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Foundations of Information and Knowledge Systems

9th International Symposium, FoIKS 2016
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Preface

This volume contains the articles that were presented at the 9th International Symposium on Foundations of Information and Knowledge Systems (FoIKS 2016) held in Linz, Austria, during March 7–11, 2016.

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 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 2016 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, 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, argumentation systems
- Logics in databases and AI: classic and non-classic logics, logic programming, description logic, spatial and temporal logics, probability logic, fuzzy logic
- Mathematical foundations: discrete structures and algorithms, automata, abstract machines, graphs, grammars, 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 modelling, 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, agents, adaptation, intelligent algorithms, ontologies
- The WWW: models of Web databases, Web dynamics, Web services, Web transactions and negotiations

The call for papers resulted in the submission of 23 articles. Each one was carefully reviewed by at least three international experts. The 12 articles judged best by the Program Committee were accepted for long presentation. In addition, two 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*.

We wish to thank all authors who submitted papers and all conference participants for fruitful discussions. We are grateful to our keynote speakers Christoph Beierle, Joachim Biskup, Reinhard Pichler, Henry Prakken, and José Maria Turull-Torres; this volume also contains articles for four of the five invited talks. We would like to thank the Program Committee members and additional reviewers for their timely expertise in carefully reviewing the submissions. We want to thank Maria Vanina Martinez for her work as publicity chair. The support of the conference provided by the European Association for Theoretical Computer Science (EATCS) and by the Software Competence Center Hagenberg is greatfully acknowledged. Last but not least, special thanks go to the local organization chair, Flavio Ferrarotti, and his dedicated team consisting of Andreea Buga, Tania Nemeş, Loredana Tec, and Mircea Boris Vleju for their support and for being our hosts during the wonderful days in Linz.

March 2016

Marc Gyssens
Guillermo Simari

Conference Organization

FoIKS 2016 was organized by the Software Competence Center Hagenberg.

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Keynote Speakers

Henry Prakken, *Utrecht University* and *University of Groningen, The Netherlands*

Short biography: Henry Prakken is Lecturer in AI at the Department of Information and Computing Sciences, Utrecht University, and Professor in Legal Informatics and Legal Argumentation at the Law Faculty, University of Groningen, from which he holds master's degrees in law (1985) and philosophy (1988). In 1993, he obtained his PhD (*cum laude*) at the Free University Amsterdam. His main research interests include computational models of argumentation and their application in multi-agent systems and legal reasoning. Prakken is past president of the International Association of AI & Law and current president of the JURIX Foundation for Legal Knowledge-Based Systems and of the steering committee of the COMMA Conferences on Computational Models of Argument. He is on the editorial board of journals such as *Artificial Intelligence*.

Keynote talk: *Some Recent Trends in Argumentation Research*

Summary: Argumentation is an important topic in symbolic AI research today, especially in the study of nonmonotonic reasoning and the study of inter-agent communication. Argumentation makes explicit the reasons for the conclusions that are drawn and how conflicts between these reasons are resolved. This provides a natural mechanism to handle inconsistent and uncertain information and to resolve conflicts of opinion between intelligent agents. In this talk, an overview will be given of some of the main current research issues, including the relation between abstract and structured models of argumentation and the relation between argumentation and probability theory.

Christoph Beierle, *University of Hagen, Germany*

Short biography: Christoph Beierle is professor of computer science and head of the knowledge-based systems group in the Faculty of Mathematics and Computer Science at the University of Hagen. In 1985, he received his PhD in computer science from the University of Kaiserslautern. He was senior researcher at the Scientific Center of IBM Germany, and is a recipient of an IBM Outstanding Innovation Award. He has been working on algebraic specifications and formal approaches for software development and on methods for knowledge-based systems and their applications. His current research interests include modeling and reasoning with uncertain knowledge.

Keynote talk: *Systems and Implementations for Solving Reasoning Problems in Conditional Logics*

Summary: Default rules like "If A, then usually B" or probabilistic rules like "If A, then B with probability x" are powerful constructs for knowledge representation. Such rules can be formalized as conditionals, denoted by $(B|A)$ of $(B|A)[x]$, and a conditional knowledge base consists of a set of conditionals. Different semantical models have been proposed for conditional knowledge bases, and the most important reasoning problems for conditional knowledge bases are to determine whether a knowledge base is consistent and to determine what a knowledge base entails. We present an overview on systems and implementations our group has been working on for solving reasoning problems in various semantics that have been developed for conditional knowledge bases. These semantics include quantitative, semi-quantitative, and qualitative conditional logics, based on both propositional logic and on first-order logic.

Reinhard Pichler, *Vienna University of Technology, Austria*

Short biography: Reinhard Pichler holds a master's degree in mathematics from the University of Innsbruck and a master's degree in mathematical computation from the University of London, QMW College. In 2000, he received his PhD in computer science from the Vienna University of Technology. From 1992 to 2005, he worked as software developer at the Program and Systems Engineering Department (PSE) of Siemens AG Austria. Since 2005, he has been Professor at the Faculty of Informatics of the Vienna University of Technology where he leads the Database and Artificial Intelligence Group. His main research interests in recent years have been in database

theory—mainly on information integration and on foundational aspects of the Semantic Web query language SPARQL.

Keynote talk: *The Challenge of Optional Matching in SPARQL*

Summary: Conjunctive queries (or, equivalently, SELECT-FROM-WHERE queries in SQL) are arguably the most widely used querying mechanism in practice and the most intensively studied one in database theory. Answering a conjunctive query (CQ) comes down to matching all atoms of the CQ simultaneously into the database. As a consequence, a CQ fails to provide any answer if the pattern described by the query does not exactly match the data. CQs might thus be too restrictive as a querying mechanism for data on the Web, which is considered as inherently incomplete. The Semantic Web query language SPARQL therefore contains the OPTIONAL operator as a crucial feature. It allows the user to formulate queries that try to match parts of the query over the data if available, but do not destroy answers of the remaining query otherwise.

