IEEE Control Systems Society
Technical Committee on Discrete Event Systems

Newsletter **February 2020**

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Welcome to the 2020 February 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.

- To **submit a new item**, please use the following website:
  https://www.control.eng.osaka-cu.ac.jp/miscellaneous/css-tc-des/submission
  or email to kai.cai@eng.osaka-cu.ac.jp.
- To **subscribe**, please email to kai.cai@eng.osaka-cu.ac.jp.
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1 Selections of Journal Publications

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

1.1. IEEE Transactions on Automatic Control

Volume: 65, Issue: 2, February 2020

- **Marking Estimation in a Class of Time Labeled Petri Nets**
  Authors: Ziyue Ma ; Zhiwu Li ; Alessandro Giua
  Abstract: This paper proposes an efficient marking estimation method for a subclass of time labeled Petri nets (TLPNs), in which each transition is associated with an infinite upper bound delay. The unobservable subnet of the considered subclass of TLPNs is backward-conflict-free, and all the output transitions of each conflict place are observable. The highlight of this method is that the markings set consistent with a given observation can be determined by a linear algebraic system based on the so-called slow-bound marking and fast-bound marking pairs. An algorithm to compute an online estimator is provided, and an example is given. By this method, the exhaustive construction of the full state space including the state class graph is avoided. This approach provides guidelines of sensor deployment in the design stage so that the online marking estimation problem can be efficiently solved.
- **Control Synthesis for Permutation-Symmetric High-Dimensional Systems With Counting Constraints**
  Authors: Petter Nilsson ; Necmiye Ozay
  Abstract: General-purpose correct-by-construction synthesis methods are limited to systems with low dimensionality or simple specifications. In this paper, we consider highly symmetrical counting problems and exploit the symmetry to synthesize provably correct controllers for systems with tens of thousands of states. The key ingredients of the solution are an aggregate abstraction procedure for mildly heterogeneous systems and a formulation of counting constraints as linear inequalities.
- **Synthesizing Communication Plans for Reachability and Safety Specifications**
  Authors: Kazumune Hashimoto ; Dimos V. Dimarogonas
  Abstract: We propose control and communication strategies for nonlinear networked control systems subject to state and input constraints. The objective is to steer the state of the system toward a prescribed target set in finite time (reachability), while at the same time remaining inside a safety set for all time (safety). By leveraging the notion of the δ-input-to-state stability (ISS) control Lyapunov function, we derive a sufficient condition to generate a communication scheduling, such that the resulting state trajectory guarantees reachability and safety. Moreover, in order to alleviate computational burden, we present a way to find a suitable communication scheduling by implementing abstraction schemes and standard graph search methodologies. Simulation examples validate the effectiveness of the proposed approach.
- **Optimal Event-Triggered Control of Nondeterministic Linear Systems**
  Authors: Dipankar Maity ; John S. Baras
  Abstract: We consider an event-triggered controller synthesis problem to replace the continuous feedback policy with an intermittent feedback policy for a nondeterministic linear system. An event-triggered framework communicates the measurement to the controller only at certain discrete time instances which are generated by an event generator. The objective of this paper is to synthesize an optimal-event generator and controller pair such that the state trajectory of the event-triggered system mimics that of the feedback system with arbitrary precision. The optimality is in the sense that the least number of state measurements are sent to the controller in order to compute the control signal. The results of this paper show that such an optimal event-triggered controller retains the linear structure when the continuous feedback controller is linear; and the optimal event generator follows a threshold-based policy, where the event generator decides to send the state measurement to the controller every time a certain signal exceeds that threshold. Finally, the similar framework was extended for a controller synthesis of infinite horizon.The structural properties of the optimal event-triggered controller and event generator remain unchanged when extended to an infinite horizon.

