PhysioDroid: an app for physiological data monitoring

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Abstract. The ever progressing technological advances on the development of mobile phones, medical sensors and wireless communication systems are supporting a new generation of unobtrusive, portable and ubiquitous health monitoring systems for a continuous patient assessment and a more personalized health care. In this paper we present PhysioDroid, an Android based application operated together with a wearable monitor capable of measuring vital information such as electrocardiogram (ECG), heart rate (HR), respiration rate (BR), skin temperature and motion directly from the human body. The application provides gathering, storage and processing features for the body sensor data. Likewise, the system works as a gateway enabling data transfer to a remote server which may be used for further processing and analysis. PhysioDroid also implements visualization of physiological information mainly intended to trigger alerts and emergency calls when abnormalities or risk situations are detected.

Keywords: Physiological monitoring, Health devices, Mobile computing, Wearable computing, eHealth, mHealth, Android, App

1 Introduction

In the context of health care delivery around the world, two situations may be identified [3]. On the one hand, health care organizations in developed countries are facing budget cuts due to the current financial crisis. The health care demand is also higher as consequence of an ageing population that suffers from multiple chronic conditions. On the other hand, health care systems in developing countries face challenges in providing care because of scarcity of personnel

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and resources. Therefore, the need for an efficient solution exists. ICT technologies appear in this context to revolutionize the sector and provide efficient and affordable solutions.

Remote health monitors may continuously inform caregivers or practitioners to respond fast in case of an emergency. However, not only could these devices be useful to enhance medical work but also to make it possible. In fact, these systems may become much valuable in regions where the trip to a care center takes several hours or a few doctors must assist thousands of patients. Besides, current technology cost limitations for developing countries are also expected to be overcome shortly. The actual rate of electronics getting smaller and cheaper is paving the path to more affordable solutions.

One of the main limitations of up-to-date mobile health monitoring devices are processing and storage capabilities. Smartphones are the perfect means to collect the data coming from these sensor devices, as well as to provide local processing or even access to cloud functionalities. In this work we present an application (app) based on the Android platform that enables the collection, sharing and exchange of physiological data registered through a pervasive wireless health monitor. The rest of the paper is organized as follows. In Section 2 a brief summary of widely-used pervasive health monitors is presented. Section 3 introduces the PhysioDroid project, which comprises the description of the hardware components as well as the app usage and main functionalities. Finally, main conclusions and future steps are presented in Section 4.

2 State of the art

Looking at the market for state-of-the-art mobile health care sensors, an estimated number of 16 million devices will be sold by the year 2016, as predicted by ABI Research [1]. Accordingly, the popularity of these sensors is increasing. The choice of which device to use for certain applications boils down to the features and incorporated sensors. Similarly, the way these devices are worn is very different just as the way they obtain data from the body or communicate with base stations for further diagnosis and presentation. Some of the manufacturers already provide software to examine the collected data on a handheld device or desktop computer, yet others provide supervision of specialists from remote servers. An extensive updated list of more than 240 different mobile health devices is provided in [6].

Examples of specific purpose commercial health monitoring devices are the Irythm Zio Patch [9], a long-term cardiac rhythm monitor specially designed to improve diagnosis of cardiac arrhythmias, the fitbit [5] for intake and activity assessment or the Zeo sleep monitor [14] which is specially indicated for sleep disorders analysis. The achievement of full hospital grade is now also possible with the release of utterly portable devices such as the Smartheart [11], the first personal mobile 12 lead ECG for the detection of ischemic cardiac events. Examples of more general commercial health monitoring devices are: the ViSiMobile [12] which measures ECG, HR, oxygen saturation, BR, non-invasive blood pressure and skin temperature; the AVIVO MPM PiiX [4] which is capable of monitoring fluid status, HR, BR, posture, activity and ECG; the Equivital LifeMonitor [8] that collects ECG, BR, skin temperature and acceleration data, and other metrics such as galvanic skin response, oxygen saturation or geopositioning through the use of additional modules; the Zephyr Bioharness [15], a garment that registers comprehensive physiological data from medical-grade ECG, HR and BR to motion; or the RS TechMedic DynaVision [13] which incorporates ECG, HR, plethysmogram, SpO2 and body temperature sensors.

3 PhysioDroid

3.1 Hardware Components

The PhysioDroid project consists of three main components:

- a wearable sensor that records different types of physiological data on a subject and transmits them wirelessly;
- a smartphone that acts as collector of the data delivered by the vital sensor, support system for medical diagnosis and health alerts, interface for user data inspection as well as gateway which forwards the data to a server for further analysis;
- a server for storing, processing and/or reviewing the data.

The first component corresponds to the physiological monitoring system. Here, the Equivital EQ01 (see Figure 1) is particularly considered. EQ01 [7] is a multi-parametric, wireless and portable health device that collects and transmits vital sign information measured from the body of the wearer to a smart computer, server or base station. Through a Bluetooth connection, the information may be sent over a network in close proximity to the device.

