

LNAI 3558

Vicenç Torra  
Yasuo Narukawa  
Sadaaki Miyamoto (Eds.)

# Modeling Decisions for Artificial Intelligence

Second International Conference, MDAI 2005  
Tsukuba, Japan, July 2005  
Proceedings

TP18-53  
M478  
2005

Vicenç Torra Yasuo Narukawa  
Sadaaki Miyamoto (Eds.)

# Modeling Decisions for Artificial Intelligence

Second International Conference, MDAI 2005  
Tsukuba, Japan, July 25-27, 2005  
Proceedings



E200501624



Springer

## Series Editors

Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA  
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

## Volume Editors

Vicenç Torra  
Institut d'Investigació en Intel·ligència Artificial  
Consejo Superior de Investigaciones Científicas  
Campus UAB, 08193 Bellaterra, Catalonia, Spain  
E-mail: vtorra@iiia.csic.es

Yasuo Narukawa  
Toho Gakuen  
3-1-10 Naka, Kunitachi, Tokyo, 186-0004, Japan  
E-mail: narukawa@d4.dion.ne.jp

Sadaaki Miyamoto  
University of Tsukuba  
School of Systems and Information Engineering  
Ibaraki 305-8573, Japan  
E-mail: miyamoto@risk.tsukuba.ac.jp

Library of Congress Control Number: 2005928987

CR Subject Classification (1998): I.2, F.4.1, H.2.8, I.6

ISSN 0302-9743  
ISBN-10 3-540-27871-0 Springer Berlin Heidelberg New York  
ISBN-13 978-3-540-27871-9 Springer Berlin Heidelberg New York

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.

Springer is a part of Springer Science+Business Media  
springeronline.com

© Springer-Verlag Berlin Heidelberg 2005  
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Olgun Computergrafik  
Printed on acid-free paper SPIN: 11526018 06/3142 5 4 3 2 1 0

