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*Special Section on Smart Wearable
Devices for Human Health and Protection*

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Guest Editorial

Special Section on Smart Wearable Devices for Human Health and Protection

OVER the past few years, research and development of smart wearable devices (SWD) for personalized services (particularly in Health and Civil Protection contexts) have been pursued extensively by Governments and Research Agencies around the world. Noticeably, this has been a major focus area in European Union Countries where public funding has supported research and development efforts as major e-Health and ICT topics. Significant examples of research projects focused on SWD's are the MyHeart Project on "Fighting Cardio-Vascular Diseases by Prevention and Early Diagnosis" and the Pro-eTEX Project on "Protection e-Textiles: MicroNanoStructured Fibre systems for Emergency-Disaster Wear" within the Framework Programme FP6. Similar efforts have been carried out in the United States and Asia. An example of the numerous projects currently ongoing in the United States is the "Oregon Center for Aging and Technology," a project focused on developing and deploying sensor technology to monitor older adults in the home. In Asia, the Hong Kong Innovation and Technology Fund has supported numerous research projects aimed at developing SWD to monitor cardiovascular function.

Wearable solutions are especially required in health management and medical applications. The development of SWD's is intended to address the challenge of reducing healthcare costs covered by National Health Services while maintaining high quality of the supplied healthcare services. Technology is expected to provide ubiquitous access to healthcare services at any time and to a large number of users. SWD's have in fact the capability of extending healthcare services beyond the traditional applications of care, prevention and support. They can include caring for disaster victims and monitoring of emergency operators. In this context, the increasing fear caused by events such as terrorist attacks, big earthquakes (and related tsunami) happened all around the world caused an increase in technological research in this field, as well as an increase in Government funding in order to prevent and address in an effective way emergency situations associated with such types of disasters.

Recent research work relies on the miniaturization of electronic circuits (including computational tools, microsensors, transmission, and dedicated signal processing devices), which allow the integration of many innovative smart features into e-textile platforms. The potential benefit of this integration is obvious because about 90% of the human skin is in contact with garments whose fabric is the most "natural" interface with the human body. Moreover, garments are typically flexible, they fit

well on the human body, they are fairly inexpensive and, finally, they can be considered disposable devices.

The goal of this special section is to present original and relevant contributions in the area of SWD's applied to the health and civil protection domains. The main topics of the special section are: Textile Sensors for Biomedicine, Intelligent Garments, Textile Electronics, Wearable Systems in Emergency Operators, No-contact Wearable Sensors, Vital Signs Parameters and Signal Processing, and Ubiquitous Computing.

Part I—*Technologies for vital sign monitoring in human health and protection*—starts with a contribution by *D. Curone et al.* entitled *Smart Garments for Emergency Operators: the ProeTEX Project*. The paper describes the results of intelligent textiles and wearable electronics implemented as part of the ProeTEX project for the protection of emergency-disaster operators. The proposed system enables the detection of health status parameters as well as environmental variables. Besides, the system performs processing tasks and relays data to a remotely located operation manager. The second paper is authored by *D. Curone et al.* and entitled "*Heart Rate and Accelerometer Data Fusion for Activity Assessment of Rescuers during Emergency Interventions*." The paper describes a microprocessor-based system, which integrates the information recorded by triaxial accelerometers and one-lead ECG. Given these inputs, a classifier assigns these signals to nine classes differentiating between certain physical activities, their intensities and postures. Specific classes are identified as dangerous to the rescuer during an operation thus allowing an alert system to be set in place. The paper by *M. di Rienzo et al.* entitled "*Textile Technology for the Vital Signs Monitoring in Telemedicine and Extreme Environments*" introduces a smart textile technology in two application areas: the home monitoring of cardiac patients and the evaluation of the effect on sleep of high altitude hypoxia during a Mount Everest climbing mission. The use of the proposed garment is reported to be simple and requiring short set-up time even in the demanding expedition environment. The following paper by *T. Vuorela et al.* is entitled "*Design and Implementation of a Portable Long-Term Physiological Signal Recorder*" and describes the design and implementation of a portable physiological recorder for measuring ECG, bio-impedance, and motor activity. The functionality of the implemented measurement device is proven by results of test measurements, which include comparison of measured signals against reference signals, testing the device operation under vigorous upper body movements and during light exercise. *C. T. Lin et al.* present a novel wireless, ambulatory, real time, and autoalarm intelligent telecardiology system in the paper entitled "*An Intelligent*