- **Periodic Event-Triggered Control for Nonlinear Networked Control Systems**
  Authors: Wei Wang ; Romain Postoyan ; Dragan Nsic ; W. P. M. H. Heemels
  Abstract: Periodic event-triggered control (PETC) is an appealing paradigm for the implementation of controllers on platforms with limited communication resources, a typical example being networked control systems. In PETC, transmissions over the communication channel are triggered by an event generator, which depends solely on the available plant and controller data and is only evaluated at given sampling instants to enable its digital implementation. In this paper, we consider the general scenario, where the controller communicates with the plant via multiple decoupled networks. Each network may contain multiple nodes, in which case a dedicated protocol is used to schedule transmissions among these nodes. The transmission instants over the networks are asynchronous and generated by local event generators. At given sampling instants, the local event generator evaluates a rule, which only involves the measurements and the control inputs available locally, to decide whether a transmission is needed over the considered network. Following the emulation approach, we show how to design local triggering generators to ensure input-to-state stability and Lp stability for the overall system based on a continuous-time output-feedback controller that robustly stabilizes the network-free system. The method is applied to a class of Lipschitz nonlinear systems, for which we formulate the design conditions as linear matrix inequalities. The effectiveness of the scheme is illustrated via simulations of a nonlinear example.
- **Corrections to "Model Predictive Control for Stochastic Max-Plus Linear Systems With Chance Constraints"**
  Authors: Ton J. J. van den Boom ; Jia Xu ; Bart De Schutter
  Abstract: This article discusses two issues in connection with the article J. Xu, T. J. J. van den Boom, and B. De Schutter, "Model predictive control for stochastic max-plus linear systems with chance constraints," IEEE Trans. Autom. Control , vol. 64, no. 1, pp. 337-342, Jan. 2019, namely an error in Proposition 7 and the assumption that the covariance matrix in the chance constraint is positive definite. First, we will discuss and correct the error in Proposition 7. Subsequently, we will consider a relaxation of the assumption in Proposition 7 and give a less-restrictive and less-conservative reformulation of the proposition.

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1.2. Automatica

Volume: 112 February 2020

- **Fault tolerant control of asynchronous sequential machines with transient faults in non-fundamental mode**
  Authors: Jung-Min Yang
  Abstract: This paper addresses fault tolerant corrective control of asynchronous sequential machines (ASMs) against transient faults causing unauthorized state transitions. While the prior work considers only those kinds of faults that comply with fundamental mode operations, the constraint is relaxed in this study. Hence the transient faults may occur not only in fundamental mode, or when the machine stays at a stable state, but also in non-fundamental mode, or when the machine passes through transient states. The condition for overcoming transient faults occurring in non-fundamental mode turns out to be stricter than the case of fundamental mode. A novel scheme of corrective control is presented to make the closed-loop system immune against any fault occurrence in non-fundamental mode. An illustrative example is provided to demonstrate the synthesis procedure of the proposed corrective controller.
- **Approximate convex hull based scenario truncation for chance constrained trajectory optimization**
  Authors: Hossein Sartipizadeh ; Behcet Acikmese
  Abstract: In this paper, we study chance constrained trajectory optimization of linear systems with general ellipsoidal and polytopic state-input constraints where the constraints must be met with some prescribed confidence level. We use the sampling techniques, specifically scenario approach, due to their generality and tractability compared to the analytical methods. To address the main drawback of scenario approach, which may require large number of samples, we introduce

an approximate convex hull-based method to significantly reduce the number of samples. Based on the allowable computational complexity, the prominent samples are selected in a proper mapping and the rest are truncated. The truncation error is later compensated for by adjusting (buffering) the constraint set, so that the satisfaction of constraints with the desired confidence level is still guaranteed. Simulation results confirm the theoretical predictions with solid performance of the proposed method after discarding about 99% of samples from the scenario approach, which remarkably speeds up the online computations.

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1.4. IEEE Transactions on Automation Science and Engineering

