

SpringerBriefs in Computer Science

Series editors

Stan Zdonik, Brown University, Providence, Rhode Island, USA

Shashi Shekhar, University of Minnesota, Minneapolis, Minnesota, USA

Xindong Wu, University of Vermont, Burlington, Vermont, USA

Lakhmi C. Jain, University of South Australia, Adelaide, South Australia, Australia

David Padua, University of Illinois Urbana-Champaign, Urbana, Illinois, USA

Xuemin (Sherman) Shen, University of Waterloo, Waterloo, Ontario, Canada

Borko Furht, Florida Atlantic University, Boca Raton, Florida, USA

V.S. Subrahmanian, University of Maryland, College Park, Maryland, USA

Martial Hebert, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA

Katsushi Ikeuchi, University of Tokyo, Tokyo, Japan

Bruno Siciliano, Università di Napoli Federico II, Napoli, Italy

Sushil Jajodia, George Mason University, Fairfax, Virginia, USA

Newton Lee, Newton Lee Laboratories, LLC, Tujunga, California, USA

More information about this series at <http://www.springer.com/series/10028>

Ilaiah Kavati · Munaga V.N.K. Prasad
Chakravarthy Bhagvati

Efficient Biometric Indexing and Retrieval Techniques for Large-Scale Systems

Ilaiah Kavati
MLR Institute of Technology
Hyderabad, Andhra Pradesh
India

Chakravarthy Bhagvati
University of Hyderabad
Hyderabad, Andhra Pradesh
India

Munaga V.N.K. Prasad
Institute for Development and Research
in Banking Technology
Hyderabad, Andhra Pradesh
India

ISSN 2191-5768
SpringerBriefs in Computer Science
ISBN 978-3-319-57659-6
DOI 10.1007/978-3-319-57660-2

ISSN 2191-5776 (electronic)
ISBN 978-3-319-57660-2 (eBook)

Library of Congress Control Number: 2017939089

© The Author(s) 2017

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.

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.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To My Family and Teachers

Preface

In our daily life, we use certain characteristics of people such as facial features, voice, gait, etc., to recognize people who are familiar to us. Automatic identification of the people by the use of their physiological (such as face, fingerprint, iris, hand geometry, etc.) and/or behavioral (such as voice, signature, gait, etc.) characteristics is called biometrics. As biometric characteristics are distinctive, cannot be forgotten or lost, and the person to be authenticated needs to be physically present at the point of access, biometric-based identification systems are gaining popularity and deployed in many important applications. In biometric identification systems, the identity corresponding to a query image is determined by sequentially matching it against all enrolled images in the database. Typically this approach works well for small databases. However, in real-life scenarios, size of biometric databases are usually high (e.g., Unique Identification Authority of India) and this sequential search makes the identification process extremely slow and computationally expensive. Efficient indexing techniques are required that enable searches over large databases in real time without compromising accuracy. Three different indexing techniques are designed, developed, tested, and described in this book.

The fundamentals of biometric recognition, importance of indexing techniques in large-scale biometric systems and their challenges, current developments and benchmarking are discussed in Chap. 1. An efficient triangulation based indexing technique for minutiae based biometrics especially for fingerprints is described in Chap. 2. This technique use an efficient representation named extended Delaunay triangulation for the fingerprints to make the system robust against distortions. Further, the extended triangulation is classified based on the type of minutiae at the vertices of each triangle. Such classification provides better partitioning of the database, leading to a significant decrease in the number of potential matches during identification. Chapter 3 discusses an indexing technique using match scores. For each image in the database, its match scores (i.e., index code) against a set of pre-selected sample images are calculated. Then a new storage mechanism is designed for the biometric databases. Like traditional database records, the biometric images are arranged in sorted order based on their scores. A set of images which are very similar to query are retrieved during identification using a voting

scheme. This results in a rapid search that takes constant time, i.e., independent of the database sizes.

A novel clustering based indexing technique using decision-level fusion is described in Chap. 4. An adaptive clustering algorithm is used that computes set of clusters in the database where each cluster is represented with an image called a ‘leader’. The set of leaders is used to compute the index code. During identification, a list of similar candidates is retrieved from the clusters as well as index table. This approach retrieves multiple evidences for identification with minimal resources. Conclusions and future scope of this work are discussed in Chap. 5. This book explores new and efficient storing structures for the biometric databases. The designed indexing approaches identify a query in less time with high level of confidence. Further, the proposed storage mechanisms prove to be effective for fast and accurate retrieval. It is suggested that future work can be done in the following areas:

- All of the existing indexing approaches are experimented over the databases which are relatively small because of the unavailability of the large biometric databases for the researchers. Hence, creating and experimenting with these techniques on such large databases may be a challenging problem.
- Securing the biometric data from theft is also another important research topic in the area of biometrics due to the limited availability of the biometric traits. Further, computing the cancelable index codes for biometric identification is also a challenging problem.

