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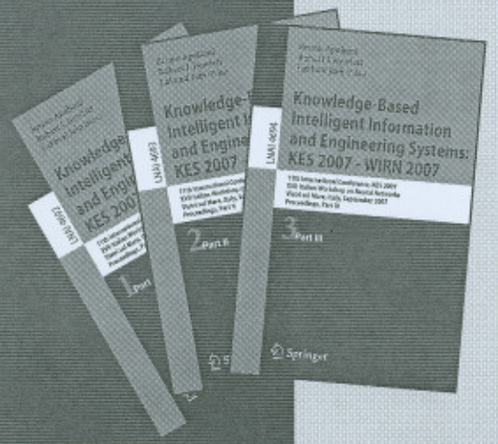

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Table of Contents – Part II

I Intelligence Everywhere

Ambient Intelligence

An Efficient Indexing Technique for Location Prediction of Moving Objects 1
Dong-Oh Kim, Kang-Jun Lee, Dong-Suk Hong, and Ki-Joon Han

Combining Smart Tags and Body Fixed Sensors for Disabled People Assistance 10
Juan Antonio Álvarez, Carlos Pérez, Cecilio Angulo, and Juan Antonio Ortega

Geometrical Representation of Quantity Space and Its Application to Robot Motion Description 18
Honghai Liu, David J. Brown, and George M. Coghill

Modeling Smart Homes for Prediction Algorithms 26
A. Fernández-Montes, J.A. Álvarez, J.A. Ortega, M.D. Cruz, L. González, and F. Velasco

Qualitative Correspondence for Object Tracking Using Dynamic Panorama 34
Farshad Fahimi, Honghai Liu, and David J. Brown

Artificial Intelligence Applications in Digital Content

A Hybrid System: Neural Network with Data Mining in an e-Learning Environment 42
David Wen-Shung Tai, Hui-Ju Wu, and Pi-Hsiang Li

A Personalization Recommendation Framework of IT Certification e-Learning System 50
Heng-Li Yang, Chen-Shu Wang, and Mu-Yen Chen

An Architecture for e-Learning System with Computational Intelligence 58
Marc El Alami, Nicolas Casel, and Denis Zampunieris

APD-A Tool for Identifying Behavioural Patterns Automatically from Clickstream Data 66
I-Hsien Ting, Lillian Clark, Chris Kimble, Daniel Kudenko, and Peter Wright

Breedbot: An Edutainment Robotics System to Link Digital and Real World 74
Orazio Miglino, Onofrio Gigliotta, Michela Ponticorvo, and Stefano Nolfi

Develop e-Learning Platform for Reinforcement Learning on Temperature Sensor 82
Wen-Jye Shyr

Modeling e-Learning System Performance Evaluation with Agent-Based Approach 90
Hsiao-Ya Chiu, Sheng Chieh Chung, and An-Pin Chen

Salable Vector Graphics (OpenVG) for Creating Animation Image in Embedded Systems 99
Sang-Yun Lee, Sunghwan Kim, Jihoon Chung, and Byung-Uk Choi

Artificial Intelligence Applications in Security

A Data Mining Methodology for Anomaly Detection in Network Data 109
Costantina Caruso and Donato Malerba

A Dedicated Hardware for Fingerprint Authentication 117
G. Danese, M. Giachero, F. Leporati, G. Matrone, and N. Nazzicari

Belnap's Logic in Sharing Protected Web Resources 125
Sylvia Encheva and Sharil Tumin

IDS Based on Bio-inspired Models 133
Paolo Gastaldo, Francesco Picasso, Rodolfo Zunino, Álvaro Herrero, Emilio Corchado, and José Manuel Sáiz

Network-Based Anomaly Intrusion Detection Improvement by Bayesian Network and Indirect Relation 141
ByungRae Cha and DongSeob Lee

Security Policies Tuning Among IP Devices 149
Simone Ferraresi, Emanuele Francocci, Alessio Quaglini, and Francesco Picasso

Artificial Intelligence Methods for Information Processing (AIMIP 2007)

A Novel Image Edge Detection Using Fractal Compression 159
Liangbin Zhang and Lifeng Xi

A Rapid Algorithm for Computing ST Reliability of Radio-Communication Networks 167
Fei Gao, Xuejun Liu, and Hanzhong Liu

A Second-Order Upwind Difference Scheme for a Singularly Perturbed Problem with Integral Boundary Condition in Netural Network 175
Zhongdi Cen and Xin Cai

Application of Genetic Algorithm to Hausdorff Measure Estimation of Sierpinski Carpet 182
Qili Xiao and Lifeng Xi

Decomposability of Implication Operators 189
Zhudeng Wang

Fault Detecting Technology Based on BP Neural Network Algorithm 194
Ran Jin, Kun Gao, Zhigang Chen, Chen Dong, Yanghong Zhang, and Lifeng Xi

Image Information Hiding Encryption Using Chaotic Sequence 202
Zhen Liu and Lifeng Xi

Improvement of an Image Encryption Algorithm Based on Combined Multidimensional Chaotic Systems 209
Chen Dong, Jifang Li, Lifeng Xi, Jie Hao, and Ran Jin

Investigation on Fitting Graph Based on Fractal Dimension's Pretreatment 217
Min Jin, Qin Wang, and Lifeng Xi

Practice of Video Encryption Algorithms Based on Chaotic Sequence and Scan Pattern 225
Qian Li

Research on WebGIS Based on Multi-agent 233
Taowei Wang, Liangbin Zhang, and Aimin Yang

