IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **February 2022**

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Welcome to the 2022 February 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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1 Selections of Journal Publications

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

1.1. IEEE Transactions on Automatic Control

Volume: 67, Issue: 2, February 2022

- **Deception in Supervisory Control**
  Authors: Mustafa O. Karabag ; Melkior Ornik ; Ufuk Topcu
  Abstract: The use of deceptive strategies is important for an agent that attempts not to reveal his intentions in an adversarial environment. We consider a setting, in which a supervisor provides a reference policy and expects an agent to follow the reference policy and perform a task. The agent may instead follow a different deceptive policy to achieve a different task. We model the environment and the behavior of the agent with a Markov decision process, represent the tasks of the agent and the supervisor with reachability specifications, and study the synthesis of optimal deceptive policies for such agents. We also study the synthesis of optimal reference policies that prevent deceptive strategies of the agent and achieve the supervisor's task with high probability. We show that the synthesis of optimal deceptive policies has a convex optimization problem formulation, while the synthesis of optimal reference policies requires solving a nonconvex optimization problem. We also show that the synthesis of optimal reference policies is NP-hard.

- **Observers for a Class of Timed Automata Based on Elapsed Time Graphs**
  Authors: Jun Li ; Dimitri Lefebvre ; Christoforos N. Hadjicostis ; Zhiwu Li
  Abstract: This article develops a novel design principle for the observer of timed discrete event systems behaving under specific time semantics. Observers devoted to discrete event systems usually ignore the timing aspects of underlying systems but this can have implications to many applications, in particular, for refinement of estimation and inference tasks. The techniques of this article use the time stamps of observations to refine the state estimation process for a class of labeled and timed automata where events occur based on constant time values. The resulting timed observer is beneficial for refining privacy and security issues. Current-state opacity is discussed as a promising application of the timed observer.

- **Automatic Trajectory Synthesis for Real-Time Temporal Logic**
  Authors: Rafael Rodrigues da Silva ; Vince Kurtz ; Hai Lin
  Abstract: Many safety-critical systems, such as autonomous vehicles and service robots, must achieve high-level task specifications with performance guarantees. Much recent progress toward this goal has been made through an automatic controller synthesis from temporal logic specifications. Existing approaches, however, have been limited to relatively short and simple specifications. Furthermore, existing methods either consider some prior discretization of the state space, deal only with a convex fragment of temporal logic, or are not provably complete. We propose a scalable, provably complete algorithm that synthesizes continuous trajectories to satisfy nonconvex temporal logic over reals (RTL) specifications. We separate discrete task planning and continuous motion planning on-the-fly and harness highly efficient Boolean satisfiability and linear programming solvers to find dynamically feasible trajectories that satisfy nonconvex RTL specifications for high-dimensional systems. The proposed design algorithms are proven sound and complete, and simulation results demonstrate our approach's scalability.

- **Partial-Order Reduction for Supervisory Controller Synthesis**
  Authors: Bram van der Sanden ; Marc Geilen ; Michel Reniers ; Twan Basten
  Abstract: A key challenge in the synthesis and subsequent analysis of supervisory controllers is the impact of state-space explosion caused by concurrency. The main bottleneck is often the memory needed to store the composition of plant and requirement automata and the resulting supervisor. Partial-order reduction (POR) is a well-established technique that alleviates this issue in the field of model checking. It does so by exploiting redundancy in the model with respect to the properties of interest. For controller synthesis, the functional properties of interest are nonblockingness, controllability, and least-restrictiveness, but also performance properties, such as throughput and latency are of interest. We propose an on-the-fly POR on the input model that

preserves both functional and performance properties in the synthesized supervisory controller. This improves the scalability of the synthesis (and any subsequent performance analysis). Synthesis experiments show the effectiveness of the POR on a set of realistic manufacturing system models.