Acknowledgements

“I’ve been blessed to find people who are smarter than I am, and they help me to execute the vision I have.”—Russell Simmons

First and above all, I praise God, the almighty for providing me this opportunity and granting me the capability to proceed successfully.

Foremost, I would like to thank my advisors, Dr. MVNK Prasad and Prof. Chakravarthy Bhagvati, for their invaluable guidance and encouragement throughout my research work. My sincere thanks to Prof. Arun K. Pujari, Dean, and all the faculty members of SCIS, UoH for their encouragement and helpful suggestions. I would like to acknowledge the financial support of IDRBT (Established by RBI), Hyderabad for my doctoral study.

I would like to express my sincere gratitude to all my teachers. Without their support and encouragement, it would not have been possible for me to continue the studies and do this research. Their hard work and positive attitude is my main source of inspiration. I wish to convey my special thanks to my friends, co-researchers for their constant support and help during this journey.

Nothing would have been possible without the moral support of my parents, brothers, and sisters who have been the pillars of strength in all my endeavors. I am always deeply indebted to them for all that they had given me. I am thankful to my wife Devi, without whom it would have been impossible for me to finish this work. I really have no words to express my gratitude for all her support, encouragement, understanding, and sacrifice. Finally, I am grateful to my children Rithvik and Nithya for allowing me to snatch their time and spending it in endless hours of research work.

Contents

- 1 Introduction** 1
 - 1.1 Introduction 1
 - 1.2 Biometric Recognition 3
 - 1.2.1 Verification 3
 - 1.2.2 Identification 5
 - 1.3 Indexing 6
 - 1.3.1 Challenges 7
 - 1.4 Biometric Indexing Techniques 8
 - 1.4.1 Key Feature Point Based Indexing Approaches 9
 - 1.4.2 Triplet-Based Indexing Approaches 10
 - 1.4.3 Match Score Based Indexing Approaches 11
 - 1.4.4 Other Indexing Approaches 12
 - 1.5 Benchmarking in Indexing and Performance Evaluation 12
 - 1.5.1 Databases 14
 - 1.5.2 Performance Metrics 14
 - 1.6 Summary 16
 - References 16
- 2 Hierarchical Decomposition of Extended Triangulation for Fingerprint Indexing** 21
 - 2.1 Introduction 21
 - 2.2 Indexing Framework 22
 - 2.2.1 Minutiae Extraction 22
 - 2.2.2 Computation of Delaunay Triangulation 23
 - 2.2.3 Retrieval of Extended Triplet Set 24
 - 2.2.4 Hierarchical Decomposition of Extended Set 26
 - 2.2.5 Enrollment 26
 - 2.3 Query Identification 30
 - 2.4 Experimental Results 31
 - 2.4.1 Parameter Selection 32

2.4.2	Results	33
2.4.3	Comparison with Other Related Approaches	35
2.4.4	Retrieval Time	37
2.5	Summary	38
	References	39
3	Efficient Score-Based Indexing Technique for Fast Palmprint	
	Retrieval	41
3.1	Introduction	41
3.2	Indexing.	42
3.2.1	Feature Extraction	43
3.2.2	Index Code Computation	43
3.2.3	Index Table Creation and User Enrolment	44
3.3	Retrieval of Best Matches for a Query.	45
3.4	Selection of Sample Images.	46
3.4.1	Max-variance Method.	47
3.4.2	k -Means Clustering.	47
3.5	Experimental Results	47
3.5.1	Neighborhood Size (λ).	47
3.5.2	Selection Rules for Sample Palmprints.	48
3.5.3	Results and Performance Comparison	48
3.5.4	Retrieval Time	50
3.6	Summary	50
	References	50
4	A New Cluster-Based Indexing Technique for Palmprint	
	Databases Using Scores and Decision-Level Fusion	53
4.1	Introduction	53
4.2	Selection of Sample Images.	54
4.3	Indexing.	55
4.4	Query Identification	56
4.4.1	Fusion of Decisions Output	58
4.5	Experimental Results	59
4.5.1	Results	59
4.5.2	Retrieval Time	60
4.5.3	Scalability of the System	60
4.5.4	Effect of Feature Type on the System Performance	60
4.5.5	Comparison with Multi-biometric Systems.	61
4.5.6	Comparison with Other Related Indexing Techniques	63
4.6	Summary	63
	References	64
5	Conclusions and Future Scope.	65
5.1	Salient Features of the Contributions	65
5.2	Future Scope	66