# Lecture Notes in Artificial Intelligence

3558

Edited by J. G. Carbonell and J. Siekmann

Subseries of Lecture Notes in Computer Science

# Lecture Notes in Artificial Intelligence (LNAI)

- Vol. 3596: F. Dau, M.-L. Mugnier, G. Stumme (Eds.), *Conceptual Structures: Common Semantics for Sharing Knowledge*. XI, 467 pages. 2005.
- Vol. 3587: P. Perner, A. Imiya (Eds.), *Machine Learning and Data Mining in Pattern Recognition*. XVII, 695 pages. 2005.
- Vol. 3575: S. Wermter, G. Palm, M. Elshaw (Eds.), *Biomimetic Neural Learning for Intelligent Robots*. IX, 383 pages. 2005.
- Vol. 3571: L. Godo (Ed.), *Symbolic and Quantitative Approaches to Reasoning with Uncertainty*. XVI, 1028 pages. 2005.
- Vol. 3559: P. Auer, R. Meir (Eds.), *Learning Theory*. XI, 692 pages. 2005.
- Vol. 3558: V. Torra, Y. Narukawa, S. Miyamoto (Eds.), *Modeling Decisions for Artificial Intelligence*. XII, 470 pages. 2005.
- Vol. 3554: A. Dey, B. Kokinov, D. Leake, R. Turner (Eds.), *Modeling and Using Context*. XIV, 572 pages. 2005.
- Vol. 3533: M. Ali, F. Esposito (Eds.), *Innovations in Applied Artificial Intelligence*. XX, 858 pages. 2005.
- Vol. 3528: P.S. Szczepaniak, J. Kacprzyk, A. Niewiadomski (Eds.), *Advances in Web Intelligence*. XVII, 513 pages. 2005.
- Vol. 3518: T.B. Ho, D. Cheung, H. Liu (Eds.), *Advances in Knowledge Discovery and Data Mining*. XXI, 864 pages. 2005.
- Vol. 3508: P. Bresciani, P. Giorgini, B. Henderson-Sellers, G. Low, M. Winikoff (Eds.), *Agent-Oriented Information Systems II*. X, 227 pages. 2005.
- Vol. 3505: V. Gorodetsky, J. Liu, V. A. Skormin (Eds.), *Autonomous Intelligent Systems: Agents and Data Mining*. XIII, 303 pages. 2005.
- Vol. 3501: B. Kégl, G. Lapalme (Eds.), *Advances in Artificial Intelligence*. XV, 458 pages. 2005.
- Vol. 3492: P. Blache, E. Stabler, J. Busquets, R. Moot (Eds.), *Logical Aspects of Computational Linguistics*. X, 363 pages. 2005.
- Vol. 3488: M.-S. Hacid, N.V. Murray, Z.W. Raś, S. Tsumoto (Eds.), *Foundations of Intelligent Systems*. XIII, 700 pages. 2005.
- Vol. 3476: J. Leite, A. Omicini, P. Torroni, P. Yolum (Eds.), *Declarative Agent Languages and Technologies II*. XII, 289 pages. 2005.
- Vol. 3464: S.A. Brueckner, G.D.M. Serugendo, A. Karageorgos, R. Nagpal (Eds.), *Engineering Self-Organising Systems*. XIII, 299 pages. 2005.
- Vol. 3452: F. Baader, A. Voronkov (Eds.), *Logic for Programming, Artificial Intelligence, and Reasoning*. XI, 562 pages. 2005.
- Vol. 3451: M.-P. Gleizes, A. Omicini, F. Zambonelli (Eds.), *Engineering Societies in the Agents World*. XIII, 349 pages. 2005.
- Vol. 3446: T. Ishida, L. Gasser, H. Nakashima (Eds.), *Massively Multi-Agent Systems I*. XI, 349 pages. 2005.
- Vol. 3445: G. Chollet, A. Esposito, M. Faundez-Zanuy, M. Marinaro (Eds.), *Nonlinear Speech Modeling and Applications*. XIII, 433 pages. 2005.
- Vol. 3438: H. Christiansen, P.R. Skadhauge, J. Villadsen (Eds.), *Constraint Solving and Language Processing*. VIII, 205 pages. 2005.
- Vol. 3430: S. Tsumoto, T. Yamaguchi, M. Numao, H. Motoda (Eds.), *Active Mining*. XII, 349 pages. 2005.
- Vol. 3419: B. Faltings, A. Petcu, F. Fages, F. Rossi (Eds.), *Constraint Satisfaction and Constraint Logic Programming*. X, 217 pages. 2005.
- Vol. 3416: M. Böhlen, J. Gamper, W. Polasek, M.A. Wimmer (Eds.), *E-Government: Towards Electronic Democracy*. XIII, 311 pages. 2005.
- Vol. 3415: P. Davidsson, B. Logan, K. Takadama (Eds.), *Multi-Agent and Multi-Agent-Based Simulation*. X, 265 pages. 2005.
- Vol. 3403: B. Ganter, R. Godin (Eds.), *Formal Concept Analysis*. XI, 419 pages. 2005.
- Vol. 3398: D.-K. Baik (Ed.), *Systems Modeling and Simulation: Theory and Applications*. XIV, 733 pages. 2005.
- Vol. 3397: T.G. Kim (Ed.), *Artificial Intelligence and Simulation*. XV, 711 pages. 2005.
- Vol. 3396: R.M. van Eijk, M.-P. Huguet, F. Dignum (Eds.), *Agent Communication*. X, 261 pages. 2005.
- Vol. 3394: D. Kudenko, D. Kazakov, E. Alonso (Eds.), *Adaptive Agents and Multi-Agent Systems II*. VIII, 313 pages. 2005.
- Vol. 3392: D. Seipel, M. Hanus, U. Geske, O. Bartenshein (Eds.), *Applications of Declarative Programming and Knowledge Management*. X, 309 pages. 2005.
- Vol. 3374: D. Weyns, H.V.D. Parunak, F. Michel (Eds.), *Environments for Multi-Agent Systems*. X, 279 pages. 2005.
- Vol. 3371: M.W. Barley, N. Kasabov (Eds.), *Intelligent Agents and Multi-Agent Systems*. X, 329 pages. 2005.
- Vol. 3369: V.R. Benjamins, P. Casanovas, J. Breuker, A. Gangemi (Eds.), *Law and the Semantic Web*. XII, 249 pages. 2005.
- Vol. 3366: I. Rahwan, P. Moraitis, C. Reed (Eds.), *Argumentation in Multi-Agent Systems*. XII, 263 pages. 2005.
- Vol. 3359: G. Grieser, Y. Tanaka (Eds.), *Intuitive Human Interfaces for Organizing and Accessing Intellectual Assets*. XIV, 257 pages. 2005.

