IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **June 2020**

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Welcome to the 2020 June 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: 65, Issue: 6, June 2020

- **Optimal Secure Control With Linear Temporal Logic Constraints**
  Authors: Luyao Niu ; Andrew Clark
  Abstract: Prior work on automatic control synthesis for cyber-physical systems under logical constraints has primarily focused on environmental disturbances or modeling uncertainties, however, the impact of deliberate and malicious attacks has been less studied. In this paper, we consider a discrete-time dynamical system with a linear temporal logic (LTL) constraint in the presence of an adversary, which is modeled as a stochastic game. We assume that the adversary observes the control policy before choosing an attack strategy. We investigate two problems. In the first problem, we synthesize a robust control policy for the stochastic game that maximizes the probability of satisfying the LTL constraint. A value iteration based algorithm is proposed to compute the optimal control policy. In the second problem, we focus on a subclass of LTL constraints, which consist of an arbitrary LTL formula and an invariant constraint. We then investigate the problem of computing a control policy that minimizes the expected number of invariant constraint violations while maximizing the probability of satisfying the arbitrary LTL constraint. We characterize the optimality condition for the desired control policy. A policy iteration based algorithm is proposed to compute the control policy. We illustrate the proposed approaches using two numerical case studies.
- **Random Directions Stochastic Approximation With Deterministic Perturbations**
  Authors: Prashanth L. A. ; Shalabh Bhatnagar ; Nirav Bhavsar ; Michael Fu ; Steven I. Marcus
  Abstract: We introduce deterministic perturbation (DP) schemes for the recently proposed random directions stochastic approximation, and propose new first-order and second-order algorithms. In the latter case, these are the first second-order algorithms to incorporate DPs. We show that the gradient and/or Hessian estimates in the resulting algorithms with DPs are asymptotically unbiased, so that the algorithms are provably convergent. Furthermore, we derive convergence rates to establish the superiority of the first-order and second-order algorithms, for the special case of a convex and quadratic optimization problem, respectively. Numerical experiments are used to validate the theoretical results.
- **Steady State Analysis of Flexible Nets**
  Authors: Jorge Julvez ; Stephen G Oliver
  Abstract: The modeling and analysis of complex dynamic systems, such as those in manufacturing, logistics, and biology, require powerful analysis methods for their study and optimization. A significant modeling and analysis challenge posed by both, artificial and natural systems, is the existence of uncertain parameters. Flexible Nets (FNs) is a novel modeling formalism, inspired by Petri nets, that can handle different types of uncertain parameters in a natural way. This paper develops an efficient method to analyse the evolution of a system modeled by an FN in the long run. More precisely, the method focuses on the computation of steady state bounds for an objective function of interest. The method makes use of a set of constraints, expressed as linear inequalities, that the state variables must satisfy in the steady state. In order to account for systems that do not reach a constant steady state, the developed constraints allow the system state to switch among different values, i.e., the steady state variables are not forced to be constant.
- **Stochastic Control Framework for Determining Feasible Alternatives in Sampling Allocation**
  Authors: Yijie Peng ; Jie Song ; Jie Xu ; Edwin K. P. Chong
  Abstract: We formulate the optimal dynamic sampling allocation decision problem for feasibility determination as a stochastic control problem in a Bayesian setting. This new formulation addresses the limitations of previous static optimization formulations. In an approximate dynamic programming paradigm, we propose an approximately optimal allocation policy that maximizes a

single feature of the value function one step ahead. Numerical results demonstrate the efficiency of the proposed method.

- **Computation of Admissible Marking Sets in Weighted Synchronization-Free Petri Nets by Dynamic Programming**
  Authors: Ziyue Ma ; Guanghui Zhu ; Zhiwu Li ; Alessandro Giua
  Abstract: We study the computation of admissible marking sets in generalized Petri nets. We first show that the admissibility checking in the generalized Petri net is NP-hard. Then, we consider a special subclass of generalized Petri nets called weighted-synchronization-free nets in which each transition has at most one input place. For a net in this subclass, we propose a generating function to compute by dynamic programming the set of admissible markings for a given generalized mutual exclusion constraint.

