# Lecture Notes in Artificial Intelligence 11617

### Subseries of Lecture Notes in Computer Science

Series Editors

Randy Goebel University of Alberta, Edmonton, Canada Yuzuru Tanaka Hokkaido University, Sapporo, Japan Wolfgang Wahlster DFKI and Saarland University, Saarbrücken, Germany

Founding Editor

Jörg Siekmann DFKI and Saarland University, Saarbrücken, Germany More information about this series at http://www.springer.com/series/1244

Cezary Kaliszyk · Edwin Brady · Andrea Kohlhase · Claudio Sacerdoti Coen (Eds.)

# Intelligent Computer Mathematics

12th International Conference, CICM 2019 Prague, Czech Republic, July 8–12, 2019 Proceedings



*Editors* Cezary Kaliszyk University of Innsbruck Innsbruck, Austria

Andrea Kohlhase University of Applied Sciences Neu-Ulm, Germany Edwin Brady University of St. Andrews St. Andrews, UK

Claudio Sacerdoti Coen University of Bologna Bologna, Italy

ISSN 0302-9743 ISSN 1611-3349 (electronic) Lecture Notes in Artificial Intelligence ISBN 978-3-030-23249-8 ISBN 978-3-030-23250-4 (eBook) https://doi.org/10.1007/978-3-030-23250-4

LNCS Sublibrary: SL7 - Artificial Intelligence

#### © Springer Nature Switzerland AG 2019

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

#### Preface

This volume contains the contributions of the 12th Conference on Intelligent Computer Mathematics, CICM 2019. The CICM conference is dedicated to promoting the advancement of machine-supported reasoning, computation, and knowledge management in science, technology, engineering, and mathematics. This year CICM took place in Prague, Czech Republic, during July 8–12, 2019, and was hosted at the Czech Institute of Informatics, Robotics, and Cybernetics (CIIRC) of the Czech Technical University in Prague (CTU). The CICM conference series is the combination of several events that were previously held separately: the Symposium on the Integration of Symbolic Computation and Mechanized Reasoning, the International Conference on Mathematical Knowledge Management, and the Digital Mathematics Library Conference.

CICM has been held annually as a joint meeting since 2008. Previous meetings took place in Birmingham (UK, 2008), Grand Bend (Canada, 2009), Paris (France, 2010), Bertinoro (Italy, 2011), Bremen (Germany, 2012), Bath (UK, 2013), Coimbra (Portugal, 2014), Washington DC (USA, 2015), Białystok (Poland, 2016), Edinburgh (UK, 2017), and Linz (Austria, 2018).

This year CICM consisted of three tracks:

- Mathematical Knowledge Management (MKM) is an interdisciplinary research area aiming at the development of innovative and ever more sophisticated ways of managing mathematical knowledge. MKM brings together and serves several communities dealing with mathematical knowledge, foremost mathematicians, computer scientists, engineers, librarians, educators, students, and publishers.
- Calculemus is dedicated to the integration of computer algebra systems and systems for mechanized reasoning such as interactive proof assistants and automated theorem provers.
- Systems and Projects: Orthogonally, the Systems and Projects track called for descriptions of digital resources, such as data and systems, and of projects, whether old, current, or new, as well as survey papers covering any topics of relevance to the CICM community.

The Program Committee (PC) accepted 19 paper out of 41 formal submissions. Each submission was refereed by at least three PC members or external reviewers appointed by the PC members. The reviewing was done in a single-blind manner, and included a response period, in which authors could answer and clarify the points raised by the reviews. In one case, an open-ended shepherding phase was used, during which the authors were allowed to improve their paper under the guidance of a designated PC member. For the preparation of these proceedings and for the general conference and discussion management, we used Andrei Voronkov's EasyChair conference management system.

The PC was chaired by the editors of the volume. Cezary Kaliszyk served as the general PC chair. Edwin Brady, Andrea Kohlhase, and Claudio Sacerdoti Coen served as track chairs of the Calculemus, MKM, and Systems and Projects tracks, respectively. Dennis Müller was the doctoral program chair.