- Vol. 3346: R.H. Bordini, M. Dastani, J. Dix, A.E.F. Seghrouchni (Eds.), *Programming Multi-Agent Systems*. XIV, 249 pages. 2005.
- Vol. 3345: Y. Cai (Ed.), *Ambient Intelligence for Scientific Discovery*. XII, 311 pages. 2005.
- Vol. 3343: C. Freksa, M. Knauff, B. Krieg-Brückner, B. Nebel, T. Barkowsky (Eds.), *Spatial Cognition IV*. XIII, 519 pages. 2005.
- Vol. 3339: G.I. Webb, X. Yu (Eds.), *AI 2004: Advances in Artificial Intelligence*. XXII, 1272 pages. 2004.
- Vol. 3336: D. Karagiannis, U. Reimer (Eds.), *Practical Aspects of Knowledge Management*. X, 523 pages. 2004.
- Vol. 3327: Y. Shi, W. Xu, Z. Chen (Eds.), *Data Mining and Knowledge Management*. XIII, 263 pages. 2005.
- Vol. 3315: C. Lemaître, C.A. Reyes, J.A. González (Eds.), *Advances in Artificial Intelligence – IBERAMIA 2004*. XX, 987 pages. 2004.
- Vol. 3303: J.A. López, E. Benfenati, W. Dubitzky (Eds.), *Knowledge Exploration in Life Science Informatics*. X, 249 pages. 2004.
- Vol. 3301: G. Kern-Isberner, W. Rödder, F. Kulmann (Eds.), *Conditionals, Information, and Inference*. XII, 219 pages. 2005.
- Vol. 3276: D. Nardi, M. Riedmiller, C. Sammut, J. Santos-Victor (Eds.), *RoboCup 2004: Robot Soccer World Cup VIII*. XVIII, 678 pages. 2005.
- Vol. 3275: P. Perner (Ed.), *Advances in Data Mining*. VIII, 173 pages. 2004.
- Vol. 3265: R.E. Frederking, K.B. Taylor (Eds.), *Machine Translation: From Real Users to Research*. XI, 392 pages. 2004.
- Vol. 3264: G. Paliouras, Y. Sakakibara (Eds.), *Grammatical Inference: Algorithms and Applications*. XI, 291 pages. 2004.
- Vol. 3259: J. Dix, J. Leite (Eds.), *Computational Logic in Multi-Agent Systems*. XII, 251 pages. 2004.
- Vol. 3257: E. Motta, N.R. Shadbolt, A. Stutt, N. Gibbins (Eds.), *Engineering Knowledge in the Age of the Semantic Web*. XVII, 517 pages. 2004.
- Vol. 3249: B. Buchberger, J.A. Campbell (Eds.), *Artificial Intelligence and Symbolic Computation*. X, 285 pages. 2004.
- Vol. 3248: K.-Y. Su, J. Tsujii, J.-H. Lee, O.Y. Kwong (Eds.), *Natural Language Processing – IJCNLP 2004*. XVIII, 817 pages. 2005.
- Vol. 3245: E. Suzuki, S. Arikawa (Eds.), *Discovery Science*. XIV, 430 pages. 2004.
- Vol. 3244: S. Ben-David, J. Case, A. Maruoka (Eds.), *Algorithmic Learning Theory*. XIV, 505 pages. 2004.
- Vol. 3238: S. Biundo, T. Frühwirth, G. Palm (Eds.), *KI 2004: Advances in Artificial Intelligence*. XI, 467 pages. 2004.
- Vol. 3230: J.L. Vicedo, P. Martínez-Barco, R. Muñoz, M. Saiz Noeda (Eds.), *Advances in Natural Language Processing*. XII, 488 pages. 2004.
- Vol. 3229: J.J. Alferes, J. Leite (Eds.), *Logics in Artificial Intelligence*. XIV, 744 pages. 2004.
- Vol. 3228: M.G. Hinchey, J.L. Rash, W.F. Truszkowski, C.A. Rouff (Eds.), *Formal Approaches to Agent-Based Systems*. VIII, 290 pages. 2004.