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1.2. Automatica

Volume: 116 June 2020

- **Current-state opacity modelling and verification in partially observed Petri nets**
  Authors: Ikram Saadaoui ; Zhiwu Li ; Naiqi Wu
  Abstract: System opacity is a widely studied security notion, implying that a secret behaviour of a given system cannot be seen or assessed by an external observer based on the system evolution. This work deals with the problem of current-state opacity formulation and verification in the context of discrete event systems modelled with partially observed Petri nets (POPNs) (i.e., Petri nets containing place sensors that measure the number of tokens in observable places and event sensors that indicate the firing of observable transitions). A Petri net system is recognized as current-state opaque if the current-state estimate is never entirely contained in the set of secret states. In this regard, we introduce the notion of discernible markings to design a reduced state estimator called a discernible reachability graph, and then come up with formal modelling of current-state opacity in POPN systems. The main idea of the proposed approach consists in proving that if a system is current-state opaque, its current-state estimate, possibly established by an intruder, contains at least one non-secret state. We exploit the mathematical feasibility to formulate this concept by defining and solving an integer linear programming problem with respect to a given secret and an observation sequence collected from sensors. In the light of the proposed modelling, necessary and sufficient conditions are proposed for opacity verification, and examples are given to expose the results.

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1.3. IEEE Control Systems Letters

Volume: 4, Issue: 3, July 2020

- **On-Line Permissive Supervisory Control of Discrete Event Systems for scLTL Specifications**
  Authors: Ami Sakakibara ; Toshimitsu Ushio
  Abstract: We propose an on-line supervisory control scheme for discrete event systems (DESs), where a control specification is described by a fragment of linear temporal logic. On the product automaton of the DES and an acceptor for the specification, we define a ranking function that returns the minimum number of steps required to reach an accepting state from each state. In addition, we introduce a permissiveness function that indicates a time-varying permissive level. At each step during the on-line control scheme, the supervisor refers to the permissiveness function as well as the ranking function in order to guarantee the control specification while handling the tradeoff between its permissiveness and acceptance of the specification. The proposed scheme is demonstrated in a surveillance problem for a mobile robot.
- **Fault-Tolerant Control of Discrete-Event Systems With Controllability Failures**
  Authors: Arun Raman ; R. S. Sreenivas

Abstract: A supervisory policy controls a Discrete-Event System (DES) by appropriately disabling a subset of events, known as controllable events , based on the observed event string generated by the supervised DES thus far. We consider supervisory control of DES in the presence of an extraneous fault that renders an arbitrary subset of controllable events to be temporarily uncontrollable. The fault is detected at the first occurrence of a controllable event that was disabled by the supervisor. It is rectified after finitely-many such unintended occurrences of controllable events following which the supervisor regains control of all controllable events and can prevent them from occurring when deemed necessary. We present a necessary and sufficient condition for the existence of a supervisor that enforces a desired language specification in the paradigm of Ramadge and Wonham, under the fault semantics described above. We also prove that such a supervisor, if it exists, can always be synthesized if the language of the plant and the specification is regular.

