Lecture Notes in Computer Science 7791

Advanced Research in Computing and Software Science

Subline of Lectures Notes in Computer Science

Ranjit Jhala   Koen De Bosschere (Eds.)

Compiler Construction

22nd International Conference, CC 2013
Held as Part of the European Joint Conferences
on Theory and Practice of Software, ETAPS 2013
Rome, Italy, March 16-24, 2013
Proceedings

Springer

Volume Editors

Ranjit Jhala
University of California, San Diego
3110 Computer Science and Engineering
9500 Gilman Drive, La Jolla, CA 92093-0404, USA
E-mail: jhala@cs.ucsd.edu

Koen De Bosschere
Ghent University
System Software Lab.
Sint Pietersnieuwstraat 41, 9000 Ghent, Belgium
E-mail: koen.debosschere@elis.ugent.be

Foreword

ETAPS 2013 is the sixteenth instance of the European Joint Conferences on Theory and Practice of Software. ETAPS is an annual federated conference that was established in 1998 by combining a number of existing and new conferences. This year it comprised six sister conferences (CC, ESOP, FASE, FOSSACS, POST, TACAS), 20 satellite workshops (ACCAT, AiSOS, BX, BYTECODE, CerCo, DICE, FESCA, GRAPHITE, GT-VMT, HAS, Hot-Spot, FSS, MBT, MEALS, MLQA, PLACES, QAPL, SR, TERMGRAPH and VSSE), three invited tutorials (*e-education*, by John Mitchell; *cyber-physical systems*, by Martin Fränzle; and *e-voting* by Rolf Küsters) and eight invited lectures (excluding those specific to the satellite events).

The six main conferences received this year 627 submissions (including 18 tool demonstration papers), 153 of which were accepted (6 tool demos), giving an overall acceptance rate just above 24%. (ETAPS 2013 also received 11 submissions to the software competition, and 10 of them resulted in short papers in the TACAS proceedings). Congratulations therefore to all the authors who made it to the final programme! I hope that most of the other authors will still have found a way to participate in this exciting event, and that you will all continue to submit to ETAPS and contribute to making it the best conference on software science and engineering.

The events that comprise ETAPS address various aspects of the system development process, including specification, design, implementation, analysis, security and improvement. The languages, methodologies and tools that support these activities are all well within its scope. Different blends of theory and practice are represented, with an inclination towards theory with a practical motivation on the one hand and soundly based practice on the other. Many of the issues involved in software design apply to systems in general, including hardware systems, and the emphasis on software is not intended to be exclusive.

ETAPS is a confederation in which each event retains its own identity, with a separate Programme Committee and proceedings. Its format is open-ended, allowing it to grow and evolve as time goes by. Contributed talks and system demonstrations are in synchronised parallel sessions, with invited lectures in plenary sessions. Two of the invited lectures are reserved for 'unifying' talks on topics of interest to the whole range of ETAPS attendees. The aim of cramming all this activity into a single one-week meeting is to create a strong magnet for academic and industrial researchers working on topics within its scope, giving them the opportunity to learn about research in related areas, and thereby to foster new and existing links between work in areas that were formerly addressed in separate meetings.

ETAPS 2013 was organised by the *Department of Computer Science of 'Sapienza' University of Rome*, in cooperation with

▷ European Association for Theoretical Computer Science (EATCS)
▷ European Association for Programming Languages and Systems (EAPLS)
▷ European Association of Software Science and Technology (EASST).