Volume: 17, Issue: 1, January 2020

- **Control of Black-Box Embedded Systems by Integrating Automaton Learning and Supervisory Control Theory of Discrete-Event Systems**
  Authors: Huimin Zhang ; Lei Feng ; Zhiwu Li
  Abstract: The paper presents an approach to the control of black-box embedded systems by integrating automaton learning and supervisory control theory (SCT) of discrete-event systems (DES), where automaton models of both the system and requirements are unavailable or hard to obtain. First, the system is tested against the requirements. If all the requirements are satisfied, no supervisor is needed and the process terminates. Otherwise, a supervisor is synthesized to enforce the system to satisfy the requirements. To apply SCT and automaton learning technologies efficiently, the system is abstracted to be a finite-discrete model. Then, a C^* learning algorithm is proposed based on the classical L^* algorithm to infer a Moore automaton describing both the behavior of the system and the conjunctive behavior of the system and the requirements. Subsequently, a supervisor for the system is derived from the learned Moore automaton and patched on the system. Finally, the controlled system is tested again to check the correctness of the supervisor. If the requirements are still not satisfied, a larger Moore automaton is learned and a refined supervisor is synthesized. The whole process iterates until the requirements hold in the controlled system. The effectiveness of the proposed approach is manifested through two realistic case studies.
- **Receding Horizon Control for Station Inventory Management in a Bike-Sharing System**
  Authors: Rebecca M. A. Swaszek ; Christos G. Cassandras
  Abstract: A docking bike-sharing system (BSS) is modeled as a network representing the underlying transportation network. Mobile agents (replenishment trucks) traverse the network making routing decisions and deciding how and when to replenish station inventories so as to prevent imbalances due to users' one-way rides as well as time-varying demand. This load balancing process entails selecting both optimal routes for the agents and the number of bikes to load/unload at a station with an objective of minimizing a user dissatisfaction metric. First, we establish a time-dependent replenishment fill-to level policy for each station based on the demand rates and station capacities. Next, we focus on developing a receding horizon controller (RHC) to find optimal routes. The controller proceeds in an event-driven manner to determine after each event the optimal routes for a fleet of agents over a finite planning horizon, with the control applied over a shorter action horizon. The proposed controller is applied to a simulated BSS with station and demand parameters taken from the public data sets of Bluebikes, the BSS in Boston, MA, USA, and a cost-benefit analysis is performed on agent shift hours. In order to demonstrate the robustness of the RHC, sensitivity analysis is also performed on the arc travel times and the demand processes.
- **A Survey on Robust Deadlock Control Policies for Automated Manufacturing Systems With Unreliable Resources**
  Authors: Nan Du ; Hesuan Hu ; MengChu Zhou
  Abstract: Deadlock is a rather undesirable case in automated manufacturing systems (AMSs). The appearance of deadlock can cause the partial or total stagnation of a system. So far, a large number of deadlock control policies have been developed; nevertheless, the majority are dependent on the assumption that allocated resources cannot break down. In the real world, an AMS consists of a set of concurrent production routes that share and compete for a limited number of resources, such as automated material/component handling devices, buffers, robots, and machines. Resource

failures occur unexpectedly. If reasonable control does not exist, a simple resource failure can lead an entire system to stagnation, which can cause enormous economic loss. Therefore, researchers have gradually paid attention to AMSs allowing resource failures in recent years. In this paper, we focus on reviewing and comparing various robust supervisory control policies from the perspective of their structural complexity, behavioral permissiveness, and computational complexity. Some potential future directions are explored. This paper provides a reference source of robust supervisory control of AMSs for researchers and practitioners in this area.

- **Adaptive Scheduling of Cluster Tools With Wafer Delay Constraints and Process Time Variation**
  Authors: Yuchul Lim ; Tae-Sun Yu ; Tae-Eog Lee
  Abstract: A cluster tool consists of several single-wafer processing chambers and a wafer-handling robot. Cluster tools are widely used for wafer fabrication in semiconductor manufacturing fabs. As the circuit width shrinks down to below 20 or even several nanometers, wafer waiting within a chamber after processing becomes more critical to wafer quality due to residual gases and heat. Conventional tool scheduling rules, such as the swap sequence and the backward sequence, may not satisfy strict upper limits on wafer delays, especially when process times fluctuate randomly. We examine a scheduling problem for cluster tools with strict upper limits on wafer delays under process time variation. We propose a new class of schedules, which not only keeps timing patterns steady as possible but also adapts timing of tasks in response to process time variation so as to satisfy wafer delay constraints robustly. We also derive conditions for which there exists such a schedule. We develop a mixed-integer programming model to find an optimal schedule among such adaptive schedules. By numerical experiments, we show that the proposed scheduling method can effectively cope with tight wafer delay constraints even under large process time variations.
- **Multi-Timescale Decision and Optimization for HVAC Control Systems With Consistency Goals**
  Authors: Zelin Nie ; Feng Gao ; Chao-Bo Yan ; Xiaohong Guan
  Abstract: Many optimization problems for heating, ventilation, and air conditioning (HVAC) control systems usually refer to multiple timescales. This paper studies a two-timescale decision problem for indoor temperature regulation by HVAC with the objective to improve user's comfort under limited energy consumption. A slow timescale is divided into several fast timescales, so the two timescales have inherent association. Using states of fast timescale to represent the state of its slow timescale properly is challenging, thereby the weighted mean type is proposed in this paper. We find that the realizability and consistency in two-timescale cannot be guaranteed in existing empirical models, which are the bases for physical application. Therefore, this paper proposes a method that building the fast timescale model first and then inducing the slow timescale model from the fast timescale model. In addition, such a problem in the high-order system is more complex, whose solution is also discussed in this paper. The results of case studies show that the induced model can guarantee the consistency and realizability and meet the user desired temperature for comfort.

