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Information Processing and Management of Uncertainty in Knowledge-Based Systems

16th International Conference, IPMU 2016
Eindhoven, The Netherlands, June 20–24, 2016
Proceedings, Part I

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Preface

These are the proceedings of the 16th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems, IPMU 2016. The conference was held during June 20–24, 2016, in Eindhoven, The Netherlands: one of the vibrant hi-tech hot spots of Europe. The IPMU conference is organized every two years with the aim of bringing together scientists working on methods for the management of uncertainty and aggregation of information in intelligent systems.

Since 1986, the IPMU conference has been providing a forum for the exchange of ideas between theoreticians and practitioners working in these areas and related fields. In addition to the many contributed scientific papers, the conference has in the past attracted prominent plenary speakers, including the Nobel Prize winners Kenneth Arrow, Daniel Kahneman, and Ilya Prigogine. Another important feature of the conference is the presentation of the Kampé de Fériet Award for outstanding contributions to the field of uncertainty and management of uncertainty. Past winners of this prestigious award were Lotfi A. Zadeh (1992), Ilya Prigogine (1994), Toshiro Terano (1996), Kenneth Arrow (1998), Richard Jeffrey (2000), Arthur Dempster (2002), Janos Aczel (2004), Daniel Kahneman (2006), Enric Trillas (2008), James Bezdek (2010), Michio Sugeno (2012), and Vladimir N. Vapnik (2014). This year, the recipient was Joseph Y. Halpern from Cornell University, USA.

IPMU 2016 had a rich scientific program. Four invited overview talks (tutorials) were given on the first day, identifying the challenges and discussing the various methods in the field of information processing and the management of uncertainty. Further, the program consisted of five invited plenary talks, 13 special sessions, 127 contributed papers that were authored by researchers from 34 different countries, industry round tables, and discussion panels. The plenary presentations were given by the following distinguished researchers: Chris Dyer (Carnegie Mellon University, USA), Joseph Y. Halpern (Cornell University, USA), Katharina Morik (Technische Universität Dortmund, Germany), Peter P. Wakker (Erasmus University Rotterdam, The Netherlands), and Ronald R. Yager (Iona College, USA). All contributed papers underwent the same review process and were judged by at least two reviewers; 90 % of the papers were reviewed by three or more referees, and some papers by as many as five referees. Furthermore, all papers were scrutinized by the program chairs, meaning that each paper was studied by three to six independent researchers. The review process also respected the usual conflict-of-interest standards, so that all papers received blinded, independent evaluations.

Organizing a conference like IPMU 2016 is not possible without the assistance, dedication, and support of many people and institutions. We want to thank our industry sponsors, the institutional sponsors, and the material sponsors. Our sponsor chair, Paul Grefen, did an excellent job in attracting the interest and support from industry for the success of IPMU 2016. We are also particularly grateful to the organizers of sessions on dedicated topics that took place during the conference—these special sessions have

always been a characteristic element of the IPMU conference. Special thanks go to Joao Sousa, who helped evaluate and select the special session proposals. The help of the members of the international Program Committee as well as multiple reviewers was essential in safeguarding the scientific quality of the conference. The local Organizing Committee is very grateful for the efforts of multiple student volunteers who provided practical support during the conference.

Finally, we gratefully acknowledge the technical support of several organizations and institutions, notably the IEEE Computational Intelligence Society, the European Society for Fuzzy Logic and Technology (EUSFLAT), and the Netherlands Research School for Information and Knowledge Systems (SIKS). Last, but not least, our greatest gratitude goes to the authors who submitted their work and presented it at the conference!

April 2016

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Plenary Lectures

Actual Causality: A Survey

Joseph Y. Halpern

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Abstract. What does it mean that an event C “actually caused” event E ? The problem of defining actual causation goes beyond mere philosophical speculation. For example, in many legal arguments, it is precisely what needs to be established in order to determine responsibility. (What exactly was the actual cause of the car accident or the medical problem?) The philosophy literature has been struggling with the problem of defining causality since the days of Hume, in the 1700s. Many of the definitions have been couched in terms of counterfactuals. (C is a cause of E if, had C not happened, then E would not have happened.) In 2001, Judea Pearl and I introduced a new definition of actual cause, using Pearl’s notion of structural equations to model counterfactuals. The definition has been revised twice since then, extended to deal with notions like “responsibility” and “blame”, and applied in databases and program verification. I survey the last 15 years of work here, including joint work with Judea Pearl, Hana Chockler, and Chris Hitchcock. The talk will be completely self-contained.

Biography Joseph Halpern received a B.Sc. in mathematics from the University of Toronto in 1975 and a Ph.D. in mathematics from Harvard in 1981. In between, he spent two years as the head of the Mathematics Department at Bawku Secondary School, in Ghana. After a year as a visiting scientist at MIT, he joined the IBM Almaden Research Center in 1982, where he remained until 1996, also serving as a consulting professor at Stanford. In 1996, he joined the CS Department at Cornell, and was department chair 2010-14.