In this talk, we will have a closer look at this optional matching feature of SPARQL. More specifically, we will concentrate on an interesting fragment of SPARQL: the so-called well-designed SPARQL graph patterns. They extend CQs by optional matching while imposing certain restrictions on how variables are allowed to occur in the query. We recall recent results that even in this small fragment of SPARQL most of the fundamental computational tasks become significantly harder than for conjunctive queries. For instance, query evaluation is now on the second level of the Polynomial Hierarchy and basic static analysis tasks such as containment or equivalence testing become even undecidable for well-designed SPARQL graph patterns. Also the semantics of query answering in the presence of ontologies (referred to as entailment regimes in SPARQL) has to be reconsidered in order to give intuitive results. It turns out that the seemingly small extension of CQs by optional matching has created several interesting research opportunities.

Joachim Biskup, *University of Dortmund, Germany*

Short biography: Joachim Biskup received his master's degree in mathematics from the Technical University of Hannover and his PhD in computer science from the RWTH in Aachen, Germany. He has been Professor of Computer Science at the University of Dortmund, University of Hildesheim, and University of Dortmund again. He has performed research in areas such as recursion and complexity theory, information systems with an emphasis on schema design, query optimization and mediation, and various aspects of security, in particular access control and inference control.

Keynote talk: *Selected Results and Related Issues of Confidentiality-Preserving Controlled Interaction Execution*

Summary: Controlled interaction execution has been developed as a security server for a specific kind of inference control shielding an isolated, logic-oriented information system when interacting over time with a client by means of messages, in particular for query and transaction processing. The control aims at provably preserving confidentiality in a fully formalized sense, intuitively and simplifying rephrased as follows: even when having (assumed) a priori knowledge, recording the interaction history, being aware of the details of the control mechanism, and unrestrictedly rationally reasoning, the client should never be able to infer the validity of any sentence declared as a potential secret in the security server's confidentiality policy. To enforce this goal, for each of a rich variety of specific situations, a dedicated censor has been designed. As far as needed, a censor distorts a functionally expected reaction message such that suitably weakened or even believably incorrect information is communicated to the client.

We consider selected results of recent and ongoing work and discuss several issues for further research and development. The topics covered range from the impact of the underlying logic, whether propositional, first-order, or non-monotonic about belief or an abstraction from any specific one, over the kinds of interactions, whether only queries or also views, updates, revisions, or even procedural programs, to the dynamic representation of control states, whether by simply logging or adapting the policy.

José Maria Turull-Torres, *Universidad Nacional de La Matanza, Argentina* and *Massey University, New Zealand*

Short biography: After 20 years of professional work in informatics in Argentina and Mexico, a further 23 years followed of academic work with research in the areas of database theory, finite model theory, and complexity, in Argentina and New Zealand. Currently, José Maria Turull-Torres is Professor in the Department of Engineering at the Universidad Nacional de La Matanza, Argentina, and holds an Honorary Research Fellowship at Massey University, New Zealand. He has been a member of the Program Committee of many international conferences, co-chair of FoIKS 2004, and is often invited as keynote speaker. His main research collaboration is with the universities of Helsinki, Joensuu, and Tampere, in Finland, the University of Warsaw, the University of Toronto, the University of Cantabria in Spain, the Ecole Polytechnique de Paris, and the Software Competence Center Hagenberg in Austria.

Keynote talk: *Relational Complexity and Higher-Order Logics*

Summary: Relational machines (RM) were introduced in 1991 as abstract machines that compute queries to (finite) relational structures, or relational database instances (dbis), which are generic (i.e., that preserve isomorphisms), and hence are more appropriate than Turing machines (TM) for query computation. RMs are TMs endowed with a relational store that holds the input dbi, as well as work relations, that can be

queried and updated through first-order logic (FO) formulas in their finite control. Consequently, k-ary RMs are incapable of computing the size of the input. However, they can compute its $size_{k,}$ i.e, the number of FO^k types of k-tuples in the dbi. Consequently, a new notion of complexity suitable for RMs had to be defined. Relational complexity was also introduced in 1991 as a complexity theory where the input dbi to a query is measured as its $size_{k,}$ and complexity classes mirroring computational complexity classes were defined. Relational complexity turned out to be a theoretical framework in which we can characterize exactly the expressive power of the well-known fixed-point quantifiers of a wide range of sorts. In 1997, several equivalences between fixed-point quantifiers (added to FO) and different relational complexity classes were proved, classifying them as either deterministic, nondeterministic, or alternating, and either inflationary or non-inflationary. These characterizations are actually very interesting and meaningful, given that it was already known that if we restrict the input to only ordered dbis, the same equivalences with computational complexity classes also hold.

Regarding the characterization of relational complexity classes with other logics, it was proved that RMs have the same computation, or expressive power, as the (effective fragment of the) well-known infinitary logic with finitely many variables. Besides, some fragments of second- and third-order logic, defined as semantic restrictions of the corresponding logic, have been proved to characterize several classes, and there is ongoing work in that direction. One interesting consequence of this is that RMs are strong enough to simulate the existence of third-order relations in their relational store. An important application of the creation of new logics to complexity theory is the search for lower bounds of problems with respect to those logics, aiming to separate computational complexity classes.

In this talk, we will give a description of RMs and NRMs, define the basic notions of relational complexity, and discuss its motivations and the tight relationship between the main classes and different fixed-point logics and fragments of second- and third-order logics.

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