- Vol. 3215: M.G. Negoita, R.J. Howlett, L.C. Jain (Eds.), *Knowledge-Based Intelligent Information and Engineering Systems, Part III*. LVII, 906 pages. 2004.
- Vol. 3214: M.G. Negoita, R.J. Howlett, L.C. Jain (Eds.), *Knowledge-Based Intelligent Information and Engineering Systems, Part II*. LVIII, 1302 pages. 2004.
- Vol. 3213: M.G. Negoita, R.J. Howlett, L.C. Jain (Eds.), *Knowledge-Based Intelligent Information and Engineering Systems, Part I*. LVIII, 1280 pages. 2004.
- Vol. 3209: B. Berendt, A. Hotho, D. Mladenec, M. van Someren, M. Spiliopoulou, G. Stumme (Eds.), *Web Mining: From Web to Semantic Web*. IX, 201 pages. 2004.
- Vol. 3206: P. Sojka, I. Kopecek, K. Pala (Eds.), *Text, Speech and Dialogue*. XIII, 667 pages. 2004.
- Vol. 3202: J.-F. Boulicaut, F. Esposito, F. Giannotti, D. Pedreschi (Eds.), *Knowledge Discovery in Databases: PKDD 2004*. XIX, 560 pages. 2004.
- Vol. 3201: J.-F. Boulicaut, F. Esposito, F. Giannotti, D. Pedreschi (Eds.), *Machine Learning: ECML 2004*. XVIII, 580 pages. 2004.
- Vol. 3194: R. Camacho, R. King, A. Srinivasan (Eds.), *Inductive Logic Programming*. XI, 361 pages. 2004.
- Vol. 3192: C. Bussler, D. Fensel (Eds.), *Artificial Intelligence: Methodology, Systems, and Applications*. XIII, 522 pages. 2004.
- Vol. 3191: M. Klusch, S. Ossowski, V. Kashyap, R. Unland (Eds.), *Cooperative Information Agents VIII*. XI, 303 pages. 2004.
- Vol. 3187: G. Lindemann, J. Denzinger, I.J. Timm, R. Unland (Eds.), *Multiagent System Technologies*. XIII, 341 pages. 2004.
- Vol. 3176: O. Bousquet, U. von Luxburg, G. Rätsch (Eds.), *Advanced Lectures on Machine Learning*. IX, 241 pages. 2004.
- Vol. 3171: A.L.C. Bazzan, S. Labidi (Eds.), *Advances in Artificial Intelligence – SBIA 2004*. XVII, 548 pages. 2004.
- Vol. 3159: U. Visser, *Intelligent Information Integration for the Semantic Web*. XIV, 150 pages. 2004.
- Vol. 3157: C. Zhang, H. W. Guesgen, W.K. Yeap (Eds.), *PRICAI 2004: Trends in Artificial Intelligence*. XX, 1023 pages. 2004.
- Vol. 3155: P. Funk, P.A. González Calero (Eds.), *Advances in Case-Based Reasoning*. XIII, 822 pages. 2004.
- Vol. 3139: F. Iida, R. Pfeifer, L. Steels, Y. Kuniyoshi (Eds.), *Embodied Artificial Intelligence*. IX, 331 pages. 2004.
- Vol. 3131: V. Torra, Y. Narukawa (Eds.), *Modeling Decisions for Artificial Intelligence*. XI, 327 pages. 2004.
- Vol. 3127: K.E. Wolff, H.D. Pfeiffer, H.S. Delugach (Eds.), *Conceptual Structures at Work*. XI, 403 pages. 2004.
- Vol. 3123: A. Belz, R. Evans, P. Piwek (Eds.), *Natural Language Generation*. X, 219 pages. 2004.
- Vol. 3120: J. Shawe-Taylor, Y. Singer (Eds.), *Learning Theory*. X, 648 pages. 2004.
- Vol. 3097: D. Basin, M. Rusinowitch (Eds.), *Automated Reasoning*. XII, 493 pages. 2004.

