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Perspectives of System Informatics

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Revised Selected Papers

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Preface

PSI is the premier international forum in Russia for academic and industrial researchers, developers, and users working on topics relating to computer, software, and information sciences. The conference serves to bridge the gaps between different communities whose research areas are covered by, but not limited to, foundations of program and system development and analysis, programming methodology and software engineering, and information technologies.

The previous 11 PSI conferences were held in 1991, 1996, 1999, 2001, 2003, 2006, 2009, 2011, 2014, 2015, and 2017, respectively, and proved to be significant international events. Traditionally, PSI offers a program of keynote lectures, presentations of contributed papers and workshops, complemented by a social program reflecting the amazing diversity of Russian culture and history.

The PSI conference series is dedicated to the memory of a pioneer in theoretical and system programming research, academician Andrei Petrovich Ershov (1931–1988). Andrei Ershov graduated from the Moscow State University in 1954. He began his scientific career under the guidance of Professor Lyapunov – the supervisor of his PhD thesis. A.P. Ershov worked at the Institute of Precise Mechanics and Computing Machnery, and later headed the Theoretical Programming Department at the Computing Center of the USSR Academy of Sciences in Moscow. In 1958 the department was reorganized into the Institute of Mathematics of Siberian Branch of the USSR Academy of Sciences, and by the initiative of the academician S.L. Sobolev Ershov, A.P. Ershov was appointed the head of this department, which later became part of the Computing Center in Novosibirsk Akademgorodok. The first significant project of the department was aimed at the development of the ALPHA system, an optimizing compiler for an extension of Algol 60 implemented on a Soviet computer M-20. Later the researchers of the department created the Algibr, Epsilon, Sigma, and Alpha-6 programming systems for the BESM-6 computers. The list of the achievements also includes the first Soviet time-sharing system AIST-0, the multilanguage system BETA, research projects in artificial intelligence and parallel programming, integrated tools for text processing and publishing, and many more. A.P. Ershov was a leader and participant of these projects. In 1974 he was nominated as a Distinguished Fellow of the British Computer Society. In 1981 he received the Silver Core Award for services rendered to IFIP. Andrei Ershov's brilliant speeches were always the focus of public attention. Especially notable was his lecture on "Aesthetic and Human Factor in Programming" presented at the AFIPS Spring Joint Computer Conference in 1972.

This edition of the conference attracted 70 submissions from 15 countries. We wish to thank all their authors for their interest in PSI 2019. Each submission was reviewed by three experts, at least two of them from the same or closely related discipline as the authors. The reviewers generally provided high quality assessment of the papers and often gave extensive comments to the authors for the possible improvement of the contributions. As a result, the Program Committee selected nine high-quality papers as

regular talks, nine papers as short talks, three papers as system and experimental talks, and eight poster presers, for presentation at the conference. A range of hot topics in computer science and informatics are covered by five keynote talks given by prominent computer scientists from various countries.

We are glad to express our gratitude to all the persons and organizations who contributed to the conference: the authors of all the papers for their effort in producing the materials included here; the sponsors for their moral, financial, and organizational support; the Steering Committee members for their coordination of the conference, the Program Committee members and the reviewers who did their best to review and select the papers; and the members of the Organizing Committee for their contribution to the success of this event and its great cultural program.

The Program Committee work was done using the EasyChair conference management system.

October 2019

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Organization

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Abstracts

Towards Knowledge Graph Based Representation, Augmentation and Exploration of Scholarly Communication

Sören Auer

Leibniz Information Centre for Science and Technology and University Library, Germany

Abstract. Despite an improved digital access to scientific publications in the last decades, the fundamental principles of scholarly communication remain unchanged and continue to be largely document-based. The document-oriented workflows in science have reached the limits of adequacy as highlighted by recent discussions on the increasing proliferation of scientific literature, the deficiency of peer-review and the reproducibility crisis. We need to represent, analyse, augment and exploit scholarly communication in a knowledge-based way by expressing and linking scientific contributions and related artefacts through semantically rich, interlinked knowledge graphs. This should be based on deep semantic representation of scientific contributions, their manual, crowd-sourced and automatic augmentation and finally the intuitive exploration and interaction employing question answering on the resulting scientific knowledge base. We need to synergistically combine automated extraction and augmentation techniques, with large-scale collaboration to reach an unprecedented level of knowledge graph breadth and depth. As a result, knowledge-based information flows can facilitate completely new ways of search and exploration. The efficiency and effectiveness of scholarly communication will significant increase, since ambiguities are reduced, reproducibility is facilitated, redundancy is avoided, provenance and contributions can be better traced and the interconnections of research contributions are made more explicit and transparent. In this talk we will present first steps in this direction in the context of our Open Research Knowledge Graph initiative and the ScienceGRAPH project.

