

21st International Conference on Types for Proofs and Programs

TYPES 2015, May 18–21, 2015, Tallinn, Estonia

Edited by

Tarmo Uustalu



Editor

Tarmo Uustalu
Department of Software Science, Tallinn University of Technology
Akadeemia tee 21B, 12618 Tallinn, Estonia
tarmo@cs.ioc.ee

ACM Classification 1998

F.4.1. Mathematical Logic and Formal Languages: Mathematical Logic – Lambda calculus and related systems

ISBN 978-3-95977-030-9

Published online and open access by

Schloss Dagstuhl – Leibniz-Zentrum für Informatik GmbH, Dagstuhl Publishing, Saarbrücken/Wadern, Germany. Online available at <http://www.dagstuhl.de/dagpub/978-3-95977-030-9>.

Publication date

March 2018

Bibliographic information published by the Deutsche Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.d-nb.de>.

License

This work is licensed under a Creative Commons Attribution 3.0 Unported license (CC-BY 3.0): <http://creativecommons.org/licenses/by/3.0/legalcode>.



In brief, this license authorizes each and everybody to share (to copy, distribute and transmit) the work under the following conditions, without impairing or restricting the authors' moral rights:

- Attribution: The work must be attributed to its authors.

The copyright is retained by the corresponding authors.

Digital Object Identifier: 10.4230/LIPIcs.TYPES.2015.0

ISBN 978-3-95977-030-9

ISSN 1868-8969

<http://www.dagstuhl.de/lipics>

LIPICs – Leibniz International Proceedings in Informatics

LIPICs is a series of high-quality conference proceedings across all fields in informatics. LIPICs volumes are published according to the principle of Open Access, i.e., they are available online and free of charge.

Editorial Board

- Luca Aceto (*Chair*, Gran Sasso Science Institute and Reykjavik University)
- Susanne Albers (TU München)
- Chris Hankin (Imperial College London)
- Deepak Kapur (University of New Mexico)
- Michael Mitzenmacher (Harvard University)
- Madhavan Mukund (Chennai Mathematical Institute)
- Anca Muscholl (University Bordeaux)
- Catuscia Palamidessi (INRIA)
- Raimund Seidel (Saarland University and Schloss Dagstuhl – Leibniz-Zentrum für Informatik)
- Thomas Schwentick (TU Dortmund)
- Reinhard Wilhelm (Saarland University)

ISSN 1868-8969

<http://www.dagstuhl.de/lipics>

■ Contents

Preface	
<i>Tarmo Uustalu</i>	0:vii
A Type Theory for Probabilistic and Bayesian Reasoning	
<i>Robin Adams and Bart Jacobs</i>	1:1–1:34
Heterogeneous Substitution Systems Revisited	
<i>Benedikt Ahrens and Ralph Matthes</i>	2:1–2:23
Towards a Cubical Type Theory without an Interval	
<i>Thorsten Altenkirch and Ambrus Kaposi</i>	3:1–3:27
Constrained Polymorphic Types for a Calculus with Name Variables	
<i>Davide Ancona, Paola Giannini, and Elena Zucca</i>	4:1–4:29
Cubical Type Theory: A Constructive Interpretation of the Univalence Axiom	
<i>Cyril Cohen, Thierry Coquand, Simon Huber, and Anders Mörtberg</i>	5:1–5:34
Efficient Type Checking for Path Polymorphism	
<i>Juan Edi, Andrés Viso, and Eduardo Bonelli</i>	6:1–6:23
A Certified Study of a Reversible Programming Language	
<i>Luca Paolini, Mauro Piccolo, and Luca Roversi</i>	7:1–7:21
Functional Kan Simplicial Sets: Non-Constructivity of Exponentiation	
<i>Erik Parmann</i>	8:1–8:25
II-Ware: Hardware Description and Verification in Agda	
<i>João Paulo Pizani Flor, Wouter Swierstra, and Yorick Sijsling</i>	9:1–9:27



■ Preface

This volume is the post-proceedings of the 21st International Conference on Types for Proofs and Programs, TYPES 2015, which was held in Tallinn, Estonia, 18–21 May 2015.

The TYPES meetings are a forum to present new and on-going work in all aspects of type theory and its applications, especially in formalized and computer assisted reasoning and computer programming. The meetings from 1990 to 2008 were annual workshops of a sequence of five EU funded networking projects. Since 2009, TYPES has been run as an independent conference series. Prior to the 2015 meeting in Tallinn, TYPES meetings had taken place in Antibes (1990), Edinburgh (1991), Båstad (1992), Nijmegen (1993), Båstad (1994), Torino (1995), Aussois (1996), Kloster Irsee (1998), Lökeberg (1999), Durham (2000), Berg en Dal near Nijmegen (2002), Torino (2003), Jouy-en-Josas near Paris (2004), Nottingham (2006), Cividale del Friuli (2007), Torino (2008), Aussois (2009), Warsaw (2010), Bergen (2011), Toulouse (2013), Paris (2014), with post-proceedings published in various outlets and since the Bergen 2011 meeting in LIPIcs.

The TYPES areas of interest include, but are not limited to: foundations of type theory and constructive mathematics; applications of type theory; dependently typed programming; industrial uses of type theory technology; meta-theoretic studies of type systems; proof assistants and proof technology; automation in computer-assisted reasoning; links between type theory and functional programming; formalizing mathematics using type theory.

