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Technical Committee on Discrete Event Systems

Newsletter **September 2024**

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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. IEEE Transactions on Automatic Control

Volume: 69, Issue: 9, September 2024

- **Estimation and Prevention of Actuator Enablement Attacks in Discrete-Event Systems Under Supervisory Control**
  Authors: Zhaoyang He ; Naiqi Wu ; Zhiwu Li
  Abstract: This article addresses the problems of estimation and prevention of actuator attacks in the framework of discrete-event systems under supervisory control, where an attack estimation helps an intruder evaluate whether a controlled system can be driven to an undesirable state after being attacked based on partial observation before an actual attack is enforced. The intruder implements an actuator enablement attack by enabling a vulnerable actuator event that has been disabled by a supervisor. To solve this problem, from the intruder's viewpoint, we first introduce a concept of strong actuator enablement estimability (AE-estimability) that allows the intruder to definitely decide that a controlled system can reach an undesirable state after receiving attacks. Then, a concept of weak AE-estimability is proposed to make the intruder incapable of accurately deciding whether an undesirable state in the controlled system subject to attacks is reached even if it has already been reached. We then construct an estimator for assisting the intruder to verify these two estimabilities. From the perspective of prevention, to protect a controlled system from attacks without changing the original behavior of the system, we design a prevention module to mislead an intruder's attack estimation by using the reverse sensor functions to modify sensor readings. Finally, an information construct called a reverse sensor structure is presented to characterize the interaction among an intruder, an estimator, and a prevention module. An algorithm is given to synthesize reverse sensor functions based on the proposed structure.
- **Deadlock Resolution and Recursive Feasibility in MPC-Based Multirobot Trajectory Generation**
  Authors: Yuda Chen ; Meng Guo ; Zhongkui Li
  Abstract: Online collision-free trajectory generation within a shared workspace is fundamental for most multirobot applications. However, many widely-used methods based on model predictive control (MPC) lack theoretical guarantees on the feasibility of underlying optimization. Furthermore, when applied in a distributed manner without a central coordinator, deadlocks often occur where several robots block each other indefinitely. Whereas heuristic methods such as introducing random perturbations exist, no profound analyses are given to validate these measures. Toward this end, we propose a systematic method called infinite-horizon model predictive control with deadlock resolution. The MPC is formulated as a convex optimization over the proposed modified buffered Voronoi with warning band. Based on this formulation, the condition of deadlocks is formally analyzed and proven to be analogous to a force equilibrium. A detection-resolution scheme is proposed, which can effectively detect deadlocks online before they even happen. Once detected, it utilizes an adaptive force scheme to resolve deadlocks, under which no stable deadlocks can exist under minor conditions on robots' target positions. In addition, the proposed planning algorithm ensures recursive feasibility of the underlying optimization at each replanning under both input and model constraints, is concurrent for all robots, and requires only local communication. Comprehensive simulation and experiment studies are conducted over large-scale multirobot systems. Significant improvements on success rate are reported, in comparison with other state-of-the-art methods and especially in crowded and high-speed scenarios.
- **A Framework of Pinning Control for Nonperiodical Stable Behaviors of Large-Scale Asynchronous Boolean Networks**
  Authors: Jie Zhong ; Qinyao Pan ; Wenying Xu ; Bo Chen
  Abstract: In this article, two pinning control (PC) schemes are proposed to achieve nonperiodical stable behaviors for asynchronous Boolean networks (BNs), from the aspects of state transition digraph (STG) and dependence digraph (DD). First, under the framework of algebraic state-space representation of asynchronous BNs, a nonuniform PC is proposed based on STG and feedback ver-

tex set. The nonuniform pinning nodes (PNs) are determined under the transformation of certain columns of the state transition matrices. Due to the high computational complexity of using STG, a uniform PC is further proposed based on the DD of asynchronous BNs, where PNs are easily found using a feedback arc set (FAS). Compared with the nonuniform PC with computational complexity $O(n2^{2n})$ (n is the size of network), the uniform PC has advantages of lower computational complexity $O(n^2 + n2^K)$ (K is the largest indegree of in-neighbors). Finally, simulations on gene networks with different sizes are given to illustrate the effectiveness of the obtained results that only almost 1%˘33% nodes are needed. Especially, as for a network with 321 genes, only two nodes (1%) are needed, which well reflects the core idea of PC approach.

