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Foundations of Information and Knowledge Systems

10th International Symposium, FoIKS 2018
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Proceedings

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Preface

This volume contains the articles that were presented at the 10th International Symposium on Foundations of Information and Knowledge Systems (FoIKS 2018) held in Budapest, Hungary, during May 14–18, 2018.

The FoIKS symposia provide a biennial forum for presenting and discussing theoretical and applied research on information and knowledge systems. The goal is to bring together researchers with an interest in this subject, share research experiences, promote collaboration, and identify new issues and directions for future research. Speakers are given sufficient time to present their ideas and results within the larger context of their research. Furthermore, participants are asked in advance to prepare a first response to a contribution of another author in order to initiate discussion.

Previous FoIKS symposia were held in Linz (Austria) in 2016, Bordeaux (France) in 2014, Kiel (Germany) in 2012, Sofia (Bulgaria) in 2010, Pisa (Italy) in 2008, Budapest (Hungary) in 2006, Vienna (Austria) in 2004, Schloss Salzau near Kiel (Germany) in 2002, and Burg/Spreewald near Berlin (Germany) in 2000. FoIKS took up the tradition of the conference series Mathematical Fundamentals of Database Systems (MFDBS), which initiated East–West collaboration in the field of database theory. Former MFDBS conferences were held in Rostock (Germany) in 1991, Visegrád (Hungary) in 1989, and Dresden (Germany) in 1987.

FoIKS 2018 solicited original contributions on foundational aspects of information and knowledge systems. This included submissions that apply ideas, theories, or methods from specific disciplines to information and knowledge systems. Examples of such disciplines are discrete mathematics, logic and algebra, model theory, information theory, complexity theory, algorithmics and computation, statistics, and optimization. Suggested topics included, but were not limited to, the following:

- Big data: models for data in the cloud, programming languages for big data, query processing
- Database design: formal models, dependencies, and independencies
- Dynamics of information: models of transactions, concurrency control, updates, consistency preservation, belief revision
- Information fusion: heterogeneity, views, schema dominance, multiple source information merging, reasoning under inconsistency
- Integrity and constraint management: verification, validation, consistent query answering, information cleaning
- Intelligent agents: multi-agent systems, autonomous agents, foundations of software agents, cooperative agents, formal models of interactions, negotiations and dialogue, logical models of emotions
- Knowledge discovery and information retrieval: machine learning, data mining, formal concept analysis and association rules, text mining, information extraction

- Knowledge representation, reasoning, and planning: non-monotonic formalisms, probabilistic and non-probabilistic models of uncertainty, graphical models and independence, similarity-based reasoning, preference modeling and handling, computation models of argument, argumentation systems
- Logics in databases and AI: classical and non-classical logics, logic programming, description logic, spatial and temporal logics, probability logic, fuzzy logic
- Mathematical foundations: discrete structures and algorithms, graphs, grammars, automata, abstract machines, finite model theory, information theory, coding theory, complexity theory, randomness
- Security in information and knowledge systems: identity theft, privacy, trust, intrusion detection, access control, inference control, secure Web services, secure Semantic Web, risk management
- Semi-structured data and XML: data modeling, data processing, data compression, data exchange
- Social computing: collective intelligence and self-organizing knowledge, collaborative filtering, computational social choice, Boolean games, coalition formation, reputation systems
- The Semantic Web and knowledge management: languages, ontologies, agents, adaptation, intelligent algorithms, ontology-based data access
- The WWW: models of Web databases, Web dynamics, Web services, Web transactions and negotiations, social networks, Web mining

The call for papers resulted in the submission of 40 articles. Each one was carefully reviewed by at least three international experts. In total, fourteen articles were accepted for long presentation and six articles were accepted for short presentation. This volume contains versions of these articles that have been revised by their authors according to the comments provided in the reviews. After the conference, authors of a few selected articles were asked to prepare extended versions of their articles for publication in a special issue of the journal *Annals of Mathematics and Artificial Intelligence*.

During this symposium we had the opportunity to celebrate Prof. Klaus-Dieter Schewe's 60th birthday. FoIKS itself is one of the many successful initiatives of Prof. Klaus-Dieter Schewe. He is the chair of the FoIKS Steering Committee and continues to be a major driving force behind the symposium. As a token of appreciation, Prof. Klaus-Dieter Schewe received a Festschrift with contributions from his former students, collaborators, and colleagues – most are researchers whose academic careers have been strongly influenced by him.

We wish to thank all authors who submitted papers and all conference participants for fruitful discussions. We are grateful to our keynote speakers Gerd Brewka, Laura Kovács, Sebastian Link, David Pearce, and Bernhard Thalheim. We would like to thank the Program Committee members and additional reviewers for their timely expertise in carefully reviewing the submissions. The support of the conference provided by the *Artificial Intelligence Journal* (AIJ), the Association for Logic Programming (ALP), the European Association for Theoretical Computer Science (EATCS), and by the Vienna Center for Logic and Algorithms (VCLA) is gratefully

acknowledged. We thank the Software Competence Center Hagenberg for hosting the FoIKS Website and specially Senén González for redesigning and maintaining it. Last but not least, special thanks go to the local organization team: Tiziana Del Viscio, Dezsõ Miklós, and Attila Sali, for their support and for being our hosts during the wonderful days at the Alfréd Rényi Institute of Mathematics in Budapest.