On Termination of Probabilistic Programs

Joost-Pieter Katoen

Aachen University, Germany

Abstract. Program termination is a key question in program verification. This talk considers the termination of probabilistic programs, programs that can describe randomised algorithms and more recently received attention in machine learning. Termination of probabilistic programs has some unexpected effects. Such programs may diverge with zero probability; they almost-surely terminate (AST). Running two AST-programs in sequence that both have a finite expected termination time – so-called positive AST – may yield an AST-program with an infinite termination time (in expectation). Thus positive AST is not compositional with respect to sequential program composition. This talk discusses that proving positive AST (and AST) is harder than the halting problem, shows a powerful proof rule for deciding AST, and sketches a Dijkstra-like weakest precondition calculus for proving positive AST in a fully compositional manner.

Safety Verification for Deep Neural Networks with Provable Guarantees

Marta Kwiatkowska

University of Oxford, UK

Abstract. Deep neural networks have achieved impressive experimental results in image classification, but can surprisingly be unstable with respect to adversarial perturbations, that is, minimal changes to the input image that cause the network to misclassify it. With potential applications including perception modules and end-to-end controllers for self-driving cars, this raises concerns about their safety. This lecture will describe progress with developing automated verification and testing techniques for deep neural networks to ensure safety and security of their classification decisions with respect to input manipulations. The techniques exploit Lipschitz continuity of the networks and aim to approximate, for a given set of inputs, the reachable set of network outputs in terms of lower and upper bounds, in anytime manner, with provable guarantees. We develop novel algorithms based on feature-guided search, games and global optimisation, and evaluate them on state-of-the-art networks. We also develop foundations for probabilistic safety verification for Gaussian processes, with application to neural networks.

The lecture will be based on the following publications:

1. X. Huang, M. Kwiatkowska, S. Wang and M. Wu, Safety Verification of Deep Neural Networks. In *Proc. 29th International Conference on Computer Aided Verification (CAV),* pages 3–29, LNCS, Springer, 2017.
2. W. Ruan, X. Huang, and M. Kwiatkowska. Reachability Analysis of Deep Neural Networks with Provable Guarantees. In *Proc. 27th International Joint Conference on Artificial Intelligence (IJCAI'18),* pages 2651–2659, 2018.
3. M. Wicker, X. Huang, and M. Kwiatkowska. Feature-Guided Black-Box Safety Testing of Deep Neural Networks. In *Proc. 24th International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS 2018),* pages 408–426. Springer, 2018.
4. M. Wu, M. Wicker, W. Ruan, X. Huang and M. Kwiatkowska. A Game-Based Approximate Verification of Deep Neural Networks with Provable Guarantees. Accepted to *Theoretical Computer Science* subject to revisions. CoRR abs/1807.03571 (2018)
5. L. Cardelli, M. Kwiatkowska, L. Laurenti, A. Patane. Robustness Guarantees for Bayesian Inference with Gaussian Processes. In Proc. AAAI 2019. To appear, 2019. CoRR abs/1809.06452 (2018)

Automated-Reasoning Revolution: From Theory to Practice and Back

Moshe Vardi

Rice University, USA

Abstract. For the past 40 years computer scientists generally believed that NP-complete problems are intractable. In particular, Boolean satisfiability (SAT), as a paradigmatic automated-reasoning problem, has been considered to be intractable. Over the past 20 years, however, there has been a quiet, but dramatic, revolution, and very large SAT instances are now being solved routinely as part of software and hardware design. In this talk I will review this amazing development and show how automated reasoning is now an industrial reality.

I will then describe how we can leverage SAT solving to accomplish other automated-reasoning tasks. Sampling uniformly at random satisfying truth assignments of a given Boolean formula or counting the number of such assignments are both fundamental computational problems in computer science with applications in software testing, software synthesis, machine learning, personalized learning, and more. While the theory of these problems has been thoroughly investigated since the 1980s, approximation algorithms developed by theoreticians do not scale up to industrial-sized instances. Algorithms used by the industry offer better scalability, but give up certain correctness guarantees to achieve scalability. We describe a novel approach, based on universal hashing and Satisfiability Modulo Theory, that scales to formulas with hundreds of thousands of variables without giving up correctness guarantees.

The Power of Symbolic Automata and Transducers

Margus Veanes

Microsoft Research, Redmond, USA

Abstract. Symbolic automata and transducers extend finite automata and transducers by allowing transitions to carry predicates and functions over rich alphabet theories, such as linear arithmetic. Therefore, these models extend their classic counterparts to operate over infinite alphabets, such as the set of rational numbers. Due to their expressiveness, symbolic automata and transducers have been used to verify functional programs operating over lists and trees, to prove the correctness of complex implementations of BASE64 and UTF encoders, and to expose data parallelism in computations that may otherwise seem inherently sequential. In this talk, I give an overview of what is currently known about symbolic automata and transducers as well as their variants. We discuss what makes these models different from their finite-alphabet counterparts, what kind of applications symbolic models can enable, and what challenges arise when reasoning about these formalisms. Finally, I present a list of open problems and research directions that relate to both the theory and practice of symbolic automata and transducers.

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