Halpern’s major research interests are in reasoning about knowledge and uncertainty, security, distributed computation, decision theory, and game theory. He is a Fellow of AAAI, AAAS (American Association for the Advancement of Science), the American Academy of Arts and Sciences, ACM, IEEE, and SEAT (Society for the Advancement of Economic Theory). Among other awards, he received the ACM SIGART Autonomous Agents Research Award in 2011, the Dijkstra Prize in 2009, the ACM/AAAI Newell Award in 2008, the Godel Prize in 1997, was a Guggenheim Fellow in 2001-02, and a Fulbright Fellow in 2001-02 and 2009-10. Two of his papers have won best-paper prizes at IJCAI (1985 and 1991), and another two received best-paper awards at the Knowledge Representation and Reasoning Conference (2006 and 2012). He was editor-in-chief of the Journal of the ACM (1997-2003) and has been program chair of a number of conferences.

The Present State of the Art of Modeling Uncertainty in Decision Theory, Resulting from an Interaction between Mathematical Economists and Empirical Psychologists

Peter P. Wakker

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Abstract. In decision theory, more than in other fields of IPMU, the modeling of uncertainty is driven by empirical findings about human behavior. Decision theorists are strict in the requirement that for every mathematical detail the empirical meaning must be exactly specified. For example, taking the lower bound of possible probabilities of an event, while accepted uncritically in most information management theories, is meaningless to a decision theorist until it has been specified whether the event in question yields good or bad outcomes.

This lecture describes how the current state of the art in uncertainty-decision theory could only come about from interactions between empirically oriented psychologists and mathematically oriented economists. At several stages in history, the next step forward could be made only by empirical intuitions from psychologists. Following up on that, the next step forward could be made only by theoretical inputs from economists with advanced technical skills. Modern views on the proper modeling of uncertainty attitudes could only arise from the merger of ideas from all the fields mentioned. It, for instance, led to a measure of information-insensitivity that is more refined than just taking supremums or infimums of uncertainty measures.

Biography Peter Wakker is a professor of decisions under uncertainty at Erasmus School of Economics of the Erasmus University Rotterdam. He works in behavioral economics, primarily on the differences between normative and descriptive decisions, and on decisions under risk and uncertainty. Wakker has published in leading journals in economics, business, medicine, psychology, statistics, and mathematics. He was nominated the best-publishing Dutch economist in the years 1994, 1998, 2003, and 2007, and was ranked 90th in the world in the ISI's most cited scientists in economics and business in 2003. He received a Frank P. Ramsey Medal in 2013 and the Medical Decision Making Career Achievement Award in 2007. Wakker regularly gives advices on insurance in the media. Wakker is director, jointly with Professor Han Bleichrodt, of the research group Behavioral Economics.

Decision Making with Multi-criteria

Ronald R. Yager

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Abstract. The construction of multi-criteria decision functions is strongly dependent upon the use of aggregation operators. Here if $D(x) = \text{Agg}(C_1(x), C_2(x), \dots, C_n(x))$ represents the satisfaction of alternative x to the collection of criteria a central problem becomes the formulation of the decision function D . The structure of the function Agg must be a reflection of the decision makers perceived relationship between the different criteria. We must provide some approaches that can be used to help in the construction of these decision functions. One approach is to allow the decision-maker to express their perceived relationship between the criteria in a linguistic like manner and then try to model this relationship using fuzzy logic formalisms. Another approach is the use of set measures for the representation of the relationship between criteria. Once having a formal representation of the decision function D we must evaluate it for each alternative. In many real world environments the values of the $C_i(x)$ can only be provided with some uncertainty. Among the different types of imprecise valuations are intervals, probability distributions, D-S belief structures, fuzzy sets, intuitionistic, Pythagorean and generalized orthopair fuzzy sets as well ordnallinguistic valuations. Finally we must choose among these alternatives based their values for $D(x)$. In the case of uncertainty in the $C_i(x)$ the value of $D(x)$ also manifests uncertainty. Choosing requires that we provide an ordering of these uncertain values. In our talk we shall discuss various topics from the above.

