Valery A. Petrushin
Latifur Khan (Eds)

Multimedia Data Mining and Knowledge Discovery

Springer

Valery A. Petrushin and Latifur Khan (Eds)

Multimedia Data Mining and Knowledge Discovery

Springer

E2007000938

Valery A. Petrushin, MS, PhD
Accenture Technology Labs
Accenture Ltd
161 N. Clark St.
Chicago, IL 60601, USA

Latifur Khan, BS, MS, PhD
EC 31
2601 N. Floyd Rd.
Richardson, TX 75080-1407, USA

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2006924373

ISBN-10: 1-84628-436-8 Printed on acid-free paper
ISBN-13: 978-1-84628-436-6

9 8 7 6 5 4 3 2 1

Springer Science+Business Media
springer.com

Preface

In recent years we witnessed the real revolution in media recordings and storage. Because of advances in electronics, computing engineering, storage manufacturing, and networking, the market is flooded with cheap computers, mass memory, camera phones, and electronic devices for digitizing and producing visual and audio information. Ten years ago only a professional studio could create an audio CD or a DVD, but today everybody can do it, using a home computer. Under threat of the digital expansion, the entertainment, show, and education industries started changing their business models. Tomorrow nobody will be surprised to find that a personal computer has a terabyte hard disk and four gigabyte RAM. This phenomenon has made corporate, public, and personal multimedia repositories widespread and fast growing. Currently, there are some commercial tools for managing and searching multimedia audio and image collections, but the need for tools to extract hidden useful knowledge embedded within multimedia collections is becoming pressing and central for many decision-making applications. The tools needed today are tools for discovering relationships between objects or segments within images, classifying images on the basis of their content, extracting patterns in sound, categorizing speech and music, recognizing and tracking objects in video streams, etc.

Today data mining efforts are going beyond the databases to focusing on data collected in fields like art, design, hypermedia, and digital media production, medical multimedia data analysis and computational modeling of creativity, including evolutionary computation. These fields use variety of data sources and structures, interrelated by the nature of the phenomenon. As a result there is an increasing interest in new techniques and tools that can detect and discover patterns that can lead to a new knowledge in the problem domain, where the data have been collected. There is also an increasing interest in the analysis of multimedia data generated by different distributed applications, like collaborative virtual environments, virtual communities, and multiagent systems. The data collected from such environments include record of the actions in them, audio and video recordings of meetings and collaborative sessions, variety of documents that are part of the business process, asynchronous threaded discussions, transcripts from synchronous communications, and other data records. These heterogeneous multimedia data records require sophisticated

preprocessing, synchronization, and other transformation procedures before even getting to the analysis stage.

On the other hand, researchers in multimedia information systems, in the search for techniques for improving the indexing and retrieval of multimedia information are looking into new methods for discovering indexing information. Variety of techniques from machine learning, statistics, databases, knowledge acquisition, data visualization, image analysis, high performance computing, and knowledge-based systems, have been used mainly as a research handcraft activity. The development of ontologies and vocabularies for multimedia data fosters the adoption and merging with the Semantic Web technology. The emerging international standards for multimedia content description (MPEG-7) and multimedia resources delivery and usage (MPEG-21) promise to expedite the progress in the field giving a uniform data representation and the open multimedia framework.

This book is based mostly on extended and updated papers that have been presented at the two Multimedia Data Mining Workshops—MDM KDD 2003 and MDM KDD 2004 that held in conjunction with the ACM SIGKDD Conference in Washington, DC, August 2003 and the ACM SIGKDD Conference in Seattle, WA, August 2004, respectively. The book also includes several invited surveys and papers. The book chapters give a snapshot of research and applied activities in the multimedia data mining.

The editors are grateful to the founders and active supporters of the Multimedia Data Mining Workshop Series Simeon Simoff, Osmar Zaiane, and Chabane Djeraba. We also thank the reviewers of book papers for their well-done job and organizers of ACM SIGKDD Conferences for their support.