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1.2. Automatica

Volume: 136, February 2022

- **Design of supervisors for linear marking specifications in labeled Petri nets**
  Authors: Ziyue Ma ; Zhou He ; Zhiwu Li ; Alessandro Giua
  Abstract: In this paper we study the problem of enforcing a generalized mutual exclusion constraint (GMEC) in a labeled Petri net that contains indistinguishable transitions by a monitor-based supervisor. We show that a monitor-based supervisor can be designed based on the influence of events if the GMEC is deterministic. On the other hand, for a nondeterministic GMEC, we introduce the notion of dependency of transitions, which provides a quantitative relation between the transition firings and the occurrence of dependent events. Based on the dependency of transitions, we propose a structural approach to compute a monitor function using Hilbert basis, which helps us develop an algorithm to design an online supervisor using the monitor function. Our approach has low online computational load since marking estimation is avoided.
- **Enhancement of opacity for distributed state estimation in cyber-physical systems**
  Authors: Liwei An ; Guang-Hong Yang
  Abstract: Opacity, a confidentiality property that characterizes whether a "secret" of a system can be inferred by an outside intruder, is an increasing concern in cyber-physical systems (CPSs). The existing distributed estimation algorithms allow each node to broadcast its explicit state information to its neighbors, which results in the disclosure of CPS's secret state. To meet the confidentiality requirement, this paper formulates a new framework for opacity for distributed state estimation. Two opacity-enhancing algorithms are proposed against the intruder models with different eavesdropping capacities for a subset of nodes. Necessary and sufficient conditions to ensure that a secret state is opaque are established in terms of the rank of constructed structural matrices of the eavesdropped nodes. Moreover, it is shown that the use of enhancement mechanism does not compromise the estimation accuracy. The framework of opacity is further extended to the case of measurement noises.
- **Optimal reconstruction of noisy dynamics and selection probabilities in Boolean networks**
  Authors: Koichi Kobayashi ; Yuhu Wu
  Abstract: In the analysis and control of complex systems, including gene regulatory networks, it is important to reconstruct a mathematical model from a priori information and noisy experimental data. A Boolean network (BN) is well known as a mathematical model of gene regulatory networks. Each state of BNs takes a binary value (0 or 1), and its update rule is given by a set of Boolean functions. In this paper, we consider the optimal reconstruction problem of finding a probabilistic BN consisting of the main dynamics and the noisy dynamics, by giving the main dynamics and the sample mean of the state obtained from noisy experimental data. In the proposed method, the selection probability of the main dynamics is maximized. We show that the optimal Boolean function of the noisy dynamics is a constant (0 or 1) map under no assumption on the structure of noisy dynamics. Finally, as a biological application, the reconstruction of a PBN model of the lac operon networks of Escherichia coli bacterium is addressed using the proposed approach.

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1.3. International Journal of Control

Volume: 95, Issue: 2, February 2022

- **Localisation-based distributed control of timed discrete-event systems with communication delay**
  Authors: Renyuan Zhang ; Kai Cai

Abstract: We study localisation-based distributed control of timed multi-component discrete-event systems with communication delay in the Brandin-Wonham framework. First, we propose channel models for inter-component event communication with bounded and unbounded delays; the channel models are treated as plant components. In this formulation, there exist multiple distinct observable event sets; thus we employ timed relative coobservability to synthesise partial-observation decentralised supervisors. Then, we localise these supervisors into local controllers and preemptors, which provably tolerate the specified bounded and unbounded communication delays. Finally, the derived local controllers and preemptors are allocated to each plant component, thereby building a purely distributed control architecture of TDES with communication delay. The above results are illustrated by a timed workcell example.

- **Verification of safe diagnosability of stochastic discrete-event systems**
  Authors: Fuchun Liu ; Pengbiao Yang ; Rui Zhao ; Zbigniew Dziong
  Abstract: Safe diagnosability of discrete-event systems (DESs) is viewed as the first necessary step of fault-tolerant supervision in the literature. For safe diagnosable systems, it is required that not only failures occurring in systems can be detected within a finite delay, but also the detection should be completed before running any unsafe operation. In this paper, we present a novel approach to deal with the safe diagnosis issue for stochastic DESs by constructing a nondeterministic automaton called the safe verifier, and the necessary and sufficient condition for safe diagnosability of stochastic DESs is presented. It is worth noting that the proposed approach has lower complexity than the existing approach based on safe diagnoser as far as the number of states.