Biography Ronald R. Yager is Director of the Machine Intelligence Institute and Professor of Information Systems at Iona College. He is editor and chief of the International Journal of Intelligent Systems. He has published over 500 papers and edited over 30 books in areas related to fuzzy sets, human behavioral modeling, decision-making under uncertainty and the fusion of information. He is among the worlds top 1 % most highly cited researchers with over 45,000 citations in Google Scholar. He was the recipient of the IEEE Computational Intelligence Society Pioneer award in Fuzzy Systems. He received the special honorary medal of the 50-th Anniversary of the Polish Academy of Sciences. He received the Lifetime Outstanding Achievement Award from International the Fuzzy Systems Association. He recently received honorary doctorate degrees, honoris causa, from the Azerbaijan Technical University and the State University of Information Technologies, Sofia Bulgaria. Dr. Yager is a fellow of the IEEE, the New York Academy of Sciences and the Fuzzy Systems Association. He has served at the National Science Foundation as program director in the Information Sciences program. He was a NASA/Stanford visiting fellow and a research associate at the University of California, Berkeley. He has been a lecturer at NATO Advanced Study Institutes. He was a program director at the National Science Foundation. He is a visiting distinguished scientist at King Saud University,

Riyadh Saudi Arabia. He was an adjunct professor at Aalborg University in Denmark. He received his undergraduate degree from the City College of New York and his Ph. D. from the Polytechnic Institute New York University. He is the 2016 recipient of the IEEE Frank Rosenblatt Award the most prestigious honor given out by the IEEE Computational Intelligent Society.

Resource-Constrained Data Analysis and Exploration

Katharina Morik

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Abstract. Computer science has always taken into account some resources needed for the execution of algorithms, namely runtime and memory space. Since the triumph of very large data centers, *energy* has become a resource of importance, additionally. In 2008, Google had its millionth server. Google's estimated yearly energy consumption is about 2024 watt hours (Wh). A search request consumes 0.3 Wh, asking and reading the result at a home computer consumes about the same, so that each query costs about 0.6 Wh¹.

Where data centers challenge resources at a global scale, the energy of cyber-physical systems and smartphones is restricted at the local device. The battery of a smartphone has a capacity of about 8 Wh. The user wants a long battery duration together with a high quality of service. Regarding machine learning, there are two ways, in which energy may be saved. On the one hand, a learning algorithm may learn from compiler logs² or from user behavior³ how to enhance the heuristics of the system's software. On the other hand, the learning algorithm itself has to become energy-efficient. This can be achieved through approximations which reduce the operations that cost the most energy⁴.

Cyber-physical systems populate diverse parts of our everyday life, they are the nodes of the Internet of Things and they produce big data. If we focus again on smartphones, each user generates about 60 GB of data per year. Learning a personal model of app usage could allow early warnings when to recharge the battery⁵. However, the analysis of such data is not easy: data may be missing, their incompleteness is not easy to recognize, and they may be wrong due to several reasons. Labels, which are needed for classifier training, are missing.

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- ¹ E. Gelenbe, Y. Caseau (2015) The impact of information technology on energy consumption and carbon emissions, in: *Ubiquity*, June, 1–15
 - ² P. Lokuciejewski, M. Stolpe, K. Morik, P. Marwedel (2010) Automatic Selection of Machine Learning Models for WCET-aware Compiler Heuristic Generation, in: 4th Workshop on Statistical and Machine Learning Approaches to ARchitecture and compilaTion (SMART)
 - ³ P. Fricke, F. Jungermann, K. Morik, N. Piatkowski, O. Spinczyk, M. Stolpe (2010) Towards Adjusting Mobile Devices to User's Behaviour, in: Intern. Workshop at ECML PKDD on Mining Ubiquitous and Social Environments
 - ⁴ N. Piatkowski, S. Lee, K. Morik (2016) Integer undirected graphical models for resource-constrained systems, in: *Neurocomputing*, 173(1), 9–23
 - ⁵ N. Piatkowski, S. Lee, K. Morik (2013) Spatio-Temporal Random Fields: Compressible Representation and Distributed Estimation, in: *Machine Learning Journal* 93(1), 115–139

Data exploration is an important, though often under-estimated first part of data analysis.

In the talk, several probabilistic graphical models will be presented together with their applications.

Biography Katharina Morik is full professor for computer science at the TU Dortmund University, Germany. She earned her Ph.D. (1981) at the University of Hamburg and her habilitation (1988) at the TU Berlin. Starting with natural language processing, her interest moved to machine learning ranging from inductive logic programming to statistical learning, then to the analysis of very large data collections, high-dimensional data, and resource awareness. She is a member of the National Academy of Science and Engineering and the North-Rhine- Westphalia Academy of Science and Art. She is the author of more than 200 papers in well acknowledged conferences and journals. Her latest results include spatio-temporal random fields and integer Markov random fields, both allowing for complex graphical models under resource constraints. Her interest in interdisciplinary research covers a large variety of fields. She successfully collaborated with linguists, engineers, physicians, and astrophysicists.

She was one of those starting the IEEE International Conference on Data Mining together with Xindong Wu, and was chairing the program of this conference in 2004. She was the program chair of the European Conference on Machine Learning (ECML) in 1989 and one of the program chairs of ECML PKDD 2008. She is in the editorial boards of the international journals Knowledge and Information Systems and Data Mining and Knowledge Discovery.

Her aim to share scientific results strongly supports open source developments. For instance, the first efficient implementation of the support vector machine, SVM_light, was developed at her lab by Thorsten Joachims. Also the leading data mining platform RapidMiner started out at her lab, which continues to contribute to it. Currently, the Java streams framework is developed, which abstracts processes on distributed data streams.