We thank the Springer-Verlag's employees Wayne Wheeler, who initiated the book project, Catherine Brett, and Frank Ganz for their help in coordinating the publication and editorial assistance.

Chicago, IL
Dallas, TX
January 2006

Valery A. Petrushin
Latifur Khan

List of Contributors

Nitin Agarwal
Department of Computer Science and Engineering
Arizona State University
Tempe, AZ 82857
USA
nitin.agarwal@asu.edu

Muhammad A. Ahmad
Rochester Institute
of Technology
102 Lomb Memorial Drive
Rochester, NY 14623-5608
USA
maa2454@cs.rit.edu

Sergio A. Alvarez
Computer Science Department
Boston College
Chestnut Hill, MA 02467
USA
alvarez@cs.bc.edu

Marie-Aude Aufaure
Computer Science Department
SUPELEC
Plateau du Moulon
3, rue Joliot Curie
F-91 192 Gif-sur-Yvette Cedex
France
Marie-Aude.Aufaure@supelec.fr

Robert P. Biuk-Aghai
Faculty of Science and Technology
University of Macau
Avenida Padre Tomás Pereira, S.J.
Taipa
Macau S.A.R.
China
robertb@umac.mo

Fatma Bouali
LIFL UMR CNRS 8022
France
Fatma.Bouali@univ-lille2.fr

Marinette Bouet
LIMOS – UMR 6158 CNRS
Blaise Pascal University of
Clermont-Ferrand II
Campus des Cézeaux 24, avenue des Landais
F-63173 Aubiere Cedex
France
Marinette.Bouet@cust.univ-bpclermont.fr

Stefan Brecheisen
Institute for Computer Science
University of Munich
Oettingenstr. 67, 80538 Munich,
Germany
brecheis@dbs.ifi.lmu.de

K. Selcuk Candan
Department of Computer Science and Engineering
Arizona State University, Tempe, AZ 82857
USA
candan@asu.edu

Min Chen
Distributed Multimedia Information System Laboratory
School of Computing & Information Sciences
Florida International University
Miami, FL 33199
USA
mchen005@cs.fiu.edu

Shu-Ching Chen
Distributed Multimedia Information System Laboratory
School of Computing & Information Sciences
Florida International University
Miami, FL 33199
USA
chens@cs.fiu.edu

Charles Daniel
Pennsylvania State University – Harrisburg
Middletown, PA 17057
USA

Marten J. den Uyl
VicarVision b.v.
Singel 160, 1015 AH
Amsterdam
The Netherlands
denuyl@vicarvision.nl

Qin Ding
Pennsylvania State University – Harrisburg
Middletown, PA 17057
USA
qding@psu.edu

Chabane Djeraba
LIFL – UMR USTL CNRS 8022
Universite de Lille1, Bât. M3
59655 Villeneuve d'Ascq Cedex
France
djeraba@lifl.fr

Jianping Fan
Dept of Computer Science
University of North Carolina – Charlotte
Charlotte, NC 28223
USA
jfan@uncc.edu

Farshad Fotouhi
Department of Computer Science
Wayne State University
Detroit, MI 48202
USA
fotouhi@wayne.edu

Roger Gaborski
Rochester Institute of Technology
102 Lomb Memorial Drive
Rochester, NY 14623-5608
USA
rsg@cs.rit.edu

Yuli Gao
Dept of Computer Science
University of North Carolina – Charlotte
Charlotte, NC 28223
USA
ygao@uncc.edu

Anatole V. Gershman
Accenture Technology Labs
Accenture Ltd.
161 N. Clark St.
Chicago, IL 60601
USA
anatole.v.gershman@accenture.com

William Grosky
Department of Computer and Information Science
University of Michigan – Dearborn
Dearborn, MI 48128
USA
wgrosky@umich.edu

Dimitrios Gunopulos
Computer Science & Engineering Department
University of California, Riverside
Riverside, CA 92521
USA
dg@cs.ucr.edu