The organising team comprised:

General Chair:	*Daniele Gorla;*
Conferences:	*Francesco Parisi Presicce;*
Satellite Events:	*Paolo Bottoni* and *Pietro Cenciarelli;*
Web Master:	*Igor Melatti;*
Publicity:	*Ivano Salvo;*
Treasurers:	*Federico Mari* and *Enrico Tronci.*

Overall planning for ETAPS conferences is the responsibility of its Steering Committee, whose current membership is:

Vladimiro Sassone (Southampton, chair), Martín Abadi (Santa Cruz), Erika Ábrahám (Aachen), Roberto Amadio (Paris 7), Gilles Barthe (IMDEA-Software), David Basin (Zürich), Saddek Bensalem (Grenoble), Michael O'Boyle (Edinburgh), Giuseppe Castagna (CNRS Paris), Albert Cohen (Paris), Vittorio Cortellessa (L'Aquila), Koen De Bosschere (Gent), Ranjit Jhala (San Diego), Matthias Felleisen (Boston), Philippa Gardner (Imperial College London), Stefania Gnesi (Pisa), Andrew D. Gordon (MSR Cambridge and Edinburgh), Daniele Gorla (Rome), Klaus Havelund (JLP NASA Pasadena), Reiko Heckel (Leicester), Holger Hermanns (Saarbrücken), Joost-Pieter Katoen (Aachen), Paul Klint (Amsterdam), Jens Knoop (Vienna), Steve Kremer (Nancy), Gerald Lüttgen (Bamberg), Tiziana Margaria (Potsdam), Fabio Martinelli (Pisa), John Mitchell (Stanford), Anca Muscholl (Bordeaux), Catuscia Palamidessi (INRIA Paris), Frank Pfenning (Pittsburgh), Nir Piterman (Leicester), Arend Rensink (Twente), Don Sannella (Edinburgh), Zhong Shao (Yale), Scott A. Smolka (Stony Brook), Gabriele Taentzer (Marburg), Tarmo Uustalu (Tallinn), Dániel Varró (Budapest) and Lenore Zuck (Chicago).

The ordinary running of ETAPS is handled by its management group comprising: Vladimiro Sassone (chair), Joost-Pieter Katoen (deputy chair and publicity chair), Gerald Lüttgen (treasurer), Giuseppe Castagna (satellite events chair), Holger Hermanns (liaison with local organiser) and Gilles Barthe (industry liaison).

I would like to express here my sincere gratitude to all the people and organisations that contributed to ETAPS 2013, the Programme Committee chairs and members of the ETAPS conferences, the organisers of the satellite events, the speakers themselves, the many reviewers, all the participants, and Springer-Verlag for agreeing to publish the ETAPS proceedings in the ARCoSS subline.

Last but not least, I would like to thank the organising chair of ETAPS 2013, Daniele Gorla, and his Organising Committee, for arranging for us to have ETAPS in the most beautiful and historic city of Rome.

My thoughts today are with two special people, profoundly different for style and personality, yet profoundly similar for the love and dedication to our discipline, for the way they shaped their respective research fields, and for the admiration and respect that their work commands. Both are role-model computer scientists for us all.

ETAPS in Rome celebrates *Corrado Böhm*. Corrado turns 90 this year, and we are just so lucky to have the chance to celebrate the event in Rome, where he has worked since 1974 and established a world-renowned school of computer scientists. Corrado has been a pioneer in research on programming languages and their semantics. Back in 1951, years before FORTRAN and LISP, he defined and implemented a *metacircular compiler* for a programming language of his invention. The compiler consisted of just 114 instructions, and anticipated some modern list-processing techniques.

Yet, Corrado's claim to fame is asserted through the breakthroughs expressed by the *Böhm-Jacopini Theorem* (CACM 1966) and by the invention of *Böhm-trees*. The former states that any algorithm can be implemented using only sequencing, conditionals, and while-loops over elementary instructions. Böhm trees arose as a convenient data structure in Corrado's milestone proof of the decidability inside the λ-calculus of the equivalence of terms in β-η-normal form.

Throughout his career, Corrado showed exceptional commitment to his roles of researcher and educator, fascinating his students with his creativity, passion and curiosity in research. Everybody who has worked with him or studied under his supervision agrees that he combines an outstanding technical ability and originality of thought with great personal charm, sweetness and kindness. This is an unusual combination in problem-solvers of such a high calibre, yet another reason why we are ecstatic to celebrate him. *Happy birthday from ETAPS, Corrado!*

ETAPS in Rome also celebrates the life and work of *Kohei Honda*. Kohei passed away suddenly and prematurely on December 4th, 2012, leaving the saddest gap in our community. He was a dedicated, passionate, enthusiastic scientist and –more than that!– his enthusiasm was contagious. Kohei was one of the few theoreticians I met who really succeeded in building bridges between theoreticians and practitioners. He worked with W3C on the standardisation of web services choreography description languages (WS-CDL) and with several companies on *Savara* and *Scribble*, his own language for the description of application-level protocols among communicating systems.