The TYPES conferences are traditionally of open and informal character. Selection of talks for presentation at the conference is based on short abstracts; reporting work in progress and work presented or published elsewhere is welcome. A formal post-proceedings volume is prepared after the conference. Papers submitted to that must represent unpublished work and are subjected to a full review process; the call for papers is open and not restricted to the authors and presentations of the conference.

The programme of TYPES 2015 included three invited talks by Gilles Barthe (IMDEA Software Institute), Andrej Bauer (University of Ljubljana) and Peter Selinger (Dalhousie University) as well as two tutorials by Joachim Kock (Autonomous University of Barcelona) and Peter LeFanu Lumsdaine (Stockholm University). The contributed part of the programme consisted of 35 talks.

TYPES 2015 was sponsored by the European Regional Development Fund through the CoE project EXCS and the ICT R&D project Coinduction.

The call for contributions to the post-proceedings of TYPES 2015 led to the present volume of nine papers documenting conference presentations at TYPES 2015 and other new work by members of the community. Four of the papers concern homotopy type theory while the rest are on a variety of topics: probabilistic reasoning, reversible programming, hardware description, patterns and dynamic rebinding. I thank both the authors and the reviewers for their hard work.

Tarmo Uustalu
Tallinn, June 2017



■ Organization

Program Committee

Andrea Asperti (Università di Bologna)
Robert Atkey (University of Edinburgh)
Ulrich Berger (Swansea University)
Jean-Philippe Bernardy (Chalmers University of Technology)
Edwin Brady (University of St Andrews)
Joëlle Despeyroux (INRIA Sophia Antipolis – Méditerranée)
Herman Geuvers (Radboud Universiteit Nijmegen)
Sam Lindley (University of Edinburgh)
Assia Mahboubi (INRIA Saclay – Île de France)
Ralph Matthes (IRIT, CNRS & Université Paul Sabatier)
Aleksandar Nanevski (IMDEA Software)
Christine Paulin-Mohring (LRI, Université Paris-Sud)
Simona Ronchi Della Rocca (Università di Torino)
Ulrich Schöpp (Ludwig-Maximilians-Universität München)
Bas Spitters (Carnegie Mellon University *to* Aarhus Universitet)
Pawel Urzyczyn (University of Warsaw)
Tarmo Uustalu (Institute of Cybernetics, Tallinn) (chair)

Organizing Committee

Tiina Laasma
Monika Perkmann
Tarmo Uustalu

Host Institution

Institute of Cybernetics at Tallinn University of Technology

Sponsor

European Regional Development Fund
through the CoE project EXCS and the ICT R&D project Coinduction



■ List of Authors

Robin Adams
Universitetet i Bergen
Bergen, Norway
robin.adams@uib.no

Benedikt Ahrens
Inria Rennes – Bretagne Atlantique
Nantes, France
benedikt.ahrens@inria.fr

Thorsten Altenkirch
University of Nottingham
Nottingham, UK
txa@cs.nott.ac.uk

Davide Ancona
Università di Genova
Genova, Italy
davide.ancona@unige.it

Eduardo Bonelli
Universidad Nacional de Quilmes
Bernal, Argentina
eabonelli@gmail.com

Cyril Cohen
Inria Sophia Antipolis – Méditerranée
Sophia Antipolis, France
cyril.cohen@inria.fr

Thierry Coquand
University of Gothenburg
Gothenburg, Sweden
thierry.coquand@cse.gu.se

Juan Edi
Universidad de Buenos Aires
Buenos Aires, Argentina
jedi@dc.uba.ar

Paola Giannini
Università del Piemonte Orientale,
Alessandria, Italy
paola.giannini@uniupo.it

Simon Huber
University of Gothenburg
Gothenburg, Sweden
simon.huber@cse.gu.se

Bart Jacobs
Radboud Universiteit
Nijmegen, The Netherlands
bart@cs.ru.nl

Ambrus Kaposi
Eötvös Loránd University
Budapest, Hungary
akaposi@inf.elte.hu

Ralph Matthes
IRIT, CNRS & Univ. Paul Sabatier
Toulouse, France
matthes@irit.fr

Andres Mörtberg
Institute for Advanced Study
Princeton, NJ, USA
amortberg@math.ias.edu

Luca Paolini
Università di Torino
Torino, Italy
lpaolini@unito.it

Erik Parmann
Universitetet i Bergen
Bergen, Norway
eparmann@gmail.com

Mauro Piccolo
Università di Torino
Torino, Italy
mrpiccol@gmail.com

João Paulo Pizani Flor
Universiteit Utrecht
Utrecht, The Netherlands
j.p.pizaniflor@uu.nl

Luca Roversi
Università di Torino
Torino, Italy
lroversi@unito.it

Yorick Sijsling
Universiteit Utrecht
Utrecht, The Netherlands
y.sijsling@uu.nl

21st International Conference on Types for Proofs and Programs (TYPES 2015).
Editors: Tarmo Uustalu



Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Wouter Swierstra
Universiteit Utrecht
Utrecht, The Netherlands
w.swierstra@uu.nl

Andrés Viso
Universidad de Buenos Aires
Buenos Aires, Argentina
aevisto@gmail.com

Elena Zucca
Università di Genova
Genova, Italy
elena.zucca@unige.it