Transient Air-Fuel Ratio Estimation in Spark Ignition Engine Using Recurrent Neural Networks 240
Yanhong Zhang, Lifeng Xi, and James Liu

Communicative Intelligence 2007

A Pattern Recognition Algorithm Used in Knowledge-Based Adaptive Control System to Select Strategy 247
Krzysztof Brzostowski and Jerzy Świątek

Alignment-Based Preprocessing of Personal Ontologies on Semantic Social Network 255
Jason J. Jung, Hong-Gee Kim, and Geun-Sik Jo

Browser Latency Impact Factors 263
Andrzej Siemiński

Global Adaptive Request Distribution with Broker 271
Leszek Borzemski, Anna Zatwarnicka, and Krzysztof Zatwarnicki

Global and Local Approach to Complex Systems Modeling Using Dynamic Neural Networks–Analogy with Multiagent Systems 279
Jarosław Drapała and Jerzy Świątek

Computation Intelligence for Image Processing and Pattern Recognition

A Content Dependent Visualization System for Symbolic Representation of Piano Stream 287
Alexander Adli, Zensho Nakao, and Yasunori Nagata

Audio Watermarking Based on the Psychoacoustic Model and Modulated Complex Lapped Transform 295
Hanane H. Mirza, Alexander Adli, Hien D. Thai, Yasunori Nagata, and Zensho Nakao

A New Optimization Algorithm of Kinoforms Based on Simulated Annealing 303
Shinya Nozaki, Yen-Wei Chen, and Zensho Nakao

Curvelet-Domain Image Watermarking Based on Edge-Embedding 311
Thai Duy Hien, Ikeda Kei, Hanane Harak, Yen Wei Chen, Yasunori Nagata, and Zensho Nakao

Linking KANSAI and Image Features by Multi-layer Neural Networks 318
Xinyin Huang, Shouta Sobue, Tomoki Kanda, and Yen-Wei Chen

Pattern Analysis and Prediction of *O*-Linked Glycosylation Sites in Protein by Principal Component Subspace Analysis 326
Yen-Wei Chen, Xuemei Yang, Masahiro Ito, and Ikuko Nishikawa

Prediction of the *O*-Glycosylation with Secondary Structure Information by Support Vector Machines 335
Ikuko Nishikawa, Hirotaka Sakamoto, Ikue Nouno, Kazutoshi Sakakibara, and Masahiro Ito

Human Computer Intelligent Systems

A Simple Model for Human-Robot Emotional Interaction 344
Isabella Cattinelli and N. Alberto Borghese

Applying Trust, Reputation and Intuition Aspects to Support Virtual Communities of Practice 353
Juan Pablo Soto, Aurora Vizcaíno, Javier Portillo-Rodríguez, and Mario Piattini

Evaluation of Trivial Dialogue Phrase Databases Through Practical Application to User-Computer Conversation - Case Study: English - Spanish 361
Calkin S. Montero and Kenji Araki

Formalizing Recognition of Sketching Styles in Human Centered Systems 369
Danilo Avola, Fernando Ferri, and Patrizia Grifoni

Fostering Multi-Modal Summarization for Trend Information 377
Tsuneaki Kato, Mitsunori Matsushita, and Noriko Kando

Interactive Virtual Oriental Brush with Pen-Tablet System 387
Won-Du Chang and Jungpil Shin

Multidimensional Emotional Appraisal Semantic Space (MEAS): Evaluating HM Affective Interactions 395
Maria Rita Ciceri and Stefania Balzarotti

Multimodal Sentence Similarity in Human-Computer Interaction Systems 403
Fernando Ferri, Patrizia Grifoni, and Stefano Paolozzi

Reconsideration of the Effectiveness on Extracting Computer Diagnostic Rules by Automatically Defined Groups 411
Yoshiaki Kurosawa, Akira Hara, Kazuya Mera, and Takumi Ichimura

Hybrid Artificial Intelligence Systems Workshop (HAIS07-KES2007)

Adaptive Mechanisms for Classification Problems with Drifting Data . . . 419
Zoheir Sahel, Abdelhamid Bouchachia, Bogdan Gabrys, and Paul Rogers

Architecture of an Hybrid System for Experimentation on Web Information Retrieval Incorporating Clustering Techniques 427
Montserrat Mateos and Carlos G. Figuerola

Automated Ham Quality Classification Using Ensemble Unsupervised Mapping Models 435
Bruno Baruque, Emilio Corchado, Hujun Yin, Jordi Rovira, and Javier González

FreeEnCal: A Forward Reasoning Engine with General-Purpose 444
Jingde Cheng, Shinsuke Nara, and Yuichi Goto

Hybrid Agents Based Architecture on Automated Dynamic Environments 453
Dante I. Tapia, Javier Bajo, Juan M. Corchado, Sara Rodríguez, and Juan M. Manzano

Hybrid Architecture for a Reasoning Planner Agent 461
Javier Bajo, Dante I. Tapia, Ana de Luis, Sara Rodríguez, Juan F. de Paz, and Juan M. Corchado

Learning Topologic Maps with Growing Neural Gas 469
José García-Rodríguez, Francisco Flórez-Revuelta, and Juan Manuel García-Chamizo

Using a Neurofuzzy Approach in a Medical Application 477
Constantinos Koutsojannis and Ioannis Hatzilygeroudis

Innovations in Intelligent Data Analysis

A Likelihood Ratio Test for Differential Metabolic Profiles in Multiple Intensity Measurements 485
Frank Klawonn, Claudia Choi, Beatrice Benkert, Bernhard Thielen, Richard Münch, Max Schobert, Dietmar Schomburg, and Dieter Jahn

