Studies in Computational Intelligence, Volume 306

Editor-in-Chief
Prof. Janusz Kacprzyk
Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warsaw
Poland
E-mail: kacprzyk@ibspan.waw.pl

Further volumes of this series can be found on our homepage: springer.com

Vol. 284. Juan R. González, David Alejandro Pelta, Carlos Cruz, Germán Terrazas, and Natalio Krasnogor (Eds.)
Nature Inspired Cooperative Strategies for Optimization (NICSO 2010), 2010
ISBN 978-3-642-12537-9

Vol. 285. Roberto Cipolla, Sebastiano Battiato, and Giovanni Maria Farinella (Eds.)
Computer Vision, 2010
ISBN 978-3-642-12847-9

Vol. 286. Zeev Volkovich, Alexander Bolshoy, Valery Kirzhner, and Zeev Barzily
Genome Clustering, 2010
ISBN 978-3-642-12951-3

Vol. 287. Dan Schonfeld, Caifeng Shan, Dacheng Tao, and Liang Wang (Eds.)
Video Search and Mining, 2010
ISBN 978-3-642-12899-8

Vol. 288. I-Hsien Ting, Hui-Ju Wu, Tien-Hwa Ho (Eds.)
Mining and Analyzing Social Networks, 2010
ISBN 978-3-642-13421-0

Vol. 289. Anne Håkansson, Ronald Hartung, and Ngoc Thanh Nguyen (Eds.)
Agent and Multi-agent Technology for Internet and Enterprise Systems, 2010
ISBN 978-3-642-13525-5

Vol. 290. Weiliang Xu and John Bronlund
Mastication Robots, 2010
ISBN 978-3-540-93902-3

Vol. 291. Shimon Whiteson
Adaptive Representations for Reinforcement Learning, 2010
ISBN 978-3-642-13931-4

Vol. 292. Fabrice Guillet, Gilbert Ritschard, Henri Briand, Djamel A. Zighed (Eds.)
Advances in Knowledge Discovery and Management, 2010
ISBN 978-3-642-00579-4

Vol. 293. Anthony Brabazon, Michael O'Neill, and Dietmar Maringer (Eds.)
Natural Computing in Computational Finance, 2010
ISBN 978-3-642-13949-9

Vol. 294. Manuel F.M. Barros, Jorge M.C. Guilherme, and Nuno C.G. Horta
Analog Circuits and Systems Optimization based on Evolutionary Computation Techniques, 2010
ISBN 978-3-642-12345-0

Vol. 295. Roger Lee (Ed.)
Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, 2010
ISBN 978-3-642-13264-3

Vol. 296. Roger Lee (Ed.)
Software Engineering Research, Management and Applications, 2010
ISBN 978-3-642-13272-8

Vol. 297. Tania Tronco (Ed.)
New Network Architectures, 2010
ISBN 978-3-642-13246-9

Vol. 298. Adam Wierzbicki
Trust and Fairness in Open, Distributed Systems, 2010
ISBN 978-3-642-13450-0

Vol. 299. Vassil Sgurev, Mincho Hadjiski, and Janusz Kacprzyk (Eds.)
Intelligent Systems: From Theory to Practice, 2010
ISBN 978-3-642-13427-2

Vol. 300. Baoding Liu (Ed.)
Uncertainty Theory, 2010
ISBN 978-3-642-13958-1

Vol. 301. Giuliano Armano, Marco de Gemmis, Giovanni Semeraro, and Eloisa Vargiu (Eds.)
Intelligent Information Access, 2010
ISBN 978-3-642-13999-4

Vol. 302. Bijaya Ketan Panigrahi, Ajith Abraham, and Swagatam Das (Eds.)
Computational Intelligence in Power Engineering, 2010
ISBN 978-3-642-14012-9

Vol. 303. Joachim Diederich, Cengiz Gunay, and James M. Hogan
Recruitment Learning, 2010
ISBN 978-3-642-14027-3

Vol. 304. Anthony Finn and Lakhmi C. Jain (Eds.)
Innovations in Defence Support Systems, 2010
ISBN 978-3-642-14083-9

Vol. 305. Stefania Montani and Lakhmi C. Jain (Eds.)
Successful Case-based Reasoning Applications, 2010
ISBN 978-3-642-14077-8

