Guest Editorial
Special Section on Personal Health Systems

I. Introduction

THE expression personal health systems (PHSs) refer to a new and fast growing concept that has emerged over the past few years. It concerns the individualization of interventions aimed to prevent and/or treat diseases via tools available as part of the healthcare system. PHSs are putting the patient at the center of healthcare. Through remote monitoring and management applications, PHSs aim to bringing continuity of care and controlling quality at all levels of the healthcare delivery chain. This continuity of care is a prerequisite for the delivery of preventive, personalized, and citizen-centered healthcare. PHS is realized through a number of tools stemming from the micro and nanosciences (e.g., wearable, implantable, and portable systems), information and communication technologies (ICT) (e.g., call centers, point-of-care systems, multiparametric decision support systems), as well as medical knowledge mining and data management systems to name a few. PHSs address the following major needs: 1) the need for ubiquitous, unobtrusive, pervasive biodata acquisition, processing, and management, and for using medical decision support systems; 2) the need for combining multilevel medical information as well as environmental information in order to promote the individualization of healthcare; and 3) the need for increasing the quality of healthcare delivery through rigorous biofeedback mechanisms, thus improving patient safety.

In recent years, advances in pervasive computing technologies [1], [2] have provided the basis for the design and development of several personal health systems and services [3], the majority of which rely on the adoption of biomedical sensors [4], [5], and networking/communication technologies [6], [7]. Specifically, recent progress in micro–nano technologies have led to various types of biomedical sensors that can be effectively used to record patient's physiological signals, data parameters, and contextual information. Also, recent technological advances allow us to transmit this information to other devices and/or systems, thus enabling the delivery of personalized healthcare services.

The addition of processing and communication capabilities to sensor technology has enabled the implementation of intelligent sensor platforms [8]. These platforms support advanced reasoning and information fusion techniques that are required for the deployment of sophisticated healthcare applications. Communication technologies such as IEEE 802.15 (http://www.ieee802.org/15/) for wireless personal area networks and IEEE 802.11 (http://www.ieee802.org/11/) for mobile Internet offer effective means for effective patient–clinician interaction via PHSs, enabling bidirectional information exchange. Sensor miniaturization, advanced power management schemes, unobtrusiveness, as well as highly available network connections also constitute relevant advances that contribute to the realization of ubiquitous, personalized healthcare services.

The adoption of PHS in several application scenarios has emerged in response to the need for ensuring individualization of healthcare solutions, prevention and continuity of healthcare services, improving patients' quality of life, and rationalizing healthcare costs. Typical PHS applications include remote monitoring for chronic disease management [9]–[12], wellness assessment [13], lifestyle management [14], ambient-assisted living for older adults and individuals with mobility-limiting conditions [15], and personal health record (PHR) systems [16], [17], to name a few. The effectiveness of such systems has been reported in several studies [11], [18], [19], illustrating significant results, such as a reduction in hospitalization rates among chronic patients, increased compliance with therapy plans, increased patient awareness and self-care, etc.

Although significant progress has been achieved during the past decade, there are still several open issues and challenges that have to be addressed in the field of PHS. Among others, we want to emphasize the following: embedding intelligence and medical knowledge in PHSs [8], properly managing medical information [20], contextualizing healthcare services [21], addressing interoperability issues across personal health systems and the healthcare infrastructure [22], increasing quality control of clinical care plans and patient acceptance [23]. It is evident that, the role of the patient in healthcare will have to be further elaborated upon as an active, mobile, and empowered participant, so as to achieve the appropriate patient motivation and involvement; thus, new patient-driven paradigms for healthcare have been introduced, considering the patient as the center of the healthcare system [24].

II. Content of the Special Section

In the present special section on PHS, we aim to present the state-of-the-art in three main areas of PHS, namely advances in micro–nano instrumentation and telemonitoring capabilities, the development of new types of information processing and management including embedding intelligence in PHS for better medical decision support, and finally, the development and use of platforms that enable monitoring the quality of care through managing and integrating information, data, and medical knowledge stemming from PHS.

The 13 papers of this special IEEE Transactions on Information Technology in Biomedicine issue on PHS are herein presented in groups that follow the three aforementioned areas of work in PHS.