- **A Bisimulation-Based Foundation for Scale Reductions of Continuous-Time Markov Chains**
  Authors: Lin Lin ; Jinde Cao ; James Lam ; Leszek Rutkowski ; Georgi Marko Dimirovski ; Shiyong Zhu
  Abstract: In this article, the scale reduction problem of continuous-time Markov chains (CT-MCs) and continuous-time controlled Markov chains (CT-CMCs) are disserted both from the bisimulation perspective. Based on the features of bisimulation, the reachability, macro-controllability, controllability, and stabilizability of CT-MCs and CT-CMCs, particularly, the large-scale ones, are addressed over the corresponding reduced chains. The bisimulation relations are defined for both CT-MCs and CT-CMCs to establish the equivalence between the original networks and their condensed networks. A computable algorithm is developed to compute the reachability-based maximal bisimulation relation for CMCs, resulting in the smallest bisimulating CMCs. Notably, one advantage of our techniques lies in their efficiency in implementing the existing analysis and control results on MCs and CMCs in a lower amount of time, with wide applications to logical networks, finite-field networks, finite automata, and Petri nets. Compared to their discrete-time counterparts, CT-MCs and CT-CMCs inherit a simplified essential network topology in the discrete-time structures while providing a quantitative description of transient functional kinetics on the microtime scale level. Besides, all the developed theoretical results for CT-MCs and CT-CMCs are operated based on the transition rate matrices of chains rather than transition probability matrices used in the traditional methods. Finally, the derived theoretical results are validated by investigating the p53-Mdm2 signaling network and a relevant case-study involving a set of randomly generated CT-CMCs.

- **Decentralized State-Dependent Markov Chain Synthesis With an Application to Swarm Guidance**
  Authors: Samet Uzun ; Nazım Kemal Üre ; Behçet Açıkmeşe
  Abstract: This article introduces a decentralized state-dependent Markov chain synthesis (DSMC) algorithm for finite-state Markov chains. We present a state-dependent consensus protocol that achieves exponential convergence under mild technical conditions, without relying on any connectivity assumptions regarding the dynamic network topology. Utilizing the proposed consensus protocol, we develop the DSMC algorithm, updating the Markov matrix based on the current state while ensuring the convergence conditions of the consensus protocol. This result establishes the desired steady-state distribution for the resulting Markov chain, ensuring exponential convergence from all initial distributions while adhering to transition constraints and minimizing state transitions. The DSMC's performance is demonstrated through a probabilistic swarm guidance example, which interprets the spatial distribution of a swarm comprising a large number of mobile agents as a probability distribution and utilizes the Markov chain to compute transition probabilities between states. Simulation results demonstrate faster convergence for the DSMC-based algorithm when compared with the previous Markov chain-based swarm guidance algorithms.

- **Indirect NRDF for Partially Observable Gauss–Markov Processes With MSE Distortion: Characterizations and Optimal Solutions**
  Authors: Photios A. Stavrou ; Mikael Skoglund
  Abstract: We study the problem of characterizing and computing the Gaussian nonanticipative rate-distortion function (NRDF) of partially observable multivariate Gauss–Markov processes with mean-squared error (MSE) distortion constraints. First, we extend Witsenhausen's "tensorization"

approach originally used for single-letter random variables to causal processes, to obtain a new modified representation of the NRDF for the specific problem. For time-varying vector processes, we prove conditions so that the new modified NRDF is achieved and study its implications when it is not achievable. For both cases (which correspond to different bounds), we derive the characterization and the optimal realization, whereas we give the optimal numerical solution using the semidefinite programming (SDP) algorithm. Interestingly, the realization (for both bounds) is shown to be a linear functional of the current time-sufficient statistic of the past and current observations signals. For the infinite time horizon, we give conditions to ensure the existence of a time-invariant characterization from the finite-time horizon problems and a numerical solution using the SDP algorithm. For the time-invariant characterization, we also give strong structural properties that enable an optimal and approximate solution via a reverse-waterfilling algorithm implemented via an iterative scheme, which executes much faster than the SDP algorithm. For both finite and infinite time horizons, we study the special case of scalar processes. Our results are corroborated with various simulation studies and are also compared with existing results in the literature.

- **Undirected Weighted Network Topologies With Best Possible Pinning Controllability**
  Authors: Saber Jafarizadeh
  Abstract: Controllability of complex networks through pinning control toward a desired trajectory is crucial for ensuring synchronization stability. Concerned with the local stability of the network's synchronization, here, the controllability problem is addressed different from the literature by incorporating weighted Laplacian and nonuniform feedback gain. This approach has led to a spectral radius minimization problem, where using its semidefinite programming (SDP) formulation leads to a unique optimal point, with uniform feedback gain, on the Pareto frontier. Using this approach, this article has systematically characterized the networks that can achieve the best possible optimal controllability measure. For such networks, it is shown that (i) network's optimal controllability measure is expressed in terms of the number of pinned and free nodes, (ii) the optimal feedback gains of pinned nodes are uniform, (iii) sum of optimal weight linked to a node is determined in terms of its type and the optimal spectral radius of network, (iv) nodes of same type have the same value for the optimal dual SDP variables.