Vol. 306. Tru Hoang Cao
Conceptual Graphs and Fuzzy Logic, 2010
ISBN 978-3-642-14086-0

Tru Hoang Cao

Conceptual Graphs and Fuzzy Logic

A Fusion for Representing and Reasoning with Linguistic Information

Springer

Tru Hoang Cao
Faculty of Computer Science & Engineering
Ho Chi Minh City University of Technology
268 Ly Thuong Kiet Street
District 10
Ho Chi Minh City
Vietnam
E-mail: tru@cse.hcmut.edu.vn

ISBN 978-3-642-14086-0 e-ISBN 978-3-642-14087-7

DOI 10.1007/978-3-642-14087-7

Studies in Computational Intelligence ISSN 1860-949X

Library of Congress Control Number: 2010930135

Typeset & *Cover Design:* Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

For my family

Preface

Form without content is empty. Content without form is so indeterminate that it cannot be grasped as an object of knowledge.
JOHN HIBBEN, *Hegel's Logic: An Essay in Interpretation*

The research for my Master's thesis and that for my PhD were related to the two separate theories that I later on recognized to have the common target of representing and reasoning with linguistic information. They are conceptual graphs invented by John Sowa and fuzzy logic founded by Lofti Zadeh. These two theories are both very important if we are to design computer systems that can capture and reason with linguistic information as humans can.

The capacity for humans to communicate using language allows us to give, receive, and understand information expressed within a rich and flexible representational framework. Moreover, we can reason based on natural language expressions, and make decisions based on the information they convey, though this information usually involves imprecise terms and uncertain facts. Anyhow, for a computer with the conventional processing paradigm to process linguistic information, a formalism is required.

Such a formal language needs to have both a "body" that could smoothly match with the syntax of natural language expressions, and a "soul" that could deal with the semantics of imprecise and uncertain linguistic information. At this crossroad, conceptual graphs provide a syntactic structure for a smooth mapping to and from natural language, while fuzzy logic provides a semantic processor for approximate reasoning with words having vague meanings.

This volume is the combined result of my research for the past few years, which has focused on the combination of conceptual graphs and fuzzy logic for various knowledge and information processing tasks that involves natural language. First, it is about fuzzy conceptual graphs and their logic programming foundations, as a graph-based order-sorted fuzzy set logic programming language for automated reasoning with fuzzy object attributes and types. Second, it extends conceptual graphs with general quantifiers and develops direct reasoning operations on these extended conceptual graphs, which could be mapped to and from generally quantified natural language statements. Third, it defines similarity and subsumption measures between object types, names, and attributes and uses them for approximate retrieval of knowledge represented in graphs. Finally, it proposes a robust ontology-based method for understanding natural language queries using nested conceptual graphs.

Engaged in this interdisciplinary research, I have had opportunities to participate in both the research communities of conceptual graphs and fuzzy logic, and met with the colleagues and students whom I would like to thank for their contribution to this book in one way or another over the years:

- Vilas Wuwongse and Peter Creasy, my Master's and PhD advisors, for their guidance at the beginning of my research.
- James Baldwin, Trevor Martin, and Jonathan Rossiter for the valuable period of the Fril++ project in which I applied the developed order-sorted fuzzy set logic programming theory.
- Lofti Zadeh and Masoud Nikravesh for hosting my research visit at BISC when I first came up with the idea of using fuzzy conceptual graphs for the Semantic Web.
- Bikash Ghosh, Hung Wing, Robert Colomb, John Sowa, Michel Chein, Marie-Laure Mugnier, Eric Salvat, Gerard Ellis, Guy Mineau, Rudolf Wille, Jonathan Lawry, and Elie Sanchez for their fruitful discussions on the topics covered in this volume.
- My students who have directly worked with me on projects relating to the recent development and applications of fuzzy conceptual graphs.

In particular in writing this book, I am sincerely grateful to Hung Nguyen and Janusz Kacprzyk for their kind support and encouragement. I would also like to thank Thomas Ditzinger, Heather King and the Springer production team for their dedication and professional expertise in the publishing process.

May 2010 Cao Hoàng Trụ

Contents