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Ilya Sergey (Ed.)

Programming Languages and Systems

**31st European Symposium on Programming, ESOP 2022
Held as Part of the European Joint Conferences
on Theory and Practice of Software, ETAPS 2022
Munich, Germany, April 2–7, 2022
Proceedings**



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ETAPS Foreword

Welcome to the 25th ETAPS! ETAPS 2022 took place in Munich, the beautiful capital of Bavaria, in Germany.

ETAPS 2022 is the 25th instance of the European Joint Conferences on Theory and Practice of Software. ETAPS is an annual federated conference established in 1998, and consists of four conferences: ESOP, FASE, FoSSaCS, and TACAS. Each conference has its own Program Committee (PC) and its own Steering Committee (SC). The conferences cover various aspects of software systems, ranging from theoretical computer science to foundations of programming languages, analysis tools, and formal approaches to software engineering. Organizing these conferences in a coherent, highly synchronized conference program enables researchers to participate in an exciting event, having the possibility to meet many colleagues working in different directions in the field, and to easily attend talks of different conferences. On the weekend before the main conference, numerous satellite workshops took place that attract many researchers from all over the globe.

ETAPS 2022 received 362 submissions in total, 111 of which were accepted, yielding an overall acceptance rate of 30.7%. I thank all the authors for their interest in ETAPS, all the reviewers for their reviewing efforts, the PC members for their contributions, and in particular the PC (co-)chairs for their hard work in running this entire intensive process. Last but not least, my congratulations to all authors of the accepted papers!

ETAPS 2022 featured the unifying invited speakers Alexandra Silva (University College London, UK, and Cornell University, USA) and Tomáš Vojnar (Brno University of Technology, Czech Republic) and the conference-specific invited speakers Nathalie Bertrand (Inria Rennes, France) for FoSSaCS and Lenore Zuck (University of Illinois at Chicago, USA) for TACAS. Invited tutorials were provided by Stacey Jeffery (CWI and QuSoft, The Netherlands) on quantum computing and Nicholas Lane (University of Cambridge and Samsung AI Lab, UK) on federated learning.

As this event was the 25th edition of ETAPS, part of the program was a special celebration where we looked back on the achievements of ETAPS and its constituting conferences in the past, but we also looked into the future, and discussed the challenges ahead for research in software science. This edition also reinstated the ETAPS mentoring workshop for PhD students.

ETAPS 2022 took place in Munich, Germany, and was organized jointly by the Technical University of Munich (TUM) and the LMU Munich. The former was founded in 1868, and the latter in 1472 as the 6th oldest German university still running today. Together, they have 100,000 enrolled students, regularly rank among the top 100 universities worldwide (with TUM's computer-science department ranked #1 in the European Union), and their researchers and alumni include 60 Nobel laureates.

The local organization team consisted of Jan Křetínský (general chair), Dirk Beyer (general, financial, and workshop chair), Julia Eisentraut (organization chair), and Alexandros Evangelidis (local proceedings chair).

ETAPS 2022 was further supported by the following associations and societies: ETAPS e.V., EATCS (European Association for Theoretical Computer Science), EAPLS (European Association for Programming Languages and Systems), and EASST (European Association of Software Science and Technology).

The ETAPS Steering Committee consists of an Executive Board, and representatives of the individual ETAPS conferences, as well as representatives of EATCS, EAPLS, and EASST. The Executive Board consists of Holger Hermanns (Saarbrücken), Marieke Huisman (Twente, chair), Jan Kofroň (Prague), Barbara König (Duisburg), Thomas Noll (Aachen), Caterina Urban (Paris), Tarmo Uustalu (Reykjavik and Tallinn), and Lenore Zuck (Chicago).

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I'd like to take this opportunity to thank all authors, attendees, organizers of the satellite workshops, and Springer-Verlag GmbH for their support. I hope you all enjoyed ETAPS 2022.

Finally, a big thanks to Jan, Julia, Dirk, and their local organization team for all their enormous efforts to make ETAPS a fantastic event.

February 2022

Marieke Huisman
ETAPS SC Chair
ETAPS e.V. President

Preface

This volume contains the papers accepted at the 31st European Symposium on Programming (ESOP 2022), held during April 5–7, 2022, in Munich, Germany (COVID-19 permitting). ESOP is one of the European Joint Conferences on Theory and Practice of Software (ETAPS); it is dedicated to fundamental issues in the specification, design, analysis, and implementation of programming languages and systems.

The 21 papers in this volume were selected by the Program Committee (PC) from 64 submissions. Each submission received between three and four reviews. After receiving the initial reviews, the authors had a chance to respond to questions and clarify misunderstandings of the reviewers. After the author response period, the papers were discussed electronically using the HotCRP system by the 33 Program Committee members and 33 external reviewers. Two papers, for which the PC chair had a conflict of interest, were kindly managed by Zena Ariola. The reviewing for ESOP 2022 was double-anonymous, and only authors of the eventually accepted papers have been revealed.

Following the example set by other major conferences in programming languages, for the first time in its history, ESOP featured optional artifact evaluation. Authors of the accepted manuscripts were invited to submit artifacts, such as code, datasets, and mechanized proofs, that supported the conclusions of their papers. Members of the Artifact Evaluation Committee (AEC) read the papers and explored the artifacts, assessing their quality and checking that they supported the authors' claims. The authors of eleven of the accepted papers submitted artifacts, which were evaluated by 20 AEC members, with each artifact receiving four reviews. Authors of papers with accepted artifacts were assigned official EAPLS artifact evaluation badges, indicating that they have taken the extra time and have undergone the extra scrutiny to prepare a useful artifact. The ESOP 2022 AEC awarded Artifacts Functional and Artifacts (Functional and) Reusable badges. All submitted artifacts were deemed Functional, and all but one were found to be Reusable.

My sincere thanks go to all who contributed to the success of the conference and to its exciting program. This includes the authors who submitted papers for consideration; the external reviewers who provided timely expert reviews sometimes on very short notice; the AEC members and chairs who took great care of this new aspect of ESOP; and, of course, the members of the ESOP 2022 Program Committee. I was extremely impressed by the excellent quality of the reviews, the amount of constructive feedback given to the authors, and the criticism delivered in a professional and friendly tone. I am very grateful to Andreea Costea and KC Sivaramakrishnan who kindly agreed to serve as co-chairs for the ESOP 2022 Artifact Evaluation Committee. I would like to thank the ESOP 2021 chair Nobuko Yoshida for her advice, patience, and the many insightful discussions on the process of running the conference. I thank all who contributed to the organization of ESOP: the ESOP steering committee and its chair Peter Thiemann, as well as the ETAPS steering committee and its chair Marieke Huisman.

Finally, I would like to thank Barbara König and Alexandros Evangelidis for their help with assembling the proceedings.

February 2022

Ilya Sergey

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