

Lecture Notes in Artificial Intelligence 6954

Subseries of Lecture Notes in Computer Science

LNAI Series Editors

Randy Goebel

*University of Alberta, Edmonton, Canada*

Yuzuru Tanaka

*Hokkaido University, Sapporo, Japan*

Wolfgang Wahlster

*DFKI and Saarland University, Saarbrücken, Germany*

LNAI Founding Series Editor

Joerg Siekmann

*DFKI and Saarland University, Saarbrücken, Germany*

JingTao Yao Sheela Ramanna Guoyin Wang  
Zbigniew Suraj (Eds.)

# Rough Sets and Knowledge Technology

6th International Conference, RSKT 2011  
Banff, Canada, October 9-12, 2011  
Proceedings

Series Editors

Randy Goebel, University of Alberta, Edmonton, Canada  
Jörg Siekmann, University of Saarland, Saarbrücken, Germany  
Wolfgang Wahlster, DFKI and University of Saarland, Saarbrücken, Germany

Volume Editors

JingTao Yao  
University of Regina  
Regina, S4S 0A2, SK, Canada  
E-mail: jtyao@cs.uregina.ca

Sheela Ramanna  
University of Winnipeg  
Winnipeg, R3B 2E9, MB, Canada  
E-mail: s.ramanna@uwinnipeg.ca

Guoyin Wang  
Chongqing University  
of Posts and Telecommunications  
Chongqing, 400065, China  
E-mail: wanggy@cqupt.edu.cn

Zbigniew Suraj  
University of Rzeszów  
35-959 Rzeszów, Poland  
E-mail: zsuraj@univ.rzeszow.pl

ISSN 0302-9743 e-ISSN 1611-3349  
ISBN 978-3-642-24424-7 e-ISBN 978-3-642-24425-4  
DOI 10.1007/978-3-642-24425-4  
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011936976

CR Subject Classification (1998): I.2, H.2.4, H.3-4, F.4.1, F.1, I.4-5

LNCS Sublibrary: SL 7 – Artificial Intelligence

© Springer-Verlag Berlin Heidelberg 2011

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

*Typesetting:* Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

# Preface

This volume contains the papers selected for presentation at RSKT 2011: The 6th International Conference on Rough Sets and Knowledge Technology held during October 8-11, 2011 in Banff, Canada.

The International Conference on Rough Sets and Knowledge Technology (RSKT) has been held every year since 2006. RSKT serves as a major forum that brings researchers and industry practitioners together to discuss and deliberate on fundamental issues of knowledge processing and management and knowledge-intensive practical solutions in the current knowledge age. Experts from around the world meet to present state-of-the-art scientific results, to nurture academic and industrial interaction, and to promote collaborative research in rough sets and knowledge technology. The first RSKT was held in 2006 in Chongqing, China, followed by RSKT 2007 in Toronto, Canada, RSKT 2008 in Chengdu, China, RSKT 2009 in Gold Coast, Australia, and RSKT 2010 in Beijing, China.

RSKT 2011 received 181 submissions from 23 countries and regions including Australia, Brazil, Burma, Canada, China, Czech Republic, Egypt, Hong Kong, Hungary, India, Iran, Iraq, Italy, Japan, Korea, Malaysia, Pakistan, Poland, Saudi Arabia, Taiwan, Ukraine, USA, and Vietnam. Following the success of the previous conferences, RSKT 2011 continued the tradition of a very rigorous reviewing process. Submissions received were subject to a brief review by Program Committee (PC) Chairs. A rough set approach was used to make three-way decisions. Submissions in the POSITIVE region were sent to PC members for a detailed review. Authors of submissions in the BOUNDARY region were asked to revise their papers according to the Chairs' comments. These revised submissions were then sent to PC members for a detailed review. Submissions in the NEGATIVE region were rejected and no further review was undertaken. Every submission was reviewed by at least two PC members and domain experts. Additional expert reviews were sought when necessary. On average, each submission received 3.1 reviews. Some papers received five reviews. As a result, only top-quality papers were chosen for presentation at the conference, including 48 regular papers (acceptance rate of 26.5%) and 42 short papers. Final camera-ready submissions were further reviewed by PC Chairs. Some authors were requested to make additional revisions. We would like to thank all the authors for contributing their best papers. Without their contribution, this conference would not have been possible.

