

Aleksander Zgrzywa
Kazimierz Choroś
Andrzej Siemiński (Eds.)

Multimedia and Internet Systems: Theory and Practice

 Springer

Editor-in-Chief

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

Aleksander Zgrzywa, Kazimierz Choroś,
and Andrzej Siemiński (Eds.)

Multimedia and Internet Systems: Theory and Practice

 Springer

Editors

Aleksander Zgrzywa
Institute of Informatics
Wrocław University of Technology
Wrocław
Poland

Andrzej Siemiński
Institute of Informatics
Wrocław University of Technology
Wrocław
Poland

Kazimierz Choroś
Institute of Informatics
Wrocław University of Technology
Wrocław
Poland

ISSN 2194-5357

ISBN 978-3-642-32334-8

DOI 10.1007/978-3-642-32335-5

Springer Heidelberg New York Dordrecht London

e-ISSN 2194-5365

e-ISBN 978-3-642-32335-5

Library of Congress Control Number: 2012943389

© Springer-Verlag Berlin Heidelberg 2013

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, 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.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

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

Preface

During the last 20 years we have witnessed a rapid development of Multimedia and Network Information Systems. What is even more important, the pace of change does not show any sign of slowing. When we look back we see how many research projects that have originated at universities or in research facilities now are part of our everyday life. This calls for a volume that addresses the capabilities, limitations, current trends and perspectives of Multimedia and Network Information Systems.

Our intention is to offer the readers of this monograph a very broad review of the recent scientific problems in that area. Solving them has become a principal task of numerous scientific teams all over the world. The volume is a selection of representative investigations, solutions and applications submitted by scientific teams working in many European countries.

Content of the book has been divided into four parts:

- I Multimedia Information Technology
- II Information System Specification
- III Information System Applications
- IV Web Systems and Network Technologies

Part I contains eight chapters that discuss new methods of visual data processing. The studies and resulting solutions described in the several chapters of this part follow the gaining momentum trend of exploiting artificial intelligence techniques, fuzzy logic, multi-agent approaches in the domain of multimedia information technology. The domain covers image alignment, video deinterlacing, cartographic representation, visual objects description, large scale 3D reconstruction, and hand gesture recognition. Two of the chapters focus on the content-based indexing and retrieval of visual data.

The second part of the book consists of seven chapters. Two of them address the specific problems of different applications of ontology's in information systems and the ontology alignment. This part also contains reports on the experiments on the evaluation of re-sampling combined with clustering and random oracle using genetic fuzzy systems and the study of parameter selection for the Dynamic Travelling Salesman Problem. One of the chapters deals with the modeling failures of

distributed systems in stochastic process algebras. The important from a practical point of view problem of tracking changes in database schemas is also discussed in the last chapter of this part.

Part III presents a handful of applications. It consists of four chapters. One of them describes an adaptive e-learning application with a catchy name of Power Chalk. Innovative solutions to the problem of unified user identification for mobile environments and smart communications for remote users are also discussed. The last chapter presents a rule based expert system that covers semantic matching, spatiotemporal relation operators, and comparison of GIS data to eliminate VAT-carousel crimes.

Part IV refers to the trends and perspectives in Web Systems and Network Technologies. It contains 6 chapters. Two of them deal with e-commerce issues discussing the evaluation of the server performance and presenting an approach to use product reviews from e-commerce websites for the product feature opinion mining task. The usefulness of Web pages can considerably suffer from poor readability. Therefore a special chapter is devoted to a methodology of creating a computer aided system for measuring text readability. Finding relevant services from a service collection is yet another important aspect of the Web Technologies. Two of the chapters in this part are devoted to the problem.

The book should be of great interest to researchers involved in all aspects of multimedia and Internet applications. We hope that it will fulfill the expectations of its readers and we will be also very pleased if the book will attract more scholars to work on the area and to inspire the research community already working on the domain. If so, the goal that motivated authors, reviewers, and editors will be achieved. It will be also the greatest prize for our joint efforts.

Aleksander Zgrzywa
Kazimierz Choroś
Andrzej Siemiński

Contents

Part I: Multimedia Information Technology

| | | |
|----------|---|-----------|
| 1 | Fuzzy Rule-Based Classifier for Content-Based Image Retrieval | 3 |
| | <i>Tatiana Jaworska</i> | |
| 1.1 | Introduction | 3 |
| 1.2 | Fuzziness | 5 |
| 1.2.1 | Fuzzy Sets | 5 |
| 1.2.2 | Fuzzy Rule-Based Classifiers | 5 |
| 1.3 | Graphical Data Representation | 7 |
| 1.4 | Classification Results | 8 |
| 1.5 | Further Use of Classified Objects in CBIR | 11 |
| 1.6 | Conclusions | 11 |
| | References | 12 |
| 2 | Decentralized Multi-Agent Algorithm for Translational 2D Image Alignment | 15 |
| | <i>Tomáš Machálek, Kamila Olševičová</i> | |
| 2.1 | Introduction | 15 |
| 2.2 | Problem Statement | 17 |
| 2.3 | Proposed Solution | 17 |
| 2.4 | Estimation of Computational Complexity | 21 |
| 2.5 | Experiments | 21 |
| 2.6 | Conclusions | 23 |
| | References | 24 |
| 3 | A Sparse Reconstruction Approach to Video Deinterlacing | 25 |
| | <i>Maria Trocan</i> | |
| 3.1 | Introduction | 25 |
| 3.2 | Background | 27 |
| 3.3 | Proposed Method | 28 |
| 3.4 | Experimental Results | 30 |
| 3.5 | Conclusion | 32 |
| | References | 32 |

