Guest Editorial Special Issue on Recent Advances in Petri Nets, Automata, and Discrete-Event Hybrid Systems

I. Introduction

RECENT years have witnessed the rapid development and deployment of cyber and computer technologies, thus highly influencing the design methodologies of discrete-event and hybrid systems, i.e., systems with discrete and mixed discrete-continuous states/inputs. Their prevalence can be found in almost all areas of human life, such as embedded software, automated manufacturing systems, work-flow management, logic controllers, communication protocols, robotics, transportation and mobility, military, smart buildings, etc. Given the criticality of such applications, such systems ought to be carefully modeled, thoroughly verified, and adequately analyzed.

II. Aims of This Special Issue

The aim of this special issue is to highlight the recent advances in Petri nets, automata, and discrete-event hybrid systems. The editorial team has selected 18 high-quality papers from those accepted in 2018 and 2019 in the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS for this special issue. In this editorial, the selected papers are split thematically into the three groups. The first one contains papers focused on the logical correctness. The second group is oriented on the aspects related to the modeling and complexity analysis, while the last one deals with the performance analysis and possible applications.

A. Correctness

Six papers selected in this special issue deal with the correctness aspects of systems. A formal methods-based approach to automatically construct and visualize system-level attack graphs is presented in Al Ghazo *et al.*, given the system components, their vulnerabilities, and connectivity. The approach is illustrated through application to a practical SCADA network. Correctness control of automated manufacturing systems described by Petri nets is the subject of the technique shown by Wang *et al.* The introduced robust control algorithm permits for deadlock avoidance.

The correctness control for automated manufacturing systems is also considered by two further papers. Feng *et al.* proposed a deadlock prevention algorithm for systems with a type of unreliable resources, by using general Petri nets. Yue *et al.* focused on the properties that the controller with robustness must satisfy in deadlock-prone unreliable systems.

A cooperative monitoring process of engineering projects is presented in Xue *et al*. The process provides three different levels of project performance progress for different roles or stakeholders. Conditions for deriving stabilizing control for certain class of hybrid systems with delays is provided in the work by He *et al*.

B. Modeling and Complexity Analysis

The modeling and complexity analysis of the system is the objective of the next six selected papers. A modeling technique of flexible discrete-event systems is proposed by Grichi *et al.* Formal syntax and semantic for a novel meta-model of an object constraint language [called reconfigurable object constraint language (ROCL)] are introduced. The presented solution is applied to reconfigurable wireless sensor networks.

The formal verification of reconfigurable timed discrete-event systems is studied in Hafidi *et al.* In particular, a new method is proposed in order to ensure the correctness of these systems with a reduced cost (decreasing the verification time and memory requirement).

An approximate analysis algorithm for live and safe Petri nets is proposed by Karatkevich *et al.* In opposite to the traditional methods, their presented solution is bounded by a polynomial in the number of places and transitions of a net.

A dynamic data slice approach is considered by Wang *et al.* to analyze the vulnerabilities in e-commerce systems. The presented technique permits for the construction of dynamic data slices in polynomial time.

Effective state space analysis of systems specified by Petri nets is performed by Karoui *et al.* Their method pays special attention to the state explosion problem. Wang *et al.* focused on the behavior similarity of workflow nets. Based on the relation profile of a workflow net, a behavioral relation matrix can be constructed leading to complexity reduction of further analysis.

C. Performance Analysis and Applications

The last group contains papers oriented on the system performance analysis and application aspects. Six papers are included. A generalized backward strategy is proposed by Yang *et al.* to solve a transient scheduling problem. The presented idea utilizes Petri net theory, and it is illustrated

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via industrial examples. Luo *et al.* proposed a chromosome representation and invent a novel deadlock-free scheduling algorithm. The technique is oriented to flexible assembly systems specified by Petri nets.

Distributed control of automated manufacturing systems is presented by Yang *et al.* Their method can be applied in the modeling of the large-scale automated systems. An approach to support emergency resource management is shown by Zeng *et al.*, by introducing a novel type of Petri net. A conflict-free model is constructed by using different resolution strategies.

Tran *et al.* employed reinforcement learning (Q-learning) to explore the relationship between actions and states allocated dynamically that allow the humanoid robot to trigger a reaction to avoid falling. The presented idea is used for fall detection and recovery perturbation during robot swinging. Wang *et al.* proposed a quadcopter control strategy based on deep reinforcement learning. The learning technique is based on a deterministic policy gradient algorithm. Their presented idea is evaluated in a flight simulator.

In conclusion, we observe that modeling, verification, and various applications of discrete-event and hybrid systems are the subject of many exciting investigations in recent years. The papers selected in this special issue have offered new ideas, methodologies, and applications that greatly advance the field of Petri nets, automata, and discrete-event hybrid systems. Our sincere hope is that this special issue will stimulate future cutting-edge research and development in this important field.

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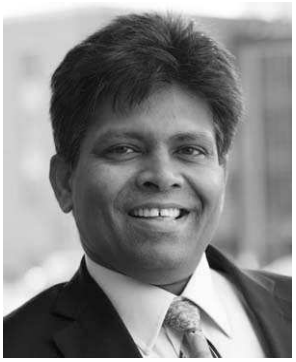

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