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Lars Michael Kristensen (Eds.)

# Transactions on Petri Nets and Other Models of Concurrency XIV

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*Guest Editors*  
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Milan, Italy

Lars Michael Kristensen  
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## **Preface by Editor-in-Chief**

The 14th issue of LNCS *Transactions on Petri Nets and Other Models of Concurrency* (ToPNoC) contains revised and extended versions of a selection of the best papers from the workshops held at the 39th International Conference on Application and Theory of Petri Nets and Concurrency (Petri Nets 2018, Bratislava, Slovakia, June 24–29, 2018), and the 18th International Conference on Application of Concurrency to System Design (ACSD 2018, Bratislava, Slovakia, June 24–29, 2018).

I would like to thank the two guest editors of this special issue: Lars Michael Kristensen and Lucia Pomello. Moreover, I would like to thank all authors, reviewers, and organizers of the Petri Nets 2018 and ACSD 2018 satellite workshops, without whom this issue of ToPNoC would not have been possible.

October 2019

Maciej Koutny

# LNCS Transactions on Petri Nets and Other Models of Concurrency: Aims and Scope

ToPNoC aims to publish papers from all areas of Petri nets and other models of concurrency ranging from theoretical work to tool support and industrial applications. The foundations of Petri nets were laid by the pioneering work of Carl Adam Petri and his colleagues in the early 1960s. Since then, a huge volume of material has been developed and published in journals and books as well as presented at workshops and conferences.

The annual International Conference on Application and Theory of Petri Nets and Concurrency started in 1980. For more information on the international Petri net community, see: <http://www.informatik.uni-hamburg.de/TGI/PetriNets/>.

All issues of ToPNoC are LNCS volumes. Hence they appear in all main libraries and are also accessible on SpringerLink (electronically). It is possible to subscribe to ToPNoC without subscribing to the rest of LNCS.

ToPNoC contains:

- Revised versions of a selection of the best papers from workshops and tutorials concerned with Petri nets and concurrency
- Special issues related to particular subareas (similar to those published in the *Advances in Petri Nets* series)
- Other papers invited for publication in ToPNoC
- Papers submitted directly to ToPNoC by their authors

Like all other journals, ToPNoC has an Editorial Board, which is responsible for the quality of the journal. The members of the board assist in the reviewing of papers submitted or invited for publication in ToPNoC. Moreover, they may make recommendations concerning collections of papers for special issues. The Editorial Board consists of prominent researchers within the Petri net community and in related fields.

## Topics

The topics covered include: system design and verification using nets; analysis and synthesis; structure and behavior of nets; relationships between net theory and other approaches; causality/partial order theory of concurrency; net-based semantical, logical and algebraic calculi; symbolic net representation (graphical or textual); computer tools for nets; experience with using nets, case studies; educational issues related to nets; higher level net models; timed and stochastic nets; and standardization of nets.

Also included are applications of nets to: biological systems; security systems; e-commerce and trading; embedded systems; environmental systems; flexible manufacturing systems; hardware structures; health and medical systems; office automation;

operations research; performance evaluation; programming languages; protocols and networks; railway networks; real-time systems; supervisory control; telecommunications; cyber physical systems; and workflow.

For more information about ToPNoC see: <http://www.springer.com/gp/computer-science/lncs/lncs-transactions/petri-nets-and-other-models-of-concurrency-topnoc-/731240>.

## **Submission of Manuscripts**

Manuscripts should follow LNCS formatting guidelines, and should be submitted as PDF or zipped PostScript files to ToPNoC@ncl.ac.uk. All queries should be addressed to the same e-mail address.

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## Preface by Guest Editors

This volume of ToPNoC contains revised versions of a selection of the best workshop papers presented at satellite events of the 39th International Conference on Application and Theory of Petri Nets and Concurrency (Petri Nets 2018) and the 18th International Conference on Application of Concurrency to System Design (ACSD 2018). In addition, this volume contains three papers based on the advanced tutorials held in conjunction with Petri Nets 2017/2018 and ACSD 2017/2018 as well as one paper submitted directly to ToPNoC.

As guest editors, we are indebted to the Program Committees of the workshops and in particular to the chairs. Without their enthusiastic efforts, this volume would not have been possible. We are also indebted to the lecturers of the advanced tutorials who took the time and effort to transform the material presented at the tutorial into self-contained papers aimed at a broad audience.

The workshop papers considered for this special issue have been selected in a close cooperation with the workshop chairs. Members of the Program Committees have participated in reviewing the new versions of the papers eventually submitted. We have received suggestions for papers for this special issue from:

- ATAED 2018: Workshop on Algorithms and Theories for the Analysis of Event Data (chairs: Wil van der Aalst, Robin Bergenthum, and Josep Carmona)
- PNSE 2018: International Workshop on Petri Nets and Software Engineering (chairs: Ekkart Kindler, Daniel Moldt, and Heiko Rölke)

The authors of the suggested papers have been invited to improve and extend their results where possible, based on the comments received before and during the workshops. Each resulting revised submission was reviewed by at least two referees. We followed the principle of asking for fresh reviews of the revised papers, also from referees not involved initially in the reviewing of the original workshop contributions. All papers have gone through the standard two-stage journal reviewing process, and eventually eight have been accepted after rigorous reviewing and revising. In addition, we invited the organizers of advanced tutorials to coordinate a paper presenting the material from the tutorial. The papers based on the advanced tutorials have also undergone a review process prior to inclusion in this special volume.