| | | |
|----------|---|----|
| 4 | Cartographic Representation of Route Reconstruction Results in Video Surveillance System | 35 |
| | <i>Karol Lisowski, Andrzej Czyżewski</i> | |
| 4.1 | Introduction | 35 |
| 4.2 | Related Work | 36 |
| 4.3 | Proposed Method | 36 |
| 4.3.1 | Topology of Camera Network | 36 |
| 4.3.2 | Obtaining Contextual Data | 37 |
| 4.3.3 | Architecture of the System | 38 |
| 4.3.4 | Augmenting Cartographic Data | 39 |
| 4.4 | Results | 40 |
| 4.5 | Conclusion | 42 |
| | References | 43 |
| 5 | Visual Objects Description for Their Re-identification in Multi-Camera Systems | 45 |
| | <i>Damian Ellwart, Andrzej Czyżewski</i> | |
| 5.1 | Introduction | 45 |
| 5.2 | Object Tracking | 47 |
| 5.2.1 | Single Camera Object Tracking | 47 |
| 5.2.2 | Multi-Camera Object Tracking | 47 |
| 5.3 | Object Description Methods | 48 |
| 5.4 | Experiments | 49 |
| 5.4.1 | Dataset Preparation | 50 |
| 5.4.2 | Feature Evaluation | 51 |
| 5.5 | Summary | 53 |
| | References | 53 |
| 6 | Compact Descriptor for Video Sequence Matching in the Context of Large Scale 3D Reconstruction | 55 |
| | <i>Roman Parys, Florian Liefers, Andreas Schilling</i> | |
| 6.1 | Introduction | 55 |
| 6.2 | Related Work | 56 |
| 6.3 | Compact Descriptor and Matching | 57 |
| 6.3.1 | Computation of Compact Descriptor | 57 |
| 6.3.2 | Computation of Similarity Measure | 58 |
| 6.3.3 | Computation of Image Occurrence Statistics | 59 |
| 6.3.4 | Computation of Matching Frames | 60 |
| 6.4 | Results | 61 |
| 6.5 | Conclusions and Future Work | 63 |
| | References | 64 |
| 7 | Headlines Usefulness for Content-Based Indexing of TV Sports News | 65 |
| | <i>Kazimierz Choroś</i> | |
| 7.1 | Introduction | 65 |

| | | |
|-----------|---|-----|
| 7.2 | Related Works | 67 |
| 7.3 | Book Structure vs. TV Sports News Structure | 67 |
| 7.4 | AVI - Automatic Video Indexer | 70 |
| 7.5 | Structure of TV Sports News | 70 |
| 7.6 | Headlines in TV Sports News | 72 |
| 7.7 | Final Conclusions and Further Studies | 74 |
| | References | 75 |
| 8 | Examining Classifiers Applied to Static Hand Gesture Recognition in Novel Sound Mixing System | 77 |
| | <i>Michał Lech, Bożena Kostek, Andrzej Czyżewski</i> | |
| 8.1 | Introduction | 77 |
| 8.2 | System Overview | 78 |
| 8.3 | Examining Classifiers Performance | 80 |
| | 8.3.1 Tests | 80 |
| | 8.3.2 Results | 81 |
| 8.4 | Conclusions | 85 |
| | References | 85 |
| | Part II: Information Systems Specification | |
| 9 | Multiple Data Tables Processing via One-Sided Concept Lattices | 89 |
| | <i>Peter Butka, Jozef Pócs, Jana Pócsová, Martin Sarnovský</i> | |
| 9.1 | Introduction | 89 |
| 9.2 | Preliminaries on One-Sided Concept Lattices | 90 |
| 9.3 | Closure Operator Defined by Multiple Data Tables | 93 |
| 9.4 | Conclusions | 97 |
| | References | 98 |
| 10 | A Multi-attribute and Logic-Based Framework of Ontology Alignment | 99 |
| | <i>Marcin Pietranik, Ngoc Thanh Nguyen</i> | |
| 10.1 | Introduction | 99 |
| 10.2 | Basic Notions | 101 |
| 10.3 | Attribute-Based Concept Alignment | 102 |
| 10.4 | Related Works | 103 |
| 10.5 | Evaluation Methodology | 104 |
| 10.6 | Summary and Future Works | 107 |
| | References | 108 |
| 11 | Application of an Ontology-Based Model to a Wide-Class Fraudulent Disbursement Economic Crimes | 109 |
| | <i>Czesław Jędrzejek, Jarosław Bąk</i> | |
| 11.1 | Introduction | 109 |
| 11.2 | The Model | 111 |
| 11.3 | Set of Rules | 113 |

| | | |
|-----------|---|------------|
| 11.4 | Queries | 116 |
| 11.5 | Conclusions | 116 |
| | References | 117 |
| 12 | Modelling Failures of Distributed Systems in Stochastic Process Algebras | 119 |
| | <i>Jerzy Brzeziński, Dariusz Dwornikowski</i> | |
| 12.1 | Introduction | 119 |
| 12.2 | Basic Definitions | 121 |
| 12.2.1 | Stochastic Process Algebras | 121 |
| 12.2.2 | Basic Failures in Distributed Systems | 121 |
| 12.3 | Modelling Failures | 122 |
| 12.3.1 | Crash-Recovery Failures | 123 |
| 12.3.2 | Crash-Stop Failure Models | 124 |
| 12.3.3 | Omission Model | 126 |
| 12.3.4 | Modelling Failure Detectors | 127 |
| 12.4 | Conclusions | 128 |
| | References | 129 |
| 13 | Experimental Evaluation of Resampling Combined with Clustering and Random Oracle Using Genetic Fuzzy Systems | 131 |
| | <i>Tadeusz Lasota, Zbigniew Telec, Bogdan Trawiński, Grzegorz Trawiński</i> | |
| 13.1 | Introduction | 131 |
| 13.2 | Methods Used in Experiments | 133 |
| 13.3 | Experimental Setup | 136 |
| 13.4 | Experimental Results | 137 |
| 13.5 | Conclusions | 140 |
| | References | 141 |
| 14 | Ant Colony Optimization Parameter Evaluation | 143 |
| | <i>Andrzej Siemiński</i> | |
| 14.1 | Introduction | 143 |
| 14.2 | Basic ACO Algorithm for Static TSP | 144 |
| 14.2.1 | ACO Basic Operations | 145 |
| 14.2.2 | Parameter Selection | 146 |
| 14.3 | Dynamic TSP | 146 |
| 14.3.1 | Related Work | 147 |
| 14.3.2 | Graph Generators | 147 |
| 14.4 | Experiment | 149 |
| 14.4.1 | Data Exploration | 150 |
| 14.4.2 | Correlation Analysis | 151 |
| 14.5 | Conclusions | 152 |
| | References | 153 |

| | |
|--|-----|
| 15 Tracking Changes in Database Schemas | 155 |
| <i>Jakub Marciniak, Tadeusz Pankowski</i> | |
| 15.1 Introduction | 155 |
| 15.2 Changes Discovering Process | 156 |
| 15.2.1 Schemas Similarity | 157 |
| 15.2.2 Rule Based Schema Matching | 158 |
| 15.2.3 Edit Distance | 160 |
| 15.2.4 Transforming Operations | 161 |
| 15.3 Conclusions | 164 |
| References | 164 |