- **Synthesis of Input-to-State Attractivity Controllers for Transition Systems With Disturbances**
  Authors: W. Alejandro Apaza-Perez ; Antoine Girard
  Abstract: In this article, we introduce the notion of input-to-state attractivity (ISA) controllers for a class of finite transition systems with disturbances. The performances of an ISA controller are characterized by a gain function that quantifies the deviation of closed-loop trajectories from the target set as a function of the amplitude of past disturbances on a bounded time window. We prove the existence of controllers that are gain-optimal (GO) in the sense that their gain function is minimal (with respect to a given order on the set of gain functions) over all possible ISA controllers. Then, we consider the problem of synthesizing ISA controllers. We present an approach based on successive refinements of controllers: starting from a controller synthesized against worst-case disturbances, the controller is iteratively refined in order to improve the closed-loop behavior under lower disturbances. We prove that our method makes it possible to synthesize an ISA controller that is shown to be a GO-ISA controller (for the colexicographic order) when a condition, which can be easily checked a posteriori, is satisfied. Finally, an application of adaptive cruise control demonstrates the effectiveness of our approach.

- **On Multirobot Path Planning Based on Petri Net Models and LTL Specifications**
  Authors: Sofia Hustiu ; Cristian Mahulea ; Marius Kloetzer ; Jean-Jacques Lesage
  Abstract: This article proposes a method exploiting the advantages of Petri net (PN) and Büchi automata models by joining them in a newly defined composed PN representation. Based on the latter model, collision-free trajectories are computed for a team of robots. The path planning algorithm is divided into two steps: computing a solution in a reduced PN model and projecting it to the PN assigned to the environment. The results, given by a set of mixed integer linear programming (MILP) problems, yield lower computational complexity when compared with previous approaches.

- **On Minimizing Total Discounted Cost in MDPs Subject to Reachability Constraints**
  Authors: Yagiz Savas ; Christos K. Verginis ; Michael Hibbard ; Ufuk Topcu
  Abstract: In this article, we study the synthesisof a policy in a Markov decision process (MDP) following which an agent reaches a target state in the MDP while minimizing its total discounted cost. The problem combines a reachability criterion with a discounted cost criterion and naturally expresses the completion of a task with probabilistic guarantees and optimal transient performance. We first establish that an optimal policy for the considered formulation may not exist but that there always exists a near-optimal stationary policy. We additionally provide a necessary and sufficient condition for the existence of an optimal policy. We then restrict our attention to stationary deterministic policies and show that the decision problem associated with the synthesis of an optimal stationary deterministic policy is NP-complete. Finally, we provide an exact algorithm based on mixed-integer linear programming and propose an efficient approximation algorithm based on linear programming for the synthesis of an optimal stationary deterministic policy.

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1.2. Automatica

Volume: 167, September 2024

- **Human-in-the-loop formation control for multi-agent systems with asynchronous edge-based event-triggered communications**
  Authors: Li Ma ; Fanglai Zhu
  Abstract: This paper discusses the human-in-the-loop (HiTL) time-varying formation (TVF) tracking control problem of multi-agent systems (MASs) with asynchronous edge-based event-triggered communication (ETC). The HiTL framework allows the human operator to regulate the MASs by broadcasting command signals to the tracking leader, with the leader's input signal unavailable to all followers. In addition, all agents are subject to unknown inputs (UIs) in both actuator and sensor channels. To address UIs, an output transformation is introduced for each agent to decouple the system output from UIs without changing the system dimension. Then, an interval observer-based unknown input observer (UIO) is constructed to provide asymptotic state estimation and UI reconstruction. Moreover, to relieve the communication burden, static and dynamic ETC schemes are proposed to enable each agent to transmit information to its out-neighbors asynchronously only when the corresponding edge-based triggering condition is satisfied. Given the UIO and ETC strategies, the observer-based fully distributed TVF protocol is developed, fulfilling the desired TVF and excluding the Zeno behavior. Finally, the theoretical results are verified in multi-robot formation control.
- **Communication-efficient distributed Nash equilibrium seeking under switching topologies: A decentralized gradient-based event-triggered scheme**
  Authors: Lei Ding ; Maojiao Ye ; Dong Yue
  Abstract: This paper is concerned with communication-efficient distributed Nash equilibrium seeking in networked games with directed and switching communication topologies. First, a decentralized gradient dynamic event-triggered scheme, which only depends on its own information of each player, is proposed to realize the efficient utilization of communication resources. Then, a distributed event-triggered Nash equilibrium seeking strategy incorporating a switching-based compensation communication mechanism is designed, where information sampling and transmission among neighborhood players only occur at triggered time instants. Moreover, some sufficient conditions for achieving the Nash equilibrium seeking exponentially are derived, where the effects of switching communication topologies on the convergence of the developed strategies can be characterized. Finally, a simulation case study is conducted to show the effectiveness of our proposed method.
- **On the reachability and controllability of temporal continuous-time linear networks: A generic analysis**
  Authors: Yuan Zhang ; Yuanqing Xia ; Long Wang
  Abstract: Temporal networks are a class of time-varying networks whose topology evolves through

