Intelligent Systems Reference Library

Volume 192

The aim of this series is to publish a Reference Library, including novel advances and developments in all aspects of Intelligent Systems in an easily accessible and well structured form. The series includes reference works, handbooks, compendia, textbooks, well-structured monographs, dictionaries, and encyclopedias. It contains well integrated knowledge and current information in the field of Intelligent Systems. The series covers the theory, applications, and design methods of Intelligent Systems. Virtually all disciplines such as engineering, computer science, avionics, business, e-commerce, environment, healthcare, physics and life science are included. The list of topics spans all the areas of modern intelligent systems such as: Ambient intelligence, Computational intelligence, Social intelligence, Computational neuroscience, Artificial life, Virtual society, Cognitive systems, DNA and immunity-based systems, e-Learning and teaching, Human-centred computing and Machine ethics, Intelligent control, Intelligent data analysis, Knowledge-based paradigms, Knowledge management, Intelligent agents, Intelligent decision making, Intelligent network security, Interactive entertainment, Learning paradigms, Recommender systems, Robotics and Mechatronics including human-machine teaming, Self-organizing and adaptive systems, Soft computing including Neural systems, Fuzzy systems, Evolutionary computing and the Fusion of these paradigms, Perception and Vision, Web intelligence and Multimedia.

** Indexing: The books of this series are submitted to ISI Web of Science, SCOPUS, DBLP and Springerlink.

More information about this series at http://www.springer.com/series/8578

Md Atiqur Rahman Ahad · Mosabber Uddin Ahmed
Editors

Signal Processing Techniques for Computational Health Informatics

Springer

Editors
Md Atiqur Rahman Ahad
Department of Electrical
and Electronic Engineering
University of Dhaka
Dhaka, Bangladesh

Mosabber Uddin Ahmed
Department of Electrical
and Electronic Engineering
University of Dhaka
Dhaka, Bangladesh

Department of Media Intelligent
Osaka University
Ibaraki, Osaka, Japan

ISSN 1868-4394 ISSN 1868-4408 (electronic)
Intelligent Systems Reference Library
ISBN 978-3-030-54931-2 ISBN 978-3-030-54932-9 (eBook)
https://doi.org/10.1007/978-3-030-54932-9

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

Foreword

I first met Ahad over a decade ago at *IEEE Face and Gesture* where we enjoyed long discussion on computational approaches to human understanding and the importance of including emerging research in Southeast Asia and the Middle East. From those early discussions, we initiated the *1st International Conference on Informatics, Electronics and Vision* (*ICIEV*) in Bangladesh in 2012. The conference series under Ahad's leadership has fostered rich exchange of ideas and collaboration among junior and senior researchers across Asia and the Middle East, Europe, and North America. This edited collection springs from this productive conference series and his passionate efforts to promote computational and signal processing research in biomedicine, mental health, and human behavior more broadly.

Ahad's and Mosabber Uddin Ahmed's comprehensive collection offers a detailed overview of signal processing and healthcare technologies, challenges, applications, and implementations. Chapters come from major research groups and ones newly ascending. The writing is full of knowledge, insight, and spark from international, multi-cultural perspectives. The ideas presented should generate research and new understanding well into the future.

Whether you are graduate student, faculty, or research scientist, you are in for a treat. Enjoy!

Jeffrey F. Cohn
Professor of Psychology
Psychiatry, and Intelligent Systems
University of Pittsburgh
Pittsburgh, PA, USA

Preface

Our edited book titled *Signal Processing Techniques for Computational Health Informatics* is about various signal processing techniques—related to computational health informatics.

Computational health informatics is the interdisciplinary study of the design, development, adoption, and application of information and technology-based innovations, specifically computational techniques that are relevant in health care and often used to describe full range of application and research topics for which biomedical informatics is the pertinent underlying scientific discipline. Given the multitude of techniques and methods used in the field of signal processing, a comprehensive and representative amount of signal processing techniques used in biomedical applications are presented in this book.

These include biosignal origin and dynamics, artifact and noise removal techniques, feature extraction techniques in time, frequency, time–frequency and complexity domain, and image processing techniques in different image modalities like PET, MRI, medical ultrasound, X-ray, computed tomography (CT), etc. Moreover, a comprehensive overview of the security and privacy challenges, opportunities and future directions for computational health informatics in the big data age has been discussed by incorporating recent techniques from the area of artificial intelligence, machine learning and human–computer interaction.

The materials presented in this book are covered in 14 chapters—from basics to methodologies to the challenges ahead. Authors are from 12 countries (Australia, Bangladesh, Canada, China, Denmark, Egypt, France, Hong Kong, Iran, Japan, Sweden, and UK), covering 21 universities/institutes.

Chapter 1 discusses the origin and dynamics of biomedical signals. It initially classifies the biomedical signals based on their origin. Afterward, some representative electrical biomedical signals named ECG, EMG, EEG, etc., along with some nonelectrical biomedical signals are analyzed thoroughly according to their physiological and pathological perspectives.