¥566.40元

# Preface

This volume contains papers presented at the 2nd International Conference on Modeling Decisions for Artificial Intelligence (MDAI 2005), held in Tsukuba, Japan, July 25–27. This conference follows MDAI 2004 (held in Barcelona, Catalonia, Spain), the proceedings of which were also published in the LNAI series (Vol. 3131).

The aim of this conference was to provide a forum for researchers to discuss about theory and tools for modeling decisions, as well as applications that encompass decision-making processes and information fusion techniques. In this second edition, special focus was given to applications related to risk, security and safety.

The organizers received 118 papers, from 14 different countries, 40 of which are published in this volume. Each submission received at least two reviews from the Program Committee and a few external reviewers. We would like to express our gratitude to them for their work. The plenary talks presented at the conference are also included in this volume.

The conference was supported by the Department of Risk Engineering of the University of Tsukuba, the Japan Society for Fuzzy Theory and Intelligent Informatics (SOFT), the Catalan Association for Artificial Intelligence (ACIA), the European Society for Fuzzy Logic and Technology (EUSFLAT) and the Generalitat de Catalunya (AGAUR 2004XT 0004).

Sabadell (Catalonia, Spain)  
Kunitachi (Japan)  
Tsukuba (Japan)

Vicenç Torra  
Yasuo Narukawa  
Sadaaki Miyamoto

April, 2005

# Modeling Decisions for Artificial Intelligence

## – MDAI 2005

### General Chair

Sadaaki Miyamoto, University of Tsukuba, Japan

### Program Chairs

Vicenç Torra, IIIA-CSIC, Catalonia, Spain

Yasuo Narukawa, Toho Gakuen, Japan

### Program Committee

G. Beliakov (Australia)

D.A. Bell (UK)

J. Domingo-Ferrer (Spain)

J. Dujmovic (USA)

M. Grabisch (France)

E. Herrera-Viedma (Spain)

K. Hirota (Japan)

M. Inuiguchi (Japan)

J. Kacprzyk (Poland)

Z.-Q. Liu (Hong Kong, China)

Y. Maeda (Japan)

L. Magdalena (Spain)

J.-L. Marichal (Luxemburg)

R. Mesiar (Slovakia)

K.-R. Muller (Germany)

T. Murofushi (Japan)

T. Onisawa (Japan)

E. Pap (Yugoslavia)

G. Pasi (Italia)

C. Sierra (Spain)

L. Sweeney (USA)

J. van den Herik (The Netherlands)

R.R. Yager (USA)

### Organization Chairs

Yasunori Endo (University of Tsukuba, Japan)

Mika Sato-Ilic (University of Tsukuba, Japan)



## **Finance Chair**

Yasunori Endo (University of Tsukuba, Japan)

## **Additional Referees**

K. Fujimoto, J. Hoshino, P. Spronck, H.H.L.M. Donkers, M. Hagiwara, J. Laub, J. Kohlmorgen, T. Suzuki, S.S. Park, J. Castellà, F. Sebé, C.A. Vallve-Guionnet, A. Martinez Ballesté, J.M. Mateo-Sanz, G. Escalada, J. Castro, J. Ozawa, H. Nobuhara, A. Valls, H. Sakai, Y. Yoshida, M. Hagiwara, D. Nettleton, J. Li, Y. Saygin, A. Soria, S. Costantini, I. Kobayashi, J. Lang, S. Greco, L. Xie, Z. Ye, J. Zeng, G. Luo, W. Feng, P. Wang, T. Fujimoto, T. Nakashima

## **Supporting Institutions**

Department of Risk Engineering of the University of Tsukuba  
Japan Society for Fuzzy Theory and Intelligent Informatics (SOFT)  
Catalan Association for Artificial Intelligence (ACIA)  
European Society for Fuzzy Logic and Technology (EUSFLAT)  
Generalitat de Catalunya (AGAUR 2004XT 0004)

# Table of Contents

## Introduction

Modeling Decisions for Artificial Intelligence: Theory, Tools and Applications .....	1
<i>Vicenç Torra, Yasuo Narukawa, and Sadaaki Miyamoto</i>	

## Invited Talks

Capacities and Games on Lattices: A Survey of Results .....	9
<i>Michel Grabisch</i>	
Cryptosystems Based on Elliptic Curve Pairing .....	13
<i>Eiji Okamoto and Takeshi Okamoto</i>	
Building a Brain-Informatics Portal on the Wisdom Web with a Multi-layer Grid: A New Challenge for Web Intelligence Research ..	24
<i>Ning Zhong</i>	
Soft Computing in Human Centered Systems Thinking .....	36
<i>Takehisa Onisawa</i>	

## Regular Papers

Qualitative Model of Game Theory .....	47
<i>Rafał Graboś</i>	
Regularity Properties of Null-Additive Fuzzy Measure on Metric Spaces...	59
<i>Jun Li, Masami Yasuda, and Jinjie Song</i>	
A Statistical Criterion of Consistency in the Analytic Hierarchy Process ..	67
<i>José Antonio Alonso and M<sup>a</sup> Teresa Lamata</i>	
Evaluating the Airline Service Quality by Fuzzy OWA Operators.....	77
<i>Ching-Hsue Cheng, Jing-Rong Chang, Tien-Hwa Ho, and An-Pin Chen</i>	
An Adaptive Module for the Consensus Reaching Process in Group Decision Making Problems.....	89
<i>Enrique Herrera-Viedma, Francisco Mata, Luis Martínez, and Luis G. Pérez</i>	
Qualitative Reasoning Model for Tradeoff Analysis .....	99
<i>Tom Wanyama and Behrouz Homayoun Far</i>	

Evaluation of Control Performance of Multi-stage Fuzzy Reasoning  
in Anti-lock Braking System for Railways Using Fuzzy Reasoning ..... 110  
*Tetsuya Asanome, Toshiaki Nonaka, Yasunori Endo,  
Shin-ichi Nakazawa, and Hiroshi Yoshikawa*

One-Way and Two-Party Authenticated ID-Based  
Key Agreement Protocols Using Pairing ..... 122  
*Takeshi Okamoto, Raylin Tso, and Eiji Okamoto*

Noise-Robust Watermarking for Numerical Datasets ..... 134  
*Francesc Sebé, Josep Domingo-Ferrer, and Agustí Solanas*

Possibilistic Approach to Kernel-Based Fuzzy *c*-Means Clustering  
with Entropy Regularization ..... 144  
*Kiyotaka Mizutani and Sadaaki Miyamoto*

