Advanced Information and Knowledge Processing

Also in this series

Gregoris Mentzas, Dimitris Apostolou, Andreas Abecker and Ron Young
Knowledge Asset Management
1-85233-583-1

Michalis Vazirgiannis, Maria Halkidi and Dimitrios Gunopulos
Uncertainty Handling and Quality Assessment in Data Mining
1-85233-655-2

Asunción Gómez-Pérez, Mariano Fernández-López and Oscar Corcho
Ontological Engineering
1-85233-551-3

Arno Scharl (Ed.)
Environmental Online Communication
1-85233-783-4

Shichao Zhang, Chengqi Zhang and Xindong Wu
Knowledge Discovery in Multiple Databases
1-85233-703-6

Jason T.L. Wang, Mohammed J. Zaki, Hannu T.T. Toivonen and Dennis Shasha (Eds)
Data Mining in Bioinformatics
1-85233-671-4

C.C. Ko, Ben M. Chen and Jianping Chen
Creating Web-based Laboratories
1-85233-837-7

Manuel Graña, Richard Duro, Alicia d'Anjou and Paul P. Wang (Eds)
Information Processing with Evolutionary Algorithms
1-85233-886-0

Colin Fyfe
Hebbian Learning and Negative Feedback Networks
1-85233-883-0

Yun-Heh Chen-Burger and Dave Robertson
Automating Business Modelling
1-85233-835-0

Dirk Husmeier, Richard Dybowski and Stephen Roberts (Eds)
Probabilistic Modeling in Bioinformatics and Medical Informatics
1-85233-778-8

Ajith Abraham, Lakhmi Jain and Robert Goldberg (Eds)
Evolutionary Multiobjective Optimization
1-85233-787-7

K.C. Tan, E.F.Khor and T.H. Lee
Multiobjective Evolutionary Algorithms and Applications
1-85233-836-9

Nikhil R. Pal and Lakhmi Jain (Eds)
Advanced Techniques in Knowledge Discovery and Data Mining
1-85233-867-9

Amit Konar and Lakhmi Jain
Cognitive Engineering
1-85233-975-6

Miroslav Kárný (Ed.)
Optimized Bayesian Dynamic Advising
1-85233-928-4

Yannis Manolopoulos, Alexandros Nanopoulos, Apostolos N. Papadopoulos
and Yannis Theodoridis
R-trees: Theory and Applications
1-85233-977-2

Sanghamitra Bandyopadhyay, Ujjwal Maulik, Lawrence B. Holder and Diane J. Cook (Eds)
Advanced Methods for Knowledge Discovery from Complex Data
1-85233-989-6

Marcus A. Maloof (Ed.)
Machine Learning and Data Mining for Computer Security
1-84628-029-X

Sifeng Liu and Yi Lin
Grey Information
1-85233-995-0

Vasile Palade, Cosmin Danut Bocaniala and Lakhmi Jain (Eds)
Computational Intelligence in Fault Diagnosis
1-84628-343-4

Mitra Basu and Tin Kam Ho (Eds)
Data Complexity in Pattern Recognition
1-84628-171-7

Samuel Pierre (Ed.)
E-learning Networked Environments and Architectures
1-84628-351-5

Arno Scharl and Klaus Tochtermann (Ed.)
The Geospatial Web
1-84628-826-5

Ngoc Thanh Nguyen

Advanced Methods for Inconsistent Knowledge Management

Springer

Ngoc Thanh Nguyen, DSc, PhD, Professor
Institute of Information Science and Engineering
Wroclaw University of Technology
Str. Janiszewskiego 11/17
50-370 Wroclaw
Poland

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2007929956

AI&KP ISSN 1610-3947
ISBN 978-1-84628-888-3 e-ISBN 978-1-84628-889-0

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

Springer Science+Business Media
springer.com

Foreword

Nowadays in the knowledge society, each member deals with a number of tasks related to knowledge management. The most often realized tasks are: decision making, knowledge integration, selection, and retrieval. In all these tasks one has to solve inconsistency of knowledge. Inconsistency is a feature of knowledge which is characterized by the lack of possibility for inference processes. Therefore, solving inconsistency of knowledge is a basic and very essential subtask in many tasks of knowledge management. The whole management process may become impossible if the inconsistency is not resolved.

This book presents a set of methods for resolving inconsistency of knowledge. It originally treats the inconsistency on two levels, syntactic and semantic, and proposes methods for processing inconsistency on these levels. The methods proposed here are consensus based. They are worked out on the basis of mathematical models for representing inconsistency as well as tools for measuring and evaluating the degree of inconsistency, defined by the author.

The presented material shows that the solution of inconsistency is strongly related to knowledge integration processes. Therefore, along with inconsistency resolution tools, the author proposes algorithms for knowledge integration, such as ontology integration, or agent knowledge states integration. The author has put across a deep and valuable analysis of the proposed models by proving a number of interesting and useful theorems and remarks. Owing to these analysis results one can decide to use the worked out algorithms for concrete practical situations.