The RSKT 2011 program was further enriched by four keynote speeches. We are grateful to our keynote speakers, Jerzy W. Grzymala-Busse, Jiye Liang, Witold Pedrycz and James F. Peters, for their visionary talks on rough sets and knowledge technology. Special thanks also go to tutorial speakers Sarjerao Nimse and Pawan Lingras.

The RSKT 2011 program included one workshop: Advances in Granular Computing 2011, and four Special Sessions: Decision-theoretic Rough Set Model and Applications, Near Sets: Foundations and Applications, Quotient Space Theory: Research and Applications, and Rough Sets in Process Mining: Theory, Technologies and Applications.

RSKT 2011 would not have been successful without the support of many people and organizations. We wish to thank the members of the Steering Committee for their invaluable suggestions and support throughout the organization process. We are indebted to the PC members and external reviewers for their effort and engagement in providing a rich and rigorous scientific program. We express our gratitude to our Special Session Chairs (Christopher Henry, Joseph Herbert, Huaxiong Li, Dun Liu, Krzysztof Pancerz, Zbigniew Suraj, Marcin Wolski, Hong Yu, Yan-ping Zhang, Jiabao Zhao, and Xianzhong Zhou) for selecting and coordinating the sessions on very interesting topics. We are also grateful to Wendy Preikchat and Marilyn Hepp of the University of Regina for the local arrangements, whose great effort ensured the success of the conference.

We greatly appreciate the co-operation, support, and sponsorship of various institutions, companies, and organizations, including the University of Regina, Canada, University of Calgary, Canada, International Rough Set Society, and Rough Sets and Soft Computation Society, Chinese Association for Artificial Intelligence, China. We are also grateful to both the Department of Computer Science and the Faculty of Science, University of Regina, for their financial and administrative support and a sponsorship of the Best Student Paper Award.

We acknowledge the use of the EasyChair conference system for paper submission, review and editing of the proceedings. The new feature of editing LNCS volumes is especially useful. We are thankful to Alfred Hofmann and the excellent LNCS team of at Springer for their support and co-operation in publishing the proceedings as a volume of the *Lecture Notes in Computer Science*.

October 2011

JingTao Yao  
Sheela Ramanna  
Guoyin Wang  
Zbigniew Suraj

# Organization

## Organizing Committee

Conference Chairs

Jiye Liang (China)  
Roman Słowiński (Poland)  
Xin Wang (Canada)

Program Chairs

JingTao Yao (Canada)  
Sheela Ramanna (Canada)  
Guoyin Wang (China)  
Zbigniew Suraj (Poland)

Organizing Chairs

Henry Leung (Canada)  
Yong Yang (China)

Special Session Chairs

Pawan Lingras (Canada)  
Wei-Zhi Wu (China)

Publicity Chairs

Joseph P. Herbert (Canada)  
Huaxiong Li (China)  
C. Raghavendra Rao (India)  
Marcin Wolski (Poland)

Steering Committee Chairs

Andrzej Skowron (Poland)  
Guoyin Wang (China)  
Yiyu Yao (Canada)

Workshop Chairs

Advances in Granular Computing

Duoqian Miao (China)  
Witold Pedrycz (Canada)  
Andrzej Skowron (Poland)  
Yiyu Yao (Canada)  
Bo Zhang (China)

## Program Committee

Aijun An (Canada)

Qiusheng An (China)

Mohua Banerjee (India)

Jan Bazan (Poland)

Theresa Beaubouef (USA)

Zbigniew Bonikowski (Poland)

Maciej Borkowski (USA)

Gianpiero Cattaneo (Italy)

Nick Cercone (Canada)

Mihir K. Chakraborty (India)

Chien-Chung Chan (USA)

Jiaying Cheng (China)