Fuzzy *c*-Means Clustering in the Presence of Noise Cluster  
for Time Series Analysis ..... 156  
*Arnold C. Alanzado and Sadaaki Miyamoto*

Quantification of Multivariate Categorical Data  
Considering Clusters of Items and Individuals ..... 164  
*Chi-Hyon Oh, Katsuhiko Honda, and Hidetomo Ichihashi*

A New Approach to Fuzzification of Memberships in Cluster Analysis .... 172  
*Katsuhiko Honda and Hidetomo Ichihashi*

Dynamic Clustering Based on Universal Gravitation Model..... 183  
*Yasunori Endo and Hayato Iwata*

Extracting Classification Rules with Support Rough Neural Networks..... 194  
*He Ming and Feng Boqin*

On a Tool for Rough Non-deterministic Information Analysis  
and Its Perspective for Handling Numerical Data ..... 203  
*Hiroshi Sakai, Tetsuya Murai, and Michinori Nakata*

Several Approaches to Attribute Reduction  
in Variable Precision Rough Set Model ..... 215  
*Masahiro Inuiguchi*

Checking Whether or Not Rough-Set-Based Methods  
to Incomplete Data Satisfy a Correctness Criterion ..... 227  
*Michinori Nakata and Hiroshi Sakai*

Fuzzy Model Based Environmental Stiffness Identification  
in Stable Force Control of a Robot Manipulator..... 240  
*Chang-Woo Park, Jongbae Lee, Minkee Park, and Mignon Park*

Omnidirectional Adaptive Behavior Control for Autonomous Mobile Robot . . . . .	252
<i>Yoichiro Maeda and Wataru Shimizuhira</i>	
Pairwise Matching of Spots in 2-DE Images Using Hopfield Network . . . . .	264
<i>Young-Sup Hwang, Hoon Park, and Yoojin Chung</i>	
A New Concept of a Similarity Measure for Intuitionistic Fuzzy Sets and Its Use in Group Decision Making . . . . .	272
<i>Eulalia Szmidt and Janusz Kacprzyk</i>	
Perceptive Evaluation for the Optimal Discounted Reward in Markov Decision Processes . . . . .	283
<i>Masami Kurano, Masami Yasuda, Jun-ichi Nakagami, and Yuji Yoshida</i>	
Cancer Prediction Using Diversity-Based Ensemble Genetic Programming .	294
<i>Jin-Hyuk Hong and Sung-Bae Cho</i>	
Language Generation for Conversational Agent by Evolution of Plan Trees with Genetic Programming . . . . .	305
<i>Sungsoo Lim and Sung-Bae Cho</i>	
Optimization of Fuzzy Systems Based on Fuzzy Set Using Genetic Optimization and Information Granulation . . . . .	316
<i>Sung-Kwun Oh, Keon-Jun Park, and Witold Pedrycz</i>	
A New Approach to Genetically Optimized Hybrid Fuzzy Set-Based Polynomial Neural Networks with FSPNs and PNs . . . . .	328
<i>Sung-Kwun Oh, Seok-Beom Roh, and Witold Pedrycz</i>	
Genetically Optimized Hybrid Fuzzy Neural Networks in Modeling Software Data . . . . .	338
<i>Sung-Kwun Oh, Byoung-Jun Park, Witold Pedrycz, and Hyun-Ki Kim</i>	
Genetically Dynamic Optimized Self-organizing Fuzzy Polynomial Neural Networks with Information Granulation Based FPNs . . . . .	346
<i>Ho-Sung Park, Sung-Kwun Oh, Witold Pedrycz, and Hyun-Ki Kim</i>	
NMF-Based Approach to Font Classification of Printed English Alphabets for Document Image Understanding . . . . .	354
<i>Chang Woo Lee and Keechul Jung</i>	
Edge-Based Spatial Descriptor Using Color Vector Angle for Effective Image Retrieval . . . . .	365
<i>N.W. Kim, T.Y. Kim, and Jong Soo Choi</i>	

Efficient 3D Model Retrieval Method Using Geometric Characteristics  
in Intersected Meshes ..... 376  
*K.H. Lee, N.W. Kim, and Jong Soo Choi*

Bipolar Queries Revisited ..... 387  
*Stawomir Zadrozny*

A Decision Support System for Rheumatic Evaluation and Treatment  
in Oriental Medicine Using Fuzzy Logic and Neural Network ..... 399  
*Cao Thang, Eric W. Cooper, Yukinobu Hoshino, and Katsuari Kamei*

