructed based on reduced-order observer by getting rid of indistinguishable states. By theoretical analysis and simulation study it is shown that the approach proposed in the paper for fault isolation requires lower computational effort than the conventional scheme of a bank of full-order observers.

Back to the contents

1.4. Control Engineering Practice

Volume: 129, December 2022

- **Residuals-based fault diagnosis of industrial automation systems using timed and un-timed Interpreted Petri nets**
  Authors: Francesco Basile ; Luigi Ferrara
  Abstract: The problem of detecting and isolating a fault using a discrete event model has received a lot of attention over the last two decades. Indeed, industrial automated systems can be usually modelled by a discrete event system. The problem is particularly significant if a fault-free model is used. Recently, residuals, well-known in continuous time systems context, have been proposed to obtain set of candidate faults from real time observations for discrete event system also. They have been obtained using finite state automata. In this paper, inspired by these works, residuals are formulated using Petri net models, both timed and un-timed ones. The computation of residuals for net models requires some efforts to update and predict the state, especially in timed models, but it returns to be highly efficient and scalable thanks to the local state representation and intrinsic distributed nature of the these models. A practical example, consisting of a plant simulated by using a 3D environment interfaced to a Programmable Logic Controller to simulate/emulate the closed-loop behaviour, is used to illustrate the results of the paper.

Back to the contents

1.5. International Journal of Control

Volume: 95, Issue: 12, December 2022

- **Current-state opacity and initial-state opacity of modular discrete event systems**
  Authors: Jingkai Yang ; Weilin Deng ; Daowen Qiu
  Abstract: The verifications of current-state opacity (CSO) and initial-state opacity (ISO) in discrete event systems (DESs) both suffer from the curse of dimensionality, as these issues were proved to be PSPACE-complete. Hence, how to reduce the state space is crucial. In this paper, we investigate CSO and ISO in modular DESs, which consist of several individual components. Necessary and sufficient conditions of CSO and ISO for modular DESs are derived under the assumption that all synchronous events are observable by each component of modular DESs. Moreover, we prove that the initial state estimator of modular system is isomorphic to the synchronous composition of initial state estimators for individual components. These results offer us the opportunity to reduce the complexity in verifying the opacity of modular DESs.

Back to the contents

1.6. Systems & Control Letters

Volume: 170, December 2022

- **Numerical over-approximation of invariance entropy via finite abstractions**
  Authors: M. S. Tomar ; C. Kawan ; M. Zamani
  Abstract: For a closed-loop system with a digital channel between the sensor and controller, invariance entropy quantifies the smallest average rate of information above which a compact subset Q of the state set can be made invariant. There exist different versions of invariance entropy for deterministic and uncertain control systems, which are equivalent in the deterministic case. In this paper, we present the first numerical approaches to obtain rigorous upper bounds of these quantities.

Our approaches are based on set-valued numerical analysis and graph-theoretic constructions. We combine existing algorithms from the literature to carry out our computations for several linear and nonlinear examples. A comparison with the theoretical values of the entropy shows that our bounds are of the same order of magnitude as the actual values.

Back to the contents

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

Volume: 52, Issue: 12, December 2022

- **Model Checking of Variable Petri Nets by Using the Kripke Structure**
  Authors: Ru Yang ; Zhijun Ding ; Tong Guo ; Meiqin Pan ; Changjun Jiang
  Abstract: The properties of dynamic interactions in mobile-interactive systems are still difficult to analyze because of the complexity of systems. Thus, we have proposed a new Petri net called the variable petri net (VPN) recently, which specializes in describing dynamic interactions in systems. To make better use of VPN, this article focuses on the model checking method of VPN. It introduces the algorithm to transform a VPN to a Kripke structure that can describe both the system running states and the system connection states in VPN, and the method to transform a property to a temporal logic formula based on VPN and its Kripke structure. The Kripke structure can be optimized by considering the specific property about the system connection states and then be used to perform the targeted verification to the property by using a model checker. A practical example is given to demonstrate the proposed methods.

Back to the contents

2 Conferences

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

2.1 **2023 ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS)**
San Antonio, USA, May 9-12, 2023
https://iccps.acm.org/2023/

2.2 **2023 American Control Conference (ACC)**
San Diego, USA, May 31 - June 2, 2023
https://acc2023.a2c2.org/

2.3 **2023 IFAC World Congress (IFAC)**
Yokohama, Japan, July 9-14, 2023
https://www.ifac2023.org/

2.4 **2023 IEEE Conference on Control Technology and Applications (CCTA)**
Bridgetown, Barbados, August 16-18, 2023.
https://ieeeccta.org/

2.5 **2023 IEEE Conference on Decision and Control (CDC)**
Singapore, December 13-15, 2023.
https://cdc2023.ieeecss.org/

Back to the contents

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 (Third Edition)

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

Back to the contents

4 Software Tools

4.1 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.

4.2 Eclipse ESCET™ version 0.7 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 September 2022, ESCET version 0.7 has been released and can be downloaded from https://www.eclipse.org/escet/download.html. The main changes in this version are

- The CIF controller property checker can now also check whether controllers satisfy the confluence property.
- The CIF examples contain a new bridge example to showcase the real-world usage of CIF for synthesis-based engineering. Furthermore, two new CIF benchmarking models have been added.
- The CIF event-based language equivalence check tool now produces correct counter examples.
- The CIF to Supremica transformation precondition check has improved output and no longer crashes on reporting certain precondition violations. The preconditions themselves have not changed.
- The CIF text editor now has theming support, and comes with a dark theme in addition to the existing light theme. The text editor now automatically uses its dark theme when the Eclipse built-in dark theme is used, and uses a light theme otherwise.

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.

4.3 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.

4.4 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.

4.5 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.

4.6 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.

Back to the contents