- Davide Ciucci (Italy)  
 Chris Cornelis (Belgium)  
 Krzysztof Cyran (Poland)  
 Jianhua Dai (China)  
 Martine De Cock (Belgium)  
 Dayong Deng (China)  
 Ivo Düntsch (Canada)  
 Lin Feng (China)  
 Yang Gao (China)  
 Anna Gomolińska (Poland)  
 Xun Gong (China)  
 Salvatore Greco (Italy)  
 Jerzy W. Grzymała-Busse (USA)  
 Jianchao Han (USA)  
 Jun He (UK)  
 Christopher Henry (Canada)  
 Daryl Hepting (Canada)  
 Joseph P. Herbert (Canada)  
 Shoji Hirano (Japan)  
 Qinghua Hu (China)  
 Xiaohua Hu (USA)  
 Masahiro Inuiguchi (Japan)  
 Lakhmi Jain (Australia)  
 Ryszard Janicki (Canada)  
 Jouni Jarvinen (Finland)  
 Richard Jensen (UK)  
 Chaozhe Jiang (China)  
 Sankar K. Pal (India)  
 Janusz Kacprzyk (Poland)  
 C. Maria Keet (South Africa)  
 Jan Komorowski (Sweden)  
 Jacek Koronacki (Poland)  
 Abd El-monem Kozae (Egypt)  
 Marzena Kryszkiewicz (Poland)  
 Yasuo Kudo (Japan)  
 Aboul Ella Hassanien (Egypt)  
 Henry Leung (Canada)  
 Daoguo Li (China)  
 Fanchang Li (China)  
 Jinjin Li (China)  
 Longshu Li (China)  
 Huaxiong Li (China)  
 Tianrui Li (China)  
 Yuefeng Li (Australia)  
 Jiye Liang (China)
- Tsau Young Lin (USA)  
 Pawan Lingras (Canada)  
 Qing Liu (China)  
 Qun Liu (China)  
 Xiaodong Liu (China)  
 Neil Mac Parthalain (UK)  
 Praditpa Maji (India)  
 Benedetto Matarazzo (Italy)  
 Ernestina Menasalvas (Spain)  
 Jusheng Mi (China)  
 Duoqian Miao (China)  
 Sadaaki Miyamoto (Japan)  
 Mikhail Moshkov (Saudi Arabia)  
 Som Naimpally (Canada)  
 Michinori Nakata (Japan)  
 Hung Son Nguyen (Poland)  
 Ewa Orłowska (Poland)  
 Hala Own (Egypt)  
 Krzysztof Pancierz (Poland)  
 Puntip Pattaraintakorn (Thailand)  
 Witold Pedrycz (Canada)  
 Alberto Guillen Perales (Spain)  
 Georg Peters (Germany)  
 James F. Peters (Canada)  
 Lech Polkowski (Poland)  
 Keyun Qin (China)  
 Guofang Qiu (China)  
 Anna Maria Radzikowska (Poland)  
 Vijay V. Raghavan (USA)  
 Sheela Ramanna (Canada)  
 C. Raghavendra Rao (India)  
 Zbigniew Raś (USA)  
 Henryk Rybiński (Poland)  
 Hiroshi Sakai (Japan)  
 Lin Shang (China)  
 Qiang Shen (UK)  
 Kaiquan Shi (China)  
 Arul Siromoney (India)  
 Andrzej Skowron (Poland)  
 Dominik Ślęzak (Poland)  
 Roman Słowiński (Poland)  
 Urszula Stańczyk (Poland)  
 Jerzy Stefanowski (Poland)  
 John Stell (UK)  
 Jarosław Stepianiuk (Poland)

Zbigniew Suraj (Poland)  
 Marcin Szczuka (Poland)  
 Li-Shiang Tsay (China)  
 Shusaku Tsumoto (Japan)  
 Aida Vitoria (Sweden)  
 Alicja Wakulicz-Deja (Poland)  
 Krzysztof Walczak (Poland)  
 Guoyin Wang (China)  
 Xin Wang (Canada)  
 Anita Wasilewska (USA)  
 Richard Weber (UK)  
 Ling Wei (China)  
 Paul Wen (Australia)  
 Szymon Wilk (Poland)  
 Marcin Wolski (Poland)  
 Tao Wu (China)  
 Wei-Zhi Wu (China)  
 Xiaohong Wu (China)  
 Jiucheng Xu (China)

Ronald Yager (USA)  
 Yong Yang (China)  
 JingTao Yao (Canada)  
 Yiyu Yao (Canada)  
 Dongyi Yie (China)  
 Hong Yu (China)  
 Jian Yu (China)  
 Sławomir Zadrozny (Poland)  
 Xianhua Zeng (China)  
 Bo Zhang (China)  
 Ling Zhang (China)  
 Qinghua Zhang (China)  
 Yan-Ping Zhang (China)  
 Shu Zhao (China)  
 Ning Zhong (Japan)  
 Shuigeng Zhou (China)  
 William Zhu (China)  
 Wojciech Ziarko (Canada)