Modeling Designers' Color Decision Processes  
Through Emotive Choice Mapping ..... 410  
*Eric W. Cooper, Yuko Ishida, and Katsuari Kamei*

An Automatic Rule Creating Method for *Kansei* Data and Its Application  
to a Font Creating System ..... 421  
*Hajime Hotta and Masafumi Hagiwara*

Video Motion Capture for Virtual Characters ..... 431  
*Atsushi Nakano and Junichi Hoshino*

Picture Languages in Medical Pattern Knowledge Representation  
and Understanding ..... 442  
*Marek R. Ogiela and Ryszard Tadeusiewicz*

Loading Problem in Multiple Containers and Pallets  
Using Strategic Search Method ..... 448  
*Shigeyuki Takahara*

Meta-data: Characterization of Input Features for Meta-learning ..... 457  
*Ciro Castiello, Giovanna Castellano, and Anna Maria Fanelli*

**Author Index** ..... 469

# Modeling Decisions for Artificial Intelligence: Theory, Tools and Applications

Vicenç Torra<sup>1</sup>, Yasuo Narukawa<sup>2</sup>, and Sadaaki Miyamoto<sup>3</sup>

<sup>1</sup> Institut d'Investigació en Intel·ligència Artificial  
Campus de Bellaterra, 08193 Bellaterra, Catalonia, Spain  
vtorra@iia.csic.es

<sup>2</sup> Toho Gakuen, 3-1-10 Naka, Kunitachi, Tokyo, 186-0004 Japan  
narukawa@d4.dion.ne.jp

<sup>3</sup> Department of Risk Engineering  
School of Systems and Information Engineering  
University of Tsukuba, Ibaraki 305-8573, Japan  
miyamoto@esys.tsukuba.ac.jp

**Abstract.** Aggregation operators, in particular, and information fusion techniques, in general are being used in several Artificial Intelligence systems for modeling decisions. In this paper we give a personal overview of current trends and challenges as well as describe our aims with respect to the MDAI conference series.

**Keywords:** Decision modeling, aggregation operators, information fusion, applications

## 1 Introduction

Methods for combining information (information fusion) have been used for different purposes for centuries. The election mechanisms (to select an alternative taking into account the preferences of different individuals) are a well known example. In fact, methods for this purpose were already proposed and studied [11] by R. Llull (S. XIII) and Cusanus (S. XV), and latter reconsidered by Condorcet and Borda (S. XVIII).

Current pervasive software systems have increased the importance of such techniques taking into account all the relevant information. Part of this information grows year by year [31] and is stored in a highly distributed environment. To further difficult the process, part of the information is *perishable* as becomes obsolete when the time passes (*e.g.*, sensory information in robots or traffic information in devices for route planning).

Several Artificial Intelligence-based applications embed aggregation operators and other information fusion tools to make such timely and appropriate decisions [26]. Existing applications include robotics where data from different sensors are fused, vision where image fusion is performed and machine learning with the so-called ensemble methods.

For all this, we can say that information fusion techniques are a basic element for decision making and that decision processes are increasingly situated in dynamic environments.

## 2 Establishing a Framework

In this section we review several issues concerning the use of information fusion tools in artificial intelligence applications.

### 2.1 Usage of Information Fusion and Aggregation Operators

Although the number of applications is rather large and fusion serves different purposes, most usages of aggregation and fusion methods can be classified according to two rough categories [33]: methods (i) to make (better) decisions and (ii) to have a better understanding of the application domain.

**Decision making:** In this case, the final goal is to make a decision. Then, the decision can be either selected from a set of alternatives (*alternative selection*) or built from several ones (*alternative construction*). Aggregation and fusion are applied in both cases but in a different way:

**Alternative selection:** Aggregation and fusion is typically used when there are several criteria for selecting each alternative. This corresponds to a multi-criteria decision problem. Software agents in an electronic auction would correspond to this situation, as the agent has to select a concrete alternative and this selection is done on the basis of several different criteria: the best price or the best quality.

This situation is modeled with a set of preferences or utility functions (one for each criteria) or using a single but multivalued preference. Then, to determine the best alternative, the preferences are aggregated. The alternative that gets the best score (in such aggregated utility or preference) is selected. As the score determines the final selection, the aggregation function used shapes the outcome.

**Alternative construction:** In this case, the alternative is constructed from a set of (partial) alternatives. Therefore, the method to build the alternative corresponds to the fusion process. Algorithms for *ensemble methods* can be studied from this perspective. Note that in ensemble methods for regression, several models are built first and each method corresponds to an alternative for deciding the outcome for a particular instance; then, all such outcomes are combined to construct the final outcome.