Chapter 2 provides a detailed overview of different signal artifacts and noises commonly encountered in different biomedical signals and techniques for those artifacts and noise removal. In this chapter, the state-of-the-art signal processing

techniques for reliable identification of these offending artifacts, and finally, removing them from the raw recordings without distorting the signal-of-interest are systematically analyzed. Finally, some quantitative and qualitative measures are demonstrated in tables, and the algorithms are assessed in terms of their computational complexity and cost.

Chapter 3 focuses on basic signal processing techniques in time, frequency, and time–frequency domain which are routinely used for feature extraction in health informatics. This chapter provides a tutorial like description of fundamental signal processing techniques such as sampling, windowing, Z-transform, Fourier transform, wavelets, and some advanced data adaptive approaches like empirical mode decomposition, variational mode decomposition, etc. along with some applications.

Chapter 4 introduces the notion of complexity used in health informatics. At first, the definitional controversies for complexity are presented, and signal properties associated with complexity are reviewed. Then, some criteria used to classify complexity measures in the literature are discussed, and finally, some representative complexity measures used in health informatics are described.

Chapter 5 covers the concept of entropy and described some entropy measures that are common in health informatics. Both one-dimensional measures for time series and two-dimensional measures for images are documented in this chapter. For each measure, its theoretical background is detailed and some medical applications are presented.

Chapter 6 reviews the image-processing techniques used in health informatics. As image processing can be executed in 2D, 3D, or even multi-dimensional image domains, it can extract useful information, which can be used for monitoring, diagnosis, and prognosis. In this chapter, both biomedical image enhancement and compression techniques are covered focusing on the three main types of medical images: X-ray/CT, MRI, and ultrasound image. Besides, some representative applications of using the image processing-based techniques in medical imaging system are reported finally.

Chapter 7 provides some more advanced signal processing techniques, which fall under the category of artificial intelligence (AI). The fundamental of AI, machine learning (ML), and machine reasoning (MR) techniques and approaches widely used in health informatics are reviewed first. Afterward, each technique is discussed to show how they can be applied in the development of a decision support system.

Chapter 8 focused on health information retrieval as searching health-related information on the World Wide Web (WWW) has been increasing in the recent past. The methodologies and techniques to access and/or retrieve information related to the health using the process of information retrieval are referred to health information retrieval (HIR). This chapter presents the noticeable challenges in HIR, the most prominent existing methods to solve the problems and future directions. It also includes the details of the datasets, evaluation metrics used, and procedures to validate the performance of any HIR methods.

Health informatics often combines biomedical engineering with information technology to develop modern eHealth system, which needs precise biosignal processing. As most of the biosignal processing units are multichannel systems with extensive datasets, conventional computation techniques often fail to offer real-time data processing. Reconfigurable architecture offers a tangible solution to this problem by utilizing fast parallel computation through hardware acceleration and designing application-specific circuits rather than using the general-purpose processors to do the signal processing. Due to its low cost and fast computation property, reconfigurable architecture is characteristically suitable for health informatics and has become one of the fastest growing research fields of recent years. Chapter 9 summarizes the state-of-the-art research trends in this research field.

Chapter 10 introduces the fundamentals of computational health informatics rigorously. With a view to relate the significance of application domains in health informatics, it represents potential challenges, opportunities, and some recommendations as future directions for health informatics.

Chapter 11 detours to focus toward the available methods of sensing mental health problems through direct and indirect measures. This chapter studies how active and passive sensing by technologies as well as reporting from relevant sources can contribute toward these detection methods. It also reviews available methods of therapeutic treatment available through digital means, and finally, highlights a few key intervention technologies that are being developed by researchers to fight against mental illness issues.

The rest of the three chapters (12–14) actually describe some case studies where different signal processing techniques discussed so far are used in real-life problems. Chapter 12 covers AI, ML, and MR techniques used for advanced Parkinson's disease, stress management, postoperative pain treatment, driver monitoring, and remote health monitoring. In each case, the challenges, current solutions, and limitations are discussed with future directions. Chapter 13 details how the ML is used in risk prediction for Cesarean Section with a view to optimize healthcare operational decisions. Finally, Chap. 14 showcases an application of epileptic seizures classification based on multi-domain feature extraction.

There is no denying the fact that there are numerous aspects of signal processing used in computational health informatics. To cover all aspects in a single monograph is difficult if not impossible. We have tried to cover at least some core aspects of signal processing used in health informatics for that matter. We hope that the systematic analysis of the state-of-the-art techniques covered in this book will help to further our understandings of the physiological processes and increase our capability in medical diagnosis and prognosis.

For any comment, please email. Finally, we would like to thank the authors and reviewers for their valuable time and efforts. Those exchanges facilitate the book to build up and mature different ideas in the line of this book. We are thankful to our former students—Anindya Das Antar (*University of Michigan*); Masud Ahmed (*University of Maryland, Baltimore County*); Kanij Mehtanin Khabir (*Norfolk State University*); and Ferdous Ali Israt (*DigiCon Telecommunication Ltd.*)—as we had a long brain-storming night in December 2018 to outline the concept of the book!