Part III: Information Systems Applications

| | |
|---|-----|
| 16 Smart Communication Adviser for Remote Users | 169 |
| <i>Miroslav Behan, Ondrej Krejcar</i> | |
| 16.1 Introduction | 169 |
| 16.2 Problem Definition | 170 |
| 16.3 Solution Design | 173 |
| 16.4 Application Prototype | 174 |
| 16.5 Conclusions | 176 |
| References | 177 |
| 17 PowerChalk: An Adaptive e-Learning Application | 179 |
| <i>Dan-El Neil Vila Rosado, Margarita Esponda-Argüero, Raúl Rojas</i> | |
| 17.1 Introduction | 179 |
| 17.2 ISDT and Related Work | 180 |
| 17.3 PowerChalk Structure | 182 |
| 17.4 PowerChalk Modules | 183 |
| 17.4.1 Main Editor Module | 183 |
| 17.4.2 Pen and Digitizer Tablets Module | 184 |
| 17.4.3 Multi-screen Manager Module | 184 |
| 17.4.4 Handwriting Recognition Module | 185 |
| 17.4.5 Communication Module | 185 |
| 17.4.6 Collaboration Modules | 186 |
| 17.4.7 Magic Panels | 187 |
| 17.4.8 Macros Module | 187 |
| 17.5 Conclusions and Future Work | 187 |
| References | 188 |
| 18 Identifying Fraudulent Shipments through Matching Shipping Documents with Phone Records | 189 |
| <i>Czesław Jędrzejek, Maciej Nowak, Maciej Falkowski</i> | |
| 18.1 Introduction | 189 |
| 18.2 A Model of Data Correlation between Invoices, CMR Documents and Driver's Phone Records | 191 |
| 18.3 A Route Verification Algorithm | 192 |

| | |
|---|------------|
| 18.4 Results for the GARO Case | 195 |
| 18.5 Conclusions and Future Work | 197 |
| References | 198 |
| 19 Open Personal Identity as a Service | 199 |
| <i>Miroslav Behan, Ondrej Krejcar</i> | |
| 19.1 Introduction | 199 |
| 19.2 Problem Definitions | 200 |
| 19.3 Related Works | 201 |
| 19.4 Solution Design | 202 |
| 19.5 Implementation | 204 |
| 19.6 Conclusions | 206 |
| References | 206 |
| Part IV: Web Systems and Network Technologies | |
| 20 The Computer-Aided Estimate of the Text Readability on the Web Pages | 211 |
| <i>Radosław Bednarski, Maria Pietruszka</i> | |
| 20.1 Introduction | 211 |
| 20.2 Typographical Text Parameters | 212 |
| 20.3 Coloured Text on the Screen | 213 |
| 20.4 Computer-Aided System for Assessing the Readability of the Text and the Selection of Its Parameters | 214 |
| 20.5 Tests of the System | 217 |
| 20.6 Conclusions | 219 |
| References | 220 |
| 21 MSALSA - A Method of Positioning Search Results in Music Information Retrieval Systems | 221 |
| <i>Zygmunt Mazur, Konrad Wiklak</i> | |
| 21.1 Introduction | 221 |
| 21.2 Description of the MSALSA Algorithm | 223 |
| 21.3 Tests Results | 225 |
| 21.4 Conclusions | 228 |
| References | 228 |
| 22 The Concept of Parametric Index for Ranked Web Service Retrieval | 229 |
| <i>Adam Czyszczoń, Aleksander Zgrzywa</i> | |
| 22.1 Introduction | 229 |
| 22.2 Related Work | 230 |
| 22.3 Web Service Structure | 230 |
| 22.4 Web Service Ranking with Vector Space Model | 231 |
| 22.4.1 Relevance Measure | 232 |

| | | |
|-----------|---|------------|
| 22.5 | Parametric Index | 232 |
| 22.5.1 | Component Concepts | 233 |
| 22.5.2 | Merged Weight Vector | 234 |
| 22.5.3 | Index Structure | 234 |
| 22.5.4 | Indexing Algorithm | 234 |
| 22.6 | Experimental Results | 236 |
| 22.7 | Conclusions and Future Work | 238 |
| | References | 238 |
| 23 | Web-Based User Interface for SOA Systems Enhanced by Ontology | 239 |
| | <i>Marek Kopel, Janusz Sobecki</i> | |
| 23.1 | Introduction | 239 |
| 23.2 | User Interfaces Enhanced by Ontology | 240 |
| 23.3 | User Interface for SOA Systems | 241 |
| 23.4 | Application of Ontology Enhanced User Interface for SOA Systems | 242 |
| 23.4.1 | Extending WSDL | 245 |
| 23.5 | Discussion and Future Works | 246 |
| | References | 246 |
| 24 | Simulation-Based Performance Study of e Commerce Web Server System - Results for FIFO Scheduling | 249 |
| | <i>Grażyna Suchacka, Leszek Borzemski</i> | |
| 24.1 | Introduction | 249 |
| 24.2 | Workload Scenarios | 250 |
| 24.3 | Simulation Results | 252 |
| 24.3.1 | Analysis of System Performance Metrics | 253 |
| 24.3.2 | Analysis of Business-Oriented Metrics | 255 |
| 24.4 | Concluding Remarks | 257 |
| | References | 258 |
| 25 | Domain Dependent Product Feature and Opinion Extraction Based on E-Commerce Websites | 261 |
| | <i>Bartomiej Twardowski, Piotr Gawrysiak</i> | |
| 25.1 | Introduction | 261 |
| 25.2 | Related Research | 262 |
| 25.3 | Proposed Approach | 263 |
| 25.3.1 | Data Acquisition | 263 |
| 25.3.2 | Data Corpus Preparation | 264 |
| 25.3.3 | Model Training | 267 |
| 25.4 | Experiment and Results | 268 |
| 25.5 | Conclusions and Feature Work | 269 |
| | References | 270 |
| | Author Index | 271 |

List of Contributors

Jarosław Bak

Poznań University of Technology
Institute of Control and
Information Engineering
pl. M. Skłodowskiej-Curie 5
60-965 Poznań
Poland
jaroslaw.bak@put.poznan.pl

Radosław Bednarski

Lodz University of Technology
Institute of Information Technology
ul. Żeromskiego 116
90-924 Łódź
Poland
radoslaw.bednarski@p.lodz.pl

Miroslav Behan

University of Hradec Kralove
FIM, Department of Information
Technologies
Rokitanskeho 62, Hradec Kralove
50003, Czech Republic
miroslav.behan@uhk.cz

Leszek Borzemski

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław
Poland
leszek.borzemski@pwr.wroc.pl