The conference issued a call for workshops and tutorials, of which five proposals were approved:

- OpenMath 2019 the 30th OpenMath Workshop organized by James Davenport and Michael Kohlhase
- LML 2019 the Large Mathematics Libraries Workshop organized by William Farmer and Dennis Müller
- FMM 2019 the 4th Workshop on Formal Mathematics for Mathematicians organized by Karol Pąk
- FVPS 2019 the Second Workshop on Formal Verification of Physical Systems organized by Sofiene Tahar, Osman Hasan, and Umair Siddique
- EMML 2019 a tutorial on Exploring the Mizar Mathematical Library organized by Adam Naumowicz, Artur Kornilowicz, and Adam Grabowski

The workshop programs were managed independently by the respective organizers. Furthermore, this year's CICM featured a doctoral program, which provided a forum for PhD students to present their research and advice from senior research members of the community serving as mentors. Finally, CICM also solicited other contributions including work-in-progress papers, demos, posters, and tutorials. These informal contributions are not a part of this volume.

In addition to the presentation of the accepted papers, CICM 2019 had three invited presentations. Makarius Wenzel gave an invited talk accompanied by a full paper on "Interaction with Formal Mathematical Documents in Isabelle/PIDE":

Isabelle/PIDE has emerged over more than 10 years as the standard Prover IDE to support interactive theorem proving in Isabelle, with numerous applications in the Archive of Formal Proofs (AFP). More recently, the scope of PIDE applications has widened toward languages that are not connected to logic and proof in Isabelle, but taken from a broader repertoire of mathematics on the computer. The present paper provides an overview of the current status of the PIDE project and its underlying document model, with built-in support for parallel evaluation and asynchronous interaction. There is also some discussion of original aims and approaches, successes and failures, later changes to the plan, and ideas for the future.

Henry Prakken gave an invited talk on: "AI Models of Argumentation and Some Applications to Mathematics":

Argumentation is the process of supporting claims with grounds and of defending the thus constructed arguments against criticism. AI researchers have for more than 30 years studied the formal and computational modelling of argumentation. This has resulted in increased understanding of argumentation and in computer tools for supporting human argumentation or performing artificial argumentation.

At first sight, the rigor of mathematical thinking would be far from the "messy" world of argumentation. However, inspired by Polya's and Lakatos's groundbreaking studies of the practice of mathematical proof, quite a few scholars have studied "mathematics in action" as a form of argumentation. Some of that work employs formal and computational tools from AI. In this talk I will first give an overview of the formal and computational study of argumentation in AI, and I will then discuss several applications to mathematical modelling and proof.

Sylvain Corlay gave an invited talk: "Jupyter: From IPython to the Lingua Franca of Scientific Computing":

Since its creation in 2011, the Jupyter notebook has exploded in popularity, with a user base growing from thousands to millions. Beyond notebooks, Jupyter is, in fact, a large collection of tools meant to facilitate workflows of researchers from the exploratory analysis to the communication of their results. In this talk, we will present the main components of the ecosystem, from JupyterLab to the interactive widgets, including Binder and JupyterHub. We will show how they work together to enable the variety of use-cases for which Jupyter is used today. Then, we will try to show where the project is going in the next few months, and present the latest updates on dashboarding tools, data visualization libraries, and new language backends.

Many people contributed to making CICM 2019 a success. We are grateful to the organizers at CIIRC, notably Jan Jakubův, Martin Suda, and Josef Urban for their support in the local organization of the meeting. We thank Serge Autexier for the publicity work. We thank all the authors of the submitted papers, participants to the conference, invited speakers, workshop organizers, and tutorial speakers.