The friendly and amazing personals of Springer made the book realizable, and we would like to thank them specially. Last but not least, we especially thank Prof. Jeffrey F. Cohn for his time to engrave a foreword for this book.

Thank you all!

Osaka, Japan

Md Atiqur Rahman Ahad, Ph.D., SMIEEE
Professor
University of Dhaka

Specially Appointed Associate Professor
Osaka University
atiqahad@du.ac.bd
ahad@am.sanken.osaka-u.ac.jp
http://ahadVisionLab.com

Dhaka, Bangladesh

Mosabber Uddin Ahmed, Ph.D., SMIEEE
Professor
University of Dhaka
mosabber.ahmed@du.ac.bd

Contents

About the Editors

Md Atiqur Rahman Ahad Senior Member, IEEE, is *Professor* of Electrical and Electronic Engineering, University of Dhaka (DU). He is currently working as *specially appointed Associate Professor* at Osaka University, Japan. He works on computer vision, imaging, IoT, health care, etc. He did B.Sc. (Honors) and Masters from the Department of Applied Physics and Electronics, DU; Masters from the School of Computer Science and Engineering, University of New South Wales; and Ph.D. from the Faculty of Engineering, Kyushu Institute of Technology (KIT). He was awarded prestigious UGC Gold Medal 2016 (handed by Honorable President of Bangladesh), JSPS Postdoctoral Fellowship, and 25+ awards/scholarships in different conferences/etc. He was Visiting Researcher at KIT. He published three books as author, two edited books (available in Springer), and a few chapters. He has published 140+ journals/conference papers. Ahad was invited as keynote/invited speakers ~80 times in different conferences/universities in Japan, BD, USA, India, Malaysia, and Indonesia. He has established several international MOU/collaborations (e.g., Clemson University, University of Hyogo, RCCIIT, Fukuoka Women University, and Kyushu University).

He has been involved with some academic and editorial activities, e.g., Editorial Board Member, *Scientific Reports, Nature*; Associate Editor, *Frontiers in ICT*; Editor, *International Journal of Affective Computing*; Associate Technical Editor (former), *IEEE ComSoc Magazine*; Editor-in-Chief: *International Journal of Computer Vision & Signal Processing*http://cennser.org/IJCVSP, General Chair, 2021 *10th International Conference on Informatics, Electronics & Vision, Japan*http://cennter.org/ICIEV; *5th International Conference on Imaging, Vision & Pattern Recognition*http://cennser.org/IVPR; *3rd International Conference on Activity & Behavior Computing*, 2021 https://abc-research.github.io; Workshop Chair, *17th IEEE PiCom*; Publication Chair, *2018 IEEE International Conference on Systems, Man, and Cybernetics* (*SMC*); Vice Publication Co-chair and Vice Award Chair, *Joint 17th World Congress of International Fuzzy Systems Association* (*IFSA*) and *9th International Conference on Soft Computing and Intelligent Systems*; General Chair, *7th International Symposium in Computational Medical and Health Technology*; and several other international conferences.

He served as Guest Editor in *Pattern Recognition Letters*, Elsevier; *Journal of Multimedia User Interface*, Springer; *Journal of Healthcare Engineering*, Hindawi; *International Journal of Innovative Computing, Information and Control*. Ahad is a Member of OSA, ACM, IEEE Computer Society, IAPR, IEEE RAS, IEEE SMC, etc. He is the founder Secretary of *IEEE Computer Society Bangladesh Chapter*, and *Bangladesh Association of Pattern Recognition*, Executive Committee member of *Bangladesh Electronics Society* (BES). He volunteered as a former Executive Committee member of BAPA, the largest environmental group. More: http://ahadVisionLab.com.

Mosabber Uddin Ahmed received B.Sc. (Hons.) and M.Sc. degrees from the Department of Applied Physics and Electronics, University of Dhaka (DU) in 1998 and 1999, respectively. He received a second M.Sc. degree in communications and signal processing and Ph.D. degree in signal processing from the Imperial College London (ICL), UK, in 2006 and 2012, respectively. From 2015 to 2016, he was a postdoctoral fellow at the Department of Electrical and Electronic Engineering at ICL. He is currently a professor at the Department of Electrical and Electronic Engineering, University of Dhaka. Till date, he has authored or co-authored more than 30 research articles that are published in refereed journals, books, and conference proceedings. His research interests include signal processing, brain signal modeling, wind modeling, time–frequency analysis, multivariate time series analysis, complexity analysis, multiscale entropy analysis, embedded system design, network and information security. He has won several fellowships and research grants including the Commonwealth Academic Fellowship, Commonwealth Scholarship, and Charles Wallace Bangladesh Trust (CWBT) grant. He is a senior member of IEEE. He was also a track/area co-chair of the 2nd and 3rd International Conference on Informatics, Electronics and Vision (ICIEV) and a program chair of the International Workshop on Artificial Intelligence and Applications (IWAIA). He has also served in various capacities such as reviewer and editorial board member in different reputed national and international journals.