Combining Bagging, Boosting and Dagging for Classification Problems 493
S.B. Kotsianti and D. Kanellopoulos

Functional Clustering and Functional Principal Points 501
Nobuo Shimizu and Masahiro Mizuta

Prescreening of Candidate Rules Using Association Rule Mining and Pareto-optimality in Genetic Rule Selection 509
Hisao Ishibuchi, Isao Kuwajima, and Yusuke Nojima

Term Clustering in Texts Based on Fuzzy Neighborhoods and Kernel Functions 517
Sadaaki Miyamoto, Satoshi Hayakawa, and Yuichi Kawasaki

Variable Based Fuzzy Blocking Regression Model 525
Mika Sato-Ilic

Intelligent Agents and Their Applications

A Design and Testing Technology for Ubiquitous Robot Companion Software Component 533
Sun-Myung Hwang, Yun-Koo Chung, and Hang-Kon Kim

A Multiagent Based Vehicle Engine Fault Diagnosis 541
Xiaobing Wu, Xueshan Gao, and Dharmendra Sharma

A Multi-agent Security Framework for e-Health Services 547
Rossilawati Sulaiman, Dharmendra Sharma, Wanli Ma, and Dat Tran

A Proactive Routing Algorithm Based on Bitmap Tables for Wireless Sensor Networks 555
Sangjoon Jung and Younky Chung

A Study on Mobile Agent Based Resource Management in Grid 565
Chen Zhao, Jian Yu, and Bencheng Chai

An Agent-Based Evolutionary Robotic System for Its Reconfiguration 571
Xueshan Gao, Koki Kikuchi, and Xiaobing Wu

Design of the Intelligence User Identification Method for the Improved Password Input Method and the Personality Security 581
Eun-Ser Lee, Haeng-Kon Kim, and Sang Ho Lee

Using Tuple Space to Coordinate Multiagent Activities 589
Wanli Ma, Dat Tran, and Dharmendra Sharma

Intelligent and Adaptive Systems in Economics, Finance and Management

Adaptive Use of Technical Indicators for Predicting the Intra-Day Price Movements 597
Mieko Tanaka-Yamawaki and Seiji Tokuoka

Credal Networks for Operational Risk Measurement and Management 604
Alessandro Antonucci, Alberto Piatti, and Marco Zaffalon

Fair Consistency Evaluation in Fuzzy Preference Relations and in AHP 612
Matteo Brunelli and Michele Fedrizzi

Making Financial Trading by Recurrent Reinforcement Learning 619
Francesco Bertoluzzo and Marco Corazza

Multiple Ant Colony Optimization for a Rich Vehicle Routing Problem: A Case Study 627
Paola Pellegrini, Daniela Favaretto, and Elena Moretti

Portfolio Optimization Through Elastic Maps: Some Evidence from the Italian Stock Exchange 635
Marina Resta

Prediction of Golden Cross and Dead Cross by Neural Networks and Its Utilization 642
Norio Baba and Kou Nin

Intelligent Automation Systems

An Agent-Based Early Manufacturability Assessment for Collaborative Design in Coating Process 649
Chii-Ruey Lin, Pei-Shu Fan, Yea-Jou Shiau, and MuDer Jeng

Design of a Simulated Environment for Flexible Manufacturing Systems 656
Yi-Sheng Huang and Pin-June Su

MyHome: A Residential Server for Smart Homes 664
Sheng-Luen Chung and Wen-Yuan Chen

Semi-automatic Production Testing of Spark Plugs 671
S.D. Walters, P.A. Howson, and R.J. Howlett

Intelligent Control Theory and Applications

A Gait Based Approach to Detect Directional Bias of Four-Legged Robots' Direct Walking Utilizing Acceleration Sensors 681
Ding-Jie Huang and Wei-Chung Teng

An Intelligent Algorithm for Scheduling Jobs on a Single Machine with a Common Due Date 689
Zne-Jung Lee, Chen-Chia Chuang, and Kuo-Ching Ying

Application of Intelligent Neural Networks to Prediction of Micro-electroforming for U-Type Micro-cavity 696
Sheau-Wen Shiah, Pai-Yu Chang, Tzeng-Yuan Heh, Po-Hung Lin, and Fu-Cheng Yang

Design of a Supervisor for Traffic Light Systems 704
Ta-Hsiang Chung and Yi-Sheng Huang

Intelligent Data Processing in Process Systems and Plants

A Knowledge-Based Approach for the Analysis of Abnormal Situations 712
Tetsuo Fuchino, Rafael Batres, and Yukiyasu Shimada

A Multi-agent Approach to Process Design 720
Rafael Batres, Hikaru Takashima, and Tetsuo Fuchino

A Sliding-Mode Control Approach in Ultra-Precision Positioning System 728
Insung Choi, Seungok Choi, Gunhaeng Heo, Kiheon Park, and Kwanho You

Integration of Multi-agent Controller and Scheduler for Multi-purpose and Multi-batch Plant 736
Takashi Hamaguchi, Masaki Inoue, Takamasa Yoshida, Koji Kawano, Hossam A. Gabbar, Kazuhiro Takeda, Yukiyasu Shimada, Teiji Kitazima, and Yoshihiro Hashimoto

Optimization Method for Design of Supercritical Water Oxidation Process Using Genetic Algorithm 744
Hiroya Yamasaki, Kazuhiro Takeda, Yukiyasu Shimada, Takashi Hamaguchi, Teiji Kitajima, and Tetsuo Fuchino