Since 2011, she is leading the collaborative research center SFB876 on data analysis under resource-constraints, an interdisciplinary center comprising 14 projects, 20 professors, and about 50 Ph.D. students or Postdocs.

Learning Representations of Complex Structures in Natural Language with Neural Networks

Chris Dyer

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Abstract. Effective processing of natural language requires integrating information from a variety of sources: an individual word's meaning depends on the context it is used in; the proper interpretation of a sentence depends on understanding the discursive context it occurs in; and, reasoning about the truth of a linguistically encoded proposition requires drawing on world knowledge. However, if we take stock of what progress has been made in language processing applications to date, it is precisely those that depend on a narrow view of context rather than those that require significant integration of contextual information where we find the most success.

In this talk I argue that the challenge of developing next-generation models that are sensitive to broader contextual information can be helpfully cast as a representation learning problem. Given a basic representation of the input signal and relevant contextual information, a unified representation suitable for making predictions needs to be computed. I discuss work from my group on using neural networks to integrate basic representations of component linguistic elements and combining them recursively to obtain composite representations of complex objects. Our work has demonstrated that taking inspiration from the linguistic structures when designing architectures is more effective than task-agnostic architectures. Applications ranging from text categorization, to language modeling, to machine translation will be discussed.

Biography Chris Dyer is an assistant professor at Carnegie Mellon University. Dyer graduated from the Duke University in 2000, where he studied computer science. He went on to obtain a Ph.D. in linguistics in 2010 from University of Maryland under the supervision of Prof. Philip Resnik. Chris Dyer's research interests line in the intersection of statistical machine translation, unsupervised learning, computational morphology and phonology, large-scale data processing, probabilistic models of natural language processing, Bayesian techniques and machine learning. He is currently supported by grants from The National Science Foundation (Lexical Borrowing), DARPA (LORELEI), Google (A Hybrid Neural Phrase-Based Model for Machine Translation) and The Army Research Office (MT/NLP for Low-Resource Languages).

Contents – Part I

Fuzzy Measures and Integrals

Decomposition Integral Based Generalizations of OWA Operators	3
<i>Radko Mesiar and Andrea Stupňanová</i>	
Finding the Set of k -additive Dominating Measures Viewed as a Flow Problem	11
<i>Pedro Miranda and Michel Grabisch</i>	
On Capacities Characterized by Two Weight Vectors	23
<i>Christophe Labreuche</i>	
Computing Superdifferentials of Lovász Extension with Application to Coalitional Games	35
<i>Lukáš Adam and Tomáš Kroupa</i>	
Conjoint Axiomatization of the Choquet Integral for Heterogeneous Product Sets	46
<i>Mikhail Timonin</i>	
Aggregation of Choquet Integrals	58
<i>Radko Mesiar, Ladislav Šípek, and Alexandra Šipošová</i>	
Inclusion-Exclusion Integral and t-norm Based Data Analysis Model Construction	65
<i>Aoi Honda and Yoshiaki Okazaki</i>	
Fuzzy Integral for Rule Aggregation in Fuzzy Inference Systems	78
<i>Leary Tomlin, Derek T. Anderson, Christian Wagner, Timothy C. Havens, and James M. Keller</i>	
On a Fuzzy Integral as the Product-Sum Calculation Between a Set Function and a Fuzzy Measure	91
<i>Eiichiro Takahagi</i>	
A 2-Additive Choquet Integral Model for French Hospitals Rankings in Weight Loss Surgery	101
<i>Brice Mayag</i>	
Benchmarking over Distributive Lattices	117
<i>Marta Cardin</i>	

Uncertainty Quantification with Imprecise Probability

Efficient Simulation Approaches for Reliability Analysis of Large Systems.	129
<i>Edoardo Patelli and Geng Feng</i>	
Bivariate p -boxes and Maxitive Functions	141
<i>Ignacio Montes and Enrique Miranda</i>	
Sets of Priors Reflecting Prior-Data Conflict and Agreement	153
<i>Gero Walter and Frank P.A. Coolen</i>	
On Imprecise Statistical Inference for Accelerated Life Testing	165
<i>Frank P.A. Coolen, Yi-Chao Yin, and Tahani Coolen-Maturi</i>	
The Mathematical Gnostics (<i>Advanced Data Analysis</i>).	177
<i>Pavel Kovanic</i>	

