
Encyclopedia of Biometrics

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Editors

Encyclopedia of Biometrics

Second Edition

With 823 Figures and 102 Tables

 **Springer** Reference

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Preface to the Second Edition

The *Encyclopedia of Biometrics* provides a comprehensive reference to concepts, definitions, technologies, challenges, and trends in the field of biometrics. The volume covers all important aspects in biometrics research, development, and applications, including sensors and devices, methods and algorithms, sample quality, system design and implementation, databases, performance testing, security, antispooofing, and standards.

The second edition consists of over 250 in-depth articles contributed by about 300 leading biometric experts around the world. Major updates in the first edition, published in 2009, are as follows:

1. Addition of a new section on biometric spoofing attacks and antispooofing methods
2. Update of the biometric standards section
3. Entries on new biometric modalities, such as EEG biometrics, pointer-based recognition, and periocular recognition
4. Addition of entries on newly encountered problems, such as effect of plastic surgery on face recognition, remote (at a distance) face recognition, and mixing fingerprints for security
5. New algorithms for age estimation, gender classification, and score normalization

The focus of the *Encyclopedia* is on up-to-date, yet comprehensive, information in an easy-to-use format that is accessible to researchers and scientists, students, system designers, engineers, practitioners, and policymakers working in the broad field of biometrics. It is available as a print edition as well as a fully searchable e-version with extensive cross-referencing and updates as new trends and terms arise in the rapidly growing field of biometrics.

Key Features at a Glance

- Serves as a single point of entry for in-depth and current information on biometrics
- Covers major biometric modalities of face, fingerprint, iris, vein, voice, and hand as well as other modalities of interest in both biometrics and forensics (ear, gait, skin, tooth, odor, skull, DNA)
- Follows an A–Z format that allows intuitive and easy-to-use access
- Consists of cross-referenced entries

- Has a distinguished editorial board from across the scientific and engineering disciplines related to biometrics
- Provides a balanced coverage of research and development in biometrics

Acknowledgments

We are grateful to a number of individuals who have assisted us in the production of the second edition of the *Encyclopedia of Biometrics*. First of all, our deep gratitude to Shengcai Liao and Zhen Lei for their proofreading and ensuring that all the authors provided their contributions on time. Our stellar team of area editors has done excellent work in writing, inviting, and reviewing contributions from the experts in their respective topics. Our sincere thanks to Andy Adler, Joseph Campbell, Raffaele Cappelli, Christophe Champod, Stephen Elliott, Julian Fierrez, Christophe Fondeur, Carmen García-Mateo, Josef Kittler, Hale Kim, Ajay Kumar, Davide Maltoni, Aleix Martinez, Mark Nixon, Geppy Parziale, Fernando Podio, Salil Prabhakar, Arun Ross, Marios Savvides, Yoichi Seto, Colin Soutar, Wei-Yun Yau, Pong C. Yuen, David Zhang, Sébastien Marcel, and John Daugman. This book would not have been possible without the support of the numerous authors who provided their contributions. Special thanks are due to the Springer staff for their advice, support, and, most importantly, patience. Neha Thapa and Sunaina Dadhwal deserve special mention for gently shepherding us throughout the book preparation and production process.

9th March 2015

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Preface to the First Edition

The Encyclopedia of Biometrics provides a comprehensive reference to concepts, technologies, issues, and trends in the field of biometrics. The volume covers all important aspects—research, development, and applications, including biometric sensors and devices, methods and algorithms, sample quality, system design and implementation, databases, performance testing, information security, and standardization. Leading experts around the world contributed to this collection of over 200 in-depth essays accompanied by more than 600 definitional entries.

The focus of the encyclopedia is on immediate, yet comprehensive, information in an easy-to-use format that is accessible to researchers and scientists, system designers, engineers, programmers, students, practitioners, and government agents working in the broad field of biometrics. It is available as a print edition as well as a fully searchable version with extensive cross-referencing and updates as new trends and terms arise.

Key Features at a Glance

- Serves as an immediate point of entry into the field for in-depth research
- Covers biometrics of the face, fingerprint, iris, vein, voice, hand, ear, gait, skin, tongue, tooth, odor, skull, and DNA
- Follows an A–Z format that allows intuitive and easy-to-use access
- Consists of cross-referenced entries
- Has an internationally renowned editorial board from across the scientific and engineering disciplines and geographies
- Provides balanced coverage

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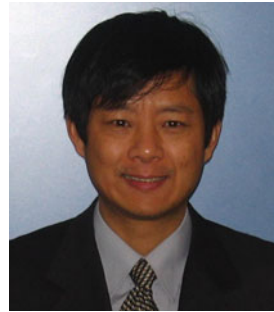
I am grateful to all the people who have played a part in the production of this encyclopedia. First of all, my deep gratitude to Anil K. Jain, Editorial Advisor, for sharing his knowledge, expertise, and important advice and suggestions for this encyclopedia. Our stellar team of area editors has done excellent work in writing, inviting, and reviewing contributions from many leaders of the field. My sincere thanks to Andy Adler, Joseph Campbell, Raffaele Cappelli, Christophe Champod, Stephen Elliott, Julian Fierrez,