Intelligent Mechanism for Knowledge Innovation

An Implementation Design of a Fine-Grained Database Access Control Policy Consistency Checking Mechanism 752
Bat-Odon Purevjii, Masayoshi Aritsugi, Sayaka Imai, and Yoshinari Kanamori

Applying Privacy Preserving Count Aggregate Queries to k-Classification 761
Hidehisa Takamizawa and Masayoshi Aritsugi

Event-Centralized Management of Geographic Information Collected from Blog 769
Shoko Yasumura, Masakazu Ikezaki, Toyohide Watanabe, and Taketoshi Ushiama

Message Flow: Design and Architecture of a Message Flow Management System 777
Hideaki Ito and Teruo Fukumura

Scalable 2-Pass Data Mining Technique for Large Scale Spatio-temporal Datasets 785
Tahar Kechadi and Michela Bertolotto

Synchronizing Music and Video of Query Results in Cross-Media Retrieval System 793
Teruhisa Hochin and Wen Xue

Intelligent Techniques for Biometric Based Authentication

A Fuzzy Approach to Multimodal Biometric Authentication 801
Antonia Azzini, Stefania Marrara, Roberto Sassi, and Fabio Scotti

An Open Source Java Framework for Biometric Web Authentication Based on BioAPI 809
Elisardo González Agulla, Enrique Otero Muras, José Luis Alba Castro, and Carmen García Mateo

Feature Distribution of the Fingerprint Template Generated by the Geometric Hashing-Based Fuzzy Vault 816
Sungju Lee, Daesung Moon, and Yongwha Chung

Hand Geometry Verification Using Time Series Representation 824
Vit Niennattrakul, Dachawut Wanichsan, and Chotirat Ann Ratanamahatana

Navigation Dynamics as a Biometrics for Authentication 832
Ernesto Damiani and Gabriele Gianini

Logic Based Intelligent Information Systems

A Cooperative Grid Computing Approach to Automated Theorem Finding and Automated Problem Proposing 840
Jingde Cheng, Yuichi Goto, Shinsuke Nara, and Takahiro Koh

A Logic Grammar for Circuit Analysis: Problems of Recursive Definition 852
Takushi Tanaka

A Natural Deduction System for Annotated Predicate Logic 861
Seiki Akama, Kazumi Nakamtsu, and Jair Minoro Abe

An Intelligent Coordinated Traffic Signal Control Based on EVALPSN 869
Kazumi Nakamatsu, Jair M. Abe, and Seiki Akama

Intelligent Design of Diagnosable Systems: A Case Study of Semiconductor Manufacturing Machines 877
YuanLin Wen, ShengLuen Chung, LiDer Jeng, and MuDer Jeng

Knowledge Assessment Based on Many-Valued Logic 885
Sylvia Encheva and Sharil Tumin

Monadic Curry Algebras Qτ 893
Jair Minoro Abe, Seiki Akama, and Kazumi Nakamatsu

II Intelligent Knowledge

Chance Discovery

A Method for Visualising Possible Contexts 901
Shigeki Amitani and Ernest Edmonds

An Interface for Medical Diagnosis Support 909
Akinori Abe, Norihiro Hagita, Michiko Furutani, Yoshiyuki Furutani, and Rumiko Matsuoka

Creating Chances Through Cognitive Niche Construction: The Role of Affordances 917
Lorenzo Magnani

Discovering Color Semantics as a Chance for Developing Cross-Cultural Design Frameworks 926
Gyoung Soon Choi, Ruediger Oehlmann, Hilary Dalke, and David Cottington

Evaluating a Constructive Meta-learning Algorithm for a Rule Evaluation Support Method Based on Objective Indices 934
Hidenao Abe, Shusaku Tsumoto, Miho Ohsaki, and Takahira Yamaguchi

Information Literacy and Everyday Life Risks 942
Yumiko Nara

Logic of Discovery in Uncertain Situations–Deciding Algorithms 950
V. Rybakov

RFID Tags Without Customers ID in Book Library for Detecting Latent Interest of User Group 959
Yukio Ohsawa, Takuma Hosoda, Takeshi Ui, Misato Ueda, and Hirofumi Tanaka

Trigger to Switch Individual's Interest Toward Unconscious Preference 970
Yoshiharu Maeno, Yukio Ohsawa, and Takaichi Ito

Visualization of Similarities and Dissimilarities Between Rules Using Multidimensional Scaling 978
Shusaku Tsumoto and Shoji Hirano

Knowledge - Based Interface Systems (I)

A Unified Approach to Web Usage Mining Based on Frequent Sequence Mining 987
Nobuhiro Inuzuka and Jun-ichi Hayakawa

DACS Web Service 995
Kazuya Odagiri, Rihito Yaegashi, Masaharu Tadauchi, and Naohiro Ishii

Estimation of Initial Contour Based on Edge Background Subtraction for Self-affine Mapping System 1005
Haruki Kawanaka, Hirofumi Kato, Fuminori Matsubara, Yuji Iwahori, and Robert J. Woodham

Improvement of Accuracy for Gaussian Curvature Using Modification Neural Network 1013
Yuji Iwahori, Takashi Nakagawa, Shinji Fukui, Haruki Kawanaka, Robert J. Woodham, and Yoshinori Adachi

Shadow Removal Method for Real-Time Extraction of Moving Objects 1021
Shinji Fukui, Nozomi Yamamoto, Yuji Iwahori, and Robert J. Woodham

Knowledge - Based Interface Systems (II)

Delayed Learning and the Organized States 1029
Toshinori Deguchi and Naohiro Ishii