Amaury Hazan
Music Technology Group
Pompeu Fabra University
Ocata 1, 08003 Barcelona
Spain
ahazan@iua.upf.es

Koichi Ideno
Graduate School of Science and Technology
Kobe University,
Nada, Kobe, 657-8501
Japan
ideno@ai.cs.scitec.kobe-u.ac.jp

Menno Israël
ParaBot Services b.v.
Singel 160, 1015 AH Amsterdam
The Netherlands
m.israel@parabots.nl

James M. Kang
Department of Computer Science and Engineering
University of Minnesota
Minneapolis, MN 55455
USA
jkang@cs.umn.edu

Takeshi Kawato
Computer Science Department
Worcester Polytechnic Institute
Worcester, MA 01609
USA
takeshi@wpi.edu

Eamonn Keogh
Computer Science & Engineering Department
University of California, Riverside
Riverside, CA 92521
USA
eamonn@cs.ucr.edu

Latifur Khan
Department of Computer Science
University of Texas at Dallas
75083 Richardson, Texas
USA
lkhan@utdallas.edu

Jong Wook Kim
Department of Computer Science and Engineering
Arizona State University
Tempe, AZ 82857
USA
jong@asu.edu

Hans-Peter Kriegel
Institute for Computer Science
University of Munich
Oettingenstr. 67,
80538 Munich
Germany
kriegel@dbs.ifi.lmu.de

Peer Kröger
Institute for Computer Science
University of Munich
Oettingenstr. 67, 80538 Munich,
Germany
kroegerp@dbs.ifi.lmu.de

Chuanjun Li
Department of Computer Science
The University of Texas at Dallas
Richardson, Texas 75083
USA
chuanjun@utdallas.edu

Xin Li
Department of Computer Science
Oklahoma City University
Oklahoma City
OK 73106
USA
xinli@okcu.edu

Jessica Lin
Department of Information and Software Engineering,
George Mason University
Fairfax, VA 22030
USA
jessica@ise.gmu.edu

Huan Liu
Department of Computer Science and Engineering
Arizona State University
Tempe, AZ 82857
USA
huan.liu@asu.edu

Hangzai Luo
Dept of Computer Science
University of North Carolina – Charlotte
Charlotte, NC 28223
USA
hluo@uncc.edu

Libor Machala
Department of Experimental Physics
Palacky University
Svobody 26
779 00 Olomouc
Czech Republic
machala@sloup.upol.cz

Esteban Maestre
Music Technology Group
Pompeu Fabra University
Ocata 1, 08003 Barcelona, Spain
emaestre@iua.upf.es

Sylvain Mongy
LIFL – UMR USTL CNRS 8022
Universite de Lille1, Bât. M3
59655 Villeneuve d'Ascq Cedex
France
mongy@lifl.fr

Clark F. Olson
Computing and Software Systems
University of Washington, Bothell
18115 Campus Way NE
Campus Box 358534
Bothell, WA 98011-8246
USA
cfolson@u.washington.edu

Nilesh Patel
Department of Computer and Information Science
University of Michigan – Dearborn
Dearborn, MI 48128
USA
patelnv@umich.edu

Valery A. Petrushin
Accenture Technology Labs
Accenture Ltd.
161 N. Clark St.
Chicago, IL 60601
USA
valery.a.petrushin@accenture.com

Martin Pfeifle
Institute for Computer Science
University of Munich
Oettingenstr. 67
80538 Munich
Germany
pfeifle@dbs.ifi.lmu.de

Balakrishnan Prabhakaran
Department of Computer Science
University of Texas at Dallas,
75083 Richardson, Texas
USA
praba@utdallas.edu

Pavel Praks
Department of Mathematics and Descriptive Geometry
Department of Applied Mathematics
VSB – Technical University of Ostrava
17 Listopadu 15, 708 33 Ostrava,
Czech Republic
pavel.praks@vsb.cz