The EQ01 is attached to the body with the help of a belt which is strapped around the chest. Embedded on the belt and the back of the device are sensors that rest directly on the skin to measure vital information through impedance measurements. The EQ01 senses ECG (2-leads at 256Hz), respiration (25.6Hz), motion (acceleration at 25.6Hz) and body temperature. The device provides a very light proprietary processing of the information, including filtering and low level knowledge extraction. Thus for example, the device is able to detect a reduced set of postures (e.g., standing, lying) from the analysis of the measured acceleration, or extract the R-R interval for electrocardiogram analysis. Moreover, the EQ01 provides alarms and system status information as part of the system main features. There are two operating modes available for the EQ01, full disclosure (which includes the raw data delivery) and partial disclosure (only calibrated data is provided). Here the first mode is considered. For more specific details regarding communication and storage protocols and information encoding the reader is referred to the product manuals and datasheets [10].

The other main device used in this work is a smartphone. In particular, Android devices have been here considered. Several advantages of the Android operating system with respect to its competitors were conclusive during the platform selection. These include, the greatest growing mobile market, opensource framework, highest performance stability and security, and continuous updates and upgrades of the application programming interface (API) among others. Different models have been tested during development and validation, from Samsung and HTC to LG or Sony devices, including a representative selection of the various Android API versions ("Gingerbread" API 2.3 and newer).

Finally, the information may be optionally uploaded to a server for further processing. For the purpose of this work, a desktop computer is normally used.

Fig. 1. Equivital device and accessories. Hidalgo®.

3.2 Application Description

App Features and Usage The PhysioDroid application is conceived to facilitate users' access to a simplified description of their health status profile as well as provide alerts on risk conditions. Besides, the app is meant to collect user physiological data that may be of worth value for well-being assessment, track of conditions evolution and even big data pattern analysis. All these contributions may potentially lead to more efficient medical diagnoses and treatments.

To that end a few features have been specifically defined with the aim of a simple, reliable and understandable application. One of the principal components applies to data retrieval and processing. As soon as both smartphone and EQ01 are Bluetooth bound the application starts collecting the data delivered by the vital monitor. The information is decoded from its original raw format to be forward used by the data management modules. These management modules enable the data adequation and real-time visualization on the smartphone. Two modes have been here considered for the data presentation, one for the experienced analyst and another for the average user. The *expert* *view* provides advanced representation of physiological data waveforms. This is particularly suited for clinical specialists that may require a precise description of the recorded information. Amongst others, the ECG, acceleration and respiration waveforms are displayed as well as the skin temperature. A simpler data presentation is provided for the regular users. The *user view* includes averaged values (HR, BR, TEMP) and visual indicators that inform about the adequacy of the measured parameters. The collected data may be also stored in a local database and/or uploaded to a remote server with the help of an internet connection. For the data uploading both WIFI and 3G may be used. In either case the user may configure the type of connection to be used. To prevent data disclosure the information is secured through user and password policies and data encryption. This login information is further used to securely label and identify the monitored data.

In Figure 2 the process to get started is depicted. After launching the app, the users are asked to insert name and password to uniquely identify and log into the application contents (Figure 2.a). Registration is only required for the first time access (Figure 2.b). Here data related to the users' personal information and vital profile such as name, age, weight and height must be inserted. This information may be used for some of the planned recommendations and alerts. Thereupon the user is logged, the main menu is accessed (Figure 2.d). This includes several items that link to the monitoring interface, database upload, configuration setup and a few additional help manuals. After accessing the monitoring menu (the one which comprises most of the recording and visualization functionalities), the user is redirected to the *user view* (Figure 3.a). The users can check here the status of the monitored vital values. For a user-friendlier inspection of the vital signs several status bars are defined. Each bar refers to a numerical range that identifies the regularity of the associated physiological parameter. To do so, a number of bars light up from left to right and green to red (green = 'OK', yellow = 'warning', red= 'danger'). From here the user may check and react to data for example following personalized clinical guidelines or recommendations. The thresholding of these states (bars) may be medically set for each subject from her/his particular health conditions demands. For the motion data interpretation, a stick that imitates the identified posture or exercise is particularly used. At the bottom of the screen the user also gets information about the EQ01 battery status, apnea occurrence, vital signs and irregular heart beat events. All these events comes from the EQ01. Finally, the *expert view* may be accessed from here by pressing the corresponding button (Figure 3.a, bottom right). In this new panel a grid is displayed and the waveforms for the selected physiological signals are plot. An example for motion data may be seen in Figure 3.b. For the sake of simplicity, this functionality remains hidden for the average user version.