Textual Data Processing

The Role of Graduality for Referring Expression Generation in Visual Scenes	191
<i>Albert Gatt, Nicolás Marín, François Portet, and Daniel Sánchez</i>	
Impact of the Shape of Membership Functions on the Truth Values of Linguistic Protoform Summaries	204
<i>Akshay Jain, Tianqi Jiang, and James M. Keller</i>	
A Solution of the Multiaspect Text Categorization Problem by a Hybrid HMM and LDA Based Technique.	214
<i>Sławomir Zadrozny, Janusz Kacprzyk, and Marek Gajewski</i>	
How Much Is “About”? Fuzzy Interpretation of Approximate Numerical Expressions	226
<i>Sébastien Lefort, Marie-Jeanne Lesot, Elisabetta Zibetti, Charles Tijus, and Marcin Detyniecki</i>	
Towards a Non-oriented Approach for the Evaluation of Odor Quality	238
<i>Massissilia Medjkoune, Sébastien Harispe, Jacky Montmain, Stéphane Cariou, Jean-Louis Fanlo, and Nicolas Fiorini</i>	

Belief Function Theory and Its Applications

Joint Feature Transformation and Selection Based on Dempster-Shafer Theory	253
<i>Chunfeng Lian, Su Ruan, and Thierry Denœux</i>	
Recognition of Confusing Objects for NAO Robot	262
<i>Thanh-Long Nguyen, Didier Coquin, and Reda Boukezzoula</i>	

Evidential Missing Link Prediction in Uncertain Social Networks 274
Sabrina Mallek, Imen Boukhris, Zied Elouedi, and Eric Lefevre

An Evidential Filter for Indoor Navigation of a Mobile Robot
in Dynamic Environment 286
*Quentin Labourey, Olivier Aycard, Denis Pellerin, Michèle Rombaut,
and Catherine Garbay*

A Solution for the Learning Problem in Evidential (Partially) Hidden
Markov Models Based on Conditional Belief Functions and EM. 299
Emmanuel Ramasso

Graphical Models

Determination of Variables for a Bayesian Network and the Most
Precious One 313
Esma Nur Cinicioglu and Taylan Yenilmez

Incremental Junction Tree Inference 326
*Hamza Agli, Philippe Bonnard, Christophe Gonzales,
and Pierre-Henri Wuillemin*

Real Time Learning of Non-stationary Processes with Dynamic
Bayesian Networks 338
*Matthieu Hourbracq, Pierre-Henri Wuillemin, Christophe Gonzales,
and Philippe Baumard*

Fuzzy Implication Functions

About the Use of Admissible Order for Defining Implication Operators. 353
*Maria Jose Asiain, Humberto Bustince, Benjamin Bedregal,
Zdenko Takáč, Michal Baczyński, Daniel Paternain,
and Graçaliz Dimuro*

Generalized Sugeno Integrals 363
Didier Dubois, Henri Prade, Agnès Rico, and Bruno Teheux

A New Look on Fuzzy Implication Functions: *FNI*-implications 375
Isabel Aguiló, Jaume Suñer, and Joan Torrens

On a Generalization of the Modus Ponens: *U*-conditionality 387
*Margalida Mas, Miquel Monserrat, Daniel Ruiz-Aguilera,
and Joan Torrens*

A New Look on the Ordinal Sum of Fuzzy Implication Functions. 399
Sebastia Massanet, Juan Vicente Riera, and Joan Torrens

Distributivity of Implication Functions over Decomposable Uninorms Generated from Representable Uninorms in Interval-Valued Fuzzy Sets Theory	411
<i>Michał Baczyński and Wanda Niemyska</i>	
On Functions Derived from Fuzzy Implications	423
<i>Przemysław Grzegorzewski</i>	
Applications in Medicine and Bioinformatics	
Non-commutative Quandles for Many-Valuedness in Applications	437
<i>Patrik Eklund, Ulrich Höhle, and Jari Kortelainen</i>	
Evaluating Tests in Medical Diagnosis: Combining Machine Learning with Game-Theoretical Concepts	450
<i>Karlson Pfannschmidt, Eyke Hüllermeier, Susanne Held, and Reto Neiger</i>	
Fuzzy Modeling for Vitamin B12 Deficiency	462
<i>Anna Wilbik, Saskia van Loon, Arjen-Kars Boer, Uzay Kaymak, and Volkher Scharnhorst</i>	
Real-World Applications	
Using Geographic Information Systems and Smartphone-Based Vibration Data to Support Decision Making on Pavement Rehabilitation	475
<i>Chun-Hsing Ho, Chieh-Ping Lai, and Anas Almonnieay</i>	
Automatic Synthesis of Fuzzy Inference Systems for Classification	486
<i>Jorge Paredes, Ricardo Tanscheit, Marley Vellasco, and Adriano Koshiyama</i>	
A Proposal for Modelling Agrifood Chains as Multi Agent Systems	498
<i>Madalina Croitoru, Patrice Buche, Brigitte Charnomordic, Jerome Fortin, Hazael Jones, Pascal Neveu, Danai Symeonidou, and Rallou Thomopoulos</i>	
Predictive Model Based on the Evidence Theory for Assessing Critical Micelle Concentration Property	510
<i>Ahmed Samet, Théophile Gaudin, Huiling Lu, Anne Wadouachi, Gwladys Pourceau, Elisabeth Van Hecke, Isabelle Pezron, Karim El Kirat, and Tien-Tuan Dao</i>	
Fuzzy Methods in Data Mining and Knowledge Discovery	
An Incremental Fuzzy Approach to Finding Event Sequences	525
<i>Trevor P. Martin and Ben Azvine</i>	