Daniela Stan Raicu
Intelligent Multimedia Processing Laboratory
School of Computer Science, Telecommunications, and Information Systems (CTI)
DePaul University
Chicago, Illinois
USA
draicu@cs.depaul.edu

Rafael Ramirez
Music Technology Group
Pompeu Fabra University
Ocata 1
08003 Barcelona
Spain
rafael@iua.upf.es

Carolina Ruiz
Computer Science Department
Worcester Polytechnic Institute
Worcester, MA 01609
USA
ruiz@cs.wpi.edu

Matthias Schubert
Institute for Computer Science
University of Munich
Oettingenstr. 67,
80538 Munich
Germany
schubert@dbs.ifi.lmu.de

Xavier Serra
Music Technology Group
Pompeu Fabra University
Ocata 1, 08003 Barcelona
Spain
xserra@iua.upf.es

Ishwar K. Sethi
Department of Computer Science and Engineering
Oakland University
Rochester, MI 48309
USA
isethi@oakland.edu

Kimiaki Shirahama
Graduate School of Science and Technology
Kobe University
Nada, Kobe 657-8501
Japan
kimi@ai.cs.scitec.kobe-u.ac.jp

Mei-Ling Shyu
Department of Electrical and Computer Engineering
University of Miami
Coral Gables, FL 33124
USA
shyu@miami.edu

Simeon J. Simoff
Faculty of Information Technology
University of Technology,
Sydney
P.O. Box 123
Broadway NSW 2007
Australia
simeon@it.uts.edu.au

Vaclav Snasel
Department of Computer Science
VSB - Technical University of Ostrava
17 Listopadu 15, 708 33 Ostrava
Czech Republic
vaclav.snasel@vsb.cz

Reshma Suvarna
Department of Computer Science and Engineering
Arizona State University
Tempe, AZ 82857, USA
reshma.suvarna@asu.edu

Ankur Teredesai
Rochester Institute of Technology
102 Lomb Memorial Drive
Rochester, NY 14623-5608, USA
amt@cs.rit.edu

Kuniaki Uehara
Graduate School of Science and Technology
Kobe University
Nada, Kobe 657-8501
Japan
uehara@ai.cs.scitec.kobe-u.ac.jp

Egon L. van den Broek
Center for Telematics and Information Technology (CTIT) and
Institute for Behavioral Research (IBR)
University Twente
P.O. box 217, 7500 AE Enschede,
The Netherlands
e.l.vandenbroek@utwente.nl

Peter van der Putten
LIACS
University of Leiden
P.O. Box 9512
2300 RA Leiden
The Netherlands
putten@liacs.nl

Michail Vlachos
IBM T. J. Watson Research Center
Hawthorne, NY 10532
USA
vlachos@ibm.com

Lei Wang
Department of Computer Science
University of Texas at Dallas,
75083 Richardson, Texas
USA
leiwang@utdallas.edu

Gang Wei
Accenture Technology Labs
Accenture Ltd.
161 N. Clark St.
Chicago, IL 60601
USA
gang.wei@accenture.com

Chengcui Zhang
Department of Computer & Information Science
University of Alabama at Birmingham
Birmingham, AL 35294-1170
USA
zhang@cis.uab.edu

Ruofei Zhang
Computer Science Department
Watson School
SUNY Binghamton
Binghamton, NY, 13902-6000
USA
rzhang@cs.binghamton.edu

Zhongfei (Mark) Zhang
Computer Science Department
Watson School,
SUNY Binghamton
Binghamton, NY 13902-6000
USA
zhongfei@cs.binghamton.edu

Arthur Zimek
Institute for Computer Science
University of Munich
Oettingenstr. 67, 80538 Munich
Germany
zimek@dbs.ifi.lmu.de

Contents

Preface ..... **xvii**

List of Contributors ..... **xix**

Part I. Introduction

1. Introduction into Multimedia Data Mining and Knowledge Discovery **3**
Valery A. Petrushin
1.1 What Is Multimedia Data Mining? 3
1.2 Who Does Need Multimedia Data Mining? 5
1.3 What Shall We See in the Future? 8
1.4 What Can You Find in This Book? 8
References 12