- **Reinforcement Learning of Control Policy for Linear Temporal Logic Specifications Using Limit-Deterministic Generalized Buchi Automata**
  Authors: Ryohei Oura ; Ami Sakakibara ; Toshimitsu Ushio
  Abstract: This letter proposes a novel reinforcement learning method for the synthesis of a control policy satisfying a control specification described by a linear temporal logic formula. We assume that the controlled system is modeled by a Markov decision process (MDP). We convert the specification to a limit-deterministic generalized Buchi automaton (LDGBA) with several accepting sets that accepts all infinite sequences satisfying the formula. The LDGBA is augmented so that it explicitly records the previous visits to accepting sets. We take a product of the augmented LDGBA and the MDP, based on which we define a reward function. The agent gets rewards whenever state transitions are in an accepting set that has not been visited for a certain number of steps. Consequently, sparsity of rewards is relaxed and optimal circulations among the accepting sets are learned. We show that the proposed method can learn an optimal policy when the discount factor is sufficiently close to one.
- **Max-Plus Linear Approximations for Deterministic Continuous-State Markov Decision Processes**
  Authors: Eloise Berthier ; Francis Bach
  Abstract: We consider deterministic continuous-state Markov decision processes (MDPs). We apply a max-plus linear method to approximate the value function with a specific dictionary of functions that leads to an adequate state-discretization of the MDP. This is more efficient than a direct discretization of the state space, typically intractable in high dimension. We propose a simple strategy to adapt the discretization to a problem instance, thus mitigating the curse of dimensionality. We provide numerical examples showing that the method works well on simple MDPs.
- **Event-Based Control for Online Training of Neural Networks**
  Authors: Zilong Zhao ; Sophie Cerf ; Bogdan Robu ; Nicolas Marchand
  Abstract: Wtasks. During its training the learning rate and the gradient are two key factors to tune for influencing the convergence speed of the model. Usual learning rate strategies are time-based, i.e., monotonous decay over time. Recent state-of-the-art techniques focus on adaptive gradient algorithms, i.e., Adam and its versions. In this letter we consider an online learning scenario and we propose two Event-Based control loops to adjust the learning rate of a classical algorithm E (Exponential)/PD (Proportional Derivative)-Control. The first Event-Based control loop will be implemented to prevent sudden drop of the learning rate when the model is approaching the optimum. The second Event-Based control loop will decide, based on the learning speed, when to switch to the next data batch. Experimental evaluation is provided using two state-of-the-art machine learning image datasets (CIFAR-10 and CIFAR-100). Results show the Event-Based E/PD is better than the original algorithm (higher final accuracy, lower final loss value), and the Double-Event-Based E/PD can accelerate the training process, save up to 67% training time compared to state-of-the-art algorithms and even result in better performance.

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

Volume: 50, Issue: 6, June 2020

- **Analysis of Unbounded Petri Net With Lean Reachability Trees**
  Authors: Jun Li ; Xiaolong Yu ; MengChu Zhou
  Abstract: At present, no efficient method is proposed for the liveness analysis of general unbounded Petri nets (UPNs) except some of their subclasses. Our previous work presents a non-Karp-Miller finite reachability tree, i.e., lean reachability tree (LRT) to represent their markings. It faithfully expresses and folds the reachability set of an unbounded net. It can totally avoid the efforts made by the existing modified Karp-Miller trees on the expression of potentially unbounded nodes and elimination of all fake markings. By exploiting it, this paper presents a method for comprehensively analyzing the properties of general UPNs. Particularly, we reveal the repeatability of deadlock with the unfolding of some unbounded leaves in LRT and present a sufficient and necessary condition of deadlock existence. Then, LRT and some partial trees generated from it, instead of entire reachability graphs, are utilized to analyze the liveness and reversibility of general UPNs rather than some special ones. The related theoretical results are proven. A unified algorithm based on LRT for analysis of boundedness, liveness, deadlock, and reversibility of general UPNs is developed for the first time. The results of a case study show that the presented method is effective for general UPNs.
- **Exploiting Symmetry of Discrete-Event Systems by Relabeling and Reconfiguration**
  Authors: Ting Jiao ; Yongmei Gan ; Guochun Xiao ; W. M. Wonham
  Abstract: Symmetric discrete-event systems (DESs) are composed of groups of identical components (machines) and buffers. As every component in each group has the same structure, they can be relabeled to a prototype machine. With respect to buffer specifications (prohibiting overflow and underflow) it is shown that optimal supervisory control of the original DES (with many machines) can be reduced to control of the much smaller collection of prototype machines. With buffer sizes fixed, the result is a small invariant supervisor which is independent of the total number of original machines. We analyze the underlying reason for this invariance property and apply the result of the invariant reduced supervisor to efficient reconfiguration triggered by the addition or removal of machines and increase or decrease of the buffer capacity.
- **Control Design for Bounded Partially Controlled TPNs Using Timed Extended Reachability Graphs and MDP**
  Authors: Dimitri Lefebvre ; Cherki Daoui
  Abstract: This paper is about the design of control sequences for discrete event systems (DESs) modeled with bounded partially controlled timed Petri nets (PC-TPNs) including a set of temporal specifications that correspond to minimal firing durations. Petri nets are well-known mathematical and graphical models that are widely used to describe distributed DESs, including choices, synchronizations, and parallelisms. The domains of application include but are not restricted to manufacturing systems, computer science, and transportation networks. Including the time in the model is important to consider many control problems. This paper is more particularly concerned with control issues in timed context and uncertain environments when unexpected events occur and when control errors disturb the system behavior from the planned policy decided by the controller. To deal with such uncertainties, we propose first to build a timed extended reachability graph (TERG) that includes the time specifications when the PC-TPN behaves with an earliest firing policy. Then, the optimal paths in TERG are found by using an approach based on discrete time Markov decision processes under discounted criterion. Several simulations illustrate the benefit of our method from the computational point of view, in particular for uncertain environments.