## Additional Reviewers

Aderemi Adewumi  
 Xiangdong An  
 Nouman Azam  
 Doungrat Chitcharone  
 Lin Feng  
 Lihe Guan  
 Piotr Hońko  
 Andrzej Janusz  
 Oleg Pianykh  
 Leszek Puzio

Andrey Savchenko  
 Michael Soltys  
 Jirapond Tadrat  
 Magdalena Topczewska  
 Nele Verbiest  
 Lidong Wang  
 Xiang Yin  
 Wei Zhang  
 Bing Zhou  
 Beata Zielosko

## Sponsoring Institutions

University of Regina, Canada  
 University of Calgary, Canada  
 International Rough Set Society  
 Rough Sets and Soft Computation Society, Chinese Association  
 for Artificial Intelligence, China



# Table of Contents

## Keynote Papers

Mining Incomplete Data—A Rough Set Approach . . . . .	1
<i>Jerzy W. Grzymala-Busse</i>	
Uncertainty and Feature Selection in Rough Set Theory . . . . .	8
<i>Jiye Liang</i>	
Towards Designing Human Centric Systems: A New View at System Modeling With Granular Membership Grades . . . . .	16
<i>Witold Pedrycz</i>	
Sufficiently Near Sets of Neighbourhoods . . . . .	17
<i>James F. Peters</i>	

## Invited Tutorial

History of Set Theory and Its Extensions in the Context of Soft Computing . . . . .	25
<i>Sarjerao Nimse and Pawan Lingras</i>	

## Attribute Reduction and Feature Selection

Comparison of Classical Dimensionality Reduction Methods with Novel Approach Based on Formal Concept Analysis . . . . .	26
<i>Eduard Bartl, Hana Rezankova, and Lukas Sobisek</i>	
Rule-Based Estimation of Attribute Relevance . . . . .	36
<i>Jerzy Błaszczyński, Roman Słowiński, and Robert Susmaga</i>	
Applications of Approximate Reducts to the Feature Selection Problem . . . . .	45
<i>Andrzej Janusz and Sebastian Stawicki</i>	
Dependence and Algebraic Structure of Formal Contexts . . . . .	51
<i>Tong-Jun Li, Ying-Xue Wu, and Xiaoping Yang</i>	
Optimal Sub-Reducts with Test Cost Constraint . . . . .	57
<i>Fan Min and William Zhu</i>	
An Efficient Fuzzy-Rough Attribute Reduction Approach . . . . .	63
<i>Yuhua Qian, Chao Li, and Jiye Liang</i>	

A Novel Attribute Reduction Approach Based on the Object Oriented  
 Concept Lattice ..... 71  
*Mingwen Shao, Li Guo, and Lan Li*

Rough-Set-Inspired Feature Subset Selection, Classifier Construction,  
 and Rule Aggregation ..... 81  
*Dominik Ślęzak and Sebastian Widz*

A Constructive Feature Induction Mechanism Founded on Evolutionary  
 Strategies with Fitness Functions Generated on the Basis of Decision  
 Trees ..... 89  
*Mariusz Wrzesień, Wiesław Paja, and Krzysztof Pancierz*

An Efficient Fuzzy Rough Approach for Feature Selection ..... 95  
*Feifei Xu, Weiguo Pan, Lai Wei, and Haizhou Du*

Partitions, Coverings, Reducts and Rule Learning in Rough Set  
 Theory ..... 101  
*Yiyu Yao and Rong Fu*

A Rough Set Approach to Feature Selection Based on Relative Decision  
 Entropy ..... 110  
*Lin Zhou and Feng Jiang*

**Generalized Rough Set Models**

A Variable Precision Covering Generalized Rough Set Model ..... 120  
*Xinwei Zheng and Jian-Hua Dai*

Dominance-Based Rough Set Approach on Pairwise Comparison Tables  
 to Decision Involving Multiple Decision Makers ..... 126  
*Salvatore Greco, Benedetto Matarazzo, and Roman Słowiński*

Generalized Parameterized Approximations ..... 136  
*Jerzy W. Grzymala-Busse*

Transversal and Function Matroidal Structures of Covering-Based  
 Rough Sets ..... 146  
*Shiping Wang, William Zhu, and Fan Min*

Some Fuzzy Topologies Induced by Rough Fuzzy Sets ..... 156  
*Wei-Zhi Wu, Yu-Fang Yang, and You-Hong Xu*