Peter Butka

Technical University of Košice
Faculty of Electrical Engineering
and Informatics
Department of Cybernetics and
Artificial Intelligence
Letná 9, 04200 Košice
Slovakia
peter.butka@tuke.sk

Jerzy Brzeziński

Poznań University of Technology
Institute of Computing Science
Piotrowo 2, 60-965, Poznań
Poland
jerzy.brzezinski@
put.poznan.pl

Kazimierz Choroś

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław, Poland
kazimierz.choros@pwr.wroc.pl

Adam Czyszczoń

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław, Poland
adam.czyszczonek@pwr.wroc.pl

Andrzej Czyżewski

Gdańsk University of Technology
 ul. Narutowicza 11/12
 80-233 Gdańsk
 Poland
 andcz@sound.eti.pg.gda.pl

Dariusz Dwornikowski

Poznań University of Technology
 Institute of Computing Science
 Piotrowo 2, 60-965, Poznań
 Poland
 dariusz.dwornikowski@
 cs.put.poznan.pl

Damian Ellwart

Gdańsk University of Technology
 Narutowicza 11/12
 80-233 Gdańsk
 Poland
 ellwart@sound.eti.pg.gda.pl

Margarita Esponda-Argüero

Freie Universität Berlin
 Department of Mathematics
 and Computer Science
 Takustrasse 9, 14195 Berlin
 Germany
 esponda@inf.fu-berlin.de

Maciej Falkowski

Poznań University of Technology
 Institute of Control and Information
 Engineering
 pl. M. Skłodowskiej-Curie 5
 60-965 Poznań
 Poland
 maciej
 falkowski@put.poznan.pl

Piotr Gawrysiak

Warsaw University of Technology
 Institute of Computer Science
 ul. Nowowiejska 15/19, 00-665
 Warszawa
 Poland
 p.gawrysiak@ii.pw.edu.pl

Tatiana Jaworska

Systems Research Institute
 Polish Academy of Sciences
 ul. Newelska 6, 01-447 Warszawa
 Poland
 tatiana.jaworska@
 ibspan.waw.pl

Czesław Jędrzejek

Poznań University of Technology
 Institute of Control and Information
 Engineering
 pl. M. Skłodowskiej-Curie 5
 60-965 Poznań, Poland
 czeslaw.jedrzejek@
 put.poznan.pl

Marek Kopel

Wrocław University of Technology
 Institute of Informatics
 Wybrzeże Wyspiańskiego 27
 50-370, Wrocław, Poland
 marek.kopel@pwr.wroc.pl

Bożena Kostek

Multimedia Systems Department
 Gdańsk University of Technology
 ul. Narutowicza 11/12
 80-233 Gdańsk, Poland
 bozenka@sound.eti.pg.gda.pl

Ondřej Krejcar

University of Hradec Kralove
 FIM, Department of Information
 Technologies
 Rokitanskeho 62, Hradec Kralove,
 50003
 Czech Republic
 ondrej.krejcar@asjournal.eu

Tadeusz Lasota

Wrocław University of Environmental
 and Life Sciences
 Department of Spatial Management
 ul. Norwida 25/27
 50-375 Wrocław
 Poland
 tadeusz.lasota@up.wroc.pl

Michał Lech

Gdańsk University of Technology
Multimedia Systems Department
ul. Narutowicza 11/12, 80-233
Gdańsk
Poland
mlech@sound.eti.pg.gda.pl

Florian Liefers

Tuebingen University, Germany
Geschwister-Scholl-Platz
72074 Tübingen
forian@liefers.com

Karol Lisowski

Gdańsk University of Technology
Multimedia Systems Department
ul. Narutowicza 11/12
80-233 Gdańsk
Poland
lisowski@sound.eti.pg.gda.pl

Tomáš Machálek

University of Hradec Králové
Faculty of Informatics and Management
Department of Information
Technologies, Rokitanského 62
Hradec Králové, 50003
Czech Republic
tomas.machalek@uhk.cz

Jakub Marciniak

Adam Mickiewicz University
Faculty of Mathematics
and Computer Science
ul. Umultowska 87
61-614 Poznań
Poland
kubam@amu.edu.pl

Zygmunt Mazur

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław
Poland
Zygmunt.Mazur@pwr.wroc.pl

Ngoc Thanh Nguyen

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław
Poland
ngoc-thanh.nguyen@pwr.wroc.pl

Maciej Nowak

Poznań University of Technology
Institute of Control and Information
Engineering
pl. M. Skłodowskiej-Curie 5
60-965 Poznań
Poland
maciej.nowak@put.poznan.pl

Kamila Olševičová

University of Hradec Králové
Faculty of Informatics and Management
Department of Information
Technologies Rokitanského 62
Hradec Králové, 500 03, Czech
Republic
kamila.olsevicova@uhk.cz

Tadeusz Pankowski

Poznań University of Technology
Institute of Control and Information
Engineering
pl. M. Skłodowskiej-Curie 5
60-965 Poznań, Poland
tadeusz.pankowski@
put.poznan.pl

Roman Parys

Tuebingen University, Germany
Geschwister-Scholl-Platz
72074 Tübingen
parys@gris.uni-tuebingen.de

Marcin Pietranik

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław
Poland
marcin.pietranik@pwr.wroc.pl

Maria Pietruszka

Lodz University of Technology
 Institute of Information Technology
 ul. Żeromskiego 116, 90-924 Łódź
 Poland
 maria.pietruszka@p.lodz.pl

Jozef Pócs

Slovak Academy of Sciences
 Mathematical Institute
 Grešakova 6, 040 01 Košice, Slovakia
 pocs@saske.sk

Jana Pócsová

Technical University of Košice
 BERG Faculty, Institute of Control
 and Informatization of Production
 Processes, Boženy Němcovej 3
 043 84 Košice, Slovakia
 jana.pocsova@tuke.sk

Raúl Rojas

Freie Universität Berlin
 Department of Mathematics
 and Computer Science
 Takustrasse 9, 14195 Berlin, Germany
 raul.rojas@fu-berlin.de

Dan-El Neil Vila Rosado

Freie Universität Berlin
 Department of Mathematics
 and Computer Science
 Takustrasse 9, 14195 Berlin, Germany
 vila80@inf.fu-berlin.de

Martin Sarnovský

Technical University of Košice
 Faculty of Electrical Engineering and
 Informatics
 Department of Cybernetics and Artificial
 Intelligence
 Letná 9, 04200 Košice, Slovakia
 martin.sarnovsky@tuke.sk

