Guest Editorial
Special Issue on Cardiovascular System Monitoring and Therapy: Innovative Technologies and Internet of Things

THE number of devices for the measurement and interpretation of biological systems that describe performance of the cardiovascular system is growing. Among others, this is due to the improvement of circuit and system design that renders the devices wearable and easy to use. Moreover, internetworking enables these devices to exchange data. Their true impact on patient care is highly dependent on the quality and relevancy of the data acquired. The design of circuits and systems to answer the growing demand and the necessity to have portable and connected devices lead to a focus on designing ultra-low power apparatus, mixed-signal devices, using nanoscale electronics. Microelectronic issues are therefore at the heart of the demand. All this requires inter-disciplinary collaborations between scientists, engineers, medical researchers, and practitioners. The interconnection of these embedded devices, known as Internet of Things, is expected to usher in the medical field, among others to study the cardiovascular system of patients. Data processing and storage will also take place in the healthcare information technology. Furthermore, key issues such as data security and privacy will be determinants of the utility of these systems and impact in healthcare monitoring and management.

This special issue aimed to provide a forum for both established experts and new investigators to share their developments, knowledge, and insights for the further design of circuits and systems aiming at being integrated in sensors to monitor or treat the cardiovascular system. Contributions for this special issue were sought on general, theoretical, and application-oriented papers in the above-mentioned technical areas with a **Circuits and Systems perspective and an application related to the cardiovascular system**. In the 10 papers selected, a wide range of methodological and technological solutions are presented, as described below.

In their paper "An analog front end ASIC for cardiac electrical impedance tomography", Rao *et al.* present an end-to-end CMOS ASIC for readout channel to be used in a system of cardiac electrical impedance tomography. A fully integrated solution for use in multiple electrode system is shown. The performance of the system is also detailed.

Tekeste *et al.* propose a real-time hardware implementation of cardiac autonomic neuropathy severity detector that comprises ECG feature extraction. Thus, in their paper "A nano-Watt real-time cardiac autonomic neuropathy detector", the authors present the proposed architecture that operates at an ultra-low power dissipation through algorithmic and architectural optimization.

"A real-time QRS detection system with PR/RT interval and ST segment measurements for wearable ECG sensors using parallel delta modulators" proposed by Tang *et al.* introduces a real-time ECG monitoring system for wearable devices. From this system, real-time PR and RT intervals, and ST segment measurements can be performed in long-term wearable ECG recording. The system is tested on the MIT-BIH Arrhythmia database for QRS complex detection and with the QT Database for the P and T wave detections. The algorithm achieves above 99%, 91%, and 98% accuracy in the QRS complex, P wave, and T wave detections, respectively.

In their paper titled "Online obstructive sleep apnea detection on medical wearable sensors", Surrel *et al.* propose an online ultra-low power wearable system to monitor – on a long term basis – obstructive sleep apnea. This approach relies on monitoring the patient with a single-channel electrocardiogram signal that is processed with a time-domain algorithm. The apparatus is tested on a publicly available database (PhysioNet Apnea-ECG).

In their paper "A 36 μW 1.1 mm^2 reconfigurable analog front-end for cardiovascular and respiratory signals recording", Xu *et al.* propose a highly reconfigurable analog front-end (AFE; 1.2 V 36 μW) for wearable and miniaturized cardiovascular and respiratory signals acquisition. The AFE occupies an area of 1.1 mm^2 and supports five sensing modes including ECG, BioZ, GSR, PPG and GPA.

"Blood cholesterol monitoring with smartphone as miniaturized electrochemical analyzer for cardiovascular disease prevention" by Fu *et al.* presents a medical smartphone system as a point-of-care device for blood total cholesterol monitoring. Due to its good portability, high reliability and internet-based data interaction, the medical smartphone can be applied for long-term prevention of cardiovascular disease.

In their paper "Estimation of the cardiac field in the esophagus using a multipolar esophageal catheter" Wildhaber *et al.* presents a novel approach to estimate a catheter displacement in esophageal ECG measurements and to estimate the electrical field projected onto the esophagus with an increased spatial

Digital Object Identifier 10.1109/TBCAS.2018.2861340

resolution. The authors show that the approach is ready to work with clinical data, recorded with commonly available equipment.

Chou *et al.* propose a novel privacy preserving data analytics framework based on compressive sensing in their paper "Low-complexity privacy-preserving compressive analysis using subspace-based dictionary for ECG telemonitoring system". The proposed privacy-preserving compressive analysis outperforms traditional compressive sensing-based security framework in both privacy and computational complexity. The proposed analysis is implemented in ECG-based atrial fibrillation detection.

In their paper "A parasitic insensitive catheter-based capacitive force sensor for cardiovascular diagnosis", Jeon *et al.* present a parasitic insensitive catheter-based capacitive force sensor interface for cardiovascular diagnosis. The proposed sensor interface demonstrates the feasibility and the potential for integrating capacitive force sensors in a smart catheter. In the capacitive sensor interface, the proposed readout technique can be applied to various applications suffering from large amounts of parasitic capacitance.

In their paper "Towards characterization and adaptive compensation of backlash in a novel robotic catheter system for cardiovascular interventions", Omisore *et al.* presents – for a novel robotic catheter system – an adaptive backlash compensation based on motion control and force modulation for accessing the human cardiac area through the radial vasculature. The proposed adaptive compensation system is validated *in vitro*, by cannulating a 10 mm phantom model with the robotic system.

The papers received were selected based on technical reviews from worldwide experts to offer the best landscape in this field. For that the Guest Editors would like to thank all the authors and reviewers. We also owe our deepest thanks to Prof. M. Sawan, Editor-in-Chief of IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, for his constant support.