**Improving the understanding of the application domain:** The main motivation for using information fusion here is that the information supplied by a single source is limited with respect to the whole application domain (it is circumscribed to a subdomain) or not reliable enough (due to errors of the information source – either intentional or unintentional – or to the transmission channel). Fusion is used to increase the area of application of the system and to increase its performance.

The use of aggregation operators and fusion helps the systems to improve their performance. Nevertheless, their use also causes difficulties as it is often

the case that information is not comparable and, in some cases, inconsistent. Therefore, systems have to embed simple fusion techniques in larger software tools so that the final outcome is consistent.

## 2.2 Integration, Fusion and Aggregation

In the previous sections we have used the terms “integration”, “fusion” and “aggregation” as if they were synonyms. For the sake of clarity, we define them below. They are presented topdown. The following three terms are considered:

**Information integration:** This is the most general term that corresponds to the whole process of using information from several sources to accomplish a particular task. Similarly, we also have integration when the information is obtained at different time instants (even in the case that it is obtained from the same information source).

**Information fusion:** The integration of information requires particular techniques for combining data. Information fusion is the actual process of combining data into a single datum.

**Aggregation operators:** These operators (see *e.g.* [4, 41]) correspond to particular mathematical functions used for information fusion. We use this term when the functions that aggregate the information can be clearly identified in the whole system and their properties studied. In general, we consider that aggregation operators are mathematical functions that combine  $N$  values in a given domain  $D$  (*e.g.*  $N$  real numbers) and return a value also in this domain (*e.g.* another real number). Denoting these functions by  $\mathbb{C}$  (from *Consensus*), aggregation operators are functions of the form:

$$\mathbb{C} : D^N \rightarrow D$$

From this point of view, it is clear that all aggregation operators are information fusion methods. However, only information fusion methods with a *straightforward* mathematical definition are considered here as aggregation operators. Therefore, not all information fusion methods are aggregation operators. In particular, methods with a complex operational definition (*e.g.* complex computer programs) are not considered in this paper as such. Naturally, the division between both terms is rather fuzzy.

Information fusion and aggregation operators heavily depend on the type of data representation (numerical, ordinal, nominal scales), kind of information they have to fuse (either redundant or complementary), etc. Accordingly, they can be studied from different perspectives.

## 3 Trends and Challenges: Theory, Tools and Applications

In this section we consider trends and challenges of information fusion focusing on aggregation operators. This section has been divided into three parts corresponding to theory, tools and applications.



### 3.1 Theory

Formal aspects of aggregation operators have been studied for a long time. Relevant topics include the characterization of operators as well as representation theorems. For example, results show that some operators can equivalently be expressed in terms of fuzzy integrals with respect to fuzzy measures [17, 24].

Results on the parameters of the operators and, more specifically, on fuzzy measures should also be considered as a present trend. In particular, current research focus on the definition of new families of fuzzy measures with reduced complexity (*i.e.*, requiring less than  $2^N$  parameters where  $N$  is the number of sources) as well as characterizations of fuzzy measures. Distorted probabilities [25] and  $p$ -symmetric fuzzy measures [18] are examples of such new families.

Another topic for research on formal aspects is the definition of new operators or new applications. In this setting, we can find dynamic operators (dynamic in the sense that their behavior changes with respect to time). A particular type of them are standard aggregation operators with dynamic weights [36].

Finally, there are several techniques that have been used for modeling decisions and for which further research is needed. Rough sets and clustering techniques [19] are some of them. In the particular case of rough sets, rough measures and integrals have been defined [28]. Extensions of fuzzy multisets (bags) [20, 21, 38] might be also relevant to model situations in which several non-overlapping decisions are considered.

### 3.2 Tools

In a recent paper (see [34] for details), three research topics were distinguished concerning tools:

**Parameter learning:** As most aggregation operators are parametric, a crucial element for having a good performance is that parameters are correctly tuned. When the operator is fixed, this problem can be considered as an optimization one. Therefore, following the machine learning jargon, either supervised, unsupervised and reinforcement learning approaches can be applied.

Most research has been done using supervised approaches (see *e.g.* [1, 33]), although recently a few unsupervised approaches have also been used in conjunction with some fuzzy integrals (see *e.g.* [17] for details on fuzzy integrals). This is, methods have been defined for learning fuzzy measures from data. [14, 15, 29, 30] are a few examples of such results.

**Function/operator selection:** Selection of the operator is another important issue. At present much research has been devoted to the characterization of existing methods. Open issues include the development of algorithms and methodologies to determine (automatically) the suitable function for a given problem (see *e.g.* [2]).

**Architecture determination:** The topic of architecture determination encompasses two different aspects. On the one hand, we have the more general