a time-ordered sequence of static networks (known as subsystems), which find wide-ranging applications in modeling complex systems such as social networks, epidemic spreading, and brain dynamics. This paper investigates the reachability and controllability of temporal continuous-time linear networks from a generic viewpoint, where only the zero-nonzero patterns of subsystem matrices are known. It is demonstrated that the reachability and controllability of temporal networks on a single temporal sequence are generic properties with respect to the parameters of subsystem matrices and the time durations of subsystems. Explicit expressions are then given for the minimal subspace that contains the reachable set across all possible temporal sequences (called overall reachable set). It is found that verifying the structural reachability/controllability and structural overall reachability is at least as difficult as the structural target controllability verification problem of a single system, implying that finding verifiable conditions for them is hard. Graph-theoretic lower and upper bounds are provided for the generic dimensions of the reachable subspace on a single temporal sequence, and of the minimal subspace that contains the overall reachable set. These bounds extend classical concepts in structured system theory, including dynamic graph and cactus, to temporal networks, and can be calculated using graph-theoretic algorithms. Finally, applications of these results to the structural controllability of switched linear systems are discussed.

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1.3. IEEE Transactions on Automation Science and Engineering

Volume: 21, Issue: 3, September 2024

- **COVID-19 Bed Management Using a Two-Step Process Mining and Discrete-Event Simulation Approach**

  Authors: Jules Le Lay ; Vincent Augusto ; Edgar Alfonso-Lizarazo ; Malek Masmoudi ; Baptiste Gramont ; Xiaolan Xie ; Bienvenu Bongue ; Thomas Celarier

  Abstract: The sudden admission of many patients with similar needs caused by the COVID-19 (SARS-CoV-2) pandemic forced health care centers to temporarily transform units to respond to the crisis. This process greatly impacted the daily activities of the hospitals. In this paper, we propose a two-step approach based on process mining and discrete-event simulation for sizing a recovery unit dedicated to COVID-19 patients inside a hospital. A decision aid framework is proposed to help hospital managers make crucial decisions, such as hospitalization cancellation and resource sizing, taking into account all units of the hospital. Three sources of patients are considered: (i) planned admissions, (ii) emergent admissions representing day-to-day activities, and (iii) COVID-19 admissions. Hospitalization pathways have been modeled using process mining based on synthetic medico-administrative data, and a generic model of bed transfers between units is proposed as a basis to evaluate the impact of those moves using discrete-event simulation. A practical case study in collaboration with a local hospital is presented to assess the robustness of the approach.

  Note to Practitioners: In this paper we develop and test a new decision-aid tool dedicated to bed management, taking into account exceptional hospitalization pathways such as COVID-19 patients. The tool enables the creation of a dedicated COVID-19 intensive care unit with specific management rules that are fine-tuned by considering the characteristics of the pandemic. Health practitioners can automatically use medico-administrative data extracted from the information system of the hospital to feed the model. Two execution modes are proposed: (i) fine-tuning of the staffed beds assignment policies through a design of experiment and (ii) simulation of user-defined scenarios. A practical case study in collaboration with a local hospital is presented. The results show that our model was able to find the strategy to minimize the number of transfers and the number of cancellations while maximizing the number of COVID-19 patients taken into care was to transfer beds to the COVID-19 ICU in batches of 12 and to cancel appointed patients using ICU when the department hit a 90% occupation rate.