Among Kohei's milestone research, I would like to mention his 1991 epoch-making paper at ECOOP (with M. Tokoro) on the treatment of asynchrony in message passing calculi, which has influenced all process calculi research since. At ETAPS 1998 he introduced (with V. Vasconcelos and M. Kubo) a new concept in type theories for communicating processes: it came to be known as '*session types*,' and has since spawned an entire research area, with practical and multi-disciplinary applications that Kohei was just starting to explore.

Kohei leaves behind him enormous impact, and a lasting legacy. He is irreplaceable, and I for one am proud to have been his colleague and glad for the opportunity to arrange for his commemoration at ETAPS 2013.

My final ETAPS '*Foreword*' seems like a good place for a short reflection on ETAPS, what it has achieved in the past few years, and what the future might have in store for it.

On April 1st, 2011 in Saarbrücken, we took a significant step towards the consolidation of ETAPS: the establishment of *ETAPS e.V.* This is a *non-profit association* founded under German law with the immediate purpose of supporting the conference and the related activities. ETAPS e.V. was required for practical reasons, e.g., the conference needed (to be represented by) a legal body to better support authors, organisers and attendees by, e.g., signing contracts with service providers such as publishers and professional meeting organisers. Our ambition is however to make of '*ETAPS the association*' more than just the organisers of '*ETAPS the conference*'. We are working towards finding a voice and developing a range of activities to support our scientific community, in cooperation with the relevant existing associations, learned societies and interest groups. The process of defining the structure, scope and strategy of ETAPS e.V. is underway, as is its first ever membership campaign. For the time being, ETAPS e.V. has started to support community-driven initiatives such as open access publications (LMCS and EPTCS) and conference management systems (Easychair), and to cooperate with cognate associations (European Forum for ICT).

After two successful runs, we continue to support POST, *Principles of Security and Trust*, as a candidate to become a permanent ETAPS conference. POST was the first addition to our main programme since 1998, when the original five conferences met together in Lisbon for the first ETAPS. POST resulted from several smaller workshops and informal gatherings, supported by IFIP WG 1.7, and combines the practically important subject of security and trust with strong technical connections to traditional ETAPS areas. POST is now attracting interest and support from prominent scientists who have accepted to serve as PC chairs, invited speakers and tutorialists. I am very happy about the decision we made to create and promote POST, and to invite it to be a part of ETAPS.

Considerable attention was recently devoted to our *internal processes* in order to streamline our procedures for appointing Programme Committees, choosing invited speakers, awarding prizes and selecting papers; to strengthen each member conference's own Steering Group, and, at the same time, to strike a balance between these and the ETAPS Steering Committee. A lot was done and a lot remains to be done.

We produced a *handbook* for local organisers and one for PC chairs. The latter sets out a code of conduct that all the people involved in the selection of papers, from PC chairs to referees, are expected to adhere to. From the point of view of the authors, we adopted a *two-phase submission* protocol, with fixed

deadlines in the first week of October. We published a *confidentiality policy* to set high standards for the handling of submissions, and a *republication policy* to clarify what kind of material remains eligible for submission to ETAPS after presentation at a workshop. We started an *author rebuttal phase*, adopted by most of the conferences, to improve the author experience. It is important to acknowledge that – regardless of our best intentions and efforts – the quality of reviews is not always what we would like it to be. To remain true to our commitment to the authors who elect to submit to ETAPS, we must endeavour to improve our standards of refereeing. The rebuttal phase is a step in that direction and, according to our experience, it seems to work remarkably well at little cost, provided both authors and PC members use it for what it is. ETAPS has now reached a healthy paper acceptance rate around the 25% mark, essentially uniformly across the six conferences. This seems to me to strike an excellent balance between being selective and being inclusive, and I hope it will be possible to maintain it even if the number of submissions increases.

