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Editorial

Data Processing and Wearable Systems for Effective Human Monitoring

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1. Introduction

The last few decades have seen an unrestrained diffusion of smart-integrated technologies that are extremely pervasive and customized based on humans' environments and habits. Wearable and mobile technologies such as smartphones, smartwatches, lightweight sensors, textile-based support systems, flexible displays, and micro-cameras are now supplied with a significant amount of computational power, low-energy wireless communication, long-life battery, and large-memory storage that make them a valid platform for monitoring the everyday life of humans [1].

In this context, a large variety of new sensors are being developed to equip such well-established wearable and mobile technologies with the aim of continuous monitoring of physical behavior, emotional state, well-being, and health condition. Interestingly, the recently improved computational resources of mobile systems allow us to acquire, process, and communicate a large set of different information. Nevertheless, this confronts us with the chance and challenge of managing an impressive amount of heterogeneous data, including physiological signals, through new ad-hoc processing, synthesis methods, and big data analysis as well as ad-hoc experimental paradigms, system designs, and models.

2. The Present Special Issue

This special issue "Data Processing and Wearable Systems for Effective Human Monitoring" includes a total of eleven papers covering a diversity of categories in physiological and behavioral data processing, wearable sensors, and environment monitoring systems.

In the wide research area of electrocardiogram (ECG) processing, Boehm et al. [2] developed a finite response model (FIR) to correct unobtrusively acquired ECG, which is commonly excluded from the clinical practice due to the signal deformations that can affect the ECG diagnosis. The model was compared with other approaches for the correction of ECG deformation showing significantly better results. Particularly, the FIR output showed a good agreement compared to a reference simultaneous ECG recording in terms of correlation coefficients and statistical comparison of the spectrum and morphological features. Billeci et al. [3] proposed a novel method for efficient discrimination between atrial fibrillation, normal rhythms, and noisy ECG recorded by a smartphone-based device. An SVM-based classification procedure was applied on a dataset made by features coming from the analysis of both the RR time-series, p-wave, and ECG morphology and included a feature selection stage based on stepwise linear discrimination analysis. The results showed remarkable performance both in short-term ($F_1 = 0.83$) and long-term recordings ($F_1 = 0.98$), with a lower number of features than in most of the previously developed algorithms and a consequently low computational time, which makes the method suitable for real-time scenario.

Cappon et al. reported on the relevance of wearable systems for glucose monitoring in diabetes treatment [4]. Specifically, the paper discussed how the realization of wearable and minimally invasive systems for glucose monitoring (i.e., continuous glucose monitoring sensors) allowed an increase in the amount of available information on blood glucose level fluctuation. Thus, it is now possible to improve prediction models and realize alarm and feedback to the users. The article discussed several challenges for the next generation of glucose monitoring devices, such as integration and data sharing with other devices, the use of optical technology to reduce invasiveness, and the increase of sensor lifetime as well as the reduction of device costs. Interestingly, this paper underlined that an improvement of personalized models is needed for the design of decision support systems. To reach this aim, the quality and amount of information about each subject has to be improved, and at the same time big data analysis approaches have to be adopted to detect relevant patterns. Ajami and Mcheick [5] introduced a framework for the integration of multimodal data information and knowledge about relevant factors for patient management. The authors presented a system to provide a medical recommendation to Chronic Obstructive Pulmonary Disease (COPD) patients. This work showed how multimodal dynamic information about the patient's status, behavior, and environment could be integrated using an ontology-based repository, following a semantic approach. The system was intended to interact with patients in order to control precarious situations, by means of alarms and feedback. Interestingly, the ontology was created to incorporate the concepts, along with mutual relationships, that were relevant in COPD disease and were treated here in a dynamical fashion, allowing adaptation of the model to patient profile as well as to changes in physiological parameters or environmental factors. Segura-Garcia et al. [6] developed a new system based on a distributed architecture for monitoring physiological parameters of athletes. The recorded physiological data were sent, through a System-on-Chip platform, to a cloud, which stored and fused the multisensor data according to the Dempster–Shafer inference theory of evidence. This fusion algorithm captured and combined certainty using Dempster's rule. Results of a network simulation showed good performance for medium-term monitoring of sports activities.