Neighborhood Rough Sets Based Matrix Approach for Calculation of  
 the Approximations ..... 166  
*Junbo Zhang, Tianrui Li, Yan Yang, and Lei Wang*

## Machine Learning with Rough and Hybrid Techniques

Case-Based Classifiers With Fuzzy Rough Sets . . . . .	172
<i>Shuang An, Qinghua Hu, and Daren Yu</i>	
Comparison of Greedy Algorithms for $\alpha$ -Decision Tree Construction . . . .	178
<i>Abdulaziz Alkhalid, Igor Chikalov, and Mikhail Moshkov</i>	
Constructing an Optimal Decision Tree for FAST Corner Point Detection . . . . .	187
<i>Abdulaziz Alkhalid, Igor Chikalov, and Mikhail Moshkov</i>	
Incremental Learning in AttributeNets with Dynamic Reduct and IQuickReduct . . . . .	195
<i>P.S.V.S. Sai Prasad, K. Hima Bindu, and C. Raghavendra Rao</i>	
LEM2-Based Rule Induction from Data Tables with Imprecise Evaluations . . . . .	201
<i>Masahiro Inuiguchi, Masahiko Tsuji, Yoshifumi Kusunoki, and Masayo Tsurumi</i>	
An Extension to Rough $c$ -Means Clustering . . . . .	208
<i>Fan Li and Qihe Liu</i>	
A Modified Cop-Kmeans Algorithm Based on Sequenced Cannot-Link Set . . . . .	217
<i>Tonny Rutayisire, Yan Yang, Chao Lin, and Jinyuan Zhang</i>	
A NIS-Apriori Based Rule Generator in Prolog and Its Functionality for Table Data . . . . .	226
<i>Hiroshi Sakai, Michinori Nakata, and Dominik Ślęzak</i>	
Towards a Practical Approach to Discover Internal Dependencies in Rule-Based Knowledge Bases . . . . .	232
<i>Roman Simiński, Agnieszka Nowak-Brzezińska, Tomasz Jach, and Tomasz Xięski</i>	
Discovering Patterns of Collaboration in Rough Set Research: Statistical and Graph-Theoretical Approach . . . . .	238
<i>Zbigniew Suraj, Piotr Grochowalski, and Łukasz Lew</i>	

## Knowledge Technology

Comparing a Clustering Density Criteria of Temporal Patterns of Terms Obtained by Different Feature Sets . . . . .	248
<i>Hidenao Abe and Shusaku Tsumoto</i>	

Similarity of Query Results in Similarity-Based Databases . . . . . 258  
*Radim Belohlavek, Lucie Urbanova, and Vilem Vychodil*

Rough Set Based Quality of Service Design for Service Provisioning in  
 Clouds . . . . . 268  
*Praveen Ganghishetti, Rajeev Wankar, Rafah M. Almuttairi, and  
 C. Raghavendra Rao*

GTrust: A Distributed Trust Model in Multi-Agent Systems Based on  
 Grey System Theory . . . . . 274  
*Lijian He, Houkuan Huang, and Xingye Dong*

Linear Necessity Measures and Their Applications to Possibilistic  
 Linear Programming . . . . . 280  
*Masahiro Inuiguchi, Tatsuya Higuchi, and Masayo Tsurumi*

Remarks on Pairwise Comparison Numerical and Non-numerical  
 Rankings . . . . . 290  
*Ryszard Janicki and Yun Zhai*

Community-Based Relational Markov Networks in Complex  
 Networks . . . . . 301  
*Huaiyu Wan, Youfang Lin, Caiyan Jia, and Houkuan Huang*

**Intelligent Systems and Applications**

Applying Multi-Criteria Decision Analysis to Global Software  
 Development with Scrum Project Planning . . . . . 311  
*Luis Henrique Almeida, Plácido Rogério Pinheiro, and  
 Adriano Bessa Albuquerque*

Accuracy Evaluation of the System of Type 1 Diabetes Prediction . . . . . 321  
*Rafal Deja*

Driver Status Recognition by Neighborhood Covering Rules . . . . . 327  
*Yong Du, Qinghua Hu, Peijun Ma, and Xiaohong Su*

Application of Gravitational Search Algorithm on Data Clustering . . . . . 337  
*Abdolreza Hatamlou, Salwani Abdullah, and  
 Hossein Nezamabadi-pour*