ETAPS signed a favourable three-year publication contract with Springer for publication in the ARCoSS subline of LNCS. This was the result of lengthy negotiations, and I consider it a good achievement for ETAPS. Yet, publication of its proceedings is possibly the hardest challenge that ETAPS – and indeed most computing conferences – currently face. I was invited to represent ETAPS at a most interesting Dagstuhl Perspective Workshop on the '*Publication Culture in Computing Research*' (seminar 12452). The paper I gave there is available online from the workshop proceedings, and illustrates three of the views I formed also thanks to my experience as chair of ETAPS, respectively on open access, bibliometrics, and the roles and relative merits of conferences versus journal publications. Open access is a key issue for a conference like ETAPS. Yet, in my view it does not follow that we can altogether dispense with publishers – be they commercial, academic, or learned societies – and with their costs. A promising way forward may be based on the '*author-pays*' model, where publications fees are kept low by resorting to learned-societies as publishers. Also, I believe it is ultimately in the interest of our community to de-emphasise the perceived value of conference publications as viable – if not altogether superior – alternatives to journals. A large and ambitious conference like ETAPS ought to be able to rely on quality open-access journals to cover its entire spectrum of interests, even if that means promoting the creation of a new journal.

Due to its size and the complexity of its programme, hosting ETAPS is an increasingly challenging task. Even though excellent candidate *locations* keep being volunteered, in the longer run it seems advisable for ETAPS to provide more support to local organisers, starting e.g., by taking direct control of the organisation of satellite events. Also, after sixteen splendid years, this may be a good time to start thinking about exporting ETAPS to other continents. The US East Coast would appear to be the obvious destination for a first ETAPS outside Europe.

The strength and success of ETAPS comes also from presenting – regardless of the natural internal differences – a homogeneous interface to authors and

participants, i.e., to look like one large, coherent, well-integrated conference rather than a mere co-location of events. I therefore feel it is vital for ETAPS to regulate the centrifugal forces that arise naturally in a 'union' like ours, as well as the legitimate aspiration of individual PC chairs to run things their way. In this respect, we have large and solid foundations, alongside a few relevant issues on which ETAPS has not yet found agreement. They include, e.g., submission by PC members, rotation of PC memberships, and the adoption of a rebuttal phase. More work is required on these and similar matters.

January 2013

Vladimiro Sassone
ETAPS SC Chair
ETAPS e.V. President

Preface

This volume contains the proceedings of the 22nd International Conference on Compiler Construction (CC) held during March 21–22, 2013, in Rome, Italy as part of the European Joint Conferences on Theory and Practice of Software (ETAPS 2013).

CC is a forum for the presentation of the latest research on processing *programs* in the most general sense, that is, in analyzing, transforming, or executing any *description* of how a computing system operates, which includes traditional compiler construction as a special case. Papers were solicited on a broad range of topics, including compilation and interpretation techniques, including program representation and analysis, code generation and code optimization; run-time techniques, including memory management and dynamic and just-in-time compilation; programming tools, from refactoring editors to checkers to compilers to virtual machines to debuggers; techniques for specific domains, such as secure, parallel, distributed, embedded or mobile environments; design of novel language constructs and their implementation.

This year, 53 papers were submitted to CC. Each submission was reviewed by three or more Program Committee members. After evaluating the quality and pertinence of each paper, the committee chose to accept 13 papers for presentation at the conference. This year's program also included an invited talk by a distinguished researcher:

– Emery Berger (University of Massachusetts, Amherst) on "Programming with People: Integrating Human-Based and Digital Computation"

The success of the conference is due to the unstinting efforts of several people. First, the authors for carrying out and submitting high-quality research to CC. Second, the Program Committee and subreviewers for their perspicacious and timely reviews, which ensured the high quality of the proceedings. Third, the ETAPS organizers and Steering Committee for hosting ETAPS and for the local co-ordination and organization. Finally, we are grateful to Andrei Voronkov whose EasyChair system eased the processes of submission, paper selection, and proceedings compilation.