App Implementation The application software consists of seven packages respectively defined as *cache*, *drawing*, *login*, *monitoring*, *upload*, *storage* and *add-ons*. The classes of each package serve the same purpose as described by

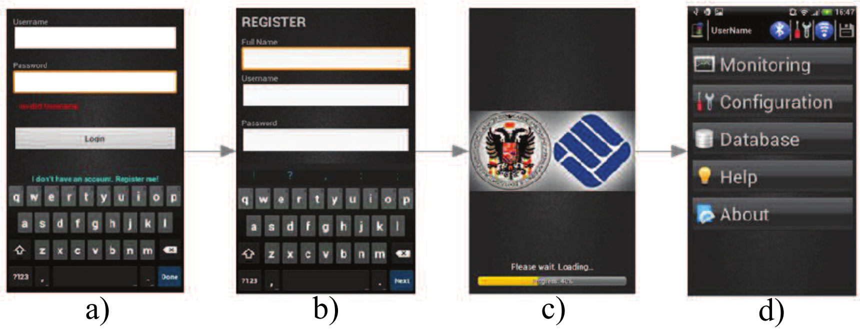

Fig. 2. Screenshot from the application wizard to get started. a) Login b) Registration c) Modules loading d) Main menu.

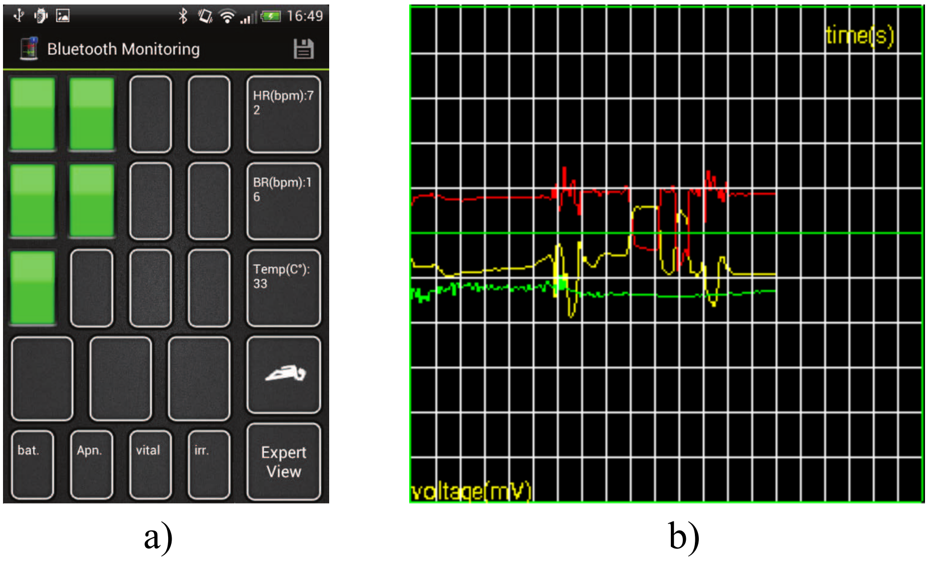

Fig. 3. Screenshot from the a) user and b) expert monitoring view. Raw acceleration signals from the EQ01 are depicted in b).

the package name. Thus, the *cache* package prototypes classes that implement a cache based on a buffer. This allows the application to perform data processing without requiring local permanent storage. The incoming data is managed and administered by the *monitoring* package, which further supports the Bluetooth connections between the vital monitor and the smartphone. These connections are defined through a Rfcomm socket and the SPP protocol. The *storage* package manages local and remote storing processes together with the *upload* package. MySQL and an Apache server is used to run the database management processes. The graphs and general data presentation are implemented through the *drawing* package. User login and registration is handled within the *login* package. Finally, the add-ons package contains classes that are not essentially needed for the application core functionalities, but makes user interaction more pleasant and provide additional features as a help screen to support the user.

The implemented software applies to Android API level 9 to 15 and makes use of the best practices recommended by Google in order to increase user experience, reduce power consumption and improve performance. The software granularity also allow developers to easily include new functionalities for signal acquisition, data storage, data analysis and data transmission as well as other add-ons whether required. It is aim of the authors to shortly release an open-access updated version of the PhysioDroid app.

4 Conclusions and future work

In this paper we have presented a physiological monitoring application solution specifically designed for Android mobile devices. This application acts as a gateway for wireless health monitoring sensors, thus supporting physiological data gathering, as well as local and remote storage. The application also allows the users to visually inspect the vital signs information collected through a mobile health monitor. This information is presented according to the users' level of expertise. Simple alerts and emergency calls are also features included as part of the app. Even whether the application has been here defined for the Equivital EQ01 monitor, it has been implemented in a way that little effort is required to make it compatible with any type of Bluetooth interfaced health monitor.

Next steps of this work aim to incorporate sophisticated data analysis and decision support techniques (e.g., daily living activities analysis [2]) that may provide a more profound description of the users' status and their evolution, key information for a customized and personalized health care.

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