IEEE CONTROL SYSTEMS SOCIETY TECHNICAL COMMITTEE ON DISCRETE EVENT SYSTEMS

Newsletter..... June 2018

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Contents:


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## Editorial

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Welcome to the newsletter of the IEEE Control Systems Technical Committee on Discrete Event Systems!

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## Activities

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### 2.1 Sponsored Activities

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2018 American Control Conference
Milwaukee, Wisconsin, United States, June 27–29, 2018
http://acc2018.a2c2.org/

2018 Conference on Control Technology and Applications
Copenhagen, Denmark, August 21-24, 2018
http://ccta2018.ieeecss.org/

2018 Conference on Decision and Control
Miami Beach, FL, USA, December 17-19, 2018
https://cdc2018.ieeecss.org/

### 2.2 Technically Co-Sponsored activities

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2018 SICE International Symposium on Control Systems
Tokyo, Japan, March 9-11, 2018
http://iscs2018.sice-ctrl.jp/

The 14th Workshop on Discrete Event Systems
Sorrento Coast, Italy, May 30 - June 1, 2018
http://wodes2018.unisa.it/

30th Chinese Control and Decision Conference (2018 CCDC)
Shenyang, China, June 9-11, 2018

http://www.ccdc.neu.edu.cn/

2018 International Conference on Unmanned Aircraft Systems
Dallas, TX, USA, June 12-15, 2018
http://www.uasconferences.com/

37th Chinese Control Conference (CCC2018)
Wuhan, China, July 25-27, 2018
http://ccc2018.cug.edu.cn/

23rd International Conference on Methods and Models in Automation and Robotics
Międzyzdroje, Poland, August 27-30, 2018
http://mmar.edu.pl/

22nd International Conference on System Theory, Control and Computing
Sinaia, Romania, October 10-12, 2018
http://www.icstcc.ugal.ro/2018/

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## Selections of Journal Publications

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

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SELECTIONS OF THE IEEE TRANSACTIONS ON AUTOMATIC CONTROL
VOLUME: 63 ISSUE: 6
June 2018

(1) Verification of Prognosability for Labeled Petri Nets

Author: Xiang Yin

Abstract

This technical note is concerned with the fault prognosis problem for partially observed discrete-event systems modeled by unbounded labeled Petri nets. The goal of this problem is to predict

the occurrence of each fault before its occurrence. The condition of prognosability provides the necessary and sufficient condition under which any fault can be predicted with no missed detection and no false alarm. In this technical note, we investigate the verification of prognosability for unbounded labeled Petri nets. First, we show that checking prognosability is decidable for Petri net languages. Our approach is based on a reduction from this verification problem to an existing Petri nets model checking problem. Then, we show that the complexity of this problem is EXPSPACE-complete. Our results extend previous works on the verification of language-based prognosability from regular languages to Petri net languages.

Full-text available at: https://ieeexplore.ieee.org/document/8049408/

(2) Observability of Finite Labeled Transition Systems

Author: Kuize Zhang ; Ting Liu ; Daizhan Cheng

Abstract

Finite labeled transition systems are nondeterministic and nontotal systems with finitely many inputs, states, and outputs. This paper provides algorithms for verifying the observability of finite labeled transition systems in the so-called multiple-experiment case, the simple-experiment case, and the arbitrary-experiment case, respectively, where these algorithms run in exponential time, exponential time, and quartic polynomial time, respectively, and are more effective than the existing algorithms in the literature.

Full-text available at: https://ieeexplore.ieee.org/document/8025800/

(3) Finite Horizon Tracking Control of Boolean Control Networks

Author: Zhihua Zhang ; Thomas Leifeld ; Ping Zhang

Abstract

In this paper, we propose an approach to design tracking controllers for Boolean control networks to track a time-varying reference output trajectory of finite length by applying the semitensor product method. First, we give necessary and sufficient conditions for the trackability of the reference output trajectory. Second, in the case of a trackable output trajectory, one control sequence that realizes exact tracking can be found directly by means of backward selection. Otherwise, ℓ4 and ℓ∞ optimization problems can be formulated to find the control sequence that minimizes the tracking error. These optimization problems can be extended to take changes in control inputs into account. An additional advantage of the proposed approaches is that state, transition, and input constraints can be easily taken into account during the design of the controllers. Finally, illustrative example is given to demonstrate the proposed approaches.