Application of Rough Sets in GIS Generalization . . . . . 347  
*Wenjing Li, Jia Qiu, Zhaocong Wu, Zhiyong Lin, and Shaoning Li*

Application of Rough Set Theory for Evaluating Polysaccharides  
 Extraction . . . . . 354  
*Shuang Liu, Lijun Sun, Yurong Guo, Jialin Gao, and Lei Liu*

Identification of Print Technology Based on Homogeneous Regions of Image .....	360
<i>Umadevi Maramreddi, Arun Agarwal, and C. Raghavendra Rao</i>	
Ant Based Clustering of MMPI Data - An Experimental Study .....	366
<i>Krzysztof Pancierz, Arkadiusz Lewicki, Ryszard Tadeusiewicz, and Jerzy Gomula</i>	
Detection of Cancer Patients Using an Innovative Method for Learning at Imbalanced Datasets .....	376
<i>Hamid Parvin, Behrouz Minaei-Bidgoli, and Hosein Alizadeh</i>	
Information Reuse in Hospital Information Systems: A Similarity-Oriented Data Mining Approach .....	382
<i>Shusaku Tsumoto and Shoji Hirano</i>	
A Model-Based Decision Support Tool Using Fuzzy Optimization for Climate Change .....	388
<i>Omar S. Soliman, Aboul Ella Hassanien, Neveen I. Ghali, Nashwa El-Bendary, and Ruhul A. Sarker</i>	
Clustering of Rough Set Related Documents with Use of Knowledge from DBpedia .....	394
<i>Marcin Szczuka, Andrzej Janusz, and Kamil Herba</i>	
Case-Based Reasoning Using Dominance-Based Decision Rules .....	404
<i>Marcin Szelaq, Salvatore Greco, Jerzy Błaszczyński, and Roman Słowiński</i>	
RoSetOn: The Open Project for Ontology of Rough Sets and Related Fields .....	414
<i>Zbigniew Suraj and Piotr Grochowalski</i>	
Fuzzy Description of Air Quality: A Case Study .....	420
<i>Jyoti Y. Yadav, Vilas Kharat, and Ashok Deshpande</i>	
A Robust Face Recognition Method Based on AdaBoost, EHMM and Sample Perturbation .....	428
<i>Yong Yang, Kan Tian, and Zhengrong Chen</i>	
Roughness Approach to Color Image Segmentation through Smoothing Local Difference .....	434
<i>Xiaodong Yue, Duoqian Miao, Yufei Chen, and Hongzhong Chen</i>	
On Local Inclusion Degree of Intuitionistic Fuzzy Sets .....	440
<i>Lei Zhou</i>	

**Special Session: Decision-Theoretic Rough Set Model**

Analysis of Data-Driven Parameters in Game-Theoretic Rough Sets . . . . 447  
*Joseph P. Herbert and JingTao Yao*

An Optimization Viewpoint of Decision-Theoretic Rough Set Model . . . . 457  
*Xiuyi Jia, Weiwei Li, Lin Shang, and Jiajun Chen*

Attribute Reduction in Decision-Theoretic Rough Set Model: A Further Investigation . . . . . 466  
*Huaxiong Li, Xianzhong Zhou, Jiabao Zhao, and Dun Liu*

A New Discriminant Analysis Approach under Decision-Theoretic Rough Sets . . . . . 476  
*Dun Liu, Tianrui Li, and Decui Liang*

Construction of  $\alpha$ -Decision Trees for Tables with Many-Valued Decisions . . . . . 486  
*Mikhail Moshkov and Beata Zielosko*

Decision Making in Incomplete Information System Based on Decision-Theoretic Rough Sets . . . . . 495  
*Xiaoping Yang, Haiguang Song, and Tong-Jun Li*

Automatically Determining the Number of Clusters Using Decision-Theoretic Rough Set . . . . . 504  
*Hong Yu, Zhanguo Liu, and Guoyin Wang*

A New Formulation of Multi-category Decision-Theoretic Rough Sets . . . 514  
*Bing Zhou*

**Special Session: Near Sets**

Parallel Computation in Finding Near Neighbourhoods . . . . . 523  
*Christopher J. Henry and Sheela Ramanna*

$\varepsilon$ -Near Collections . . . . . 533  
*James F. Peters and Maciej Borkowski*