Andreas Schilling

Tuebingen University, Germany
 Geschwister-Scholl-Platz
 72074 Tübingen
 schilling@uni-tuebingen.de

Andrzej Siemiński

Wrocław University of Technology
 Institute of Informatics
 Wybrzeże Wyspiańskiego 27
 50-370, Wrocław
 Poland
 andrzej.sieminski@
 pwr.wroc.pl

Janusz Sobiecki

Wrocław University of Technology
 Institute of Informatics
 Wybrzeże Wyspiańskiego 27
 50-370, Wrocław
 Poland
 Janusz.Sobiecki@pwr.wroc.pl

Grażyna Suchacka

Opole University, Faculty of
 Mathematics
 Physics and Computer Science
 ul. Oleska 48
 45-052 Opole
 Poland
 g.suchacka@gmail.com

Zbigniew Telec

Wrocław University of Technology
 Institute of Informatics, Wybrzeże
 Wyspiańskiego 27
 50-370 Wrocław
 Poland
 zbigniew.telec@pwr.wroc.pl

Bogdan Trawiński

Wrocław University of Technology
 Institute of Informatics
 Wybrzeże Wyspiańskiego 27
 50-370, Wrocław, Poland
 bogdan.trawinski@pwr.wroc.pl

Grzegorz Trawiński

Wrocław University of Technology
 Faculty of Electronics
 Wybrzeże Wyspiańskiego 27
 50-370 Wrocław, Poland
 grzegorztrawinski@wp.pl

Maria Trocan

Institut Supérieur d'Electronique
de Paris Signal
and Image Processing Department
28 rue Notre Dame des Champs
Paris, France
maria.trocan@isep.fr

Bartomiej Twardowski

Warsaw University of Technology
Institute of Computer Science
ul. Nowowiejska 15/19
00-665 Warszawa
Poland
b.twardowski@ii.pw.edu.pl

Konrad Wiklak

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370 Wrocław, Poland
konrad.wiklak@gmail.com

Aleksander Zgrzywa

Wrocław University of Technology
Institute of Informatics
Wybrzeże Wyspiańskiego 27
50-370, Wrocław
Poland
aleksander.zgrzywa@
pwr.wroc.pl

Part I
Multimedia Information Technology

Chapter 1

Fuzzy Rule-Based Classifier for Content-Based Image Retrieval

Tatiana Jaworska

Abstract. At present a great deal of research is being done in different aspects of Content-Based Image Retrieval System (CBIR). Thus, it is necessary to develop appropriate information systems to efficiently manage datasets. Image classification is one of the most important services in image retrieval that must support these systems. The primary issue we have addressed is: how can the fuzzy set theory be used to handle crisp data for images. We propose how to introduce fuzzy rule-based classification for image objects. To achieve this goal we have constructed fuzzy rule-based classifiers, taking into account crisp data. In this chapter we present the results of the use of this fuzzy rule-based system in our CBIR.

1.1 Introduction

In recent years, the availability of image resources on the WWW and large image datasets has increased tremendously. This has created a demand for effective and flexible techniques for automatic image classification and retrieval. Although attempts to perform the Content-Based Image Retrieval (CBIR) in an efficient way have been made before, a major problem in this area has been computer perception, to which it is hard to introduce an additional semantic data model. In other words, there is a necessity to introduce fuzzy information models into image retrieval, based on high-level semantic concepts that perceive an image as a complex whole.

Images and graphical data are complex in terms of visual and semantic contents. Depending on the application, images are modelled and indexed using their

- visual properties (or a set of relevant visual features),
- semantic properties,
- spatial or temporal relationships of graphical objects.

Tatiana Jaworska

Polish Academy of Sciences, Systems Research Institute, Warsaw, Poland

e-mail: Tatiana.Jaworska@ibspan.waw.pl

Over the last decade a number of concepts of the CBIR [1], [2], [3], [4], have been used. Proposals can be found for the relational [5], object-oriented [6], [7] databases. For about 10 years the fuzzy proposition has been applied in object-relation database models [8], [9]. Zadeh's fuzzy sets theory has allowed us to develop limited programming tools, concerned with graphical applications and dealing with imperfect pictorial data. Within the scope of semantic properties, as well as graphical object properties, the first successful attempt was made by Candan and Li [10], who constructed the Semantic and Cognition-based Image Retrieval (SEMCOG) query processor to search for images by predicting their semantic and spatial imperfection.

The feature vector is used for tentative object classification at the local level of a separated object. First, we have to classify objects in order to assign them to a particular class which is later used to describe spatial relationships characteristic of a particular image. In our system spatial object location in an image is used as the global feature; then it supports full identification of graphical elements based on rules of location. Next, classified objects are used to enable the user to compose their own image in the GUI. Finally, we apply classes in order to compare objects coming from different images [21].

We have chosen a fuzzy rule-based classification to support our pattern library which is constructed to enable the user to build their image query in as natural a way as possible. 'Natural' here means handling such objects as houses, trees, water instead of a red square, blue rectangle, etc.

In this chapter we present the fuzzy rule-based classifiers for object classification which takes into account object features, together with different spatial location of segmented objects in the image. In order to improve the comparison of two images, we need to label these objects in a semantic way.

In general, our system consists of four main blocks:

1. the image preprocessing block (responsible for image segmentation), applied in Matlab, cf. [11];
2. the Oracle Database, storing information about whole images, their segments (here referred to as graphical objects), segment attributes, object location, pattern types and object identification, cf. [12];
3. the search engine responsible for the searching procedure and retrieval process based on feature vectors for objects and spatial relationship of these objects in an image, applied in Matlab;
4. the graphical user's interface (GUI) allows users to compose their own image, consisting of separate graphical objects as a query. Classification helps in the transition from rough graphical objects to human semantic elements. We have had to create a user-friendly semantic system, also applied in Matlab.

There have been several attempts to design efficient, invariant, flexible and intelligent image archival and retrieval systems based on the perception of spatial relationships. Chang [13] proposed a symbolic indexing approach, called the nine directional lower triangular (9DLT) matrix to encode symbolic images. Using the concept of 9DLT matrix, Chang and Wu [14] proposed an exact match of the retrieval scheme, based upon principal component analysis (PCA). Unfortunately, it transpired that the first principal component vectors (PCVs) associated with the

image and the same image rotated are not the same. Eventually, an invariant scheme for retrieval of symbolic images based upon the PCA was prepared by Guru and Punitha [15].

