

# 22nd International Conference on Types for Proofs and Programs

TYPES 2016, May 23–26, 2016, Novi Sad, Serbia

Edited by

Silvia Ghilezan

Herman Geuvers

Jelena Ivetić



*Editors*

Herman Geuvers  
Eindhoven University of Technology  
Radboud University  
herman@cs.ru.nl

Silvia Ghilezan  
Mathematical Institute SASA, Belgrade  
University of Novi Sad  
gsilvia@uns.ac.rs

Jelena Ivetić  
Faculty of Technical Sciences  
University of Novi Sad  
jelenaivetic@uns.ac.rs

*ACM Classification 2012*

Theory of computation → Type theory

**ISBN 978-3-95977-065-1**

*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/978-3-95977-065-1>.

*Publication date*

October, 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.2016.0

**ISBN 978-3-95977-065-1**

**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)
- Christel Baier (TU Dresden)
- Javier Esparza (TU München)
- 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>Silvia Ghilezan, Herman Geuvers, and Jelena Ivetić</i> .....	0:vii
List of Authors	
.....	0:ix–0:x

### Invited Papers

Mechanized Metatheory Revisited: An Extended Abstract	
<i>Dale Miller</i> .....	1:1–1:16
Intersection Types and Denotational Semantics: An Extended Abstract	
<i>Simona Ronchi Della Rocca</i> .....	2:1–2:7

### Regular Papers

A Normalizing Computation Rule for Propositional Extensionality in Higher-Order Minimal Logic	
<i>Robin Adams, Marc Bezem, and Thierry Coquand</i> .....	3:1–3:20
On Natural Deduction for Herbrand Constructive Logics II: Curry-Howard Correspondence for Markov’s Principle in First-Order Logic and Arithmetic	
<i>Federico Aschieri and Matteo Manighetti</i> .....	4:1–4:17
Design and Implementation of the Andromeda Proof Assistant	
<i>Andrej Bauer, Gaëtan Gilbert, Philipp G. Haselwarter, Matija Pretnar, and     Christopher A. Stone</i> .....	5:1–5:31
Realizability at Work: Separating Two Constructive Notions of Finiteness	
<i>Marc Bezem, Thierry Coquand, Keiko Nakata, and Erik Parmann</i> .....	6:1–6:23
Parametricity, Automorphisms of the Universe, and Excluded Middle	
<i>Auke B. Booij, Martín H. Escardó, Peter LeFanu Lumsdaine, and Michael Shulman</i> .....	7:1–7:14
Coq Support in HAHA	
<i>Jacek Chrząszcz, Aleksy Schubert, and Jakub Zakrzewski</i> .....	8:1–8:26
A Shallow Embedding of Pure Type Systems into First-Order Logic	
<i>Lukasz Czajka</i> .....	9:1–9:39
Permutability in Proof Terms for Intuitionistic Sequent Calculus with Cuts	
<i>José Espírito Santo, Maria João Frade, and Luís Pinto</i> .....	10:1–10:27
Covering Spaces in Homotopy Type Theory	
<i>Kuen-Bang Hou (Favonia) and Robert Harper</i> .....	11:1–11:16
Defining Trace Semantics for CSP-Agda	
<i>Bashar Igried and Anton Setzer</i> .....	12:1–12:23
On Subtyping in Type Theories with Canonical Objects	
<i>Georgiana Elena Lungu and Zhaohui Luo</i> .....	13:1–13:31

22nd International Conference on Types for Proofs and Programs (TYPES 2016).

Editors: Silvia Ghilezan, Herman Geuvers, and Jelena Ivetić

Leibniz International Proceedings in Informatics



Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

**0:vi**      **Contents**

A Formal Study of Boolean Games with Random Formulas as Payoff Functions <i>Érik Martin-Dorel and Sergei Soloviev</i> .....	14:1–14:22
The Completeness of <i>BCD</i> for an Operational Semantics <i>Richard Statman</i> .....	15:1–15:5

## ■ Preface

This issue is the post-proceedings of the 22nd International Conference on Types for Proofs and Programs, TYPES 2016, which was held in Novi Sad, Serbia, May 23-26, 2016.