Full-text available at: https://ieeexplore.ieee.org/document/8047259/

(4) Extremum Cycle Times in Time Interval Models

Author: Philippe Declerck

Abstract

In this paper, we analyze the 1-periodic schedule of a class of time interval models under the form of a polyhedron which can describe Timed Event Graphs and P-time Event Graphs. Using the duality and Stiemke's theorem, the main contribution is the determination of conditions where the extremum cycle times are finite and characteristic of a class of models.

Full-text available at: https://ieeexplore.ieee.org/document/8052174/

(5) Compositional Abstraction and Safety Synthesis Using Overlapping Symbolic Models

Author: Pierre-Jean Meyer ; Antoine Girard ; Emmanuel Witrant

Abstract

In this paper, we develop a compositional approach to abstraction and safety synthesis for a general class of discrete-time nonlinear systems. Our approach makes it possible to define a symbolic abstraction by composing a set of symbolic subsystems that are overlapping in the sense that they can share some common state variables. We develop compositional safety synthesis techniques using such overlapping symbolic subsystems. Comparisons, in terms of conservativeness and of computational complexity, between abstractions and controllers obtained from different system decompositions are provided. Numerical experiments show that the proposed approach for symbolic control synthesis enables a significant complexity reduction with respect to the centralized approach, while reducing the conservatism with respect to compositional approaches using nonoverlapping subsystems.

Full-text available at: https://ieeexplore.ieee.org/document/8038845/

(6) Toward Event-Triggered Extended State Observer

Author: Yuan Huang ; Junzheng Wang ; Dawei Shi ; Ling Shi

Abstract

In this note, we consider event-triggered extended state observer (ET-ESO) design for a continuous-time nonlinear system with uncertainty and disturbance. Since the convergence of the ET-ESO depends on the design of the triggering condition directly, the goal is to design a realizable triggering condition not relying on the state of the plant. For the extended state

observer considered, an event-triggered transmission strategy is proposed such that the observation error is uniformly bounded. Furthermore, under mild conditions, the observation error can be guaranteed to be bounded at any time. It is shown that there is no Zeno behavior for the event-based transmission strategy. The obtained theoretical results are validated through numerical simulations.

Full-text available at: https://ieeexplore.ieee.org/document/8046022/

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SELECTIONS OF AUTOMATICA
VOLUME: 92
June 2018

(1) Stochastic stability in Max-Product and Max-Plus Systems with Markovian Jumps

Author: Ioannis Kordonis, Petros Maragos, George P. Papavassilopoulos

Abstract

We study Max-Product and Max-Plus Systems with Markovian Jumps and focus on stochastic stability problems. At first, a Lyapunov function is derived for the asymptotically stable deterministic Max-Product Systems. This Lyapunov function is then adjusted to derive sufficient conditions for the stochastic stability of Max-Product systems with Markovian Jumps. Many step Lyapunov functions are then used to derive necessary and sufficient conditions for stochastic stability. The results for the Max-Product systems are then applied to Max-Plus systems with Markovian Jumps, using an isomorphism and almost sure bounds for the asymptotic behavior of the state are obtained. A numerical example illustrating the application of the stability results on a production system is also given.

Full-text available at: https://www.sciencedirect.com/science/article/pii/S0005109818300888

(2) Minimal controllability of conjunctive Boolean networks is NP-complete

Author: Eyal Weiss, Michael Margaliot, Guy Even

Abstract

Given a conjunctive Boolean network (CBN) with state-variables, we consider the problem of finding a minimal set of state-variables to directly affect with an input so that the resulting conjunctive Boolean control network (CBCN) is controllable. We give a necessary and sufficient condition for controllability of a CBCN; an -time algorithm for testing controllability; and prove

that nonetheless the minimal controllability problem for CBNs is NP-hard.

Full-text available at: https://www.sciencedirect.com/science/article/pii/S0005109818300748

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SELECTIONS OF DISCRETE EVENT DYNAMIC SYSTEMS: THEORY AND APPLICATIONS
VOLUME: 28 ISSUE: 2 (Special Issue on Diagnosis, Opacity and Supervisory Control of Discrete Event Systems)
June 2018

(1) Current-state opacity enforcement in discrete event systems under incomparable observations

Author: Yin Tong, Zhiwu Li, Carla Seatzu, Alessandro Giua

Abstract

In this paper we tackle the opacity enforcement problem in discrete event systems using supervisory control theory. In particular, we consider the case where the intruder and the supervisor may observe different sets of events and neither of these sets needs to be contained in the other one. Moreover, there may be controllable events that cannot be observed by the supervisor. We propose a finite structure, called an augmented I-observer, to characterize the strings that will not leak the secret. Based on such a structure, a locally optimal supervisor enforcing current-state opacity is designed.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0264-7

