THE DESCRIPTION LOGIC HANDBOOK

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Theory, implementation, and applications

Edited by

FRANZ BAADER
DIEGO CALVANESE
DEBORAH L. McGUINNESS
DANIELE NARDI
PETER F. PATEL-SCHNEIDER

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Contributors

Franz Baader
Institut für Theoretische Informatik
Fakultät Informatik
TU Dresden
01062 Dresden, Germany
`baader@tcs.inf.tu-dresden.de`
`http://wwwtcs.inf.tu-dresden.de/~baader/`

Alex Borgida
Department of Computer Science
Rutgers University
Piscataway, NJ 08855, U.S.A.
`borgida@cs.rutgers.edu`
`http://www.cs.rutgers.edu/~borgida/`

Ronald J. Brachman
Corporation for National Research Initiatives, U.S.A.
`rjb@brachman.org`
`http://www.brachman.org/`

Diego Calvanese
Dipartimento di Informatica e Sistemistica
Università di Roma "La Sapienza"
Via Salaria 113, 00198 Roma, Italy
`calvanese@dis.uniroma1.it`
`http://www.dis.uniroma1.it/~calvanese/`

Giuseppe De Giacomo
Dipartimento di Informatica e Sistemistica
Università di Roma "La Sapienza"
Via Salaria 113, 00198 Roma, Italy
`degiacomo@dis.uniroma1.it`
`http://www.dis.uniroma1.it/~degiacomo/`

Francesco M. Donini
Dipartimento di Elettrotecnica ed Elettronica
Politecnico di Bari
Via Re David 200, 70125 Bari, Italy
donini@poliba.it
http://dee.poliba.it/dee-web/doniniweb/donini.html

Enrico Franconi
Faculty of Computer Science
Free University of Bozen-Bolzano
Dominikanerplatz 3, I-39100 Bozen, Italy
franconi@inf.unibz.it
http://www.inf.unibz.it/~franconi/

Volker Haarslev
Computer Science Department
Concordia University
1455 de Maisonneuve Blvd. W., Montreal, Quebec H3G IM8, Canada
haarslev@cs.concordia.ca
http://www.cs.concordia.ca/~faculty/haarslev/

Ian Horrocks
Information Management Group
Department of Computer Science
University of Manchester
Manchester M13 9PL, U.K.
horrocks@cs.man.ac.uk
http://www.cs.man.ac.uk/~horrocks/

Ralf Küsters
Institut für Informatik und Praktische Mathematik
Christian-Albrechts-Universität zu Kiel
Olshausenstraße 40, 24098 Kiel, Germany
kuesters@ti.informatik.uni-kiel.de
http://www.ti.informatik.uni-kiel.de/~kuesters/

Maurizio Lenzerini
Dipartimento di Informatica e Sistemistica
Università di Roma "La Sapienza"
Via Salaria 113, 00198 Roma, Italy
lenzerini@dis.uniroma1.it
http://www.dis.uniroma1.it/~lenzerini/

Deborah L. McGuinness
Knowledge Systems Laboratory
Gates Building 2A, Stanford University
Stanford, CA 94305-9020, U.S.A.
dlm@ksl.stanford.edu
http://ksl.stanford.edu/people/dlm/

Ralf Molitor
Swiss Life
IT Research and Development Group
General Guisan Quai 40, CH-8002 Zürich, Switzerland
`ralf.molitor@swisslife.ch`
`http://research.swisslife.ch/~molitor/`

Ralf Möller
Computer Science Department
University of Hamburg
Vogt-Kölln-Straße 30, 22527 Hamburg, Germany
`moeller@informatik.uni-hamburg.de`
`http://kogs-www.informatik.uni-hamburg.de/~moeller/`

Daniele Nardi
Dipartimento di Informatica e Sistemistica
Università di Roma "La Sapienza"
Via Salaria 113, 00198 Roma, Italy
`nardi@dis.uniroma1.it`
`http://www.dis.uniroma1.it/~nardi/`