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1.5. IEEE/CAA Journal of Automatica Sinica

Volume: 7, Issue: 3, May 2020

- **Scheduling dual-arm cluster tools with multiple wafer types and residency time constraints**
  Authors: Jipeng Wang ; Hesuan Hu ; Chunrong Pan ; Yuan Zhou ; Liang Li

Abstract: Accompanying the unceasing progress of integrated circuit manufacturing technology, the mainstream production mode of current semiconductor wafer fabrication is featured with multi-variety, small batch, and individual customization, which poses a huge challenge to the scheduling of cluster tools with single-wafer-type fabrication. Concurrently processing multiple wafer types in cluster tools, as a novel production pattern, has drawn increasing attention from industry to academia, whereas the corresponding research remains insufficient. This paper investigates the scheduling problems of dual-arm cluster tools with multiple wafer types and residency time constraints. To pursue an easy-to-implement cyclic operation under diverse flow patterns, we develop a novel robot activity strategy called multiplex swap sequence. In the light of the virtual module technology, the workloads that stem from bottleneck process steps and asymmetrical process configuration are balanced satisfactorily. Moreover, several sufficient and necessary conditions with closed-form expressions are obtained for checking the system's schedulability. Finally, efficient algorithms with polynomial complexity are developed to find the periodic scheduling, and its practicability and availability are demonstrated by the offered illustrative examples.

- **Robust deadlock avoidance policy for automated manufacturing system with multiple unreliable resources**

  Authors: Jianchao Luo ; Zhiqiang Liu ; Shuogang Wang ; Keyi Xing

  Abstract: This work studies the robust deadlock control of automated manufacturing systems with multiple unreliable resources. Our goal is to ensure the continuous production of the jobs that only require reliable resources. To reach this goal, we propose a new modified Banker's algorithm (MBA) to ensure that all resources required by these jobs can be freed. Moreover, a Petri net based deadlock avoidance policy (DAP) is introduced to ensure that all jobs remaining in the system after executing the new MBA can complete their processing smoothly when their required unreliable resources are operational. The new MBA together with the DAP forms a new DAP that is robust to the failures of unreliable resources. Owing to the high permissiveness of the new MBA and the optimality of the DAP, it is tested to be more permissive than state-of-the-art control policies.