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TABLE I
MAIN ADVANCES IN PHS INSTRUMENTATION AND SENSORS

Paper Authors	*Main points related to PHS*
Coyle Sirley et al. [25]	• In the paper new textile sensors which can be integrated into fabric were developed for the measurement of physiological parameters and the chemical composition of bodily fluids, especially sweat • There is a textile based fluid handling system for sweat sample collection and transport with a number of sensors including sodium, conductivity and pH sensors • Through this network of sensors for the first time it has been possible to monitor a number of physiological parameters together with sweat composition in real-time
Weber Sonja et al [26]	• A new "wound mapping" device has been developed based on Electric Impedance Spectroscopy (EIS) • This can characterize the electrical properties of the tissue over a range of frequencies and thus characterize and map wounds without the need for removing clothing • This device and also protect the wound from interference and contamination thus easing the wound healing process
Scilingo, Enzo Pasquale et al [27]	• In this paper a number of respiratory rate monitoring techniques which are integrated on wearable systems are tested and compared with a spirometer. These techniques are Inductive plethysmography, impedance plethysmography, pneumography based on piezoresistive textile sensor, and plethysmography based on piezoelectric sensor. • The plethysmography based on piezoelectric sensor shows the best characteristics to • be used for breathing frequency monitoring, even when subject is moving.
Hegarty, Meghan et al [28]	• An integrated sensing and therapeutic compression module is developed for use in the treatment of leg ulcers • The wearable device is based on compression bandages and stockings as well as intermittent pneumatic compression (IPC) device • Wireless monitoring of leg ulcers is achieved via integrating such communication modules with the aforementioned wearable devices based on compression with the IPC based device showing a capability on some degree of control over the pressure regimen • This wearable vascular health monitoring system has the potential to revolutionize the compression therapy market by individualizing therapy, leading to reduced treatment times.

A. New Micro–Nano Instrumentation, Sensors, and Sensor-Based Systems

These papers leverage wearable sensors to measure physiological variables such as electrocardiographic activity, respiration, sweat, and skin conductivity (to assess stress levels). Besides, sensor technology to monitor wounds and leg ulcers is presented within this set of papers. We believe that this group of papers and the presented systems constitute the most mature part of the PHS field. Sensor systems such as the BIOTEX system for measuring sweat, pH and Na and the SPECT wound recording assessment system constitute major advances in the instrumentation domain and are expected to play a major role in the future of PHS.

Table I summarizes the main advances and elements that these papers bring into the PHS field.

TABLE II
PHS INFORMATION PROCESSING AND CLASSIFICATION TECHNIQUES

Paper Authors	*Main points related to PHS*
Augustyniak, Piotr [29]	• This work focuses on ECG interpretation in a distributed surveillance network. The proposed approach is based on performing the interpretation process as a distributed computing task. The computational tasks are flexibly shared between the remote recorder and the central server and automatically controlled via bi-directional digital wireless transmission channel. • The adaptability built into the data interpretation and transmission systems is based on diagnostic parameters measuring continuously the data quality . The adaptation process is also modulated by estimates of remote resources including battery status, CPU workload, memory usage and wireless link quality.
Fayn, Jocelyne et al [30]	• This manuscript presents an Enhanced Personal, Intelligent and Mobile system for Early Detection and Interpretation of Cardiac Syndromes (EPI-MEDICS). • This is a personal self-care system that allows citizens to self-record high quality electrocardiograms (ECG) on demand with a smart portable device, which has ICT capabilities. The system has embedded intelligence that allows one to achieve ECG processing and interpretation. It also has Web Server and wireless communication capabilities. • This system addresses issues of interoperability in medical devices and has been tested in multi-center trials across Europe.
Setz, Cornelia et al [31]	• This manuscript presents a PHS for detecting stress levels. • This system is based on the analysis of electrodermal activity (EDA) that is leveraged upon to distinguish stress induced by cognitive tasks. • The system is based on a wearable device measuring skin conductance. EDA peaks and the instantaneous peak EDA rate are shown to carry the most relevant information concerning stress levels.
Goulermas, John et al. [32]	• This manuscript presents a PHS that employs the analysis of biomechanical microenvironment variables like pressure and thermal fields. The focus is on foot kinematics. Kernel principal component analysis (KPCA) is relied upon for nonlinear dimensionality reduction of features, followed by Fisher's linear discriminant analysis for the classification of patients with different types of foot lesions. The paper establishes an association between foot motion and lesion formation. • This work shows that foot kinematics contains information that is highly relevant to pathology classification and also that the nonlinear KPCA approach has considerable power in unraveling abstract biomechanical features into a relatively low-dimensional pathology-relevant space.
Ghasemzadeh, Hassan et al. [33]	• This manuscript presents a system using inexpensive, off-the-shelf inertial sensor nodes that collect bio-medical signals from human body and generate transcripts of movements that reduce the complexity of the original signal. • A particular movement is coded using a sequence of symbols related to a motion template. • Via a distributed algorithm the number of active nodes is reduced thus resulting into a simpler movement classification and decision making process.