The TYPES meetings are a forum to present new and on-going work on all aspects of type theory and its applications, especially in formalized and computer assisted reasoning and computer programming. The meetings have started in the late 1980s, from 1990 to 2008 they were the annual workshops of EU funded projects, from 2009 to 2015 TYPES was run as an independent conference. TYPES 2016 was the annual meeting of the COST Action CA15123 EUTypes - The European research network on types for programming and verification. Previous TYPES meetings were held in Antibes (1990), Edinburgh (1991), Baåstad (1992), Nijmegen (1993), Baåstad (1994), Turin (1995), Aussois (1996), Kloster Irsee (1998), Lökeberg (1999), Durham (2000), Berg en Dal (2002), Turin (2003), Jouy-en-Josas (2004), Nottingham (2006), Cividale del Friuli (2007), Turin (2008), Aussois (2009), Warsaw (2010), Bergen (2011), Toulouse (2013), Paris (2014) and Tallinn (2015).

The TYPES conference is traditionally open for work in all areas of type theory, discussing work in progress and work presented elsewhere or published. The post-proceedings is based on an open call, not restricted to the participants of the meeting.

The program of the conference comprised three invited talks by Dale Miller, Simona Ronchi della Rocca and Simon Gay, and 46 contributed talks. The meeting was attended by over 120 participants. There was a satellite event CLA 2016 - 9th Workshop Computational Logic and Applications.

The Program Committee members of TYPES 2016 were:

Thorsten Altenkirch (University of Nottingham), UK; Zena Ariola (University of Oregon), USA; Andrej Bauer (University of Ljubljana), Slovenia; Marc Bezem (University of Bergen), Norway; Małgorzata Biernacka (University of Wrocław), Poland; Edwin Brady (University of St Andrews), UK; Thierry Coquand (University of Gothenburg), Sweden; José Espírito Santo (University of Minho), Portugal; Ken-etsu Fujita (Gunma University), Japan; Silvia Ghilezan (University of Novi Sad) (co-chair), Serbia; Hugo Herbelin (INRIA Paris-Rocquencourt), France; Jelena Ivetić (University of Novi Sad) (co-chair), Serbia; Marina Lenisa (University of Udine), Italy; Elaine Pimentel (Federal University of Rio Grande do Norte), Brazil; Andrew Polonsky (University Paris Diderot), France; Jakob Rehof (Technical University of Dortmund), Germany; Claudio Sacerdoti Coen (University of Bologna), Italy; Carsten Schürmann (IT University of Copenhagen), Denmark; Wouter Swierstra (Utrecht University), The Netherlands; Nicolas Tabareau (INRIA), France; Tarmo Uustalu (Tallinn University of Technology), Estonia.

There were 20 submissions to this open post-proceedings, which received at least two reviews by 46 anonymous referees with a second round of reviewing.

We would like to thank the authors and the program committee members for their contribution to this volume. We are grateful to the referees for their expertise which led to improvement of the content. The submissions were handled via the EasyChair platform. We thank Michael Wagner and Schloss Dagstuhl for the final editing and publishing of this volume.

Silvia Ghilezan  
Herman Geuvers  
Jelena Ivetić  
July 2018

22nd International Conference on Types for Proofs and Programs (TYPES 2016).

Editors: Silvia Ghilezan, Herman Geuvers, and Jelena Ivetić



Leibniz International Proceedings in Informatics

LIPIC Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany





## ■ List of Authors

Robin Adams  
Chalmers tekniska högskola, Data- och  
informationsteknik  
Göteborg, Sweden  
robinad@chalmers.se

Federico Aschieri  
Institut für Diskrete Mathematik und  
Geometrie, Technische Universität Wien  
Vienna, Austria

Andrej Bauer  
University of Ljubljana  
Ljubljana, Slovenia

Marc Bezem  
Universitetet i Bergen, Institutt for  
Informatikk  
Bergen, Norway  
bezem@ii.uib.no