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2 Conferences

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

2.1 **2020 International Workshop on Discrete Event Systems**
Rio de Janeiro, Brazil, June 13-15, 2020 (Postponed)
https://wodes2020.eventos.ufrj.br https://codit2020.com

2.2 **2020 American Control Conference**
Denver, Colorado, USA, July 1-3, 2020 (Virtual)
http://acc2020.a2c2.org

2.3 **2020 IEEE International Conference on Control & Automation**
Sapporo, Hokkaido, Japan, July 6-9, 2020 (Postponed)
http://www.ieee-icca.org

2.4 **2020 IFAC World Congress**
Berlin, Germany, July 12-17, 2020 (Virtual)
https://www.ifac2020.org

2.5 **2020 IEEE Conference on Automation Science and Engineering**
Hong Kong, China, August 20-24, 2020
https://www.imse.hku.hk/case2020

2.6 **2020 IEEE Conference on Control Technology and Applications**
Montréal, Canada, August 24-26, 2020
https://ccta2020.ieeecss.org

2.7 **2020 IEEE Conference on Decision and Control**
Jeju Island, Republic of Korea, December 8-11, 2020
https://cdc2020.ieeecss.org

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3 Books

3.1 **Estimation and Inference in Discrete Event Systems — A Model-Based Approach with Finite Automata**

Author: Christoforos N. Hadjicostis

Description: Estimation and Inference in Discrete Event Systems chooses a popular model for emerging automation systems—finite automata under partial observation—and focuses on a comprehensive study of the key problems of state estimation and event inference. The text includes treatment of current, delayed, and initial state estimation. Related applications for assessing and enforcing resiliency—fault detection and diagnosis—and security—privacy and opacity—properties are discussed, enabling the reader to apply these techniques in a variety of emerging applications, among them automated manufacturing processes, intelligent vehicle/highway systems, and autonomous vehicles.

The book provides a systematic development of recursive algorithms for state estimation and event inference. The author also deals with the verification of pertinent properties such as:
• the ability to determine the exact state of a system, "detectability";
• the ability to ensure that certain classes of faults can be detected/identified, "diagnosability"; and
• the ability to ensure that certain internal state variables of the system remain "hidden" from the outside world regardless of the type of activity that is taking place, "opacity".
This book allows students, researchers and practicing engineers alike to grasp basic aspects of state estimation in discrete event systems, aspects like distributivity and probabilistic inference, quickly and without having to master the entire breadth of models that are available in the literature.

More details: https://www.springer.com/gp/book/9783030308209

3.2 **Path Planning and Control of Cooperative Mobile Robots Using Discrete Event Models**

Authors: Cristian Mahulea, Marius Kloetzer, Ramon Gonzalez
ISBN: 978-1-119-48632-9, January 2020, Wiley-IEEE Press, 240 Pages
https://bit.ly/2MYphKe

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4 Call for Papers

4.1 PID Control for Discrete-Event, Switched, and Hybrid Systems

International Journal of Robust and Nonlinear Control

Guest Editors: Dan Ma ; Silviu-Iulian Niculescu ; Lei Guo ; Jie Chen

Call for Papers: This special issue seeks to respond to the recent trends of PID control and aims to report recent analytical studies and practical applications, with a focus on the robustness, performance, optimization and analytical design. All theoretical and practical aspects central to this theme will be of interest. Particularly welcomed is the latest progress of PID control to emerging problem areas such as hybrid, event-triggered control, networked and multi-agent control, to new control design methods such as data-driven design, model predictive control, and machine learning design, for new technological advances such as cyber-physical systems, cloud-based control, and to broad application areas such as biological systems, smart grid, and micro/nano-scale networks on chip. Potential topics include, but are not limited to the following:

- Robustness and fragility of PID control
- Performance and optimization of PID controllers
- Structural and improved PID control
- PID control for nonlinear systems
- PID control for distributed parameter systems
- PID control for discrete-event, switched, and hybrid systems
- Sampled-data/event-triggered PID control
- Distributed PID control over networks
- PID control design by data-driven methods
- PID control design by machine learning methods
- Applications of PID control

Prospective authors are invited to submit manuscripts prepared as per the International Journal of Robust and Nonlinear Control guidelines, no later than December 1, 2020. Manuscripts should be submitted electronically online at: https://mc.manuscriptcentral.com/rnc-wiley. For inquiries, authors June contact one of the four guest editors below.

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5 Software Tool

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.

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