Abbreviations

AMI	Acuity Market Intelligence
ATM	Automatic Teller Machine
<i>B</i> -tree	Binary tree
CCD	Charge Coupled Device
CMC	Cumulative Match Characteristics
DCT	Discrete Cosine Transform
dpi	Dots Per Inch
FBI	Federal Bureau of Investigation
FVC	Fingerprint Verification Competition
<i>FVList</i>	List of Feature Vectors
HR	Hit Rate
IAFIS	Integrated Automated Fingerprint Identification System
<i>I_{id}List</i>	List of Image Identities
<i>k</i> d-tree	<i>k</i> Dimensional tree
<i>kdb</i> -tree	<i>k</i> -dimensional B-tree
K-L	Karhunen–Loève
k-NN	K Nearest Neighbor
LBP	Local Binary Pattern
LSH	Locality Sensitive Hashing
MBC	Minutiae Binary Code
MCC	Minutiae Cylindric Code
MR	Miss Rate
PCA	Principal Component Analysis
PolyU	Hong Kong Polytechnic University
PR	Penetration Rate
SIFT	Scale-Invariant Feature Transform
SURF	Speed-Up Robust Features
UIDAI	Unique Identification Authority of India
USD	United States Dollar
VA+	Vector Approximation +

List of Figures

Fig. 1.1	Personal authentication techniques: a Traditional methods such as identity cards, Passwords, etc., b Biometric characteristics [16].	2
Fig. 1.2	Different biometric traits for personal recognition	4
Fig. 1.3	Different modes of operation of a generic biometric system [16]	5
Fig. 1.4	Acuity Market Intelligence (AMI) Report.	6
Fig. 1.5	Process of Biometric identification using indexing approach [16]	7
Fig. 2.1	Overview of the proposed approach.	22
Fig. 2.2	a A sample fingerprint b Retrieved minutiae (<i>circle</i> - bifurcation points; <i>square</i> - endpoints)	23
Fig. 2.3	Minutiae position and its orientation extraction process	23
Fig. 2.4	Triangulation for a sample fingerprint [22]: a Delaunay triangulation; b Structure of the Delaunay triangulation after missing a minutiae point (missing minutiae is shown with star); c Extended triangulation.	23
Fig. 2.5	Minutiae triangle.	27
Fig. 2.6	Relative orientation of a minutiae [22].	27
Fig. 2.7	a Proposed 3D Index space (<i>ISPACE</i>) structure, b Process of enrolling a triplet into the <i>ISPACE</i> : A triplet with index (4, 50, 65) is stored into the (50, 65)th location (shown with color) of the 4th partition in the <i>ISPACE</i> , where f is the feature vector of the triplet and x is its image identity	29
Fig. 2.8	Range of locations considered in the <i>ISPACE</i> , to retrieve the similar triplets for a query triplet	31
Fig. 2.9	Effect of neighborhood size on the indexing performance for FVC 2002 databases.	33
Fig. 2.10	Effect of neighborhood size on the indexing performance for FVC 2004 databases.	34

Fig. 2.11	Performance of the proposed indexing approach on FVC 2002 databases	35
Fig. 2.12	Performance of the proposed indexing approach on FVC 2004 databases	36
Fig. 2.13	Comparison of the proposed approach with other approaches over FVC 2002 Databases	37
Fig. 2.14	Comparison of the proposed approach with other approaches over FVC 2004 Databases	38
Fig. 3.1	Overview of the proposed approach.	43
Fig. 3.2	Index code computation process	44
Fig. 3.3	Performance of the system using different selection rules for representative images over PolyU database	49
Fig. 4.1	Overview of the proposed indexing approach	54
Fig. 4.2	Selection of sample images.	55
Fig. 4.3	Retrieval of similar palmprints for a query	57
Fig. 4.4	Performance of the proposed approach.	59
Fig. 4.5	Performance of the proposed approach for different number of users	61
Fig. 4.6	Performance of the proposed indexing approach with different features	61
Fig. 4.7	Comparison of the proposed approach with multi-biometric systems	62

List of Tables

Table 1.1	Key feature point based indexing approaches	10
Table 1.2	Triplet-based indexing approaches	11
Table 1.3	Match score based indexing approaches.	12
Table 1.4	Other indexing approaches.	13
Table 1.5	Characteristics of the databases used in the experiments	15
Table 2.1	Hierarchical decomposition of extended triangles	26
Table 2.2	Effect of neighborhood size on the indexing performance	33
Table 2.3	Optimum neighborhood size (λ) obtained for different databases.	34
Table 2.4	PR and HR (i.e., $HR = 100 - MR$) of the proposed system at $MR = PR$ for different databases.	36
Table 3.1	Palmprints are arranged in ascending order of their scores against sample palmprint	42
Table 3.2	Index table consists of $k + 1$ columns where the first column is the key and remaining k columns are corresponding to one palmprint of the sample set	44
Table 3.3	Effect of neighborhood size λ on indexing performance.	48
Table 3.4	PR (%) of the system at maximum HR (%) achieved using different techniques	49
Table 4.1	Index table consists of $k + 1$ columns, where the first column is the key and remaining k columns are corresponding to one palmprint of the sample set	56
Table 4.2	PR (%) of the system at 100% HR	60
Table 4.3	PR (%) of the system at maximum HR (%) achieved using different techniques	63