TABLE III
KEY FEATURES OF THE PHS PLATFORMS

Paper Authors	*Main points related to PHS*
Bächlin, Marc et al. [34]	• This paper presents a wearable assistant for Parkinson's disease (PD) patients who experience freezing of gait (FOG). The system uses on-body accelerometers to measure the body motion. To automatically detect FOG, the system analyzes the frequency components of the body motion. When FOG is detected, the wearable assistant provides a cueing sound to assist the patient to 'help themselves out' of the freezing episode. • The results show that the proposed system can effectively provide online assistive feedback for PD patients when they experience FOG. The system detected FOG events with a sensitivity of 73.1% and a specificity of 81.6%. The majority of the patients indicated that the context aware automatic cueing is beneficial for them. •
Vehkaoja, Antti et al. [35]	• This paper presents a general purpose home area sensor network and monitoring platform intended for eHealth applications ranging from elderly monitoring to early home-coming after hospitalization. • The monitoring platform is multipurpose, meaning that the system is easily configurable for various user needs and easy to set up. • The system consists of a chosen set of sensors, a wireless sensor network, a home client, and a distant server. • Two cases that are relevant to PHS are herein presented, i.e. monitoring an elderly woman living in a sheltered housing facility and monitoring a patient followinga hip-surgery during his rehabilitation.
Mattila, Elina et al. [36]	• This paper presents the Wellness Diary (WD), i.e. a mobile application designed to support citizens learning about their behavior and making and maintaining behavior changes. • The results of the study suggest that the WD approach works well when subjects receive attention from experts and are well-introduced to the benefits of self-observations and the use of WD. • Personalization and profiling should be implemented in WD to enable tailoring of the application to personal self-management needs or the requirements of a specific intervention or disease management program. The needs and preferences vary from one individual to another, depending on the cultural and individual preferences and health status. • Combining WD with a decision support (DS) system based on evidence-based clinical data would enhance the feedback by providing rule-based interpretation of the data.
Koutkias Vassilios et al. [37]	• This manuscript aims at extending the delivery of personalized home care services by introducing a novel framework for monitoring the patient's condition and safety with respect to the medication treatment administered. • The authors use a Body Area Network (BAN) with advanced sensors and a Mobile Base Unit (MBU) as the central communication hub. On the side of the clinical environment, an architecture was developed offering tools for the detection of possible Adverse Drug Events (ADEs) and the assessment of medication responses, supported by mechanisms enabling bidirectional communication between the BAN and the clinical site. • Communication and information flow aspects that were addressed in the manuscript by defining/adopting appropriate formal information structures as well as the Service-oriented Architecture (SoA) paradigm. • This framework is illustrated via an application scenario in hypertension management.

B. New Information Processing Technology via Embedding Intelligence in PHS

These papers address the development of new modules for information processing as well as the development of classification techniques applied to biosignals and vital signs with the aim of deriving clinically meaningful parameters from sensor data. The focus of these papers is on topics such as the interpretation of ECG data, the analysis of skin resistance data, the analysis of data recorded from sensors capturing the effect of foot pressure lesions.

Table II summarizes the key features of the techniques used for information processing and classification as well as for embedding intelligent algorithms in these systems.

C. PHS Platforms—Clinical Care Plans—Patient Safety

The papers in this group present complete solutions based on PHS and the deployment of such solutions to address specific clinical applications including the management of cardiovascular diseases, Parkinson disease, and mental disorders. Furthermore, this group of papers presents platforms designed to facilitate the titration of medications and wellness management in chronic diseases.

Table III summarizes the key features of the PHS platforms presented in this special section and relates them to specific clinical applications.

III. CONCLUSION

This presentation of the state of the art in PHS spans a wide spectrum of scientific and application topics thus reflecting the complexity of the field. Recent advances in PHS are contributed by new types of sensors and newly developed wearable systems that allow one to measure physiological data of great clinical relevance. Clinical applications that now fall within the area of work achieved via PHS require high quality of the data recorded, thus making it necessary the development of new processing algorithms that are now becoming a major aspect of a new generation of PHS. Issues remain in the areas of communication and user interface design. Addressing these issues will be a further step toward empowering individuals by creating viable personalized health services. If the technical issues described in this special section are properly addressed, PHS will become an integral part of the healthcare system. The papers contained in this IEEE TRANSACTIONS ON INFORMATION TECHNOLOGY IN BIOMEDICINE special section on PHS show that the state of the art in the field is promising and that PHS have indeed the potential to become an essential tool to deploy high-quality clinical care.

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