1.2 Fuzziness

1.2.1 Fuzzy Sets

Let $T = \{t_1, \dots, t_n\}$ be a set of objects, where $t_i \neq t_j$, the attributes of t_i and t_j are different. Let $U = \{A_1, \dots, A_m\}$ be the set of attributes over t_1, \dots, t_n . Each attribute A_i has been associated with a domain, denoted by $U(A_i)$. The value of attribute A_i is either a crisp or fuzzy value. According to Zadeh [16], a fuzzy set F in $U \subseteq \mathbb{R}$ is uniquely specified by its membership function $\mu_f: U \rightarrow [0,1]$. Thus, the fuzzy set is described as follows:

$$F = \{(u, \mu_f(u)) | u \in U\} \quad (1.1)$$

Two important concepts of *core* and *support* are related to a fuzzy set F :

$$\text{core}(F) = \{u | u \in U \wedge \mu_f(u) = 1\}$$

and

$$\text{support}(F) = \{u | u \in U \wedge \mu_f(u) > 0\}.$$

For our purpose, we use a trapezoidal membership function MF which is mathematically defined by four parameters $\{a, b, c, d\}$:

$$\text{trap mf}(u; a, b, c, d) = \begin{cases} 0, & u < a \\ \frac{u-a}{b-a}, & a \leq u \leq b \\ 1, & b \leq u \leq c \\ \frac{d-u}{d-c}, & c \leq u \leq d \\ 0, & d < u \end{cases} \quad (1.2)$$

Let F and G be two fuzzy sets in the universe U , we say that $F \subseteq G \Leftrightarrow \mu_F(u) \leq \mu_G(u), \forall u \in U$. The complement of F , denoted by F^c , is defined by $\mu_{F^c}(u) = 1 - \mu_F(u)$. Furthermore, $F \cap G$ (respectively $F \cup G$) is defined the following way: $\mu_{F \cap G} = \min(\mu_F(u), \mu_G(u))$ (respectively $\mu_{F \cup G} = \max(\mu_F(u), \mu_G(u))$).

1.2.2 Fuzzy Rule-Based Classifiers

We assume that we have an M -class pattern classification problem in an n -dimensional normalized hyper-cube $[0, 1]^n$. For this problem, we use fuzzy rules of the following type:

$$\text{Rule } R_q : \text{If } x_1 \text{ is } A_{q1} \text{ and } \dots \text{ and } x_n \text{ is } A_{qn} \text{ then Class } C_q \text{ with } CF_q, \quad (1.3)$$

where R_q is the label of the q^{th} fuzzy rule, $\mathbf{x} = (x_1, \dots, x_n)$ is an n -dimensional pattern/feature vector, A_{q_i} is an antecedent fuzzy set ($i = 1, \dots, n$), C_q is a class label,

CF_q is a real number in the unit interval [0,1] which represents a rule weight. The rule weight can be specified by a heuristic manner or it can be adjusted by a learning algorithm [17], [18]. We use the n -dimensional fuzzy vector $A_q = (A_{q1}, \dots, A_{qn})$ to represent the antecedent part of the fuzzy rule R_q in (3) in a concise manner.

Let S be a set of fuzzy rules of the type in (3). That is, S is a fuzzy rule-based classifier. When an n -dimensional pattern/feature $\mathbf{x}_p = (x_{p1}, \dots, x_{pn})$ is presented to S , first the compatibility grade of \mathbf{x}_p with the antecedent part A_q of each fuzzy rule R_q in S is calculated by the product operator as

$$\mu_{A_q}(\mathbf{x}_p) = \mu_{A_{q1}}(x_{p1}) \times \dots \times \mu_{A_{qn}}(x_{pn}) \text{ for } R_q \in S, \quad (1.4)$$

where $\mu_{A_{qi}}(\cdot)$ shows the membership function of A_{qi} . Then a single winner rule $R_{w(\mathbf{x}_p)}$ is identified for \mathbf{x}_p as follows:

$$CF_{w(\mathbf{x}_p)} \times \mu_{A_{w(\mathbf{x}_p)}}(\mathbf{x}_p) = \max \{CF_q \times \mu_{A_q}(\mathbf{x}_p) \mid R_q \in S\}, \quad (1.5)$$

where $w(\mathbf{x}_p)$ denotes the rule index of the winner rule for \mathbf{x}_p .

The pattern \mathbf{x}_p is classified by the single winner rule $R_{w(\mathbf{x}_p)}$ as its consequent class. If there is no fuzzy rule with a positive compatibility grade with \mathbf{x}_p (i.e., if \mathbf{x}_p is not covered by any fuzzy rules in S), the classification of \mathbf{x}_p is rejected. The classification of \mathbf{x}_p is also rejected if multiple fuzzy rules with different consequent classes have the same maximum value on the right-hand side of (5). In this case, \mathbf{x}_p is exactly on the classification boundary between the different classes.

We use the single winner-based fuzzy reasoning method in (5) for pattern classification. This is because a responsible fuzzy rule can be always identified for the classification result of each input pattern when we use the single winner-based fuzzy reasoning method.

An ideal theoretical example of a simple three-class, two-dimensional pattern classification problem with 20 patterns from each class is considered in [19]. There three linguistic values (*small*, *medium* and *large*) were used as antecedent fuzzy sets for each of the two attributes and 3×3 fuzzy rules were generated. S_1 was the fuzzy rule-based classifier with the 9 fuzzy rules shown below:

S_1 : fuzzy rule-based classifier with 9 fuzzy rules

- R_1 : If x_1 is *small* and x_2 is *small* then Class2 with 1.0,
- R_2 : If x_1 is *small* and x_2 is *medium* then Class2 with 1.0,
- R_3 : If x_1 is *small* and x_2 is *large* then Class1 with 1.0,
- R_4 : If x_1 is *medium* and x_2 is *small* then Class2 with 1.0,
- R_5 : If x_1 is *medium* and x_2 is *medium* then Class2 with 1.0,
- R_6 : If x_1 is *medium* and x_2 is *large* then Class1 with 1.0,
- R_7 : If x_1 is *large* and x_2 is *small* then Class3 with 1.0,
- R_8 : If x_1 is *large* and x_2 is *medium* then Class3 with 1.0,
- R_9 : If x_1 is *large* and x_2 is *large* then Class3 with 1.0,

| | | |
|-------|-------|-------|
| R_3 | R_6 | R_9 |
| R_2 | R_5 | R_8 |
| R_1 | R_4 | R_7 |

Fig. 1.1 Classification boundaries for fuzzy rule-based classifier S_1 .

For simplicity, the rule weight is 1.0 in S_1 . The location of each rule is shown in Fig. 1.1.