The author also presents two concrete applications of the proposed methods. The first refers to recommendation processes in intelligent learning systems. Using the method for rough classification, a model for representing learner profiles, learning scenarios, and the choice of a proper scenario for a new learner is proposed. The recommendation mechanisms are built by means of consensus methods and clustering algorithms. As a result, there is the possibility to adapt the learning path to learner needs and preferences. The second application is related to the conception of a multiagent metasearch engine for information retrieval from the Internet.

The conception consists of the structure agent knowledge and a set of procedures enabling knowledge exchange, recommendation processes, and decision-making processes of the agents.

Another aspect of this book is related to quality analysis of expert knowledge using consensus methods. The author has shown the relationships between the consistency degree of expert solutions for some problem and the distance between their consensus and the proper solution of the problem. He has proved, with some restrictions, that the consensus of the set of expert solutions is better than these solutions. The results are original and very interesting. I would like to congratulate Professor Nguyen for his wonderful contribution.

In my opinion, the methods for knowledge inconsistency resolution and integration included in this book are very valuable and many readers such as postgraduate and PhD students in computer science, as well as scientists who are working on knowledge management, ontology integration, and multiagent systems, will find it interesting.

Lakhmi C. Jain

Preface

Inconsistent knowledge management (IKM) is a subject which is the common point of knowledge management and conflict resolution. IKM deals with methods for reconciling inconsistent content of knowledge. Inconsistency in the logic sense has been known for a long time. Inconsistency of this kind refers to a set of logic formulae which have no common model. However, inconsistency of knowledge has a larger aspect which may be considered on two levels: syntactic and semantic. On the syntactic level inconsistency may be treated in the same way as the inconsistency of logic formulae mentioned above, but in a larger context. On the semantic level, on the other hand, inconsistency appears when these formulas are interpreted in some concrete structures and some real world. For solving a large number of conflicts, and especially, for resolving inconsistency of knowledge on the semantic level, consensus methods have been shown to be useful.

This book is about methods for processing inconsistent knowledge. The need for knowledge inconsistency resolution arises in many practical applications of computer systems. This kind of inconsistency results from the use of various sources of knowledge in realizing practical tasks. These sources often are autonomous and they use different mechanisms for processing knowledge about the same real world. This can lead to inconsistency. This book provides a wide snapshot of some intelligent technologies for knowledge inconsistency resolution.

This book completes the newest research results of the author in the period of the last five years. A part of these results has been published in prestigious international journals and conference proceedings. In this book, along with other new results, the results are completed, extended, and presented in a comprehensive and unified way.

The material of each chapter of this book is self-contained. I hope that the book can be useful for graduate and PhD students in computer science; participants of courses in knowledge management and multiagent systems; researchers and all readers working on knowledge management and/or ontology integration; and specialists from social choice.

I wish to express my great gratitude to Professor Lakhmi C. Jain, the editor of this series, for his encouragement, inspiration, and interest. Thanks are also due to my colleagues at the Institute of Information Science and Engineering of Wroclaw University of Technology, for their nurturing of this project. Special thanks go to Catherine Brett for her kind contacts and advice in preparing this book. Finally, I cordially thank my wife Bich Ngoc and my sons Ngoc Trung and Ngoc Khanh for their great patience and understanding during the preparation of this book.

This work was supported by the Polish Ministry of Science and Higher Education under the grant no N516 013 32/1733.

Ngoc Thanh Nguyen

Table of Contents

Foreword ..... **v**
Preface ..... **vii**

Chapter 1: Inconsistency of Knowledge **1**
1.1. Introduction 1
1.2. Levels of Knowledge Inconsistency 5
1.3. Knowledge Inconsistency and Integration 7
1.4. The Subject of this Book 8
1.5. The Structure of this Book 9

Chapter 2: Model of Knowledge Conflict **13**
2.1. Introduction 13
2.2. What is Conflict? 16
2.3. Conflict Representation 18
2.3.1. Basic Notions 18
2.3.2. Definition of Knowledge Conflict 21
2.3.3. Credibility Degree of Conflict Participants 24
2.4. Consistency Measure for Conflict Profiles 24
2.4.1. Notion of Conflict Profile Consistency 24
2.4.2. Postulates for Consistency Functions 26
2.4.3. Analysis of Postulates 32
2.4.4. Consistency Functions 38
2.4.5. Reflecting Weights in Consistency Measure 43
2.4.6. Practical Aspect of Consistency Measures 44
2.5. Conclusions 46

Chapter 3: Consensus as a Tool for Conflict Solving **47**
3.1. Introduction 47
3.2. Consensus Theory – A Case Study 48
3.2.1. An Overview 48
3.2.2. Consensus versus Conflicts 52
3.3. Consensus Functions 55
3.3.1. Definition of Consensus Function 55
3.3.2. Postulates for Consensus Function 56
3.3.3. Analysis of Postulates 59
3.3.4. Other Consensus Choice Functions 70