- **Response time evaluation of industrial-scale distributed control systems by discrete event systems formalisms**
  Authors: Ouail Himrane ; Alain Ourghanlian ; Saïd Amari
  Abstract: This research deals with the temporal performance analysis of distributed networked automation systems. It describes a new formal approach that estimates the maximum limit of response time in Networked Control Systems (NCS) that use a producer/consumer protocol. Two different tools of discrete event systems have been used: Timed Event Graphs (TEGs) and (Max,+) algebra. First, the contribution is to model all components of NCS with TEGs, and to represent the behaviour of these graphs by (Max,+) linear equations, and then to determine the upper bounds of the response time by an analytical formula. The main novelty of these results is to introduce a modular method capable of providing crucial validation elements regarding temporal performances for an industrial scale NCS that includes inter CPU communication. Moreover, the modular aspect of the presented approach remains in considering the end-to-end delays introduced by the network as model parameters, calculated from other models.

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1.4. IEEE Transactions on Automation Science and Engineering

Volume: 19, Issue: 1, January 2022

- **Scheduling Robotic Cellular Manufacturing Systems With Timed Petri Net, A* Search, and Admissible Heuristic Function**
  Authors: Bo Huang ; MengChu Zhou ; Abdullah Abusorrah ; Khaled Sedraoui
  Abstract: System scheduling is a decision-making process that plays an important role in improving the performance of robotic cellular manufacturing (RCM) systems. Timed Petri nets (PNs) are a formalism suitable for graphically and concisely modeling such systems and obtaining their reachable state graphs. Within their reachability graphs, timed PNs' evolution and intelligent search algorithms can be combined to find an efficient operation sequence from an initial state to a goal one for the underlying systems of the nets. To schedule RCM systems, this work proposes an A* search with a new heuristic function based on timed PNs. When compared with related approaches, the proposed one can deal with token remaining time, weighted arcs, and multiple resource copies commonly seen in the PN models of RCM systems. The admissibility of the proposed heuristic function is proved. Finally, experimental results are given to show the effectiveness and efficiency of the proposed method and heuristic function.

- **Heuristic Scheduling of Batch Production Processes Based on Petri Nets and Iterated Greedy Algorithm**
  Authors: Ziyan Zhao ; Shixin Liu ; Mengchu Zhou; Dan You ; Xiwang Guo
  Abstract: Wire rod and bar rolling is an important batch production process in steel production systems. A scheduling problem originated from this process is studied in this work by considering the constraints on sequence-dependent family setup time and release time. For each serial batch to be scheduled, it contains several jobs and the number of late jobs within it varies with its start time. First, we model a rolling process using a Petri net (PN), where a so-called rolling transition describes a rolling operation of a batch. The objective of the concerned problem is to determine a firing sequence of all rolling transitions such that the total number of late jobs is minimal. Next, a mixed-integer linear program is formulated based on the PN model. Due to the NP-hardness of the concerned problem, iterated greedy algorithm (IGA)-based methods by using different neighborhood structures and integrating a variable neighborhood descent method are developed to obtain its near-optimal solutions. To test the accuracy, speed, and stability of the proposed algorithms, we compare their solutions of different-size instances with those of CPLEX (a commercial software) and four heuristic peers. The results indicate that the proposed algorithms outperform their peers and have great potential to be applied to industrial production process scheduling.
- **Secure Recovery Procedure for Manufacturing Systems Using Synchronizing Automata and Supervisory Control Theory**
  Authors: Lucas V. R. Alves ; Patrícia N. Pena
  Abstract: Manufacturing systems may be subject to external attacks and failures, so it is important to deal with the recovery of the system after these situations. This article deals with the problem of recovering a manufacturing system, modeled as a discrete event system (DES) using the supervisory control theory (SCT), when the control structure, called supervisor, desynchronizes from the physical plant. The desynchronization may be seen as plant and supervisor being in uncorresponding states. The recovery of the system may be attained if there is a word, the synchronizing word, that regardless the state of each one of them, brings the system and supervisor back to a known state. The concepts of synchronizing automata are used to do so. In this article, we show under what conditions a set of synchronizing plants and specifications leads to a synchronizing supervisor obtained by the SCT. The problem is extended to cope with multiple supervisors, proposing a local recovery when possible. We also present a simple way to model problems, composed of machines and buffers, as synchronizing automata such that it is always possible do restore synchronization between the control (supervisor) and the plant.