The tutorial paper “A Tour in Process Mining: From Practice to Algorithmic Challenges” by Wil van der Aalst, Josep Carmona, Thomas Chatain, and Boudewijn van Dongen gives an introduction to the field of process mining which in recent years has shown to be a highly successful approach for bridging the gap between traditional model-based process analysis and data-centric analysis techniques. The paper describes a range of techniques central to the discovery of process models from event logs, and in addition covers conformance checking techniques that can be applied for investigation how process models deviates from reality.

The tutorial paper by Karsten Wolf entitled “How Petri Net Theory Serves Petri Net Model Checking: A Survey” shows how the performance of verification based on reachability graphs can be improved by exploiting the rich structure theory developed for Petri nets. The paper provides a highly interesting demonstration of how different branches of Petri net research can be integrated. Specifically, the paper discusses how place and transition invariants, siphons, and traps make it possible to eliminate or simplify atomic propositions in the properties to be verified; provide more compact representation of markings (states); and detect behavioral cycles and diamonds. It is shown how this can be exploited in CTL and LTL model checking and in the stubborn sets and sweep-line methods.

Many concurrent and distributed systems contain multiple copies of the same components. The tutorial paper “Parametric Verification: An Introduction” by Étienne André, Michał Knapik, Didier Lime, Wojciech Penczek, and Laure Petrucci gives an introduction to the field of research exploring how to efficiently verify systems with such characteristics. The paper concentrates on approaches based on parametric timed automata, parametric interval markov chains, parametric Petri Nets, and action synthesis. The paper also surveys software tools supporting the practical application of techniques for parametric verification.

The development of domain specific models requires appropriate tool support for modeling and execution. The paper “Integrated Simulation of Domain-Specific Modeling Languages with Petri Net-based Transformational Semantics” by David Mosteller, Michael Haustermann, Daniel Moldt, and Dennis Schmitz presents an approach to visually execute a simulation on a DSML, which semantics have been defined using a transformation to Petri nets, using the Renew Meta-Modeling and Transformation framework. To illustrate the approach, the authors present the integrated simulation of a selected subset of Business Process Model and Notation (BPMN) and refer to a model transformation to Petri nets.

Machine to Machine (M2M) communication and Internet of Things (IoT) are becoming more pervasive with the increase of use of communicating devices. Publish-subscribe protocols such as the Message Queuing Telemetry Transport (MQTT) protocol are widely used in this context. The paper “Formal Modelling and Incremental Verification of the MQTT IoT Protocol” by Alejandro Rodríguez, Lars Michael Kristensen, and Adrian Rutle presents a Coloured Petri Net (CPN) model of the MQTT protocol logic using CPN Tools. The modeling approach is incremental: the functionality of the protocol is gradually introduced using a set of CPN modeling patterns and properties are verified in each incremental step. As a main advantage, the effect of the state explosion problem in model checking is reduced.

The paper “Kleene Theorems for Free Choice Automata over Distributed Alphabets” by Ramchandra Phawade deals with the characterization of languages generated by free choice nets. It considers safe, state machine decomposable labeled free choice nets, with acceptance conditions. The labels are taken over an alphabet which is distributed consistently with the sequential components of the net. Syntactic expressions are given for the corresponding accepted languages by using synchronous products and Zielonka automata.

Raymond Devillers, Evgeny Erofeev, and Thomas Hujsa in their paper “Synthesis of Weighted Marked Graphs from Constrained Labelled Transition Systems: A Geometric Approach” extended recent work on investigating the problems of analyzing Petri nets and synthesizing them from labeled transition systems (LTS). They provide new conditions for the synthesis of Weighted Marked Graphs (WMGs), a well-known and useful class of weighted Petri nets in which each place has at most one input and one output. They also tackle geometrically the WMG-solvability of finite, acyclic LTS with any number of labels.

The paper “Evaluating Conformance Measures in Process Mining using Conformance Propositions” by Anja F. Syring, Niek Tax, and Wil M. P. van der Aalst provides a rich collection of conformance propositions and uses these to evaluate current existing conformance checking measures that are available in the process mining area. This includes the recall (fitness), precision, and generalization. Many recall, precision, and generalization measures have been developed and the paper formulates the challenges and requirements related to these measures.

The paper “Relabelling LTS for Petri Net Synthesis via Solving Separation Problems” by Uli Schlachter and Harro Wimmel, submitted directly to ToPNoC, deals with the problem of finding an unlabeled Petri net with a reachability graph isomorphic to a given usually finite labeled transition system.

As guest editors, we would like to thank all authors and referees who have contributed to this issue. The quality of this volume is the result of the high scientific value of their work. Moreover, we would like to acknowledge the excellent cooperation throughout the whole process that has made our work a pleasant task. We are also grateful to the Springer/ToPNoC team for the final production of this issue.

September 2019

Lucia Pomello  
Lars Michael Kristensen

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