Werner Nutt
Department of Computing and Electrical Engineering
Heriot-Watt University
Edinburgh, EH14 4AS, U.K.
`nutt@cee.hw.ac.uk`
`http://www.cee.hw.ac.uk/~nutt/`

Peter F. Patel-Schneider
Bell Labs Research
600 Mountain Avenue
Murray Hill, NJ 07974, U.S.A.
`pfps@research.bell-labs.com`
`http://www.bell-labs.com/user/pfps/`

Alan Rector
Medical Informatics Group
Department of Computer Science
University of Manchester
Manchester M13 9PL, U.K.
`rector@cs.man.ac.uk`
`http://www.cs.man.ac.uk/mig/`

Riccardo Rosati
Dipartimento di Informatica e Sistemistica
Università di Roma "La Sapienza"
Via Salaria 113, 00198 Roma, Italy
`rosati@dis.uniroma1.it`
`http://www.dis.uniroma1.it/~rosati/`

Ulrike Sattler
Institut für Theoretische Informatik
Fakultät Informatik
TU Dresden
01062 Dresden, Germany
sattler@tcs.inf.tu-dresden.de
http://wwwtcs.inf.tu-dresden.de/~uli/

Christopher A. Welty
Knowledge Structures Group
IBM Watson Research Center
19 Skyline Dr., Hawthorne, NY 10532, U.S.A.
weltyc@us.ibm.com

Frank Wolter
Institut für Informatik
Universität Leipzig
Augustus-Platz 10–11, 04109 Leipzig, Germany
wolter@informatik.uni-leipzig.de
http://www.informatik.uni-leipzig.de/~wolter/

Preface

Knowledge Representation is the field of Artificial Intelligence that focuses on the design of formalisms that are both epistemologically and computationally adequate for expressing knowledge about a particular domain. One of the main lines of investigation has been concerned with the principle that knowledge should be represented by characterizing classes of objects and the relationships between them The organization of the classes used to describe a domain of interest is based on a hierarchical structure, which not only provides an effective and compact representation of information, but also allows the relevant reasoning tasks to be performed in a computationally effective way.

The above principle drove the development of the first frame-based systems and semantic networks in the 1970s. However, these systems were in general not formally defined and the associated reasoning tools were strongly dependent on the implementation strategies. A fundamental step towards a logic-based characterization of required formalisms was accomplished through the work on the KL-ONE system, which collected many of the ideas stemming from earlier semantic networks and frame-based systems, and provided a logical basis for interpreting objects, classes (or concepts), and relationships (or links, roles) between them. The first goal of such a logical reconstruction was the precise characterization of the set of constructs used to build class and link expressions. The second goal was to provide reasoning procedures that are sound and complete with respect to the semantics. The article 'The tractability of subsumption in Frame-Based Description Languages' by Ron Brachman and Hector Levesque, presented at AAAI 1984, addressing the tradeoff between the expressiveness of KL-ONE like languages and the computational complexity of reasoning, is usually regarded as the origin of research on *Description Logics*.

Subsequent research came under the label *terminological systems* to emphasize the fact that classes and relationships were used to establish the basic terminology adopted in the modeled domain. Still later, the emphasis was on the set of concept forming constructs admitted in the language, giving rise to the name *concept languages*. Recently, attention has moved closer to the properties of the underlying logical systems, and the term *Description Logics* has become popular.

Research on Description Logics has covered theoretical aspects, implementation of knowledge representation systems (modern frame-based systems) and the use of such systems to realize applications in several areas. This pattern of development is an example of one of the standard research methodologies, as is recognized by the Artificial Intelligence community. The key element has been the very close interaction between theory and practice. On the one hand, there are various implemented systems based on Description Logics, offering a palette of description formalisms with differing expressive power, and which are employed in various application domains (such as natural language processing, configuration of technical systems, databases). On the other hand, the formal and computational properties (like decidability, complexity) of various description formalisms have been studied in detail. These investigations are usually motivated by the use of certain constructors in systems or the need for these constructors in specific applications, and the results of such investigations have strongly influenced the design of new systems.