A. HUMEAU-HEURTIER, *Guest Editor*
University of Angers
Angers 49000, France

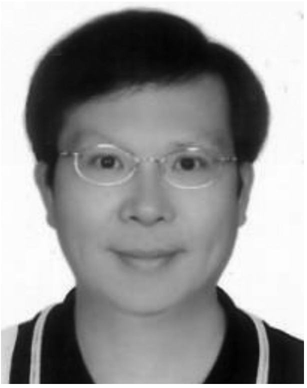
S.-Y. LEE, *Guest Editor*
National Cheng Kung University
Tainan 70101, Taiwan

Y.-H. LIU, *Guest Editor*
National Taipei University of Technology
Taipei 10608, Taiwan

M. MILANOVA, *Guest Editor*
University of Arkansas at Little Rock
Little Rock, AR 72204 USA

L. EDUARDO VIRGILIO SILVA, *Guest Editor*
University of São Paulo
Ribeirão Preto 14085, Brazil

Anne Humeau-Heurtier received the Ph.D. degree in biomedical engineering in France. She is currently a Full Professor in engineering with the University of Angers, Angers, France. She is an author and co-author of more than 80 papers in peer-reviewed journals, and participated to the organization of several conferences and workshops. Her research interests include signal and image processing, mainly multiscale and entropy-based analyses and data-driven methods. Main applications concern the study of the microvascular perfusion. She is also an Associate Editor for the Engineering Medicine and Biological Society Conference. She is member of the editorial board for the Journal *Entropy*. She was a Guest Editor for several special issues in the Journal *Entropy* and a Guest Editor for special issues in Journals as *Complexity* and *Computational and Mathematical Methods in Medicine*. She is member of the IEEE-EMBS Technical Committee on Cardiopulmonary Systems.



Shuenn-Yuh Lee received the Ph.D. degree from the National Cheng Kung University, Tainan, Taiwan, in 1999. He is currently a Full Professor with the Department of Electrical Engineering, National Cheng Kung University, Tainan, Taiwan. His current research activities involve the design of analog and mixed-signal integrated circuits including filter, high-speed ADC/DAC, and sigma-delta ADC/DAC, biomedical circuits and systems with machine learning, low-power and low-voltage analog circuits, and RF front-end integrated circuits for wireless communications. From 2013 to 2016, he was the Chairman of IEEE Solid-State Circuits Society Tainan Chapter. From 2016 to 2017, he was the Vice Chairman of IEEE Tainan Section. He is currently an Associate Editor of the IEEE TRANSACTION ON BIOMEDICAL CIRCUITS AND SYSTEMS. He is a member of Circuits and Systems Society, Solid-State Circuits Society, and Medicine and Biology Society of IEEE. He is also a member of IEICE.

Yi-Hung Liu (M'04) received the Ph.D. degree in mechanical engineering from National Taiwan University, Taipei, Taiwan, in 2003. He was an Assistant and an Associate Professor with the Department of Mechanical Engineering, Chung Yuan Christian University, Chungli, Taiwan. He is currently an Associate Professor with the Department of Mechanical Engineering, National Taipei University of Technology, Taipei, Taiwan. He is the author/co-author of more than 40 articles in referred journals. His research interests are machine learning, bio-signal processing, electroencephalography-based brain-computer interface, internet of brains, and medical mechatronics. He is an Associate Editor of the *International Journal of Automation and Smart Technology*, and was also the Guest Editor for many *SCI-indexed* journals, such as the Special Issue on Fuzzy Brain-Computer Interface Systems of the International Journal of Fuzzy Systems, and the Special Issue on Medical Mechatronics for Healthcare of the Journal of Healthcare Engineering. Since 2013, he has been the Co-Chair of the Technical Committee on Medical Mechatronics of IEEE Systems, Man, and Cybernetic Society. He was the recipient of the 2014 Most Active IEEE SMC Technical Committee Award.

Mariofonna Milanova received the M.Sc. degree in expert systems and artificial intelligence, in 1991, and the Ph.D. degree in computer science from the Technical University, Sofia, Bulgaria, in 1995. She conducted a Postdoctoral research in visual perception at the University of Paderborn, Germany. Since 2001, she is a Professor with Computer Science Department, University of Arkansas at Little Rock (UA Little Rock), Little Rock, AR, USA. She is a Faculty Fellow of Bioinformatics Program, Engineering Program and Fellow of Emerging Analytics Center with UA Little Rock. She has an extensive academic experience at various academic and research organizations worldwide. She serves as a book editor for two books and as associate editor for various international journals. She has authored and co-authored more than 130 publications, more than 53 journal papers, 19 book chapters, and numerous conference papers and has 2 patents. Her main research interests are in the areas of artificial intelligence, computer vision and communications, machine learning, privacy and security based on biometric research. Dr Milanova is a member of Governing Board of International Association of Pattern Recognition, a member of Technical Committee 9 of IAPR, and a member of TC on Knowledge Acquisition in Intelligent Systems of IEEE SMC.

Luiz Eduardo Virgilio Silva received the B.S. degree in biomedical informatics, the M.S. and Ph. D. degrees in physics applied to medicine and biology, all from the University of São Paulo, Ribeirão Preto, Brazil. From 2017 to 2018, he was an Adjunct Professor with the Institute of Mathematics and Computer Science, University of São Paulo. He is currently a Research Fellow with the Department of Physiology, School of Medicine of Ribeirão Preto, University of São Paulo. He is an author and co-author of more than 20 papers in peer-reviewed journals. His research interests include biomedical signal and image analysis, with special focus on the analysis of cardiovascular signals by nonlinear methods, analysis of physiological complexity, heart rate variability and baroreflex control.