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

Volume: 50, Issue: 2, February 2020

- **Liveness Analysis and Deadlock Control for Automated Manufacturing Systems With Multiple Resource Requirements**
  Authors: Yanxiang Feng ; Keyi Xing ; MengChu Zhou ; Huixia Liu
  Abstract: This paper focuses on the liveness analysis and deadlock control for automated manufacturing systems (AMSs) with multiple resource requirements. Such an AMS is modeled by a class of generalized Petri nets called systems of simple sequential processes with multiple resources (S^3PMR). It is shown that a deadlock of the considered AMSs can be characterized by the saturation of a structural object in S^3PMR, called perfect resource transition-circuit (PRT-circuit). As a consequence, an S^3PMR is live if and only if no PRT-circuit is saturated at any reachable marking. To ensure the system liveness, one has to prevent all PRT-circuits from being saturated at

all reachable markings. To develop a structurally simple Petri net deadlock controller, we present the concept of an effective transition cover, which is a special subset of PRT-circuits that may be saturated. Then by designing a control place with a proper control variable for each PRT-circuit in an effective transition cover, we obtain a deadlock controller for the system. The needed control variables are determined by an integer linear program. Since the number of PRT-circuits in an effective transition cover is much less than that of all PRT-circuits that need to control, our controller is of small structural size. For an AMS with saturable PRT-circuits, there exists at least a transition cover. An algorithm is presented for checking the effectiveness of transition covers, and transforming noneffective transition covers into effective ones. Finally, some examples are used to illustrate the proposed method.

- **Modeling and Analysis of Patient Transitions in Community Hospitals: A Systems Approach**

  Authors: Hyo Kyung Lee ; Jingshan Li ; Albert J. Musa ; Philip A. Bain ; Kenneth Nelson

  Abstract: A patient's stay at a hospital may encompass various departments or units. Since many critical and complex problems occur at the interfaces of healthcare delivery systems, safe and efficient transitions between the departments within a hospital has significant importance. This paper presents a Markov chain-based model to study patient transitions between emergency department, intensive or critical care unit, and hospital ward in small and medium-sized community hospitals. To make the analytical study tractable, an iteration method is introduced to approximate the system performance during transitions, including direct transferring probabilities without waiting, average patient occupancy in each department, and average patient length of stay. In addition, system properties, such as monotonicity and sensitivity, are analyzed. It is shown that such a method has a high accuracy in performance estimation and can be used to study and improve patient transitions in small or medium-sized hospitals.

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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, May 13-15, 2020
https://wodes2020.eventos.ufrj.br

2.2 **2020 International Conference on Control, Decision and Information Technologies**
Prague, Czech Republic, June 29 - July 02, 2020
https://codit2020.com

2.3 **2020 American Control Conference**
Denver, Colorado, USA, July 1-3, 2020
http://acc2020.a2c2.org

2.4 **2020 IEEE International Conference on Control & Automation**
Sapporo, Hokkaido, Japan, July 6-9, 2020
http://www.ieee-icca.org

2.5 **2020 IFAC World Congress**
Berlin, Germany, July 12-17, 2020
https://www.ifac2020.org

2.6 **2020 IEEE Conference on Automation Science and Engineering**
Hong Kong, China, August 20-24, 2020
https://www.imse.hku.hk/case2020

2.7 **2020 IEEE Conference on Control Technology and Applications**
Montréal, Canada, August 24-26, 2020
https://ccta2020.ieeecss.org

2.8 **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 International Graduate School on Control

Introduction to Discrete Event Systems

Lecturers: Stéphane Lafortune, Christos Cassandras

Location: Marseille, France, June 8-12, 2020

Message from Lecturers:
Dear Colleagues,

We are pleased to inform you that we will be the main lecturers for a module of 21 hours on "Introduction to Discrete Event Systems", to be offered as part of the European Embedded Control Institute (EECI) International Graduate School on Control in 2020. This course will be held from June 8 to 12, 2020 in Marseilles, France. See: http://www.eeci-igsc.eu/venues/

While the area of discrete event systems started as a sub-discipline in control engineering almost 40 years ago, the study of discrete event systems (DES) remains highly relevant to control engineering problems nowadays, such as in cyber-physical systems, transportation, software engineering, and in the study of privacy and security in engineered systems. In fact, DES form the centerpiece of the event-driven (cyber) component in the hybrid systems that comprise much of today's technology, complementing the time-driven (physical) components.

This course will strike a balance between introducing the students to the key concepts, models, and results of discrete-event control theory for logical and stochastic models, while at the same time emphasizing current research trends in DES theory and applications.

More details about the program can be found at:
https://www.web-events.net//doc/users/395/bib/2019-2020/eeciigsc2020summariesvf31oct.pdf
Students can apply to get financial support. The registration is open at:
http://www.eeci-igsc.eu/registration/
The early registration deadline is March 8. Please register by that date to ensure participation.