January 2013   Koen De Bosschere
                                                                Ranjit Jhala

Organization

Program Chairs

Koen De Bosschere   Ghent University, Belgium
Ranjit Jhala   University of California, San Diego, USA

Program Committee

Gogul Balakrishnan   NEC, Princeton, USA
Francois Bodin   CAPS entreprise, France
Albert Cohen   École Normale Supérieure, Paris, France
Koen De Bosschere   Ghent University, Belgium
Bjöorn Franke   University of Edinburgh, UK
Grigori Fursin   INRIA, France
Mary Hall   University of Utah, USA
Ben Hardekopf   University of California, Santa Barbara, USA
Ranjit Jhala   University of California, San Diego, USA
Christian Lengauer   University of Passau, Germany
Matt Might   University of Utah, USA
Alan Mycroft   Cambridge University, UK
George Necula   University of California, Berkeley, USA
Keshav Pingali   University of Texas, Austin, USA
Jurgen Vinju   CWI Amsterdam, The Netherlands
Eelco Visser   TU Delft, The Netherlands
Greta Yorsh   ARM, UK
Ben Zorn   Microsoft Research, USA

Additional Reviewers

Aldous, Peter	Fahndrich, Manuel
Baranga, Silviu	Gilray, Thomas
Basten, Bas	Gould, Miles
Basu, Protonu	Groesslinger, Armin
Berdine, Josh	Hills, Mark
Calvert, Peter	Khoo, Wei Ming
Chen, Juan	Klint, Paul
Dolan, Stephen	Koestler, Harald

Lyde, Steven
Ma, Kin-Keung
Maleki, Saeed
Margiolas, Christos
McPeak, Scott
Mytkowicz, Todd
Nguyen, Donald
Orchard, Dominic
Pasteur, Cédric
Petricek, Tomas
Petter, Michael
Powell, Daniel
Proust, Raphael

Reames, Philip
Regis-Gianas, Yann
Renggli, Lukas
Sergey, Ilya
Simbuerger, Andreas
van der Storm, Tijs
Venkat, Anand
Voigt, Janina
Wei, Tao
Westbrook, Edwin
Yi, Qing
Zhang, Yingzhou

Programming with People: Integrating Human-Based and Digital Computation (Invited Talk)

Emery Berger

University of Massachusetts, Amherst (USA)
`emery@cs.umass.edu`

Humans can perform many tasks with ease that remain difficult or impossible for computers. Crowdsourcing platforms like Amazon's Mechanical Turk make it possible to harness human-based computational power on an unprecedented scale. However, their utility as a general-purpose computational platform remains limited. The lack of complete automation makes it difficult to orchestrate complex or interrelated tasks. Scheduling human workers to reduce latency costs real money, and jobs must be monitored and rescheduled when workers fail to complete their tasks. Furthermore, it is often difficult to predict the length of time and payment that should be budgeted for a given task. Finally, the results of human-based computations are not necessarily reliable, both because human skills and accuracy vary widely, and because workers have a financial incentive to minimize their effort.

This talk presents AutoMan, the first fully automatic crowd programming system. AutoMan integrates human-based computations into a standard programming language as ordinary function calls, which can be intermixed freely with traditional functions. This abstraction allows AutoMan programmers to focus on their programming logic. An AutoMan program specifies a confidence level for the overall computation and a budget. The AutoMan runtime system then transparently manages all details necessary for scheduling, pricing, and quality control. AutoMan automatically schedules human tasks for each computation until it achieves the desired confidence level; monitors, reprices, and restarts human tasks as necessary; and maximizes parallelism across human workers while staying under budget.

AutoMan is available for download at `www.automan-lang.org`

Table of Contents

Session IV: Machine Learning

Session V: Refactoring