Scenario Query Based on Association Rules (SQAR)	537
<i>Carlos Molina, Belen Prados-Suárez, and Daniel Sanchez</i>	
POSGRAMI: Possibilistic Frequent Subgraph Mining in a Single Large Graph.	549
<i>Mohamed Moussaoui, Montaceur Zaghdoud, and Jalel Akaichi</i>	
Mining Consumer Characteristics from Smart Metering Data through Fuzzy Modelling.	562
<i>Joaquim L. Viegas, Susana M. Vieira, and João M.C. Sousa</i>	
Soft Computing for Image Processing	
Approximate Pattern Matching Algorithm	577
<i>Petr Hurtik, Petra Hodáková, and Irina Perfilieva</i>	
Image Reconstruction by the Patch Based Inpainting	588
<i>Pavel Vlačánek and Irina Perfilieva</i>	
Similarity Measures for Radial Data	599
<i>Carlos Lopez-Molina, Cedric Marco-Detchart, Javier Fernandez, Juan Cerron, Mikel Galar, and Humberto Bustince</i>	
Application of a Mamdani-Type Fuzzy Rule-Based System to Segment Periventricular Cerebral Veins in Susceptibility-Weighted Images	612
<i>Francesc Xavier Aymerich, Pilar Sobrevilla, Eduard Montseny, and Alex Rovira</i>	
On the Use of Lattice OWA Operators in Image Reduction and the Importance of the Orness Measure	624
<i>Daniel Paternain, Gustavo Ochoa, Inmaculada Lizasoain, Edurne Barrenechea, Humberto Bustince, and Radko Mesiar</i>	
A Methodology for Hierarchical Image Segmentation Evaluation	635
<i>J. Tinguaro Rodríguez, Carely Guada, Daniel Gómez, Javier Yáñez, and Javier Montero</i>	
Higher Degree F-transforms Based on B-splines of Two Variables	648
<i>Martins Kokainis and Svetlana Asmuss</i>	
Gaussian Noise Reduction Using Fuzzy Morphological Amoebas	660
<i>Manuel González-Hidalgo, Sebastia Massanet, Arnau Mir, and Daniel Ruiz-Aguilera</i>	
Clustering	
Proximal Optimization for Fuzzy Subspace Clustering	675
<i>Arthur Guillon, Marie-Jeanne Lesot, Christophe Marsala, and Nikhil R. Pal</i>	

Participatory Learning Fuzzy Clustering for Interval-Valued Data	687
<i>Leandro Maciel, Rosangela Ballini, Fernando Gomide, and Ronald R. Yager</i>	
Fuzzy <i>c</i> -Means Clustering of Incomplete Data Using Dimension-Wise Fuzzy Variances of Clusters	699
<i>Ludmila Himmelspach and Stefan Conrad</i>	
On a Generalized Objective Function for Possibilistic Fuzzy Clustering	711
<i>József Mezei and Peter Sarlin</i>	
Seasonal Clustering of Residential Natural Gas Consumers.	723
<i>Marta P. Fernandes, Joaquim L. Viegas, Susana M. Vieira, and João M.C. Sousa</i>	
Author Index	735

Contents – Part II

Fuzzy Logic, Formal Concept Analysis and Rough Sets

(Ir)relevant T-norm Joint Distributions in the Arithmetic of Fuzzy Quantities.	3
<i>Andrea Sgarro and Laura Franzoi</i>	
Knowledge Extraction from L -Fuzzy Hypercontexts	12
<i>Cristina Alcalde and Ana Burusco</i>	
A Semantical Approach to Rough Sets and Dominance-Based Rough Sets. . .	23
<i>Lynn D’eer, Chris Cornelis, and Yiyu Yao</i>	
Graded Generalized Hexagon in Fuzzy Natural Logic	36
<i>Petra Murinová and Vilém Novák</i>	
On a Category of Extensional Fuzzy Rough Approximation L -valued Spaces.	48
<i>Aleksandrs Elkins, Alexander Šostak, and Ingrida Uljane</i>	
The Syntax of Many-Valued Relations.	61
<i>Patrik Eklund</i>	
Reduct-Irreducible α -cut Concept Lattices: An Efficient Reduction Procedure to Multi-adjoint Concept Lattices	69
<i>M. Eugenia Cornejo, Jesús Medina, and Eloísa Ramírez-Poussa</i>	
Towards Galois Connections over Positive Semifields	81
<i>Francisco J. Valverde-Albacete and Carmen Peláez-Moreno</i>	