3.4. Quality of Consensus 73
3.5. Susceptibility to Consensus 76
3.5.1. Criteria for Consensus Susceptibility 77
3.5.2. Consensus Susceptibility versus Consistency 84
3.6. Methods for Achieving Consensus Susceptibility 87
3.6.1. Profile Modification 88
3.6.2. Using Weights 89
3.7. Reduction of Number of Consensuses 95
3.7.1. Additional Criterion 96
3.7.2. Profile Modification 98
3.8. Conclusions 100

Chapter 4: Model for Knowledge Integration 101
4.1. Introduction 101
4.2. A General Model for Knowledge Integration 103
4.2.1. Basis notions 103
4.2.2. Distance Functions between Attribute Values 105
4.2.2.1. Functions Minimizing Transformation Costs 106
4.2.2.2. Functions Reflecting Element Shares in the Distance 108
4.3. Knowledge Integration Problem 113
4.4. Postulates for Knowledge Integration 115
4.5. Algorithms for Integration 120
4.6. Conclusions 122

Chapter 5: Processing Inconsistency on the Syntactic Level 123
5.1. Introduction 123
5.2. Conjunctive Structure of Knowledge 124
5.2.1. Basic Notions 124
5.2.2. Distance Function between Conjunctions 127
5.2.3. Integration Problem and Postulates for Consensus 129
5.2.4. Analysis of Postulates 132
5.2.5. Heuristic Algorithm for Determining Consensus 141
5.3. Disjunctive Structure of Knowledge 145
5.3.1. Basic Notions 146
5.3.2. Distance Function between Clauses 149
5.3.3. Integration Problem and Postulates for Consensus 150
5.3.4. Heuristic Algorithm for Consensus Determination 156
5.4. Fuzzy Structure of Knowledge 158
5.4.1. Basic Notions 159
5.4.2. Distance Function 159
5.4.3. Integration Problem and Algorithm for Consensus Choice 161
5.5. Conclusions 163

Chapter 6: Processing Inconsistency on the Semantic Level 165
6.1. Introduction 165
6.2. Conjunctive Structure 166
6.2.1. Basic Notions 166
6.2.2. Conjunctions of Literals 167
6.2.3. Distance Function between Attribute Values 175
6.2.4. Inconsistency Representation 176
6.2.5. Integration Problem 178
6.2.6. Consensus Determination for Subprofiles 178
6.3. Disjunctive Structure 185
6.3.1. Basic Notions 185
6.3.2. Inconsistency Representation 192
6.3.3. Integration Problem and Consensus 193
6.4. Dependences of Attributes 194
6.5. Conclusions 201

Chapter 7: Consensus for Fuzzy Conflict Profiles 203
7.1. Introduction 203
7.2. Basic Notions 204
7.3. Postulates for Consensus 207
7.4. Analysis of Postulates 211
7.5. Algorithms for Consensus Choice 216
7.6. Conclusions 222

Chapter 8: Processing Inconsistency of Expert Knowledge 223
8.1. Introduction 223
8.2. Basic Notions 226
8.3. Consensus Determination Problems 227
8.4. The Quality Analysis 232
8.5. Conclusions 239

Chapter 9: Ontology Integration 241
9.1. Introduction 241
9.2. Problem of Ontology Integration 244
9.3. Inconsistency Between Ontologies 245
9.3.1. Basic Notions 245
9.3.2. Inconsistency on the Instance Level 247
9.3.3. Inconsistency on the Concept Level 248
9.3.4. Inconsistency on the Relation Level 251
9.3.5. Some Remarks 253
9.4. Inconsistency Resolution and Ontology Integration 253
9.4.1. For the Instance Level 253
9.4.2. For the Concept Level 254
9.4.3. For the Relation Level 258
9.5. Conclusions 262

Chapter 10: Application of Inconsistency Resolution Methods in Intelligent Learning Systems 263
10.1. Introduction 263
10.2. Structure of Knowledge 266
10.2.1. Basic Notions 266
10.2.2. Distance Functions between Scenarios 271
10.3. Learner Profile and Classification 277
10.3.1. User Data 277
10.3.2. Usage Data 279
10.3.3. Learner Classification Process 279
10.4. Recommendation Process 281
10.4.1. Recommendation Procedure 281
10.4.2. Algorithm for Determination of Opening Scenario 283
10.5. Learners Clustering Process 289
10.6. Rough Learner Classification Method 292
10.6.1. Pawlak's Concept 292
10.6.2. Our Concept 293
10.6.3. Basic Notions 293
10.6.4. Rough Learner Classification 296
10.7. Conclusions 306

Chapter 11: Processing Inconsistency in Information Retrieval 307
11.1. Introduction 307
11.2. Agent Technology for Information Retrieval 310
11.3. A Conception for a Metasearch Engine 313
11.3.1. Knowledge Base of Searching Agents 313
11.3.2. Retrieval Process of a Searching Agent 320
11.3.3. Cooperation between Searching Agents 323
11.4. Recommendation Process 323
11.4.1. Recommendation without User Data 325
11.4.2. Recommendation with User Profiles 326
11.4.3. Recommendation by Query Modification 328
11.5. Conclusions 333

Chapter 12: Conclusions 335

References 337

Index 349