Telecardiology System Using a Wearable and Wireless ECG to Detect Atrial Fibrillation." The system aims to improve health-care services for subjects affected by a cardiovascular disease. It consists of a lightweight and power-saving wireless ECG device equipped with a built-in automatic warning expert system. *J. J. Oresko et al.* propose a clinically oriented solution for real-time arrhythmia detection in the manuscript entitled "A Wearable Smartphone-based Platform for Real-Time Cardiovascular Disease Detection via Electrocardiogram Processing." The authors show that it is possible to perform a real-time ECG acquisition and display, feature extraction, and beat classification via a smartphone-based system integrated with a wearable CVD detection platform. The paper by *A. M. Bianchi et al.* entitled "Processing of signals Recorded Through Smart Devices: Sleep Quality Assessment" aims at addressing the problem of sleep evaluation using heart rate variability and respiratory signals for automatic sleep staging, arousal detection, and apnea recognition. The system is suitable for home monitoring of sleep. A wearable device (for example, a sensorized T-shirt) or a system integrated into the environment (sensorized bed) are possible implementation means to fulfill the objective of performing unobtrusive sleep monitoring. The contribution by *J. Jiang et al.* "A Mobile Monitoring System of Blood Pressure for Underserved in China by Information and Communication Technology Service," summarizes the authors' work toward achieving early diagnosis of hypertension (which has become the main risk factor for important cardiovascular events) through a mobile monitoring system gathering blood pressure data. The system is conceived for use in remote and rural areas. The system facilitates connection between major clinical facilities and community doctors.

Part II of this special section—*Innovative Sensors for Wearable Applications*—is opened by a paper authored by *M. Barbaro et al.* "Active Devices based on Organic Semiconductors for Wearable Applications." This contribution deals with organic field effect transistors (OFET) solutions for the implementation of plastic electronics, which allows one to obtain active electronic circuits on flexible and non-planar surfaces, thus paving the way to implementing "functional yarns." These features have the potential to overcome the limitations of electronics based on crystalline semiconductors and foster an extensive development of wearable systems. The following paper by *L. Shu et al.* entitled "In-Shoe Plantar Pressure Measurement and Analysis System based on Fabric Pressure Sensing Array" presents an in-shoe plantar pressure system, based upon a textile fabric sensor array, which is soft, light and is marked by a high pressure sensitivity and long service life. A real-time display and analysis software is presented that allows one to calculate parameters that are shown to be reliable in both static and dynamic conditions. *J. M. Kortelainen et al.*

authored the following paper entitled "Sleep Staging based on Signal Acquired through Bed Sensors." This work introduces a novel sensor embedded in the bed mattress which allows one to capture the heart beat interval signal (HBI) using an Emfit foil made by a porous polypropylene material including large internal voids which are permanently electrically charged. This foil is placed into the bed mattress, and through proper data processing sleep staging classification is achieved (awake/REM/non-REM) with good accuracy compared to the classification provided by a clinical expert. Finally, *M. Z. Poh et al.* authored the paper entitled "Motion Tolerant Magnetic Earring Sensor and Wireless Earpiece for Wearable Photoplethysmography" which concludes the special section devoted to SWD's. The paper describes a novel embodiment for wearable photoplethysmography comprising a magnetic in-ear sensor and a wireless earpiece. The sensor can be comfortably worn and contains an accelerometer that provides motion reference for adaptive noise cancellation.

The research and development work on SWD's presented in the papers of this special section demonstrates that the field is making big strides toward the deployment of SWD's in the real world. Whereas initial work in this field was almost solely focused on the development of enabling technologies, we have recently witnessed growing interest and significant contributions focused on specific clinical applications. We trust that the readership of IEEE TITB will find the material presented in this special section to be stimulating and a good picture of the state of the art in the field.

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Prof. Cerutti was an Elected Member of the IEEE Engineering in Medicine and Biology Society (IEEE-EMBS) Administrative Committee (Region 8) from 1993 to 1996. He is a Fellow Member of the IEEE and of the European Alliance in Medical and Biological Engineering and Science. He is an Associate Editor of the IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING. He is a member of the Steering Committee of the IEEE-EMBS Summer School on Biomedical Signal Processing. He received the IEEE-EMBS Academic Career Achievement Award in 2009.



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Dr. Bonato is an elected member of the IEEE Engineering in Medicine and Biology Society (EMBS) AdCom, and President of the International Society of Electrophysiology and Kinesiology. He was the Chair of the IEEE EMBS Technical Committee on Wearable Biomedical Sensors and Systems in 2008 and has been a member of this committee since its inception in 2006. He is

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