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Editors

Signal Processing Techniques for Computational Health Informatics

 Springer

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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!

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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!

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