May 2018

Flavio Ferrarotti
Stefan Woltran

Conference Organization

FoIKS 2018 was organized by the Alfréd Rényi Institute of Mathematics.

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Keynote Speakers

Computational Models of Argument: A New Perspective on Persisting KR Problems

Gerhard Brewka

University of Leipzig, Germany

Short Biography: Gerhard Brewka is a Professor of Intelligent Systems at Leipzig University, Germany. His research focuses on knowledge representation, in particular logic programming, nonmonotonic reasoning, preference and inconsistency handling, and computational models of argumentation. He served as President of EurAI (formerly ECCAI), the European Association of AI, and of Knowledge Representation Inc. In 2002, Brewka was awarded a EurAI Fellowship. He is a member of the IJCAI Board of Trustees and was Conference Chair of IJCAI-16 in New York.

Summary: In the last two decades the area of knowledge representation and reasoning (KR) has seen a steady rise of interest in the notion of argument, an old topic of study in philosophy. This interest was fueled by a certain dissatisfaction with existing approaches, especially to default reasoning and inconsistency handling, and by the demands of applications in legal reasoning and several related fields.

The ultimate goal of computational argumentation is to enable the development of computer-based systems capable to support – and to participate in – argumentative activities. To achieve this goal one has to come up with models which formally capture the way we usually come to conclusions and make decisions, namely by

1 constructing arguments for and against various options,
2 establishing relationships among the arguments, most notably the attack relation, and
3 identifying interesting subsets of the arguments which represent coherent positions based on these relations.

In the talk we will highlight some of the main ideas and key techniques that have been developed in the field and show how they address issues of representing knowledge, handling inconsistencies, and reasoning by default. We will mainly focus on Abstract Dialectical Frameworks (ADFs) which substantially generalize the well-known and widely used Dung Frameworks. In particular, we will demonstrate how the operator-based techniques underlying ADFs allow us to turn directed graphs with arbitrary edge labels, which are widely used to visualize argumentation and reasoning scenarios, into full-fledged knowledge representation formalisms with a whole range of precisely defined semantics.

Automated Reasoning for Systems Engineering

Laura Kovács

TU Wien, Austria

Short Biography: Laura Kovács is a full professor at the Faculty of Informatics of Vienna University of Technology (TU Wien). She also holds a part-time professor position at the Department of Computer Science and Engineering of the Chalmers University of Technology. She has a diploma in computer science and math from the West University of Timisoara, Romania and a PhD with highest distinction in computer science from the Research Institute of Symbolic Computation (RISC-Linz) of the Johannes Kepler University Linz, Austria. Prior to her appointment to Vienna, she was an associate professor at Chalmers.

In her research, Laura Kovács deals with the design and development of new theories, technologies, and tools for program analysis, with a particular focus on automated assertion generation, symbolic summation, computer algebra, and automated theorem proving. She is the co-developer of the Vampire theorem prover. In 2014, she received the Wallenberg Academy Fellowship and an ERC Starting Grant.

Summary: Automated reasoning, and in particular first-order theorem proving, is one of the earliest research areas within artificial intelligence and formal methods. It is undergoing a rapid development thanks to its successful use in program analysis and verification, semantic Web, database systems, symbolic computation, theorem proving in mathematics, and other related areas. Breakthrough results in all areas of theorem proving have been obtained, including improvements in theory, implementation, and the development of powerful theorem proving tools.

In this talk I give a brief overview on the main ingredients of automated theorem proving, and focus on recent challenges and developments in the area. Further, I will discuss recent applications of theorem proving in rigorous systems engineering.

Old Keys that Open New Doors

Sebastian Link

University of Auckland, New Zealand

Short Biography: Sebastian is a full professor at the Department of Computer Science in the University of Auckland. His research interests include conceptual data modeling, semantics in databases, foundations of mark-up languages, and applications of discrete mathematics to computer science. Sebastian received the Chris Wallace Award for Outstanding Research Contributions in recognition of his work on the semantics of SQL and XML data. Sebastian has published more than 150 research articles. He is a member of the editorial board of the journal Information Systems.

Summary

Keys enforce Codd's integrity for entities,
Giving fast access to data since the seventies.
The issue of missing information remains fundamental,
Better notions of keys will prove to be instrumental.

We review keys on classical relations,
Recalling the simplest of all axiomatisations.
An extremal cardinality a non-redundant family retains,
Whenever it lives up to Sperner's anti-chains.
Armstrong relations are built after an anti-key hunt,
The discovery by hypergraph transversals is simply elegant.