1.3 Graphical Data Representation

In our system, Internet images are downloaded. Firstly, the new image is segmented, creating a collection of objects. Each object, selected according to the algorithm presented in detail in [21], is described by some low-level features. The features describing each object include: average colour k_{av} , texture parameters T_p , area A , convex area A_c , filled area A_p , centroid $\{x_c, y_c\}$, eccentricity e , orientation α , moments of inertia m_{11} , bounding box $\{bb_1(x,y), \dots, bb_s(x,y)\}$ (s – number of vertices), major axis length m_{long} , minor axis length m_{short} , solidity s and Euler number E and Zernike moments Z_{00}, \dots, Z_{33} . All features, as well as extracted images of graphical objects, are stored in the DB. Let F_o be a set of features where:

$$F_o = \{k_{av}, T_p, A, A_c, \dots, E\} \quad (1.6)$$

For ease of notation we will use $F_o = \{f_1, f_2, \dots, f_r\}$, where r – number of attributes. For an object, we construct a feature vector O containing the above-mentioned features:

$$O = \begin{bmatrix} O(k_{av}) \\ O(T_p) \\ O(A) \\ \vdots \\ O(Z_{33}) \end{bmatrix} = \begin{bmatrix} O(f_1) \\ O(f_2) \\ O(f_3) \\ \vdots \\ O(f_r) \end{bmatrix}. \quad (1.7)$$

The next complex feature attributed to objects is texture. Texture parameters are found in the wavelet domain (the Haar wavelets are used). The algorithm details are also given in [21]. The use of this algorithm results in obtaining two ranges for the horizontal object dimension h and two others for the vertical one v :

$$T_p = \left\{ \begin{array}{l} h_{\min_{1,2}}; h_{\max_{1,2}} \\ v_{\min_{1,2}}; v_{\max_{1,2}} \end{array} \right\}. \quad (1.8)$$

Additional features of the low level for objects are shape descriptors. They are also included in the above-mentioned feature vector. We apply the two most important shape descriptors such as moments of inertia:

$$\mu_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q f(x, y), \quad p, q = 0, 1, 2 \quad (1.9)$$

and Zernike moments [20]. Zernike moments are a set of complex polynomials $\{V_{pq}(x,y)\}$ which form a complete orthogonal set over the unit disk of $x^2 + y^2 \leq 1$. Hence, the definition of 2D Zernike moments with p^{th} order with repetition q for intensity function $f(x,y)$ of the image is described as:

$$Z_{pq} = \frac{p+1}{\pi} \iint_{x^2+y^2 \leq 1} V_{pq}^* (x, y) f(x, y) dx dy \quad (1.10)$$

where:
$$V_{pq}^*(x, y) = V_{p, -q}(x, y). \quad (1.11)$$

For our purpose, the first 10 Zernike moments are sufficient, which means we calculate moments from Z_{00} to Z_{33} .

1.4 Classification Results

The feature vector \mathbf{O} (cf. (7)) is used here as a pattern/feature vector \mathbf{x} for object classification. We collected $n = 32$ features for each graphical object. Based on the data collected in our CBIR system, we have analysed the most distinguished features to present our experimental results. We have chosen three classes from graphical objects in the training subset, namely: class1 - horizontal line, class2 - caret and class3 - vertical line, presented respectively in Fig. 1.2.

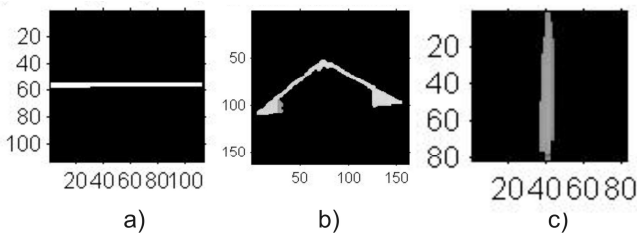


Fig. 1.2 Examples of graphical objects used as class1 - horizontal line a), class2 – caret b) and class3 - vertical line c) from the training subset.

For our fuzzy rule-based classifier we have chosen a trapezoidal MF (cf. (1.2)), as it better represents the character of our data. We have classified data from a training subset according to the fuzzy rule-based classifier S_1 . As we mentioned earlier, in our experiment we used a three-class problem for two features: x_1 – area and x_2 – minor axis length (shown in Fig. 1.3).

Thanks to the use of the fuzzy rule-based classifier S_1 , we can classify a new object (depicted as a magenta square in Fig. 1.4) from unknown class? to class2. After a comparison with the real image object, we can conclude that the classified object, in fact, belongs to class2. This confirms that we can use the single winner-based fuzzy reasoning method for our pattern classification (see Fig. 1.4).

In a multi-objective fuzzy rule-based classifier design, the accuracy of classifiers is not viewed as a factor related to interpretability. This is because accuracy is handled as a separate goal from interpretability in a multi-objective fuzzy rule-based classifier design. However, the accuracy of the winner rule seems to be an important factor, related to the explanation capacity for fuzzy rule-based classifiers [19].

Now, we show the use of a fuzzy rule-based classifier with three rules for our three-class problem, where:

S_2 : fuzzy rule-based classifier with three fuzzy rules [19]

R_{123} : If x_1 is *small* then Class2 with 1.0,

R_{456} : If x_1 is *medium* then Class2 with 1.0,

R_{789} : If x_1 is *large* then Class3 with 1.0,

For this purpose we have chosen the fuzzy rule-based classifier S_2 . As we have mentioned earlier, in our second experiment we used a three-class problem for two features: x_1 – minor axis length and x_2 – Zernike moment Z_{00} . We used a trapezoidal MF because the data are not normalised to the interval $[0,1]$, according to the assumption from the fuzzy rules definition. We use the same classes (class1 - horizontal line, class2 - caret and class3 - vertical line). As it is shown in Fig. 1.5, the three rules are enough to separate the objects described by real data.

Through the use of the fuzzy rule-based classifier S_2 , we can classify a new object (depicted as a magenta square in Fig. 1.6) from unknown class? to class2. After a comparison with the real image object, we can conclude that the classified object in fact belongs to class2. This confirms that we can use a single winner-based fuzzy reasoning method for our pattern classification (see Fig. 1.6).