- **Probabilistic Reachability Prediction of Unbounded Petri Nets: A Machine Learning Method**

  Authors: Hongda Qi ; Mingjian Guang ; Junli Wang ; Chungang Yan ; Changjun Jiang

  Abstract: Unbounded Petri nets (UPNs) can describe and analyze discrete event systems with infinite states (DESIS). Due to the infinite state space and the combination explosion problem, the

reachability analysis of UPNs is an NP-Hard problem. The existing reachability analysis methods cannot achieve an accurate result at reasonable costs (computational time and space) due to the finite reachability tree with ω-numbers. Based on the idea of approximating infinite space with finite states, given some limited reachable markings of a UPN, we propose a method that can quantitatively solve the UPN's reachability problem with machine learning. Firstly, we define the probabilistic reachability of markings and transform the UPN's reachability problem into the prediction problem of markings. The proposed method based on positive and unlabeled learning (PUL) and bagging trains a classifier to predict the probabilistic reachability of unknown markings. Finally, to predict the markings outside the positive sample set and unlabeled sample set, an iterative strategy is designed to update the classifier. Based on seven general UPNs, the results of the experiments show that the proposed method has a good performance in the accuracy and time consumption for the UPN's reachability problem.

Note to Practitioners: In discrete event systems, the reachability problem mainly studies reachable states of the system and the relationship between states, which is the basis of the system's states, behaviors, attributes and performance analysis. For discrete event systems with infinite states, it is hard to analyze the reachable relationship between states within a finite time due to the infinite state space and the combination explosion problem. The main motivation of the paper is to propose a method that can predict the reachable relationship between the states with a probability value within a finite time. By machine learning algorithms, the method learns the feature information of the known reachable states. The reachability of unknown states in the infinite state space can be predicted approximately. The proposed approximation method can be applied to analyze the reachability properties of general discrete event systems with infinite states, such as checking whether a fault occurs in operating systems, whether a message is delivered in communication and so on.

- **State Estimation and Detectability of Networked Discrete Event Systems With Multi-Channel Communication Networks**

  Authors: Marcos V. S. Alves ; João C. Basilio

  Abstract: In this paper, we extend existing results on detectability of Discrete Event Systems (DES) to Networked Discrete Event Systems (NDES), a class of DES whose communication between the plant and the agent (supervisor, diagnoser, prognoser, etc) is carried out through a network that can have several channels. We assume that each channel is subject to different communication delays, which may cause changes in the order of the event observations with respect to their actual occurrences in the system automaton, and also that event transmission may be lost in the communication channels causing loss of observations. We follow a previously presented approach to construct an equivalent nondeterministic untimed automaton, and, based on this model, we present a method for the state estimation of NDES. We extend existing D-detectability definitions of DES to NDES subject to delays and loss of observation, referred here to as strong networked D-detectability, weak networked D-detectability, strong periodic networked D-detectability, weak periodic networked D-detectability. Finally, necessary and sufficient conditions for the networked D-detectability notions proposed here are proposed and algorithms for their verification are developed.

  Note to Practitioners: State estimation is an important problem that appear in several practical applications, e.g. industrial systems, aircraft control and business management. Of current interest is the problem of distinguishing in real time if the system is not in pairs of states, the so-called D-detectability. In practical terms, it is not necessary to actually know the current state of the system but if the system may not be in two or more conflicting states. With the use of communication networks, additional features such as communication delay must also be taken into account in the process of performing D-detectability. In this paper we consider discrete event systems, a class of systems used to model a wide class of practical engineering problems whose dynamic evolution is driven by event occurrences, that are embedded in a communication network; we will refer to these systems as networked discrete event systems. In this regard, we generalize existing notions of D-detectability, and we call them networked D-detectability. Algorithms for networked D-detectability verification and a method to perform online state estimation are given in the paper.

- **A New Hybrid Supervisory Control System for Cabinet-Type Firebox Furnaces**

Authors: Zohreh Rostamnezhad ; Tahmineh Adili ; Milad Moradi Heydarloo ; Ali Chaibakhsh ; Mojtaba Kordestani ; Mehrdad Saif

Abstract: In this paper, an intelligent hybrid Industrial Control System (ICS) and a Supervisory Control System (SCS) are proposed to improve the efficiency, safety, availability, and control capabilities of industrial furnaces. The main components of ICS are process control systems and advanced control systems that consist of overheating protection and load control. New soft sensors are designed as a combination of Laguerre filters and an artificial neural network to estimate the surface temperature of the furnace's tubes, which allows the protection system to adjust fuel flow rate via overriding commands. Model-based fault detection systems are developed to detect faults in the combustion system and fouling in the furnace tubes and prepare features for the supervisory system. The supervisory control system is responsible for interfering between different components, evaluating the situation, and decision making based on the unit status and process conditions. An intuitionistic fuzzy inference system is employed as the core of the supervisory controller to tolerate disturbance and faults by switching the control modes. Test studies using experimental data of the furnace indicate the capability of the proposed monitoring and control system to operate in various loading situations and recover the system from abnormal conditions.