Nearness of Subtly Different Digital Images . . . . . 543  
*Leszek Puzio and James F. Peters*

A Generalization of Near Set Model . . . . . 553  
*Lidong Wang, Xiaodong Liu, and Xiaojuan Tian*

Gauges, Pregauges and Completions: Some Theoretical Aspects of Near and Rough Set Approaches to Data . . . . . 559  
*Marcin Wolski*

## Special Session: Quotient Space Theory

Path Queries on Massive Graphs Based on Multi-granular Graph Partitioning .....	569
<i>Fu-gui He, Yan-ping Zhang, Jie Chen, and Ling Zhang</i>	
A Minimal Test Suite Generation Method Based on Quotient Space Theory .....	579
<i>Lei Wu and Longshu Li</i>	
Audio Signal Blind Deconvolution Based on the Quotient Space Hierarchical Theory .....	585
<i>Chao Zhang, Yuan Zhang, and Xiao-pei Wu</i>	
The Optimal Approximation of Fuzzy Tolerance Relation .....	591
<i>Ling Zhang, Yan-ping Zhang, and Shu Zhao</i>	

## Special Session: Rough Sets in Process Mining

A New Method for Inconsistent Multicriteria Classification .....	600
<i>Weibin Deng, Guoyin Wang, Shuangxia Yang, and Feng Hu</i>	
Probabilistic Similarity-Based Reduct .....	610
<i>Wojciech Froelich and Alicja Wakulicz-Deja</i>	
Inference Processes in Decision Support Systems with Incomplete Knowledge .....	616
<i>Alicja Wakulicz-Deja, Agnieszka Nowak-Brzezińska, and Tomasz Jach</i>	
Synthesis of Synchronized Concurrent Systems Specified by Information Systems .....	626
<i>Zbigniew Suraj and Krzysztof Panczer</i>	
Efficiency of Complex Data Clustering .....	636
<i>Alicja Wakulicz-Deja, Agnieszka Nowak-Brzezińska, and Tomasz Xięski</i>	

## Workshop: Advances in Granular Computing 2011

The Extraction Method of DNA Microarray Features Based on Experimental $A$ Statistics .....	642
<i>Piotr Artiemjew</i>	
Granular Structures in Graphs .....	649
<i>Guang Chen and Ning Zhong</i>	
Fuzzy Rough Granular Self Organizing Map .....	659
<i>Avatharam Ganivada, Shubhra Sankar Ray, and Sankar Kumar Pal</i>	

Knowledge Acquisition in Inconsistent Multi-scale Decision Systems . . . .	669
<i>Shen-Ming Gu and Wei-Zhi Wu</i>	
Text Clustering Based on Granular Computing and Wikipedia . . . . .	679
<i>Liping Jing and Jian Yu</i>	
Rough Relations, Neighborhood Relations, and Granular Computing . . .	689
<i>He Lin and Yao Zhou</i>	
Comparing Clustering Schemes at Two Levels of Granularity for Mobile Call Mining . . . . .	696
<i>Pawan Lingras, Parag Bhalchandra, Satish Mekewad, Ravindra Rathod, and Santosh Khamitkar</i>	
Granular-Based Partial Periodic Pattern Discovery over Time Series Data . . . . .	706
<i>Aibao Luo, Xiuyi Jia, Lin Shang, Yang Gao, and Yubin Yang</i>	
Approximations of Functions: Toward Rough Granular Calculus . . . . .	712
<i>Andrzej Skowron and Jaroslaw Stepaniuk</i>	
Bipartite Graphs and Coverings . . . . .	722
<i>Shiping Wang, William Zhu, and Fan Min</i>	
Covering-Based Reduction of Object-Oriented Concept Lattices . . . . .	728
<i>Ling Wei and Qiang Li</i>	
Top-Down Progressive Computing . . . . .	734
<i>Yiyu Yao and Jigang Luo</i>	
Least Absolute Deviation Cut . . . . .	743
<i>Jian Yu and Liping Jing</i>	
Hierarchical Qualitative Inference Model with Substructures . . . . .	753
<i>Zehua Zhang, Duoqian Miao, and Jin Qian</i>	
Decision Rules for Decision Tables with Many-Valued Decisions . . . . .	763
<i>Igor Chikalov and Beata Zielosko</i>	
<b>Author Index . . . . .</b>	<b>769</b>