Educational System Using Self-monitor Study and Streaming 1037
Masahiro Ozaki, Yoshinori Adachi, Saori Takeoka, Ai Sugimura, and Naohiro Ishii

Influence of Presence of Frame on Writer Recognition 1045
Yoshinori Adachi, Masahiro Ozaki, Yuji Iwahori, and Naohiro Ishii

Information Extraction by XLM 1051
Masashi Okada, Naohiro Ishii, and Nariaki Kato

The Characteristics Evaluation of Stacked-Type Electrostatic Actuators by the Neural Network 1059
Masashi Kawaguchi, Katsuhisa Yamano, Kazuo Okuda, Takashi Jimbo, and Naohiro Ishii

Knowledge and Information Management in Social Community

A Piecewise Linear Representation Method of Time Series Based on Feature Points 1066
Yuelong Zhu, De Wu, and Shijin Li

A Regional Safety Information Sharing System Based on CMS and Online Map System 1073
Akira Hattori, Masato Goto, Takami Yasuda, and Shigeki Yokoi

Avoidance of Traffic Delay for Panicking Crowds Subject to Information Propagation 1081
Naoto Mukai, Toyohide Watanabe, and Jun Feng

Building the Virtual Community to Support Interregional Exchange Between Rural and Urban 1089
Yoshida Chiho, Yasuda Takami, and Yokoi Shigeki

Indexing of Moving Objects on Road Network Using Composite Structure 1097
Jun Feng, Jiamin Lu, Yuelong Zhu, Naoto Mukai, and Toyohide Watanabe

Optimization of Vehicle Assignment for Car Sharing System 1105
Kentaro Uesugi, Naoto Mukai, and Toyohide Watanabe

Knowledge and Ontological Engineering for (KOS)

An Application of Decision Trees for Rule Extraction Towards Telecommunications Fraud Detection 1112
Constantinos S. Hilas and John N. Sahalos

Assisting Dialogical Agents Modeled from Novice User's Perceptions 1122
David Leray and Jean-Paul Sansonnet

Combining Empirical Studies of Audio-Lingual and Visual-Facial Modalities for Emotion Recognition 1130
M. Virvou, G.A. Tsihrintzis, E. Alepis, I.-O. Stathopoulou, and K. Kabassi

Learning Objects Repository for Training of Power Systems Operators 1138
G. Arroyo-Figueroa, L. Argotte-Ramos, and G. Rodríguez-Ortíz

Mining Meaningful Student Groups Based on Communication History Records 1146
Yang-Sae Moon, Hun-Young Choi, Hea-Suk Kim, and Jinho Kim

Ontological Engineering for Practical Knowledge Work 1154
Tatiana Gavrilova

Semantic Modeling of Product Manuals 1162
Rossitza Setchi, Nikolaos Lagos, and Ammar Huneiti

Knowledge Engineering in Multi Robot Systems

Appearance-Based Multi-robot Following Routes Using Incremental PCA 1170
Luis Payá, Oscar Reinoso, Arturo Gil, Jose M. Pedrero, and Mónica Ballesta

Contribution to Legged Robot Visual Servoing 1179
Zelmar Echegoyen, Alicia d'Anjou, and Manuel Graña

Incremental Evolution of Stigmergy-Based Multi Robot Controllers Through Utility Functions 1187
P. Caamaño, J.A. Becerra, R.J. Duro, and F. Bellas

Lattice Independence and Vision Based Mobile Robot Navigation 1196
I. Villaverde, M. Graña, and J.L. Jimenez

ROBMAT: Teleoperation of a Modular Robot for Collaborative Manipulation 1204
Juan A. Escalera, Manuel Ferre, Rafael Aracil, and José Baca

Knowledge-Based Creativity Support Systems

Data Mining of Time-Series Medical Data by Formal Concept Analysis 1214
Kenji Sato, Yoshiaki Okubo, Makoto Haraguchi, and Susumu Kunifuji

A Case Study on Project-Management Training-Support Tools for Japanese/Chinese/Indian Offshore Development Engineers 1222
Sadamitsu Toyoda, Motoki Miura, and Susumu Kunifuji

A Modelling Framework for Sharing Knowledge 1230
Reyes Grangel, Ricardo Chalmeta, and Cristina Campos

An Assistant Interface for Finding Query-Related Proper Nouns 1238
Tomoya Iwakura, Kanji Uchino, and Seishi Okamoto

Community Support System for Extensive Readers: Case Study in a Domain 'Knowledge Science' 1246
Kohei Ishikawa, Kanayo Ogura, and Kozo Sugiyama

Design and Evaluation a Knowledge Management System by Using Mathematical Model of Knowledge Transfer 1253
Kouji Aoyama, Takanori Ugai, and Jun Arima

Development of a Mimamori-Care System for Persons with Dementia Based on the Real World-Oriented Approach 1261
Kenichi Nakagawa, Taro Sugihara, Hitoshi Koshiba, Ryozo Takatsuka, Naotaka Kato, and Susumu Kunifuji

Overview of Network Information by Using Anchored Maps 1269
Kazuo Misue

Spreadsheet Interface Which Simplifies the Visualization of the Network Structures 1277
Satoshi Koike, Kazuo Misue, and Jiro Tanaka

Knowledge-Based Multi-criteria Decision Support

A Fuzzy Ranking Approach to Data Envelopment Analysis 1285
Hsuan-Shih Lee, Pei-Di Shen, and Wen-Li Chyr

A New Information Fusion Method for Fuzzy Information Retrieval 1293
Hsuan-Shih Lee, Ming-Tao Chou, Wei-Kuo Tseng, Hsin-Hsiung Fang, and Chen-Huei Yeh