Jean-Christophe Fondeur, Carmen García-Mateo, Josef Kittler, Hale Kim, Ajay Kumar, Davide Maltoni, Aleix Martinez, Mark Nixon, Geppy Parziale, Fernando Podio, Salil Prabhakar, Arun Ross, Marios Savvides, Yoichi Seto, Colin Soutar, Wei-Yun Yau, Pong C. Yuen, and David Zhang. I would like to thank these area editors for their help in creating this book and the numerous authors for their individual contributions. Special thanks are due to people at Springer for their enthusiasm, advice, and support. Jennifer Evans, Susan Lagerstrom-Fife, Michaela Bilic, Tina Shelton, and Anil Chandy have played key roles at different times in the development of this book.

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An IEEE Fellow, Stan Z. Li received his B.Eng. from Hunan University, China, M.Eng. from National University of Defense Technology, China, and Ph.D. degree from Surrey University, UK. He is currently a professor at the National Laboratory of Pattern Recognition and the director of the Center for Biometrics and Security Research (CBSR), Institute of Automation (CASIA), and the director of the Center for Visual Internet of Things Research (VIOT), Chinese Academy of Sciences. He worked at Microsoft Research Asia as a researcher from 2000 to 2004. Prior to that, he was an associate professor at Nanyang Technological University, Singapore. He was elevated to for his contributions to the fields of face recognition, pattern recognition, and computer vision.

His research interest includes pattern recognition and machine learning, image and vision processing, face recognition, and video analytics. He has published over 300 papers in international journals and conferences and authored and edited eight books, among which *Markov Random Field Models in Image Analysis* (Springer, 1st edition 1995, 2nd edition 2001, 3rd edition 2009) has been cited more than 2000 times (by Google Scholar). Other works include *Handbook of Face Recognition* (Springer, 1st edition 2005, 2nd edition 2011) and *Encyclopedia of Biometrics* (Springer Reference Work, 1st edition 2010, 2nd edition 2014). He served as an associate editor of *IEEE*

Transactions on Pattern Analysis and Machine Intelligence and a cochair of the International Conference on Biometrics 2007 and 2009 and has been involved in organizing other international conferences and workshops in the fields of his research interest.

Stan Z. Li is an expert in face recognition, biometrics, and intelligent video surveillance. The EyeCU face recognition system he developed at Microsoft Research Asia was demonstrated by Bill Gates on a CNN interview. He has been leading several national and international projects in biometrics and intelligent video surveillance. The AuthenMetric face recognition system and intelligent video surveillance system have been deployed in several national projects, including Beijing 2008 Olympic Games, Shanghai 2010 World Expo, and immigration control at China borders. He is a cochair of SAC/TC100/SC2 for biometrics standardization in China and delivered a plenary speech on Biometrics in China at ISO/IEC JTC1/SC37 on behalf of the China National Body.



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He has received Guggenheim fellowship, Humboldt Research Award, Fulbright fellowship, IEEE Computer Society Technical Achievement Award, IEEE W. Wallace McDowell Award, IAPR King-Sun Fu Prize, IEEE ICDM Research Contribution Award, and the MSU Withrow Teaching Excellence Award for contributions to pattern recognition and biometrics. He also received the best paper awards from the IEEE Transactions on Neural Networks (1996) and the *Pattern Recognition* journal (1987, 1991, and 2005). He served as the Editor-in-Chief of the IEEE Transactions on Pattern Analysis and Machine Intelligence (1991–1994). He is a Fellow of the ACM, IEEE,

AAAS, IAPR, and SPIE. He has been listed among the “18 Indian Minds Who Are Doing Cutting Edge Work” in the fields of science and technology and felicitated with the 2014 Innovator of the Year Award at MSU.

Anil K. Jain has been assigned six US patents on fingerprint matching and two Korean patents on surveillance. He is the author of several books, including *Introduction to Biometrics* (2011), *Handbook of Biometrics* (2007), *Handbook of Multibiometrics* (2006), *Handbook of Face Recognition* (first edition 2005, second edition 2011), *Handbook of Fingerprint Recognition* (first edition 2003, second edition 2009) (received the PSP award from the Association of American Publishers), *Markov Random Fields: Theory and Applications* (1993), and *Algorithms for Clustering Data* (1988). ISI has designated him as a highly cited researcher (Scholar). According to CiteSeer, his book, *Algorithms for Clustering Data* is ranked # 75 in the Most Cited Articles in Computer Science (over all times) and his paper “Data Clustering: A Review” (*ACM Computing Surveys*, 1999) is consistently ranked in the Top 10 Most Popular Magazine and Computing Survey Articles Downloaded.

He served as a member of the National Academies panels on Information Technology, Whither Biometrics, and Improvised Explosive Devices (IED). He also served as a member of the Defense Science Board. He currently serves as a member of the Forensic Science Standards Board.

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