Note to Practitioners: In petrochemical industries, several reports have been issued about the load reduction of fired-heater furnaces imposed by combustion system faults and emergency shutdowns to carry out un-planned repairs due to fouling and wax-formation in tubes. Different activities such as detecting abnormal conditions, identifying faults, and enforcing corrective action can be performed by operators through manual actions. This paper is focused on designing a new supervisory control system (SCS) to be able to recover the fired heater furnace from abnormal conditions and keep running the plant. The SCS evaluates the condition of the unit by acquiring information from main variables, sensors, actuators, operating status of components and utilities, and operator commands. By identifying the root cause of faults, SCS makes decision on recognizing hazard degree, raising alarms, and applying automatic corrective actions.

- **State Space-Based Hybrid Heuristic Search Algorithm for Scheduling Deadlock-Prone Automated Manufacturing Systems**

Authors: Xiaoling Li ; MengChu Zhou ; Keyi Xing ; Qingchang Lu

Abstract: This work addresses the scheduling problem of deadlock-prone automated manufacturing systems (AMSs) modeled by a class of Petri nets called systems of simple sequential processes with resources (S3PRs), and proposes a novel hybrid heuristic search (HHS) algorithm to minimize the makespan. First, based on place-timed Petri net models of AMSs, a timed state space (TSS) composed of timed states is defined. TSS-based breadth-first search and A* algorithms are developed, through which the optimal solutions for small-scale problems can be obtained. Then, in order to effectively solve the scheduling problems of AMSs with different scales, TSS is condensed, and HHS is designed to search the condensed state space (CSS). In HHS, a duplicate detection policy is proposed for ensuring that only one transition path is reserved for each state in CSS. A pruning policy is proposed for pruning unpromising states to achieve the goal of searching a small part of CSS only, and three different cost estimation functions are developed for evaluating states. A hybrid search strategy is defined to achieve high search efficiency and find better solutions. The integration of the proposed duplicate detection policy, pruning policy, and hybrid search strategy ensures the high optimization performance and computational efficiency of HHS. Experimental results on benchmark AMS instances demonstrate the superiority of the proposed algorithm over the existing ones. The applicability of HHS in solving different industrial problems and manufacturing scheduling problems is also verified.

Note to Practitioners: Automated manufacturing systems (AMSs) are computer-controlled manufacturing systems. They exhibit a high degree of resources sharing and route flexibility and can be highly adaptable to various production plans. Solving their scheduling problems is of great significance to manufacturers. When designing a scheduling algorithm for such systems, engineers face two challenges: how to deal with deadlocks caused by jobs competing for limited resources, and how to maintain high solution ability when solving large-scale problems. Existing algorithms for scheduling deadlock-prone AMSs have to rely on specific deadlock handling strategies to ensure their feasibility, and are unable to find high-quality solutions for large-scale problems. This article

presents a hybrid heuristic search (HHS) algorithm for minimizing the makespan of deadlock-prone AMSs, in which a duplicate detection policy, a pruning policy, and a hybrid search strategy are specially designed. The combination of these policies ensure that HHS can find a high-quality solution in a short computation time, even if no deadlock handling strategy is used in the algorithm. Experimental tests and comparisons show that HHS significantly outperforms existing algorithms. The proposed HHS can be applied to other AMS scheduling problems, and can be used as an online or real-time scheduling method due to its high computational efficiency.

- **Design of Supervisors for Partially Observed Discrete Event Systems Using Quiescent Information**
  Authors: Yihui Hu ; Ziyue Ma ; Zhiwu Li
  Abstract: In this paper, we study the nonblocking supervisor synthesis problem in partially observed discrete event systems modeled by finite-state automata. We consider a particular type of supervisors that can observe not only the execution of observable events in a plant but also the quiescence of it. We first define a q-observer to characterize the behavior of a plant with observable quiescence. Comparing with the classical observer structure, the q-observer contains the quiescence information of a plant, which can be used to improve state estimation. Then we propose a method to detect the blocking states in a q-observer. Finally, we develop an iterative method to synthesize a nonblockingness enforcement supervisor from the q-observer. Since quiescence provides additional information on state estimation, the supervisor synthesized by the proposed method is in general more permissive than those synthesized by the existing approaches that do not monitor the quiescence. A manufacturing system example is also given to elucidate the effectiveness of the developed approach.
  Note to Practitioners: A discrete event system is a discrete-state and event-driven system, covering a deluge of contemporary computer-integrated man-made constructs, such as automated manufacturing systems, smart urban transportation systems and computer communication networks. Such a system is in general partially observed due to the limited sensor deployment, which complicates its controller design. This research studies the typical supervisory control problem for a partially observed discrete event system. A supervisor is designed to restrict the dynamics of the system in order to guarantee a safe operation through a different control scheme by using the quiescence information that can be usually provided by a real-world system. The practitioners in control and automation community are capable of practicing the formulated control scheme for engineering applications.