May 2019

Cezary Kaliszyk Edwin Brady Andrea Kohlhase Claudio Sacerdoti Coen

#### Organization

#### **Program Committee**

Akiko Aizawa Edwin Brady Cyril Cohen Howard Cohl William Farmer Cezar Ionescu Mateja Jamnik Cezary Kaliszyk Fairouz Kamareddine Andrea Kohlhase Michael Kohlhase Laura Kovacs Zoltán Kovács Adam Naumowicz Grant Passmore Markus Pfeiffer Florian Rabe **Bas Spitters** Claudio Sacerdoti Coen Freek Wiedijk Wolfgang Windsteiger Abdou Youssef Richard Zanibbi

University of Tokyo, Japan University of St Andrews, UK Inria, France NIST, USA McMaster University, Canada Oxford University, UK University of Cambridge, UK University of Innsbruck, Austria Heriot-Watt University, UK University of Applied Sciences Neu-Ulm, Germany FAU Erlangen-Nuremberg, Germany Vienna University of Technology, Austria JKU Linz, Austria University of Białystok, Poland Aesthetic Integration, UK University of St Andrews, UK FAU Erlangen-Nürnberg, Germany and LRI, France Aarhus University, Denmark University of Bologna, Italy Radboud University, The Netherlands RISC, Linz, Austria The George Washington University, USA Rochester Institute of Technology, USA

#### **Additional Reviewers**

Ed Ayers Gabor Bakos Robert Belleman Katja Berčič Jonas Betzendahl Frédéric Chyzak Floris van Doorn Daniel Huang Joe Hurd Katya Komendantskaya Dennis Müller Julien Narboux Bernard Parisse Daniel Raggi Jan Schaefer Zohreh Shams Dan Shiebler Aaron Stockdill Laurent Théry Benoît Viguier Duo Wang

## Contents

| Interaction with Formal Mathematical Documents in Isabelle/PIDE <i>Makarius Wenzel</i>  | 1   |
|---|-----|
| Beginners' Quest to Formalize Mathematics: A Feasibility Study<br>in Isabelle   | 16  |
| Jonus Bayer, Marco Davia, Adnik Fai, and Beneaiki Slock   |     |
| Towards a Unified Mathematical Data Infrastructure: Database<br>and Interface Generation  | 28  |
| A Tale of Two Set Theories<br>Chad E. Brown and Karol Pąk   | 44  |
| Relational Data Across Mathematical Libraries   | 61  |
| Variadic Equational Matching<br>Besik Dundua, Temur Kutsia, and Mircea Marin  | 77  |
| Comparing Machine Learning Models to Choose the Variable Ordering<br>for Cylindrical Algebraic Decomposition<br>Matthew England and Dorian Florescu         | 93  |
| Towards Specifying Symbolic Computation<br>Jacques Carette and William M. Farmer  | 109 |
| Lemma Discovery for Induction: A Survey   | 125 |
| Experiments on Automatic Inclusion of Some Non-degeneracy Conditions<br>Among the Hypotheses in Locus Equation Computations<br>Zoltán Kovács and Pavel Pech | 140 |
| Formalization of Dubé's Degree Bounds for Gröbner Bases<br>in Isabelle/HOL  | 155 |
| The Coq Library as a Theory Graph<br>Dennis Müller, Florian Rabe, and Claudio Sacerdoti Coen  | 171 |

| BNF-Style Notation as It Is Actually Used<br>Dee Quinlan, Joe B. Wells, and Fairouz Kamareddine   | 187 |
|---|-----|
| MMTTeX: Connecting Content and Narration-Oriented<br>Document Formats   | 205 |
| Diagram Combinators in MMT  | 211 |
| Inspection and Selection of Representations<br>Daniel Raggi, Aaron Stockdill, Mateja Jamnik, Grecia Garcia Garcia,<br>Holly E. A. Sutherland, and Peter CH. Cheng | 227 |
| A Plugin to Export Coq Libraries to XML<br>Claudio Sacerdoti Coen   | 243 |
| Forms of Plagiarism in Digital Mathematical Libraries   | 258 |
| Integrating Semantic Mathematical Documents and Dynamic Notebooks<br>Kai Amann, Michael Kohlhase, Florian Rabe, and Tom Wiesing                                   | 275 |
| Explorations into the Use of Word Embedding in Math Search<br>and Math Semantics  | 291 |
| Author Index  | 307 |