As nulls in applications do require some finesse,
We review key sets that have high expressiveness.
Establishing an axiomatisation that is binary,
We show implication to be complete for coNP.
Armstrong relations do not necessarily exist,
The discovery of keys sets as an open problem we enlist.

Key sets with singletons avoid the likely intractability curtain,
Leading to keys that hold in every world so certain.
We look at possible and certain keys together with NOT NULL,
Which lead to problems that are anything but dull.
Implication is easily characterised axiomatically and algorithmically,
The structure and computation of Armstrong relations is captured non-trivially.
Extremal families occupy two levels with some gaps,
The discovery can use transversals in two steps.

We briefly summarise keys on data with veracities,
considering probabilities, possibilities, and contextualities.
Concluding with problems for minds that are bright,
We hope the talk sparks research with heaps of insight.

The Logical Basis of Knowledge Representation in Answer Set Programming

David Pearce

Universidad Politécnica de Madrid, Spain

Short Biography: David Pearce studied Philosophy, Logic and Scientific Method at the Universities of Sussex and Oxford, obtaining his D Phil (Sussex) in 1980. From 1982–94 he worked at the Philosophy Institute of the Free University Berlin as a Lecturer and later Heisenberg Research Fellow. From 1992–94 he was Acting Professor at the Universities of Göttingen and Heidelberg. In 1994 he moved to the German AI Research Centre (DFKI) in Saarbrücken, where until 2000 he coordinated one of the founding European Networks of Excellence: Compulog Net. From 2000–2002 he worked at the Future and Emerging Technologies Unit of the European Commission in Brussels where he was involved in the management and supervision of EU research programmes. He then moved to Madrid as Ramón y Cajal Research Fellow at the Rey Juan Carlos University, later becoming professor in the Technical University of Madrid in 2009. From 2011–14 he coordinated the EU funded action: the European Network for Social Intelligence (SINTELNET).

David Pearce has worked mainly in the areas of Logic and Knowledge Representation, with a special interest in nonmonotonic reasoning and logic programming. He has made numerous contributions to the field of Answer Set Programming (ASP). In the late 1980s, together with Gerd Wagner, he introduced the concept of strong negation into logic programming. From 1995 onwards he developed Equilibrium Logic as a new logical foundation for ASP. In 2001, together with Vladimir Lifschitz and Agustín Valverde, he initiated the study of strongly equivalent logic programs which opened up a new research area in nonmonotonic reasoning and KRR that is still active today. His current research interests include combining Artificial Intelligence with Social Ontology. Pearce was elected ECCAI (now EurAI) Fellow in 2014.

Summary: In this talk I give an introduction to the underlying logic of Answer Set Programming. The basis is a non-classical, intermediate logic and its non-monotonic extension, known as *equilibrium logic*. Together they provide an alternative to the standard paradigm of two-valued, classical logic. In view of the origins of answer set programming, it seems appropriate to call this new approach *stable reasoning*. The talk will focus on the intuitive meaning of the main logical definitions, and explain their effect with some example programs. I will also discuss some of the main extensions of the basic language that may be useful for knowledge representation.

Revisiting the Database Constraints Theory

Bernhard Thalheim

Christian-Albrechts-University at Kiel, Germany

Short Biography: Prof. Dr.rer.nat.habil. Bernhard Thalheim (Director, Department of Computer Science, Faculty of Engineering at Christian-Albrechts University Kiel, Germany) (MSc, PhD, DSc) is full professor at Christian Albrechts University in Germany. His major research interests are database theory, logic in databases, and systems development methodologies, in particular for web information systems. He has published more than 300 refereed publications, edited more than 30 conference volumes, co-founded three international conferences, and has been programme committee chair for almost three dozen international conferences such as MFDBS, ER, FoIKS, ASM, SDKB, NLDB and ADBIS. He got several international awards, e.g. the Kolmogorov professorship at Lomonossow University Moscow and the P. P. Chen award of Elsevier. He has been an associated professor at Dresden University of Technology, a visiting professor at Kuwait University, Alpen-Adria University Klagenfurt and others, and a full professor at Rostock University and Brandenburg University of Technology at Cottbus.

Summary: The theory of database constraints has been developed for a long time within the relational database modelling setting. The 80ies brought a large body of knowledge and led to the impression that the theory development is completed. A typical example is normalisation theory that has been developed inside the relational understanding. It must already be reconsidered for the table database modelling setting. Cardinality constraints defined in an entity-relationship modelling setting were the most essential addition to the theory of relational constraints. It seems that the theory of object-relational constraints is still a lacuna. Therefore, monographs and textbooks remain to be on the level of the early 90ies as far as constraints are considered. Database technology brought however powerful and sophisticated systems. So, the constraints that might be supported without loss of performance are far richer. Database applications need more sophisticated constraints. So, the paper presents some solutions for constraint enhancement, constraint handling, structure optimisation, and database modelling at the conceptual level. It completes with open problems.

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