An Analytic Approach for Synthesizing Comparison Matrices in AHP 1299
Hsuan-Shih Lee, Cheng-Chi Chung, Su-Man Wang, Ming-Tao Chou, and Chen-Huei Yeh

Estimating Missing Values in Incomplete Additive Fuzzy Preference Relations 1307
Hsuan-Shih Lee, Ming-Tao Chou, Hsin-Hsiung Fang, Wei-Kuo Tseng, and Chen-Huei Yeh

Fuzzy Logic Based Reputation System for Mobile Ad Hoc Networks 1315
Jin-Long Wang and Shih-Ping Huang

Synthesizing Comparison Matrices of AHP Under Group Decision 1323
Ming-Tao Chou, Hsuan-Shih Lee, Ching-Wu Chu, and Chao-Yuan Cheng

Knowleged Based Systems for e-Business

A Proposal of Adequate and Efficient Designing of UML Documents for Beginners 1331
Masakazu Takahashi, Satoru Takahashi, and Yoshikatsu Fujita

Analysis of the Relation Between Stock Price Returns and Headline News Using Text Categorization 1339
Satoru Takahashi, Masakazu Takahashi, Hiroshi Takahashi, and Kazuhiko Tsuda

Evaluation of a Hierarchical Shaper as a Policy Execution Point 1346
Takeshi Aimoto, Takeki Yazaki, Takashi Isobe, Yoshihiko Sakata, and Kenichi Yoshida

Query Message Delivery over Community-Based Overlay Network 1354
Yoshikatsu Fujita, Yasufumi Saruwatari, Jun Yoshida, and Kazuhiko Tsuda

Relation Analysis on Information System Life Cycle Processes by KeyGraph Algorithms 1362
Tadashi Tsukahara, Atsuo Hazeyama, and Kazuhiko Tsuda

Author Index 1369

Applying Trust, Reputation and Intuition Aspects to Support Virtual Communities of Practice

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Abstract. Communities of Practice (CoPs) are places in which the flow of knowledge is generated as a result of the confidence that members have in each other. The main goal of this research is to emulate these communities' behavior in knowledge management systems. As a consequence of this, an increase in the exchange information between the members of a virtual community is expected. However, upon starting this work, we encountered several problems. For instance, how could we implement or rate social aspects such as trust and reputation?. This paper describes our advances in resolving these problems.

Keywords: Trust, Reputation, Communities of Practice.

1 Introduction

In recent years Knowledge Management (KM) has become an important success factor for companies. The purpose of knowledge management is to help companies to create, share and use knowledge more effectively [5]. Information technologies play a key role in achieving these goals but are only a small component in an overall system that must integrate the supporting technology with people-based business processes. KM is not a technology solution but is rather primarily a people oriented process, dealing with, for example, leadership, culture, expertise and learning, with technology playing a supporting role. Using this idea as a base we have studied how people obtain and increase their knowledge in their daily work. From this study we realised that employees frequently exchange knowledge with people who work on similar topics as them and consequently, either formally or informally, communities are created which can be called "communities of practice", by which we mean groups of people with a common interest where each member contributes knowledge about a common domain [17].

Communities of practice (CoPs) enable their members to benefit from each other's knowledge. This knowledge resides not only in people's minds but also in the interaction between people and documents. CoPs share values, beliefs, languages, and ways of doing things. Many companies report that such communities help reduce problems due to lack of communication, and save time by "working smarter" [18]. An

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interesting fact is that members of a community are frequently more likely to use knowledge built by their community team members than that created by members outside their group [6]. This factor occurs because people trust in the information offered by a member of their community more than in that which is supplied by a person who does not belongs to that community. Of course, the fact of belonging to the same community of practice already implies that the members have similar interests and perhaps the same level of knowledge about a topic. Consequently, the level of trust within a community is often higher than that which exists outside the community. Because of this, as is claimed in [6], knowledge reuse tends to be restricted within groups. Therefore, people, in real life in general and in companies in particular, prefer to exchange knowledge with "trustworthy people" by which we mean people they trust. It is for these reasons that we consider the implementation of a mechanism in charge of measuring and controlling the confidence level in a community where the members share information to be important.

Bearing in mind that people exchange information with "trustworthy knowledge sources", we have designed a prototype in which software agents try to emulate the human process of evaluating knowledge sources with the goal of fostering the use of knowledge bases in companies where agents provide the employees with "trustworthy knowledge".

The remainder of this work is organized as follows. The next section defines two important concepts that take place in the process of obtaining information (trust and reputation). Then, in Section 3 our proposal to rate reputation is described. In Section 4 we illustrate how the formulas defined for calculating reputation in virtual communities has been implemented in a prototype which detects and suggests trustworthy documents for members of CoPs. Finally, in Section 5, conclusions are described.

2 Trust and Reputation

Trust and reputation mechanisms have been proposed for use in various domains such as e-commerce [20], peer-to-peer computing [15], recommender systems [14], etc. However, there is no universal agreement on the definition of trust and reputation. Because the main goal of our work is to rate the credibility of information sources and of knowledge we first need to define these two important concepts.

2.1 Trust

Trust is a complex notion whose study is usually narrowly scoped. This has given rise to an evident lack of coherence amongst researchers in the definition of trust. For instance in [3] the authors define trust as confidence in the ability and intention of an information source to deliver correct information. Wang and Vassileva in [15] define trust as a peer's belief in another peer's capabilities, honesty and reability based on his/her own direct experiences. In [12] trust is defined as a subjective expectation an agent has about another's future behavior based on the history of their encounters.