The Description Logics research community currently consists of at least 100 active researchers. In addition, other communities are now becoming interested in Description Logics, most notably the Databases community and, more recently, the Semantic Web one. After more than a decade of research on Description Logics there is a substantial body of work and well-established technical literature. However, there is no comprehensive presentation of the major achievements in the field, although survey papers have been published and workshop proceedings are available.

Now, since 1989 a workshop dedicated to Description Logics has been held, initially every two years but annually from 1994. At the 1997 workshop a Working Group was formed to develop a proposal for a book that would provide a systematic introduction to Description Logics, covering all aspects of the research in the field, namely: theory, implementation, and applications. Following the spirit that fostered this research, the *Description Logic Handbook* would provide a thorough introduction to Description Logics both for the more theoretically oriented reader interested in the formal study of Description Logics and for the more practically oriented reader aiming at a principled usage of knowledge representation systems based on Description Logics. Although some refinements have been made to the initial proposal to embody recent developments in the field, the final structure of the *Handbook* reflects the original intentions.

The *Handbook* is organized into three parts plus an initial chapter providing a general introduction to the field.

Part I addresses the theoretical work in Description Logics and includes five chapters. Chapter 2 introduces Description Logics as a formal language for representing knowledge and reasoning about it. Chapter 3 addresses the computational complexity of reasoning in several Description Logics. Chapter 4 explores the relationship with other representation formalisms, within and outside the field of Knowledge Representation. Chapter 5 covers extensions of the basic Description Logics introduced in Chapter 2 by very expressive constructs that require advanced reasoning techniques.

Chapter 6 considers extensions of Description Logics by representation features and non-standard inference problems not available in the basic framework.

Part II is concerned with the implementation of knowledge representation systems based on Description Logics. Chapter 7 describes the features that need to be provided, in addition to the inference engine for a particular Description Logic, to build a knowledge representation system. Chapter 8 reviews implemented knowledge representation systems based on Description Logics that have played or play an important role in the field. Chapter 9 describes the implementation of the reasoning services which form the core of Description Logic knowledge representation systems.

Part III addresses the deployment of Description Logics in the design and implementation of fielded applications. Chapter 10 discusses the issues involved in the development of an ontology for some universe of discourse, which is to become a conceptual model or knowledge base represented and reasoned with using Description Logics. Chapter 11 presents applications of Description Logics in the area of software engineering. Chapter 12 introduces the problem of configuration and the largest and longest lived family of Description Logic-based configurators. Chapter 13 is concerned with the use of Description logics in various kinds of applications in medical informatics—terminology, intelligent user interfaces, decision support and semantic indexing, language technology, and systems integration. Chapter 14 reviews the applications of Description Logics in web-based information systems, and the more recent developments related to languages for the Semantic Web. Chapter 15 analyzes the uses of Description Logics for natural language processing to encode syntactic, semantic, and pragmatic elements needed to drive semantic interpretation and natural language generation processes. Chapter 16 surveys the major classes of application of Description Logics and their reasoning facilities to the issues of data management, including the expression of the conceptual domain model/ontology of the data source, the integration of multiple data sources, and the formulation and evaluation of queries.

The syntax and semantics for Description Logics is summarized in an Appendix, which has been used as a reference to unify the notation throughout the book.

Finally, an extended, integrated bibliography is provided and, within each chapter, comprehensive guides through the relevant literature are given.

The chapters are written by some of the most prominent researchers in the field, introducing the basic technical material before taking the reader to the current state of the subject. The chapters have been reviewed in a two step process, which involved two or three reviewers for each chapter. We have relied on the work of several external reviewers, selected both within the Description Logic community, and outside the field, to increase the readability for non experts. In addition, each chapter has been read also by authors of other chapters, to improve the overall coherence.

As such, the book is conceived as a unique reference for the subject. Although not intended as a textbook, the *Handbook* can be used as a basis for specialized courses on Description Logics. In addition, some of the chapters can be used as teaching material in Knowledge Representation courses. The *Handbook* is also a comprehensive reference to the subject in more introductory courses in the field of Artificial Intelligence.

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