(2) Diagnosability of repairable faults

Author: Eric Fabre, Loïc Hélouët, Engel Lefaucheux, Hervé Marchand

Abstract

The diagnosis problem for discrete event systems consists in deciding whether some fault event occurred or not in the system, given partial observations on the run of that system. Diagnosability checks whether a correct diagnosis can be issued in bounded time after a fault, for all faulty runs of that system. This problem appeared two decades ago and numerous facets of it have been explored, mostly for permanent faults. It is known for example that diagnosability of a system can be checked in polynomial time, while the construction of a diagnoser is exponential. The present paper examines the case of transient faults, that can appear and be

repaired. Diagnosability in this setting means that the occurrence of a fault should always be detected in bounded time, but also before the fault is repaired, in order to prepare for the detection of the next fault or to take corrective measures while they are needed. Checking this notion of diagnosability is proved to be PSPACE-complete. It is also shown that faults can be reliably counted provided the system is diagnosable for faults and for repairs.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0255-8

(3) Codiagnosability of networked discrete event systems subject to communication delays and intermittent loss of observation

Author: Carlos E. V. Nunes, Marcos V. Moreira, Marcos V. S. Alves, Lilian K. Carvalho, João Carlos Basilio

Abstract

Failure diagnosis is a crucial task in modern industrial systems, and several works in the literature address this problem by modeling the system as a Discrete-Event System (DES). Most of them assume perfect communication between sensors and diagnosers, i.e., no loss of observation of events, or event communication delays between the measurement sites and the diagnosers. However, industrial systems can be large and physically distributed, in which cases, communication networks are used to provide an efficient way to establish communication between devices. In diagnosis systems, the use of networks can introduce delays in the communication of event occurrences from measurement sites to the local diagnosers, leading to an incorrect observation of the order of occurrence of events generated by the system and, as a consequence, to an incorrect diagnosis decision by the local diagnoser. In this paper, we address the problem of decentralized diagnosis of networked Discrete-Event Systems subject to event communication delays, and we introduce the definition of network codiagnosability of the language generated by a DES subject to both event communication delays and intermittent loss of observation, and present necessary and sufficient conditions for a language to be network codiagnosable, for short. We also propose an algorithm to verify this property.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0265-6

(4) Faults prognosis using partially observed stochastic Petri-nets: an incremental approach

Author: Rabah Ammour, Edouard Leclercq, Eric Sanlaville, Dimitri Lefebvre

Abstract

This article deals with the problem of fault prognosis in stochastic discrete event systems. For that purpose, partially observed stochastic Petri nets are considered to model the system with its sensors. The model represents both healthy and faulty behaviors of the system. Our goal is, based on a timed measurement trajectory issued from the sensors, to compute the probability

that a fault will occur in a future time interval. To this end, a procedure based on an incremental algorithm is proposed to compute the set of consistent behaviors of the system. Based on the measurement dates, the probabilities of the consistent trajectories are evaluated and a state estimation is obtained as a consequence. From the set of possible current states and their probabilities, a method to evaluate the probability of future faults is developed using a probabilistic model. An example is presented to illustrate the results.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0252-y

(5) Characterizations and effective computation of supremal relatively observable sublanguages

Author: Kai Cai, Renyuan Zhang, W. M. Wonham

Abstract

Recently we proposed relative observability for supervisory control of discrete-event systems under partial observation. Relative observability is closed under set unions and hence there exists the supremal relatively observable sublanguage of a given language. In this paper we present a new characterization of relative observability, based on which an operator on languages is proposed whose largest fixpoint is the supremal relatively observable sublanguage. Iteratively applying this operator yields a monotone sequence of languages; exploiting the linguistic concept of support based on Nerode equivalence, we prove for regular languages that the sequence converges finitely to the supremal relatively observable sublanguage, and the operator is effectively computable. Moreover, for the purpose of control, we propose a second operator that in the regular case computes the supremal relatively observable and controllable sublanguage.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0250-0