2. Multimedia Data Mining: An Overview **14**
Nilesh Patel and Ishwar Sethi
2.1 Introduction 14
2.2 Multimedia Data Mining Architecture 15
2.3 Representative Features for Mining 18
2.3.1 Feature Fusion 21
2.4 Supervised Concept Mining 21
2.4.1 Annotation by Classification 21
2.4.2 Annotation by Association 23
2.4.3 Annotation by Statistical Modeling 24
2.5 Concept Mining Through Clustering 25
2.6 Concept Mining Using Contextual Information 27
2.7 Events and Feature Discovery 29
2.8 Conclusion 33
References 33

Part II. Multimedia Data Exploration and Visualization

3. A New Hierarchical Approach for Image Clustering **41**
Lei Wang and Latifur Khan
3.1 Introduction 41
3.2 Related Works 42
3.3 Hierarchy Construction and Similarity Measurement 43
3.3.1 Object Clustering 44
3.3.2 Vector Model for Images 47
3.3.3 Dynamic Growing Self-Organizing Tree (DGSOT) Algorithm .. 47
3.4 Experiment Results 52
3.5 Conclusion and Future Works 54
References 55

4. Multiresolution Clustering of Time Series and Application to Images **58**
Jessica Lin, Michail Vlachos, Eamonn Keogh, and Dimitrios Gunopulos
4.1 Introduction 58
4.2 Background and Related Work 59
4.2.1 Background on Clustering 59
4.2.2 Background on Wavelets 61
4.2.3 Background on Anytime Algorithms 62
4.2.4 Related Work 62
4.3 Our Approach—the *ik-means* Algorithm 62
4.3.1 Experimental Evaluation on Time Series 64
4.3.2 Data Sets and Methodology 65
4.3.3 Error of Clustering Results 65
4.3.4 Running Time 68
4.4 *ik-means* Algorithm vs. *k-means* Algorithm 69
4.5 Application to Images 71
4.5.1 Clustering Corel Image Data sets 74
4.5.2 Clustering Google Images 75
4.6 Conclusions and Future Work 77
Acknowledgments 77
References 77

5. Mining Rare and Frequent Events in Multi-camera Surveillance Video **80**
Valery A. Petrushin
5.1 Introduction 80
5.2 Multiple Sensor Indoor Surveillance Project 82
5.3 Data Collection and Preprocessing 83
5.4 Unsupervised Learning Using Self-Organizing Maps 86
5.4.1 One-Level Clustering Using SOM 86

5.4.2 Two-Level Clustering Using SOM 89
5.4.3 Finding Unusual Events 90
5.5 Visualization Tool 91
5.6 Summary 92
References 92

6. Density-Based Data Analysis and Similarity Search 94
Stefan Brecheisen, Hans-Peter Kriegel, Peer Kröger, Martin Pfeifle, Matthias Schubert, and Arthur Zimek
6.1 Introduction 94
6.2 Hierarchical Clustering 96
6.3 Application Ranges 98
6.3.1 Data Analysis 98
6.3.2 Navigational Similarity Search 100
6.4 Cluster Recognition for OPTICS 100
6.4.1 Recent Work 101
6.4.2 Gradient Clustering 102
6.4.3 Evaluation 106
6.5 Extracting Cluster Hierarchies for Similarity Search 108
6.5.1 Motivation 108
6.5.2 Basic Definitions 109
6.5.3 Algorithm 110
6.5.4 Choice of ε in the i-th Iteration 112
6.5.5 The Extended Prototype CLUSS 113
6.6 Conclusions 114
References 114

