Guest Editorial: Integrative Sensor Networks, Informatics, and Modeling for Precision and Preventative Medicine

I. Introduction

THE topics of integrative sensor networks, informatics and modeling bring together the tightly coupled and rapidly developing fields of biomedical and health informatics and body sensor networks. Biomedical and health informatics encompasses methods to extract and communicate information from data in order to impact health, healthcare, life sciences and biomedicine. Body sensor networks provide one means to measure the needed data, through continuous monitoring in both clinical and free-living environments. Developments in these areas were highlighted at two co-located conferences: the 2019 IEEE-EMBS International Conferences on Biomedical and Health Informatics (BHI'19) and Wearable and Implantable Body Sensor Networks (BSN'19). BHI and BSN are long-standing IEEE EMBS conferences that provide a forum for researchers and leaders from academia, government and industry to share technical advances and new initiatives in these important areas.

Through an open call for this special issue, eleven papers have been included for publication. The majority were presented in an initial form at the 2018 or 2019 BHI and BSN conferences. Nine of the papers were selected through a rigorous peer review. In addition, two keynote speakers from BHI'19 and BSN'19 have provided short position papers.

II. Brief Overview of the Papers in this Special Issue

A. Invited Position Papers

Two short papers from BHI'19 and BSN'19 keynote speakers provide perspectives from industrial leaders. Ketan Paranjape *et al.* discuss the critical role of health informatics as part of the drive toward personalized medicine. Companies are developing targeted therapies for personalized treatments. AI is increasingly being applied to exponentially increasing digital data such as genomics and imaging in order to determine which therapy is best suited for a particular individual. In this context, AI needs to address practical challenges such as explainability, liability and privacy. David Duffy provides a perspective on progress to increase sensor sensitivity, in order to detect single molecules of target analytes. This technology is needed to monitor an individual's continuum from health to disease. Increased sensitivity for a broader range of protein biomarkers is expected to eventually allow wearable devices to monitor more disease conditions, expanding on current applications for continuous glucose monitors.

B. Gait Analysis

Gait analysis based on wearable accelerometers and inertial measurement units (IMUs) has been a longstanding area of research, with applications ranging from monitoring disease conditions, such as Parkinson's, to enhancing athlete performance. Progress continues to be made. Ulrich *et al.* report on improving gait detection, which is the first processing step that is needed before applying specific analytics. Improved methods are developed and assessed for foot-worn IMUs in order to reduce false alarms while maintaining high detection probability. As one type of specific analytic application, Lueken and team describe progress in measuring stride time variability, which is important to assess gait stability. The goal is to implement a general algorithm that can operate for IMUs at different wear positions (wrist, pocket or belt, necklace).

C. Cardiovascular Applications

For cardiovascular applications, sensing and informatics are needed to both monitor disease conditions and to monitor status of assistive devices. In the first category, Jonathan Zia *et al.* introduce a method to model the seismocardiogram (SCG) signal, which measures the mechanical aspects of cardiovascular health and performance. The paper demonstrates that SCG waveforms follow consistent patterns in low-dimensional subspace and furthermore demonstrates algorithmic correction for sensor misplacement for generative factor inference. The proposed SCG processing method adapts to the patient's anatomy and physiology as well as the position of the sensor for accurate assessment of cardiomechanical indicators, which may enable the noninvasive assessment of cardiomechanical function in clinical and outpatient environments. In the second category, Beren Semiz *et al.* report that the acoustical signals measured on the chest of patients with left ventricular assist devices, combined with machine learning algorithms, can detect pump thrombosis with improved accuracy. When tested on post-thrombolysis data, the

Digital Object Identifier 10.1109/JBHI.2020.2996319

algorithm suggested possible pump abnormalities that were not identified by the reference pump power or biomarker abnormalities. This technology may potentially enable the remote monitoring and management of pump thrombosis.

D. Mental Health

Two papers provide examples of addressing mental health, with one paper focusing on predicting suicide ideation and the other on control of noninvasive vagal nerve stimulation to treat traumatic stress. Gen-Min Lin *et al.* utilize six machine learning techniques to predict the presence of suicide ideation of military personnel. Based on analyzing a data set of 3,546 military members, six machine learning methods yielded accuracies of over 98% for predicting suicide ideation, with the multilayer perceptron and support vector machine providing the best predictions. This paper demonstrates improved performance over a previous scoring method, and thus may provide an effective approach for early warning and prevention of suicide. Nil Gurel *et al.* propose multimodal signal fusion methods to provide information on therapy response for transcutaneous cervical vagal nerve stimulation. Cardiopulmonary signals were collected from 26 participants with traumatic stress and features were extracted from physiological parameters related to autonomic nervous system activity for analysis. The paper demonstrates that signals and features obtained from electrocardiogram and photoplethysmogram, such as heart rate, vasomotor activity, and pulse arrival time, provided the most salient markers to determine target engagement. In the future, the methods may be deployed in wearable devices allowing for home-based therapy.

E. Additional Health Informatics Applications

Additional health informatics topics in this special issue relate to dietary assessment, pathological voice repair and cancer data analytics. In the first paper, Frank Lo and colleagues review algorithms, mathematical models and methodologies for image-based dietary assessment. Extensive comparisons of state-of-the-art methods for recognizing food and estimating volume and weight are provided to highlight the main advantages and challenges of different approaches. Moreover, the paper discusses the feasibility and potential of recent deep-learning-based approaches to assess dietary intake. The authors found that integrating different approaches could be a potential solution to improve the overall accuracy in food volume estimation. The second paper by Tao Zhang *et al.* addresses the need for smart devices such as hearing aids, phones, and speakers to repair vowels spoken by people with speech disorders, in order to understand them. Vowel repair algorithms were developed to extract pitch using wavelet and Hilbert-Huang transforms, and to reconstruct formants using a line spectrum pair feature. The approach was validated for the vowels /a/, /i/ and /u/ on a standard database and the experimental results demonstrated good repair effects. The third paper by Shamimul Hasan *et al.* presents a knowledge graph-based approach for cancer data analytics. The proposed approach has advantages of conveniently handling scenario-specific queries, linking third-party data, managing schema changes, and visualizing data. A prototype knowledge graph was developed based on the Louisiana Tumor Registry dataset. The results demonstrated that the proposed method can perform complex queries, improve query run-time performance by up to 76%, more easily conduct iterative analysis, and enhance understanding of cancer registry data by knowledge graph visualization.

III. Concluding Remarks

The papers presented in this special issue provide a snapshot of the latest advances in the areas of integrative sensor networks, informatics and modeling, as well as illustrating the diversity of important topics showcased at the BHI and BSN conferences. We look forward to BHI'21 and BSN'21.

The editors cordially thank all involved in the preparation of this special issue: contributors, reviewers and IEEE J-BHI editors and staff.

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