Best regards,

Stéphane Lafortune and Christos Cassandras

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4 Books

4.1 **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

4.2 **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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5 Call for Papers

5.1 IEEE Conference on Decision and Control
Invited Session: Security, Safety and Resilience of Discrete Event Systems

Organizers: Xiang Yin ; Rong Su ; Kai Cai

Description: An invited session is planned on *Security, Safety and Resilience of Discrete Event Systems* at IEEE Conference on Decision and Control, to be held in Jeju Island, Republic of Korea, December 8-11, 2020. The objective of this invited session is to present recently developed novel approaches devoted to the analysis and design of safety-critical networked control systems using DES models. The focus of this session is on the following topics:

- modeling and analysis of cyber-security of discrete event systems
- supervisory control and fault-tolerant control of networked discrete event systems
- opacity, diagnosability, observability analysis of discrete event systems
- analysis and design of discrete-event system under cyber-attacks
- performance analysis and enhancement techniques for discrete event systems

If you are interested or have questions, please contact Dr. Xiang Yin yinxiang@sjtu.edu.cn.

5.2 IEEE Conference on Automation Science and Engineering
Special Session: AI enabled Discrete Event Dynamic Systems

Organizers: Li Xia ; Qianchuan Zhao

Submission information: code 11i61; deadline: 2020.03.01

Goal: Discrete event dynamic systems (DEDS) aim at studying the man-made systems driven by events, such as the systems of manufacturing, transportation, computer, communication, energy, robots, etc. The foundation of DEDS is built on mathematical models, such as Markov systems, queueing systems, Petri net, automata, etc. The decision and control of DEDS is fundamental to improve the operation efficiency of those man-made systems, which involves the optimization theory such as Markov decision process (MDP), optimal control, etc. Recently, the remarkable successes of AI attract intensive attention on the study of data-driven learning and optimization. One of the main research streams of AI is to handle the dynamic decision-making problem with reinforcement learning, whose mathematical foundation is MDP. Therefore, with these facts, the research development of DEDS theory encounters a crossroad, combining the techniques of AI and enabling the study of DEDS in a manner of data-driven learning and optimization.
This special session aims to bring together the international scholars and industry practitioners to discuss the recent progress of DEDS in the background of big development of AI techniques, while focusing on the field of automation science and engineering. The potential topics include but are not limited to the development of DEDS theory such as Markov systems, queueing systems, Petri net, automata, the development of reinforcement learning & MDP theory, the AI enabled solution to dynamic games & multi-agent systems, and the application of above theories to solve engineering problems in the field of automation science and engineering.

5.3 J-DEDS Topical Collection on Smart Cities
Discrete Event Dynamic Systems: Theory and Applications

Topical Collection on Smart Cities

Guest Editors: (Samuel) Qing-Shan Jia ; Mariagrazia Dotoli ; Qianchuan Zhao

Call for Papers: Smart cities have attracted more and more attention in recent years due to the close relationship to sustainable development and to the daily lives of citizens in developed as well as developing countries. The research focus in smart cities involves but is not limited to buildings,

transportation, mobility, water system management, security, and pollution control. In order to make cities smarter, a technological infrastructure is required to connect networks of sensors and actuators embedded throughout the urban terrain, and to interact with wireless mobile devices. Smart city is also a great example for cyber-physical systems and the Internet of Things and is a rich domain for research and education.

In this special topical collection on smart cities, we focus on the application of theories and models of discrete event dynamic systems in the general field of smart cities. Papers in the following directions are especially encouraged for submission: Smart Buildings, Intelligent Transportation Systems, Smart Grids, Water System Management, Cyber-security.

The final deadline for paper submission is March 1, 2020. Papers will be reviewed promptly according to the normal J-DEDS review process, and will appear online as soon as they are accepted.

While the area of discrete event systems started as a sub-discipline in control engineering almost 40 years ago, the study of discrete event systems (DES) remains highly relevant to control engineering problems nowadays, such as in cyber-physical systems, transportation, software engineering, and in the study of privacy and security in engineered systems. In fact, DES form the centerpiece of the event-driven (cyber) component in the hybrid systems that comprise much of today's technology, complementing the time-driven (physical) components.

This course will strike a balance between introducing the students to the key concepts, models, and results of discrete-event control theory for logical and stochastic models, while at the same time emphasizing current research trends in DES theory and applications.

Submissions should be made through the journal website (https://www.editorialmanager.com/disc/default.aspx), under the TC: Smart Cities category. Contributors are strongly encouraged to read Instructions at https://www.springer.com/mathematics/applications/journal/10626?detailsPage=pltci_2530565 while preparing their manuscript. Both short papers (less than 12 pages) and regular papers are welcome.

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