Graded and Many-Valued Modal Logics

From Kripke to Neighborhood Semantics for Modal Fuzzy Logics	95
<i>Petr Cintula, Carles Noguera, and Jonas Rogger</i>	
Łukasiewicz Public Announcement Logic	108
<i>Leonardo Cabrer, Umberto Rivieccio, and Ricardo Oscar Rodriguez</i>	
Possibilistic Semantics for a Modal $KD45$ Extension of Gödel Fuzzy Logic . . .	123
<i>Félix Bou, Francesc Esteva, Lluís Godo, and Ricardo Oscar Rodriguez</i>	
A Calculus for Rational Łukasiewicz Logic and Related Systems	136
<i>Paolo Baldi</i>	

Negation of Graded Beliefs 148
*Bénédicte Legastelois, Marie-Jeanne Lesot,
 and Adrien Revault d’Allonnes*

Comparing Some Substructural Strategies Dealing with Vagueness 161
Pablo Cobreros, Paul Egré, David Ripley, and Robert van Rooij

Imperfect Databases

An Incremental Algorithm for Repairing Training Sets with Missing Values . . . 175
Bas van Stein and Wojtek Kowalczyk

Analysis and Visualization of Missing Value Patterns 187
Bas van Stein, Wojtek Kowalczyk, and Thomas Bäck

Efficient Skyline Maintenance over Frequently Updated
 Evidential Databases 199
*Sayda Elmi, Mohamed Anis Bach Tobji, Allel Hadjali,
 and Boutheina Ben Yaghlane*

Multiple Criteria Decision Methods

Prediction Model with Interval Data -Toward Practical Applications-. 213
Michihiro Amagasa and Kiyoshi Nagata

β -Robustness Approach for Fuzzy Multi-objective Problems. 225
Oumayma Bahri, Nahla Ben Amor, and El-Ghazali Talbi

Construction of an Outranking Relation Based on Semantic Criteria
 with ELECTRE-III 238
Miriam Martínez-García, Aida Valls, and Antonio Moreno

Argumentation and Belief Revision

Argumentation Framework Based on Evidence Theory 253
Ahmed Samet, Badran Raddaoui, Tien-Tuan Dao, and Allel Hadjali

Constrained Value-Based Argumentation Framework. 265
Karima Sedki and Safa Yahi

Belief Revision and the EM Algorithm 279
Inés Couso and Didier Dubois

Causal Belief Inference in Multiply Connected Networks 291
Oumaima Boussarsar, Imen Boukhris, and Zied Elouedi

Databases and Information Systems

Indexing Possibilistic Numerical Data: The Interval B^+ -tree Approach. 305
Guy De Tré, Robin De Mol, and Antoon Bronselaer

Ordinal Assessment of Data Consistency Based on Regular Expressions 317
Antoon Bronselaer, Joachim Nielandt, Robin De Mol, and Guy De Tré

A Fuzzy Approach to the Characterization of Database Query Answers 329
Aurélien Moreau, Olivier Pivert, and Grégory Smits

Making the Skyline Larger: A Fuzzy-Neighborhood-Based Approach 341
Djamal Belkasm, Allel Hadjali, and Hamid Azzoune

Describing Rough Approximations by Indiscernibility Relations
in Information Tables with Incomplete Information 355
Michinori Nakata and Hiroshi Sakai

A Possibilistic Treatment of Data Quality Measurement. 367
Antoon Bronselaer and Guy De Tré

Computing Theoretically-Sound Upper Bounds to Expected Support
for Frequent Pattern Mining Problems over Uncertain Big Data 379
Alfredo Cuzzocrea and Carson K. Leung

In-Database Feature Selection Using Rough Set Theory. 393
Frank Beer and Ulrich Bühler

Computational Aspects of Data Aggregation and Complex Data Fusion

Linear Optimization for Ecological Indices Based on
Aggregation Functions. 411
Gleb Beliakov, Andrew Geschke, Simon James, and Dale Nimmo

A Qualitative Approach to Set Achievable Goals During the Design Phase
of Complex Systems 423
*Diadie Sow, Abdelhak Imoussaten, Pierre Couturier,
and Jacky Montmain*

Unbalanced OWA Operators for Atanassov Intuitionistic Fuzzy Sets 435
*Laura De Miguel, Edurne Barrenechea, Miguel Pagola, Aranzazu Jurio,
Jose Sanz, Mikel Elkano, and Humberto Bustince*

Fuzzy K-Minpen Clustering and K-nearest-minpen Classification
Procedures Incorporating Generic Distance-Based Penalty Minimizers 445
Anna Cena and Marek Gagolewski

Fuzzy Sets and Fuzzy Logic

Adjoint Fuzzy Partition and Generalized Sampling Theorem. 459
Irina Perfilieva, Michal Holčápek, and Vladik Kreinovich

How to Incorporate Excluding Features in Fuzzy Relational Compositions
 and What for 470
Nhung Cao and Martin Štěpnička