- **An Efficient Distributed Task Allocation Method for Maximizing Task Allocations of Multirobot Systems**
  Authors: Shengli Wang ; Youjiang Liu ; Yongtao Qiu ; Simin Li ; Jie Zhou
  Abstract: This paper addresses the distributed task allocation problem for maximizing the total number of successfully executed tasks of multirobot systems. Due to the deadline time of tasks and fuel limits of robotic vehicles, not all tasks can be successfully executed sometimes. Based on the performance impact (PI) algorithm, an effective and efficient performance impact (EEPI) algorithm is proposed, its novelty lies in its cost function and task release procedure. The fundamental ideas of the proposed cost function are as follows. First, the traveling time from the initial position of each vehicle to the positions of its tasks is minimized, so that more time can be left for the vehicle to execute more tasks due to the limited fuel. Second, the start time of each task should be close enough to its deadline, so that tasks with earlier deadlines can be assigned earlier than those with later deadlines. To avoid invalid removal performance impacts (RPIs) and inclusion performance impacts (IPIs), the tasks assigned to a vehicle are all released if the number of tasks removed by the vehicle during the task removal phase is the most, which further increases the total number of successfully executed tasks. Both simulations and hardware-in-the-loop experiments suggest that compared with the state-of-the-art distributed task allocation algorithms, the proposed EEPI is not only effective in maximizing the number of successfully executed tasks but efficient in saving the number of iterations and time to converge.
  Note to Practitioners: This work was motivated by the limitations of the existing distributed task allocation algorithms for maximizing the total number of successfully executed tasks. The

consensus-based bundle algorithm (CBBA) has been proven to guarantee convergence and 50% optimality under the diminishing marginal gain (DMG) assumption in previously published works. Based on CBBA, a performance impact (PI) algorithm was proposed, and simulations show that it can assign more tasks than CBBA when applied to time-critical scenarios with low task-to-vehicle ratios. Starting from the results of PI, a rescheduling method named PI for maximizing assignments (PI-maxAss) was proposed, which has been demonstrated to assign more tasks than PI with high task-to-vehicle ratios. However, much more iterations and time are required by PI-maxAss to converge to globally consistent assignments because of the rescheduling. Due to the above considerations, an effective and efficient performance impact (EEPI) algorithm is proposed in this paper to maximize the number of successfully executed tasks without any rescheduling. Both simulations and hardware-in-the-loop experiments suggest that compared with the algorithms mentioned above, the proposed EEPI is effective in maximizing the number of successfully executed tasks and efficient in saving the number of iterations and time to converge. In future work, the distributed task allocation problem in which several vehicles execute a task at the same time cooperatively or a vehicle executes several tasks simultaneously will be further addressed.

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

Volume: 52, Issue: 3, March 2022

- **Robust Stability of Boolean Networks Subject to Edge Perturbations**

  Authors: Wenrong Li ; Haitao Li ; Xinrong Yang

  Abstract: Edge perturbations (EPs) are often induced by disease-causing mutations, which include edge removal and edge sign switch. This article explores the robust stability of Boolean networks (BNs) with these two kinds of EPs. At first, both edge removal perturbation and edge sign switch perturbation are converted to multibit function perturbations (FPs). After that, the parameterized reachability matrix is constructed to verify the robust stability of BNs with multibit FP. As applications, several new criteria are established for the robust stability of BNs subject to edge removal perturbation and edge sign switch perturbation. Finally, the results are demonstrated by the Boolean models of p53 pathways network and Toll pathway of Drosophila signaling pathway network.

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2 Conferences

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

2.1 **2024 International Conference on Systems, Man, and Cybernetics (SMC)**
Sarawak, Malaysia, October 7-10, 2024.
https://www.ieeesmc2024.org/

2.2 **2024 IEEE Conference on Decision and Control (CDC)**
Milan, Italy, December 16-19, 2024.
https://cdc2024.ieeecss.org/

2.3 **2025 IEEE International Conference on Robotics and Automation (ICRA)**
Atlanta, USA, May 19-23, 2025.
https://2025.ieee-icra.org/

2.4 **2025 European Control Conference (ECC)**
Thessaloniki, Greece, June 24-27, 2025.
https://ecc25.euca-ecc.org/

2.5 **2025 American Control Conference (ACC)**
Denver, Colorado, USA, July 8-10, 2025.
https://acc2025.a2c2.org/

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3 Books

3.1 Cybersecurity of Discrete Event Systems—From Smart Attacks to Resilient Defence

Author: Rong Su, Nanyang Technological University.