Auke B. Booij  
School of Computer Science, University of  
Birmingham  
Birmingham, UK  
abb538@cs.bham.ac.uk

Jacek Chrzaszcz  
University of Warsaw  
Warsaw, Poland  
chrzaszc@mimuw.edu.pl

Thierry Coquand  
Chalmers tekniska högskola, Data- och  
informationsteknik  
Göteborg, Sweden  
coquand@chalmers.se

Lukasz Czajka  
DIKU, University of Copenhagen  
Copenhagen, Denmark  
luta@di.ku.dk

Martín H. Escardó  
School of Computer Science, University of  
Birmingham  
Birmingham, UK  
m.escardo@cs.bham.ac.uk

José Espírito Santo  
Centro de Matemática, Universidade do  
Minho  
Braga, Portugal

Maria João Frade  
HASLab/INESC TEC and Universidade do  
Minho  
Braga, Portugal

Gaëtan Gilbert  
École Normale Supérieure de Lyon  
Lyon, France

Robert Harper  
Computer Science Department, Carnegie  
Mellon University  
Pittsburgh, PA, USA  
rwh@cs.cmu.edu

Philipp G. Haselwarter  
University of Ljubljana  
Ljubljana, Slovenia

Kuen-Bang Hou (Favonia)  
Department of Computer Science and  
Engineering, University of Minnesota Twin  
Cities  
Minneapolis, MN, USA  
favonia@umn.edu

Bashar Igried  
The Hashemite University, Faculty of Prince  
Al-Hussein Bin Abdallah II for Information  
Technology  
Zarqa, Jordan  
bashar.igried@yahoo.com

Peter LeFanu Lumsdaine  
Mathematics Department, Stockholm  
University  
Stockholm, Sweden  
p.l.lumsdaine@math.su.se

Georgiana Elena Lungu  
Department of Computer Science, Royal  
Holloway, University of London  
London, UK  
georgiana.lungu.2013@live.rhul.ac.uk

22nd International Conference on Types for Proofs and Programs (TYPES 2016).

Editors: Silvia Ghilezan, Herman Geuvers, and Jelena Ivetić



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

Zhaohui Luo  
Department of Computer Science, Royal  
Holloway, University of London  
London, UK  
Zhaohui.Luo@rhul.ac.uk

Matteo Manighetti  
Institut für Diskrete Mathematik und  
Geometrie, Technische Universität Wien  
Vienna, Austria

Érik Martin-Dorel  
Lab. IRIT, Univ. of Toulouse, CNRS  
Toulouse, France  
erik.martin-dorel@irit.fr

Dale Miller  
Inria and LIX, École Polytechnique  
Palaiseau, France

Keiko Nakata  
SAP Innovation Center Network  
Potsdam, Germany

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

Luís Pinto  
Centro de Matemática, Universidade do  
Minho  
Braga, Portugal

Matija Pretnar  
University of Ljubljana  
Ljubljana, Slovenia

Simona Ronchi Della Rocca  
Università degli Studi di Torino, dept  
Computer Science  
Torino, Italy  
ronchi@di.unito.it

Aleksy Schubert  
University of Warsaw  
Warsaw, Poland  
alx@mimuw.edu.pl

Anton Setzer  
Swansea University, Dept. of Computer  
Science  
Swansea, Wales, UK  
a.g.setzer@swansea.ac.uk

Michael Shulman  
Department of Mathematics, University of  
San Diego  
San Diego, USA  
shulman@sandiego.edu

Sergei Soloviev  
Lab. IRIT, Univ. of Toulouse, CNRS  
Toulouse, France  
sergei.soloviev@irit.fr

Richard Statman  
Carnegie Mellon University, Department of  
Mathematical Sciences  
Pittsburgh, PA, USA  
statman@cs.cmu.edu

Christopher A. Stone  
Harvey Mudd College  
Claremont, CA, USA

Jakub Zakrzewski  
University of Warsaw  
Warsaw, Poland  
j.zakrzewski@mimuw.edu.pl