Towards Fuzzy Partial Set Theory. 482
Libor Běhounek and Martina Daňková

On Perception-based Logical Deduction with Fuzzy Inputs. 495
Antonín Dvořák and Martin Štěpnička

Graded Dominance and Cantor-Bernstein Equipollence of Fuzzy Sets 510
Michal Holčápek

Uninorms on Interval-Valued Fuzzy Sets 522
Martin Kalina and Pavol Král

Algorithm for Generating Finite Totally Ordered Monoids 532
Milan Petřík and Thomas Vetterlein

Decision Support

Constructing Preference Relations from Utilities and Vice Versa. 547
Thomas A. Runkler

A Characterization of the Performance of Ordering Methods in TTRP with
 Fuzzy Coefficients in the Capacity Constraints 559
*Isis Torres-Pérez, Carlos Cruz, Alejandro Rosete-Suárez,
 and José Luis Verdegay*

Preferences on Gambles Representable by a Choquet Expected Value
 with Respect to Conditional Belief and Plausibility Functions. 569
*Letizia Caldari, Giulianella Coletti, Davide Petturiti,
 and Barbara Vantaggi*

A New Vision of Zadeh’s Z-numbers 581
Sebastia Massanet, Juan Vicente Riera, and Joan Torrens

Comparison Measures

Comparing Interval-Valued Estimations with Point-Valued Estimations 595
Hugo Saulnier, Olivier Strauss, and Ines Couso

On Different Ways to be (dis)similar to Elements in a Set. Boolean Analysis and Graded Extension	605
<i>Henri Prade and Gilles Richard</i>	
Comparing System Reliabilities with Ill-Known Probabilities	619
<i>Lanting Yu, Sébastien Destercke, Mohamed Sallak, and Walter Schon</i>	
Machine Learning	
Visualization of Individual Ensemble Classifier Contributions.	633
<i>Catarina Silva and Bernardete Ribeiro</i>	
Feature Selection from Partially Uncertain Data Within the Belief Function Framework	643
<i>Asma Trabelsi, Zied Elouedi, and Eric Lefevre</i>	
On the Suitability of Type-1 Fuzzy Regression Tree Forests for Complex Datasets.	656
<i>Fathi Gasir and Keeley Crockett</i>	
Social Data Processing	
Dynamic Analysis of Participatory Learning in Linked Open Data: Certainty and Adaptation	667
<i>Marek Z. Reformat, Ronald R. Yager, and Jesse Xi Chen</i>	
Online Fuzzy Community Detection by Using Nearest Hubs	678
<i>Pascal Held and Rudolf Kruse</i>	
Creating Extended Gender Labelled Datasets of Twitter Users	690
<i>Marco Vicente, Fernando Batista, and Joao Paulo Carvalho</i>	
Temporal Data Processing	
Suppression of High Frequencies in Time Series Using Fuzzy Transform of Higher Degree	705
<i>Michal Holčapek and Linh Nguyen</i>	
A Modular Fuzzy Expert System Architecture for Data and Event Streams Processing	717
<i>Jean-Philippe Poli and Laurence Boudet</i>	
Estimation and Characterization of Activity Duration in Business Processes . . .	729
<i>Rodrigo M.T. Gonçalves, Rui Jorge Almeida, João M.C. Sousa, and Remco M. Dijkman</i>	

Fuzzy Modeling Based on Mixed Fuzzy Clustering for Multivariate Time Series of Unequal Lengths	741
<i>Cátia M. Salgado, Susana M. Vieira, and João M.C. Sousa</i>	
Time Varying Correlation Estimation Using Probabilistic Fuzzy Systems	752
<i>Nalan Baştürk and Rui Jorge Almeida</i>	
Aggregation	
Fitting Aggregation Functions to Data: Part I - Linearization and Regularization	767
<i>Maciej Bartoszuik, Gleb Beliakov, Marek Gagolewski, and Simon James</i>	
Fitting Aggregation Functions to Data: Part II - Idempotization.	780
<i>Maciej Bartoszuik, Gleb Beliakov, Marek Gagolewski, and Simon James</i>	
Mean Estimation Based on FWA Using Ranked Set Sampling with Single and Multiple Rankers	790
<i>Bekir Cetintav, Gozde Ulutagay, Selma Gurler, and Neslihan Demirel</i>	
On the Sensitivity of the Weighted Relevance Aggregation Operator and Its Application to Fuzzy Signatures	798
<i>István Á. Harmati and László T. Kóczy</i>	
Some Results on Extension of Lattice-Valued XOR, XOR-Implications and E-Implications	809
<i>Eduardo Palmeira and Benjamín Bedregal</i>	
Fuzzy Block-Pulse Functions and Its Application to Solve Linear Fuzzy Fredholm Integral Equations of the Second Kind	821
<i>Shokrollah Ziari and Reza Ezzati</i>	
Author Index	833