(6) Probabilistic system opacity in discrete event systems

Author: Christoforos Keroglou, Christoforos N. Hadjicostis

Abstract

In many emerging security applications, a system designer frequently needs to ensure that a certain property of a given system (that may reveal important details about the system’s operation) be kept secret (opaque) to outside observers (eavesdroppers). Motivated by such applications, several researchers have formalized, analyzed, and described methods to verify notions of opacity in discrete event systems of interest. This paper introduces and analyzes a notion of opacity in systems that can be modeled as probabilistic finite automata or hidden Markov models. We consider a setting where a user needs to choose a specific hidden Markov model (HMM) out of m possible (different) HMMs, but would like to “hide” the true system from

eavesdroppers, by not allowing them to have an arbitrary level of confidence as to which system has been chosen. We describe necessary and sufficient conditions (that can be checked with polynomial complexity), under which the intruder cannot distinguish the true HMM, namely, the intruder cannot achieve a level of certainty about its decision, which is above a certain threshold that we can a priori compute.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0263-8

(7) Implementation of inference-based diagnosis: computing delay bound and ambiguity levels

Author: Shigemasa Takai, Ratnesh Kumar

Abstract

Inference-based decentralized diagnosis is a framework introduced in the authors' former work, where inferencing over the ambiguities of the self and the others is used to issue diagnosis decisions. The implementation of the framework requires the online computation of the ambiguity levels by each of the local decision makers, following each of their local observations. This in turn requires knowing the delay bound of diagnosis, which needs to be computed offline, prior to the online monitoring for fault detection. The paper presents the offline computation of the delay bound of diagnosis, along with a certain set of languages, which together aid the online computation of the ambiguity levels.

Full-text available at: https://link.springer.com/article/10.1007/s10626-017-0253-x

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SELECTIONS OF IEEE Transactions on Automation Science and Engineering
VOLUME: 15 ISSUE: 2
April 2018

(1) Automated Partitioning of Concurrent Discrete-Event Systems for Distributed Behavioral Identification

Author: Jeremie Saives ; Gregory Faraut ; Jean-Jacques Lesage

Abstract

The aim of behavioral identification of discrete-event systems is to build, from a sequence of observed inputs/outputs events, an understandable model that exhibits both the direct relations between inputs and outputs events (i.e., the observable behavior of the system) and the internal state evolutions (i.e., the unobservable behavior). Since parallelism hinders the construction of

monolithic models, distributed identification builds instead the models of subsystems. This paper proposes an automated partitioning of the system and optimal regarding the readability of the identified distributed models, thus fitting reverse-engineering purposes. To solve the optimization problem, a first solution is extracted from the observable behavior; then additional solutions are computed by agglomerative clustering. The approach is applied to a benchmark, resulting in an adequate functional partition.

Full-text available at: https://ieeexplore.ieee.org/document/7976383/

(2) Safety-Level Aware Bin-Packing Heuristic for Automatic Assignment of Power Plants Control Functions

Author: Mohamed Benazouz ; Jean-Marc Faure

Abstract

Finding a suitable set of controllers to which a large set of control functions with different safety levels can be assigned, while minimizing cost, is a significant task during the design of the operational control system of a critical process, such as a power plant. This task is currently performed by experts and extremely time-consuming, which explains why its automation is a real concern. This paper shows first that the above-mentioned assignment problem can be identified as a multiple-choice vector bin packing (BP) with conflicts problem, a combination of different variants of the well-known 1-D BP problem. Such a problem is known to be strongly NP-hard and exact techniques to solve it on large-sized examples are too time and/or space-consuming because of the combinatorial explosion. To solve this problem in polynomial time, this paper proposes a fast heuristic based on a first-fit decreasing approach. Two strategies to perform this heuristic and several criteria to rank the functions before assignment are defined. These strategies and criteria are then compared on the basis of numerous experiments. These experiments show that the proposed heuristic scales well and provides results that are very close to optimum; the difference in the worst case is less than 1%.

Full-text available at: https://ieeexplore.ieee.org/document/7855714/

(3) Automatic Segmentation of Stabilometric Signals Using Hidden Markov Model Regression

Author: Khaled Safi ; Samer Mohammed ; Ferhat Attal ; Yacine Amirat ; Latifa Oukhellou ; Mohamad Khalil ; Jean-Michel Gracies ; Emilie Hutin
Abstract