Social scientists have collectively identified three types of trust, which are:

- *Interpersonal trust* which is the trust one agent has in another agent directly. This trust is agent and context specific [10].

- *System trust* or *impersonal trust* refers to trust that is not based on any property or state of trustee but rather on the perceived properties or reliance on the system or institution within which that trust exists. For instance, inherited experiences of an organization.
- *Dispositional trust*, or *Basic trust*, describes the general trusting attitude of the truster. This is "a sense of basic trust, which is a pervasive attitude toward oneself and the world" [10].

Experience and knowledge form the basis for trust in future familiar situations [9]. For this reason, the frequency and intensity of interactions between people provide an increased level of habituation which reinforces trust between the parties. Another concept highly related to trust is reputation which is described in the following section.

2.2 Reputation

Several definitions of 'reputation' can be found in literature. For instance, Mui et al in [12] define reputation as a perception that one agent has of another's intentions and norms. Barber and Kim define this concept as the amount of trust an agent has in an information source, created through interactions with information sources [3]. This definition is the most appropriate for our research since the level of confidence in a source is based on previous experience of it. The reputation of an information source not only serves as a means of belief revision in a situation of uncertainty, but also serves as a social law that obliges us to remain trustworthy to other people. Additionally, a good reputation may also be used to a person's advantage, as reputation is also considered as a form of social capital, especially in commerce [4]. Therefore, people, in real life in general and in companies in particular, prefer to exchange knowledge with "trustworthy people" by which we mean people they trust. People with a consistently low reputation will eventually be isolated from the community since others will rarely accept their justifications or arguments and will limit their interaction with them. It is for this reason that the remainder of this paper deals mainly with reputation. However, if we attempt to imitate the behavior of the employees in a company when they are exchanging and obtaining information we observe that apart from the concept of reputation other factors also influence. For this reason, in this paper we argue that reputation is not a single notion but one of multiple parts. These are:

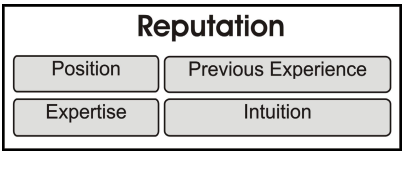

Fig. 1. Reputation factors

- *Position:* employees often consider information that comes from a boss as being more reliable than that which comes from another employee in the same (or a lower) position as him/her [16]. However, this is not a universal truth and

depends on the situation. For instance in a collaborative learning setting collaboration is more likely to occur between people of a similar status than between a boss and his/her employee or between a teacher and pupils [7]. In an enterprise this position can be established in different ways, for instance by using an organizational diagram or classifying the employees according to the knowledge that a person has, as can be seen in Allen's proposal in [2], which distinguishes between:

- Technological gatekeepers, defined as those actors who have a high level of knowledge interconnectedness with other local firms and also with extra-community sources of knowledge. These act basically by channeling new knowledge into the community and diffusing it locally.
- External stars, that are highly interconnected with external sources of knowledge but have hardly any interaction with other local firms.

Such different positions inevitably influence the way in which knowledge is acquired, diffused and eventually transformed in the local area. Because of this, as will later be explained, this factor will be calculated in our research by taking into account a weight that can strengthen this factor to a greater or to a lesser degree.

- *Expertise*: this term can be briefly defined as the skill or knowledge of a person who knows a great deal about a specific thing. This is an important factor since people often trust in experts more than in novice employees. In addition, "individual" level knowledge is embedded in the skills and competencies of the researchers, experts, and professionals working in the organization [13].
- *Previous experience*: People have greater trust in those sources from which they have previously obtained more "valuable information". Therefore, a factor that influences the increasing or decreasing reputation of a source is "previous experience" and this factor can help us to detect trustworthy sources or knowledge.
- *Intuition*: When people do not have any previous experience they often use their "intuition" to decide whether or not they are going to trust something. Other authors have called this issue "indirect reputation or prior-derived reputation" [11]. In human societies, each of us probably has different prior beliefs about the trustworthiness of strangers we meet. Sexual or racial discrimination might be a consequence of such prior belief [11]. We have tried to model intuition according to the similarity between the user profiles: the greater the similarity between one agent and another, the greater the level of intuition.

Taking all these factors into account, we have defined our own "concept of reputation", which is summarized in Figure 1.

3 Our Proposal

In order to implement this concept we have developed a reputation model. The main goal of this model is to rate the level of confidence in an information source or in a provider of knowledge. As the model is going to be used in virtual communities where people are usually distributed in different locations we have implemented a multi-agent architecture where each software agent acts on behalf of a person.

We have chosen the agent paradigm because it constitutes a natural metaphor for systems with purposeful interacting agents, and this abstraction is close to the human way of thinking about their own activities [19]. This foundation has led to an increasing interest in social aspects such as motivation, leadership, culture or trust [8]. Our research is related to this last concept of "trust" since artificial agents can be made more robust, resilient and effective by providing them with trust reasoning capabilities.

Considering that the reputation concept described in Section 2 is composed of position, expertise, previous experiences and intuition, we propose a formula to measure the level of reputation in agents' communities.

R_{ij} is the value of reputation of j in the eyes of i. This value is computed as follows:

$$R_{ij} = w_e * E_j + w_p * P_j + w_i * I_{ij} + (\sum_{j=1}^{n} QC_{ij})/n \quad (1)$$

where E_j is the value of expertise which is calculated according to the degree of experience that the person upon whose behalf the agent acts has in a domain.

P_j is the value assigned to a person's position.

I_{ij} is the value assigned to intuition which is calculated by comparing each user's profile.