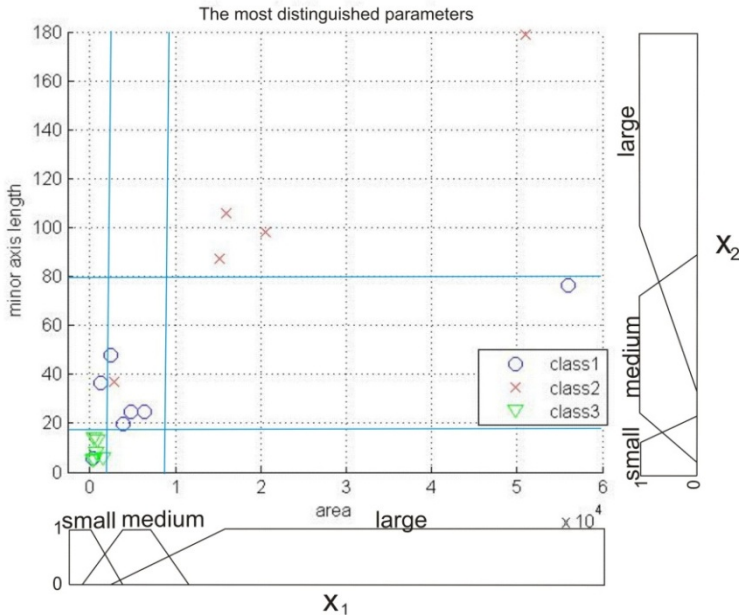


Fig. 1.3 Three-class problem for two features: x_1 - minor axis length and x_2 - area.

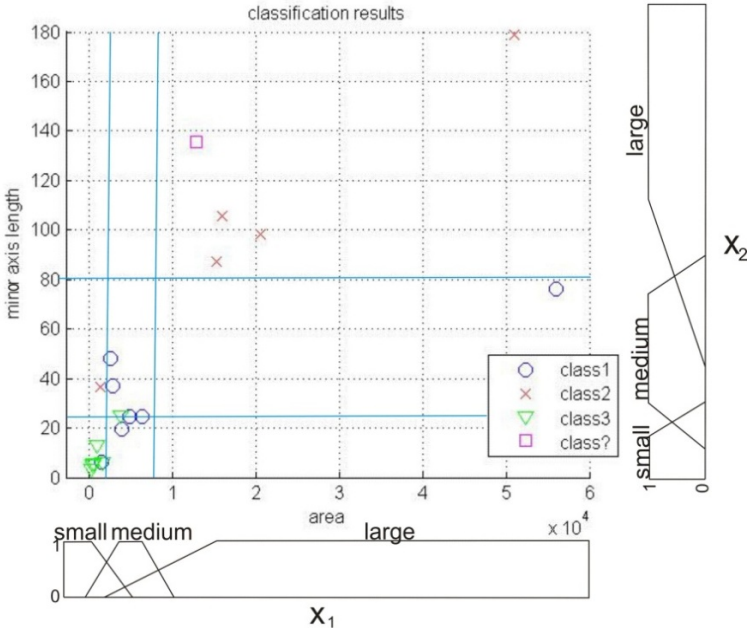


Fig. 1.4 The magenta square is a classified element for the fuzzy rule classifier S1 with 9 rules.

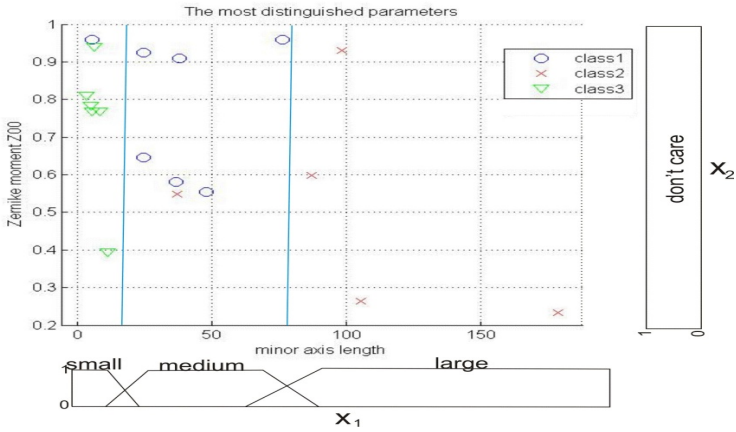


Fig. 1.5 Classification with three fuzzy rules S2

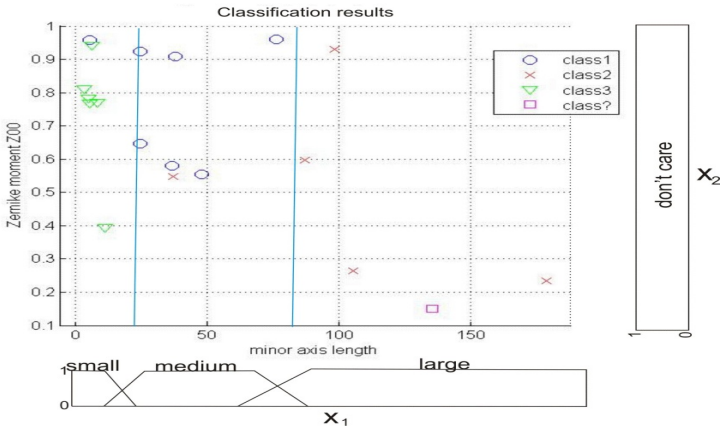


Fig. 1.6 Classification results for a classifier with three fuzzy rules S2

1.5 Further Use of Classified Objects in CBIR

Therefore, we have to classify objects in order to [21]:

1. use particular classes as patterns. We store these data in DB to use them in CBIR algorithms.
2. specify a spatial object location in our system. In our system spatial object location in an image is used as the global feature. The object's mutual spatial relationship is calculated based on the algorithm adopted from the concept of principal component analysis (PCA), proposed by Chang and Wu [14] and later modified by Guru and Punitha [15], to determine the first principal component vectors (PCVs).
3. to help the user ask a query in GUI. The user chooses for a query graphical objects semantically collected in groups.
4. compare image objects coming from the same class as a stage in the image retrieval process. Let a query be an image I_q , such as $I_q = \{o_{q1}, o_{q2}, \dots, o_{qn}\}$. An image in the database will be denoted as I_b , $I_b = \{o_{b1}, o_{b2}, \dots, o_{bm}\}$. In order to answer the query, represented by I_q , we compare it with each image I_b in DB. We determine the similarity between vectors of their signatures. Next, we find the spatial similarity between their PCVs. Later, we proceed to the final step, namely, we compare the similarity of the objects representing both images I_q and I_b , respectively between objects of the same class.

1.6 Conclusions

In this chapter, first we have determined the ability of fuzzy sets and fuzzy rule-based classifiers to classify graphical objects in our CBIR system. We have shown an example of classification based on nine and three fuzzy rules according to the