Description: This book describes analysis and control against smart cyberattacks in discrete event systems (DES), modelled by regular languages or finite-state automata. “Smart attacks" cannot be detected by the supervisor until an irreversible process towards ensured damage occurs. An attack may be conducted either in the observation channel (i.e., the input of the supervisor) or in the command channel (i.e., the output of the supervisor), or both simultaneously. Therefore, defense strategies against these attacks are urgently needed. This book provides an overview of the latest theories and includes empirical examples to illustrate concepts and methods. By centering on what information is available and how such information is used, the readers are provided with methods to evaluate the cyber vulnerability of a given system and to design a resilient supervisor against relevant smart attacks. By focusing on a conceptual introduction and systematic analysis, this book provides a solid theoretical foundation for future exploration by researchers and graduate students who are interested in cybersecurity research, not necessarily limited to those in the DES community. Readers are recommended to have a background in formal language theory.

Additional information on the book can be found at
https://www.routledge.com/Cybersecurity-of-Discrete-Event-Systems-From-Smart-Attacks-to-Resilient
Su/p/book/9781032368108?srsltid=AfmBOor9fqjhOR7YfMgGE8coz0rHXF6YyKhoucc7UzqYlY9GhcWpQBg3,
where an inspection copy is possible for educational institutions.

3.2 Graph-Theoretical Methods in Systems Theory and Control

Author: Jan Lunze, Ruhr-University, Germany

Description: The book describes for numerous scenarios how to use the structural properties of a system represented by a graph to simplify modelling, analysis, and design tasks. For example, block diagrams and coupling graphs can be used to decompose systems, automata graphs to analyse discrete-event systems and Markov chains, structure graphs to find generic properties of linear systems or communication graphs to design networked control systems. The book includes many examples derived from diverse fields of application, exercises with solutions and MATLAB scripts to implement graph-theoretical methods for systems analysis.

Additional information on the book can be found at
www.editionmora.de/gmsc

The book is produced as “print-on-demand" and can be ordered directly at the printer:
https://publish.bookmundo.de/books/349971

3.3 Safe Autonomy with Control Barrier Functions: Theory and Applications

Authors: Wei Xiao, Christos G. Cassandras, and Calin Belta

Description: The book presents the concept of Control Barrier Function (CBF), which captures the evolution of safety requirements during the execution of a system and can be used to enforce safety. Safety is central to autonomous systems since they are intended to operate with minimal or no human supervision. The book includes both theoretical and application perspectives on how safety can be guaranteed. It explains how the CBF approach is computationally efficient and can easily deal with nonlinear models and complex constraints used in a wide spectrum of applications, including autonomous driving, robotics, and traffic control. Safety guarantees can be integrated into the operation of such autonomous systems, including typical safety requirements that involve collision avoidance, technological system limitations, and bounds on real-time executions. Adaptive and event-driven approaches for safety are also discussed for time-varying execution bounds and noisy dynamics, as well as for systems with unknown dynamics.

Additional information on the book can be found at
https://link.springer.com/book/10.1007/978-3-031-27576-0
where an eBook version can also be downloaded (free for some educational institutions).

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4 Software Tools

4.1 Eclipse ESCET™ version 4.0 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 toolkit's website at https://www.eclipse.dev/escet/.

In June 2024, ESCET version 4.0 has been released and can be downloaded from https://www.eclipse.dev/escet/download.html. he main changes in this version are

- Several improvements to model annotations, including a new annotation 'controller:properties'. Furthermore, annotations can be added to wider range of elements of the CIF language.
- The CIF controller properties checker now has an additional check, the bounded response check. The bounded response check improves upon the finite response check by checking for finite response also for uncontrollable events, not just for controllable events. Additionally, for both controllable and uncontrollable events, the new check also computes the bounds on the number of transitions that can be executed. Furthermore, the new check does not suffer from false negatives. The bounded response check is now recommended instead of the finite response check.
- The CIF controller properties checker now has an additional check, the non-blocking under control check, that should hold for all supervisor models before controller code is generated from them.
- Several improvements to the (still experimental) new CIF PLC code generator have been included.
- The CIF data-based synthesis tool has improved performance by using compounded operations for applying edges, using partial transition relations, and taking runtime errors into account once before the main synthesis fixed point computations, rather than repeatedly during synthesis. On average it is about 3.4 times faster, and it also uses less memory. However, the gain depends on the model being synthesized.

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.dev/escet/release-notes.html.

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