Posture analysis in quiet standing is an essential element in evaluating human balance control. Many factors enhance the human control system's ability to maintain stability, such as the visual system and base of support (feet) placement. In contrast, many neural pathologies, such as Parkinson's disease (PD) and cerebellar disorder, disturb human stability. This paper addresses

the problem of the automatic segmentation of stabilometric signals recorded under four different conditions related to vision and foot position. This is achieved for both control subjects and PD subjects. A hidden Markov model (HMM)regression-based approach is used to carry out the segmentation between the different conditions using simple and multiple regression processes. Twenty-eight control subjects and thirty-two PD subjects participated in this study. They were asked to stand upright while recording stabilometric signals in mediolateral and anteroposterior directions under two permutations: feet apart and together with eyes open or closed. The results show high values for the correct segmentation rates, up to 98%, for the separation between the different conditions. The present findings could help clinicians better understand the motor strategies used by the patients during their orthostatic postures and may guide the rehabilitation process. The proposed method compares favorably with standard segmentation approaches.

Full-text available at: https://ieeexplore.ieee.org/document/7839989/

(4) An Automated Methodology for Worker Path Generation and Safety Assessment in Construction Projects

Author: Md Mahbubur Rahman ; Leonardo Bobadilla ; Ali Mostafavi ; Triana Carmenate ; Sebastian A. Zanlongo

Abstract

Collisions between automated moving equipment and human workers in job sites are one of the main sources of fatalities and accidents during the execution of construction projects. In this paper, we present a methodology to identify and assess project plans in terms of hazards before their execution. Our methodology has the following steps: 1) several potential plans are extracted from an initial activity graph; 2) plans are translated from a high-level activity graph to a discrete-event simulation model; 3) trajectories and safety policies are generated that avoid static and moving obstacles using existing motion planning algorithms; 4) safety scores and risk-based heatmaps are calculated based on the trajectories of moving equipment; and 5) managerial implications are provided to select an acceptable plan with the aid of a sensitivity analysis of different factors (cost, resources, and deadlines) that affect the safety of a plan. Finally, we present illustrative case study examples to demonstrate the usefulness of our model.

Full-text available at: https://ieeexplore.ieee.org/document/7790844/

(5) Scheduling Single-Armed Cluster Tools With Chamber Cleaning Operations

Author: Tae-Sun Yu ; Hyun-Jung Kim ; Tae-Eog Lee

Abstract

As wafer circuit widths shrink down, wafer fabrication processes require stringent quality control.

Therefore, fabs recently tend to clean a chamber after processing each wafer, in order to remove chemical residuals within the chamber. Such chamber cleaning, called purge operation, increases scheduling complexity in robotized cluster tools. In this paper, we examine scheduling problems of single-armed cluster tools with purge operations for series-parallel chambers. By extending the wellknown backward sequence, we propose a backward(z) sequence that allows partial loading for parallel chambers, where vector z specifies how many chambers zi of each process step i are kept empty for cleaning. We then propose a way of finding optimal vector z* and identify when backward(z*) achieves the minimum cycle time among all possible sequences. We present experimental results on the accuracy of backward(z*).

Full-text available at: https://ieeexplore.ieee.org/document/7903590/

(6) Scheduling Cluster Tools in Semiconductor Manufacturing: Recent Advances and Challenges

Author: ChunRong Pan ; MengChu Zhou ; Yan Qiao ; NaiQi Wu

Abstract

Cluster tools are automated robotic manufacturing systems containing multiple computer-controlled process modules. They have been increasingly used for wafer fabrication. This paper reviews the modeling and scheduling methods for cluster tools with both nonrevisiting and revisiting processes. For nonrevisiting processes, we focus on the modeling and scheduling problems of cluster tools with different constraints. Then, their solution methods are reviewed and compared. For revisiting processes, this paper first discusses the scheduling problem of some general manufacturing systems with revisiting. Then, the modeling and scheduling methodologies used to solve the scheduling problems of cluster tools with revisiting processes are reviewed. Future research directions and conclusions are finally discussed. Note to Practitioners-Semiconductor manufacturing systems are among the most advanced and complicated manufacturing systems. Their key equipment is highly automated robot-based cluster tools. With wafer residency time constraints, wafer revisiting, activity time variation, chamber cleaning requirements, and failure-prone process modules (PMs), it is very challenging to schedule and control them. This paper surveys their modeling and scheduling methods. Scheduling them requires one to schedule their robot tasks and processing activities simultaneously. Owing to wafer residency time constraints and the lack of buffers among PMs, it is difficult to conduct their optimal scheduling. This paper presents a thorough review of the state-ofthe-art research results about modeling and optimal scheduling of clusters tools and indicates the future research directions.

Full-text available at: https://ieeexplore.ieee.org/document/7876736/

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