In addition, previous experience should also be calculated. We suppose that when an Agent *i* consults information from another Agent *j*, the Agent *i* should evaluate how useful this information was. This value is called QC_{ij} (Quality of *j*'s Contribution according to the Agent *i*). To attain the average value of an agent's contribution, we calculate the sum of all the values assigned to these contributions by the Agent i, for instance n and we divide it by the number of evaluations (n).

Finally, w_e, w_p and w_i are weights with which the reputation value can be adjusted to the needs of the organizations or communities. These weights represent different values depending on the category of each employee. For instance, if an enterprise considers that all its employees have the same category, then $w_p = 0$. The same could occur when the organization does not take its employee's intuitions or expertise into account.

In this way, an agent can obtain a value related to the reputation of another agent and decide to what degree it is going to consider the information obtained from this agent.

Moreover, when a user wants to join to a community in which no member knows anything about him/her, the reputation value assigned to the user in the new community is calculated on the basis of the reputation assigned from other communities where the user is or was a member. For instance, a User Agent called j, will ask each community manager where s/he was previously a member to consult each agent which knows him/her with the goal of calculating the average value of his/her reputation (R_{Aj}). This is calculated as:

$$R_{Aj} = (\sum_{i=1}^{n} R_{ij})/n \quad (2)$$

where n is the number agents who know j and R_{ij} is the value of j's reputation in the eyes of i. In the case of being known in several communities the average of the values R_{Aj} will be calculated. Then, the User Agent j presents this reputation value (similar to when a person presents his/her curriculum vitae when s/he wishes to join a company) to the Manager Agent of the community to which it is "applying". This mechanism is similar to the "word-of-mouth" propagation of information for a human [1].

In the case of the user being new in the system then this user is assigned a "new" label in order for the situation to be identified.

Once the Community Manager has obtained a Reputation value for Agent j it is added to the community member list.

4 Prototype

In order to test our proposal we have developed a prototype system into which people can introduce documents and where these documents can also be consulted by other people. The goal of this prototype is to allow software agents to help employees to discover information that may be useful to them thus decreasing the overload of information that employees often have and strengthening the use of knowledge bases in enterprises. In addition, we try to avoid the situation of employees storing valueless information in the knowledge base.

When a person searches for knowledge in a community, and after having used the knowledge obtained, that person then has to evaluate the knowledge in order to indicate whether the knowledge was useful and how it was related to the topic of the search (for instance a lot, not too much, not at all).

To design this prototype we have implemented a *User Agent* and a *Manager Agent*. The former is used to represent each person that may consult or introduce knowledge in a knowledge base. Therefore, the *User Agent* can assume three types of behavior or roles similar to the tasks that a person can carry out in a knowledge base. The User Agent plays one role or another depending upon whether the person that it represents carries out one of the following actions:

- The person contributes new knowledge to the communities in which s/he is registered. In this case the User Agent plays the role of **Provider (Pr)**.
- The person uses knowledge previously stored in the community. Then, the User Agent will be considered as a **Consumer (Co)**.
- The person helps other users to achieve their goals, for instance by giving an evaluation of certain knowledge. In this case the role is of a **Partner (Pa)**.

The second type of agent within a community is called the *Manager Agent* (which must manage and control its community.

The prototype provides the options of using community documents and updating reputation values, proposing new topics in the community, etc. Due to space limitations, we shall now describe only one situation:

Using community documents and updating reputation values. People can search for documents in every community in which they are registered. When a person searches for a document relating to a topic his/her User Agent consults the Manager Agent about which documents are related to their search. Then, the Manager Agent answers with a list of documents. The User Agent sorts this list according to the reputation

value of the authors, which is to say that the contributions with the best reputations for this Agent are listed first. On the other hand, when the user does not know the contributor then the User Agent consults the Manager Agent about which members of the community know the contributors. Thus, the User Agent can consult the opinions that other agents have about these contributors, taking advantage of other agents' experience. To do this the Manager consults its interaction table and responds with a list of the members who know the User Agent. Then, this User Agent contacts each of them which answer the R_{sj} value, obtained from formula 1 explained in the previous section. If nobody knows the contributors then the information is listed, taking their authors' expertise and positions into account. In this way the User Agent can detect how worthy a document is, thus saving employees' time, since they do not need to review all the documents related to a topic but only those considered most relevant by the members of the community or by him/her according to his/her previous experience with the document or its authors.

Once the person has chosen a document, his/her User Agent adds this document to its own document list (list of consulted documents), and if the author of the document is not known by the person because it is the first time that s/he has worked with him/her, then the Community Manager adds this relation to the interaction table. This step is very important since when the person evaluates the document consulted s/he provides the QC of the contribution and his/her User Agent will be able to assign a trustworthy value for this document, and will thus gradually obtain the reputation values of all the members with which it has interacted.

Therefore, this is a prototype where agents are continuously learning by their own experience and thank to the exchange of messages between agents they can also learn from the other's experience, increasing in this way the knowledge of all the community.

5 Conclusions

The main contributions of this paper are the reputation model and our proposal to give support to virtual communities by using software agents since according to literature the exchange of knowledge is likely to take place in these communities thanks to the trust that members have in each other. Therefore, the goals of this research are:

- To assist employees in identifying trustworthy entities and to foster the idea of sharing experiences.
- To help groups work effectively together.
- To encourage knowledge exchange between community members.
- To identify individuals with the right knowledge: expertise locator.

All these advantages provide organizations with a better control over their knowledge, which will be more trustworthy, and consequently it is expected that employees will feel more willing to use it.

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