7. Feature Selection for Classification of Variable Length Multiattribute Motions 116
Chuanjun Li, Latifur Khan, and Balakrishnan Prabhakaran
7.1 Introduction 116
7.2 Related Work 118
7.3 Background 120
7.3.1 Support Vector Machines 120
7.3.2 Singular Value Decomposition 121
7.4 Feature Vector Extraction Based on SVD 123
7.4.1 SVD Properties of Motion Data 123
7.4.2 Feature Vector Extraction 125
7.5 Classification of Feature Vectors Using SVM 127
7.6 Performance Evaluation 128
7.6.1 Hand Gesture Data Generation 128
7.6.2 Motion Capture Data Generation 128
7.6.3 Performance Evaluation 129
7.6.4 Discussion 133
7.7 Conclusion 135

Acknowledgments 136
References 136

Part III. Multimedia Data Indexing and Retrieval

8. FAST: Fast and Semantics-Tailored Image Retrieval 141
Ruofei Zhang and Zhongfei (Mark) Zhang
8.1 Introduction 141
8.2 Fuzzified Feature Representation and Indexing Scheme 144
8.2.1 Image Segmentation 144
8.2.2 Fuzzy Color Histogram for Each Region 146
8.2.3 Fuzzy Representation of Texture and Shape for Each Region 147
8.2.4 Region Matching and Similarity Determination 148
8.3 Hierarchical Indexing Structure and HEAR Online Search 150
8.4 Addressing User's Subjectivity Using ITP and ARWU 153
8.5 Experimental Evaluations 157
8.6 Conclusions 165
References 165

9. New Image Retrieval Principle: Image Mining and Visual Ontology 168
Marinette Bouet and Marie-Aude Aufaure
9.1 Introduction 168
9.2 Content-Based Retrieval 170
9.2.1 Logical Indexation Process 171
9.2.2 Retrieval Process 172
9.3 Ontology and Data Mining Against Semantics Lack in Image Retrieval 173
9.3.1 Knowledge Discovery in Large Image Databases 174
9.3.2 Ontologies and Metadata 175
9.4 Toward Semantic Exploration of Image Databases 176
9.4.1 The Proposed Architecture 176
9.4.2 First Experimentations 179
9.5 Conclusion and Future Work 181
References 182

10. Visual Alphabets: Video Classification by End Users 185
Menno Israël, Egon L. van den Broek, Peter van der Putten, and Marten J. den Uyl
10.1 Introduction 185
10.2 Overall Approach 186
10.2.1 Scene Classification Procedure 187

10.2.2 Related Work 187
10.2.3 Positioning the Visual Alphabet Method 189
10.3 Patch Features 189
10.3.1 Distributed Color Histograms 190
10.3.2 Histogram Configurations 190
10.3.3 Human Color Categories 191
10.3.4 Color Spaces 191
10.3.5 Segmentation of the HSI Color Space 192
10.3.6 Texture 193
10.4 Experiments and Results 194
10.4.1 Patch Classification 195
10.4.2 Scene Classification 196
10.5 Discussion and Future Work 197
10.6 Applications 198
10.6.1 Vicar 199
10.6.2 Porn Filtering 200
10.6.3 Sewer Inspection 201
10.7 Conclusion 203
Acknowledgments 203
References 203

Part IV. Multimedia Data Modeling and Evaluation

11. Cognitively Motivated Novelty Detection in Video Data Streams 209
James M. Kang, Muhammad Aurangzeb Ahmad, Ankur Teredesai, and Roger Gaborski
11.1 Introduction 209
11.2 Related Work 211
11.2.1 Video Streams 211
11.2.2 Image Novelty 212
11.2.3 Clustering Novelty in Video Streams 212
11.2.4 Event vs. Novelty Clustering 213
11.3 Implementation 213
11.3.1 Machine-Based Process 213
11.3.2 Human-Based System 217
11.3.3 Indexing and Clustering of Novelty 220
11.3.4 Distance Metrics 223
11.4 Results 225
11.4.1 Clustering and Indexing of Novelty 225
11.4.2 Human Novelty Detection 228
11.4.3 Human vs. Machine 228
11.5 Discussion 229
11.5.1 Issues and Ideas 229