All the aforementioned works show how the information about subject behavior is more and more relevant. The characterization of daily life activities is not simply a possibility offered by current technologies, but it rather represents a compelling need. In fact, subject behavior, position, and motion represent a relevant source of information per se and also for the classification of concurrent acquired information, such as those obtained by physiological parameter monitoring. In this issue, several discussed works are facing subject posture and position monitoring. In such a category, Shirahama and Grzegorzek [7] applied a codebook approach to unobtrusive wearable/mobile sensor data recorded during different activity recognition tasks. Subsequences extracted from accelerometers and electro-oculogram sequences using the codebook method were classified by a support vector machine. Results demonstrated good performance in recognizing different activity tasks, suggesting also a practical implication for end-users like clinicians. Luczak et al. [8] proposed liquid metal sensors to monitor complex ankle movements such as plantar flexion, dorsiflexion, inversion, and eversion. These sensors showed good stretch linearity for different stretching forces and temperatures. An ankle complex model was developed for demonstrating a significant relationship between plantar flexion movements and sensor resistance changes. Results suggested that liquid metal sensors can be a valid substitute for the inertial measurement units in capturing specific joint angles and movements. Sasakawa et al. [9] presented a system to monitor the human posture identification scheme through an array of MIMO radars. This system is designed to be a safety-monitoring system to aid the elderly in danger of falling. A new methodology is implemented for a three-dimensional estimation of the human orientation by combining information from the time-differential channel technique and the Doppler radar cross-section (RCS). Experimental results showed that the human location and posture identification achieved an accuracy of over 90%. Another method for the estimation of the human body orientation was proposed by Shiraki et al. [10]. To this aim, they analyzed the temporal responses captured by multiple antennas of a Multiple-Input Multiple-Output time-variant channel radar. Specifically, a system of antennas were placed surrounding the participant, and their vital signs such as respiration and heartbeat were recorded from the reflected microwaves. The human body orientation was estimated by identifying the antenna which receives the signal with the largest rhythmic fluctuation. This is assumed to be associated with the frontal side of the human body. Results showed that the median values of the cumulative distribution function of the orientation estimation error ranged from 9.01 to 23.35 degree. In the work by Murakami et al. [11], a smart use of systems largely available in indoor environments was proposed to detect the position of humans and animals. Specifically, this paper proposed monitoring the changes in WLAN signals in order to extract some relevant information. The novelty of this paper lies in the efficient use of a measuring station, aimed at collecting the channel state information and improving detection accuracy.

Yaganoglu et al. [12] provided an example of how to develop wearable systems to support disabled people by using a combination of state-of-the-art low-cost electronic systems and signal processing methods. Specifically, such a wearable device helped hearing-impaired people to detect and classify specific ambient sounds in real-time, e.g., a barking dog, a ringing phone, and a honking sound. The system estimated a set of sound features in real-time to create a sound fingerprint that would then be compared to those of target sounds. Vibratory feedback was then given to the subject.

3. Future Research

In the last decades, scientific research on the topic of data processing and wearable systems for human monitoring has been largely investigated and is still expanding thanks to novel technologies and methodologies. From a technological point of view, an expanding area focuses on the development of various unobtrusive contactless systems for physiological signal monitoring. These can follow different realization methods and can be integrated into a large variety of everyday objects. One very relevant issue is the assessment of data quality, especially when a large amount of information is acquired. For instance, these new technologies, as well as all wearable monitoring systems in general, can be dramatically affected by motion artifacts. These limit their application outside the laboratory setting. Therefore, a substantial effort of future research should concern the development of new strategies for filtering or mitigating the effect of movements on the quality of recorded data. In more general terms, an effort will be made to assure and verify data quality. Finally, the large quantity of information collected by wearable and mobile sensors during long-term recording sessions will inevitably lead to new models and methods for data integration. Future work should exploit state-of-the-art approaches for big data analytics, as well as collaborate with users, clinicians, and stakeholders to build new frameworks for the development of personalized models. To this end, the information extracted through the analysis of recorded data as well as a priori knowledge has to be integrated to apply such novel, complex human monitoring systems in real-world scenarios.

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