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1.5. IEEE/CAA Journal of Automatica Sinica

Volume: 9, Issue: 2, February 2022

- **Computation of Minimal Siphons in Petri Nets Using Problem Partitioning Approaches**
  Authors: Dan You ; Oussama Karoui ; Shouguang Wang
  Abstract: A large amount of research has shown the vitality of siphon enumeration in the analysis and control of deadlocks in various resource-allocation systems modeled by Petri nets (PNs). In this paper, we propose an algorithm for the enumeration of minimal siphons in PN based on problem decomposition. The proposed algorithm is an improved version of the global partitioning minimal-siphon enumeration (GPMSE) proposed by Cordone et al. (2005) in IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, which is widely used in the literature to compute minimal siphons. The experimental results show that the proposed algorithm consumes lower computational time and memory compared with GPMSE, which becomes more evident when the size of the handled net grows.

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2 Conferences

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

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

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

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

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

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

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

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

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

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3 Books

3.1 Analysis and Control for Resilience of Discrete Event Systems

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

Description: System resilience captures the ability of the system to withstand a major disruption within acceptable performance degradation and to recover within an acceptable time frame. In this monograph we consider two possible sources of major disruptions, i.e., component faults and cyber intrusions. A component fault is an indigenous activity that renders unavailability or inaccessibility of certain functions within a component, either permanently or temporarily. It typically generates safety and performance concerns. Cyber intrusion on the other hand is an exogenous activity that tampers privacy, confidentiality, availability, or integrity of the system. These two sources are not always independent from each other. For example, a cyber intrusion may trigger a component fault, whereas a component fault may open a door for cyber intrusion, e.g., by keeping it undetected. For cyber intrusion, we will focus on opacity, which describes the system's ability to hide certain secrets from an external observer (or eavesdropper), and sensor and actuator attacks that exploit the system's 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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4 Call for Papers

4.1 Advanced Robotics: Special Issue on Control Technology for Networked and Distributed Robotics

Guest Editors:

- Prof. Masaaki Nagahara (The University of Kitakyushu, Japan)
- Prof. Kai Cai (Osaka City University, Japan)
- Prof. Takeshi Hatanaka (Tokyo Institute of Technology, Japan)
- Prof. Yutaka Hori (Keio University, Japan)
- Prof. Hideaki Ishii (Tokyo Institute of Technology, Japan)

Lead Guest Editor

- Prof. Debasish Chatterjee (Indian Institute of Technology Bombay, India)
- Prof. Nikhil Chopra (The University of Maryland, USA)
- Prof. Daniel E. Quevedo (Queensland University of Technology, Australia)
- Prof. Michel Reniers (Eindhoven University of Technology, Netherlands)

Publication in Vol. 37, Issue 1 (January 2023)

Submission deadline: 28 February 2022

Control technology is one of the fundamental disciplines of robotics. The technology has been developed for more than 100 years and expanded in many research areas. In particular, control technology for networked and distributed robotics has been recently emerging thanks to the development of embedded systems and wireless communications. An example of networked and distributed robotics is a drone light show, which was presented in the opening ceremony of Tokyo Olympic Games 2020, where multiple drones are operated from the main computer located on the ground that controls multiple drones through wireless networks. The purpose of this special issue is to present recent theory and practice of control technology that can be effectively applied to networked and distributed robotics. It aims at collecting a representative body of innovative theoretical contributions that have potential applications to networked and distributed robotics as well as applicative robotics researches that show successful implementation of recent theory of networked and distributed control. Prospective contributed papers are invited to cover, but are not limited to, theoretical and applicative researches on the following topics

- control of multi-agent systems (e.g. consensus control, coverage control, formation)
- networked control systems
- discrete-event systems and hybrid systems
- resource-aware control (e.g. event-triggered control, sparse control)
- secure, resilient, and safe control
- machine learning and data driven methods for networked robotics
- human-in-the-loop and human-machine interaction

The full-length manuscript (either PDF or Microsoft Word file) should be sent to the office of Advanced Robotics, Robotics Society of Japan, through its homepage at: https://www.rsj.or.jp/pub/ar/submission.html. Templates for the manuscript as well as instructions for the Authors are available at the homepage.

Further information will be provided via the following website: (to be opened soon)

5 Software Tools

5.1 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.

5.2 Supremica 2.7, New Version

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

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

New in this version:

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

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

5.3 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.

5.4 DESpot 1.10.0 Released

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

DESpot 1.10.0 supports a number of new Features:

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

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

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

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

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