Droid Jacket: Using an Android based smartphone for Team Monitoring

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Abstract—Professionals such as First Responders are frequently exposed to extreme environmental conditions, inducing stress and fatigue during extensive periods of time. In this scenario, the main issues are the quantification and evaluation of stress and fatigue, since uncontrolled levels have a profound and negative impact on human health and performance.

Based on an existing wearable monitoring solution - the Vital Jacket® – we propose an individual and team monitoring mobile solution called DroidJacket. DroidJacket is based on Android mobile devices and provides data aggregation, processing, visualization and optionally relaying services. The DroidJacket design is plugin oriented, integrating analysis modules, namely online ECG plugin for both real time pulse and arrhythmia detection.

Keywords—mobile computing, alarm detection, wearable technologies, monitoring system

I. INTRODUCTION

First responders live many stress situations on their daily work and being able to real time monitoring of their human stress under adverse conditions can be a valuable asset namely in understanding physical and emotional exhaustion (fatigue) patterns [1]. A recent clinical study reveals that these kind of activity has a toll of the professionals life expectancy in relation to other “normal” professions [3]. This is especially relevant as their tasks imply exemplar performance in critical situations, where they and other individuals depend on their reactions and decisions.

Typically first responder monitoring is based on periodic medical visits where certain pathologies such as arrhythmia episodes can remain unnoticed [2]. The chance of these or similar events being detected increases with continuous monitoring, making possible to evaluate more accurately their health status, and detected time related trends not perceivable in sporadic events, but only on wider time periods. This could be used to support decisions like keeping or not first responders in the mission front line. As an added bonus it would also allow obtaining a physiological characterization comprising of both normal and extreme situations (e.g. during and after critical interventions) namely a follow-up of stress levels that is known to change the autoimmune system and increases the probability for developing cardiovascular diseases [4]. Other examples can include other emotional and physical symptoms such as sleeping disturbances, fatigue, headache (physical), psychiatric disorders, anxiety and depression (emotional) [5].

Obtaining such data is useful to achieve a realistic physiological assessment of the monitored subjects. However performing this continuously implies being able to acquire and gather real-time information of body signals, and process and disseminate them in operational conditions at the same time.

Over the last years, new technological advances in mobile devices and wireless communications brought novel resources for supporting of monitoring systems. This can be observed in the impact of mobile devices in areas such as medicine, which are investing in solutions where mobile devices are active components of their architecture. For instances several physiological signal monitoring systems rely on PDA or PC for detection and analysis of biologic signals [6] [7] [8].

Mobile devices, such as smartphones, which integrate in one device mobility, computational power, and friendly interaction capabilities, started being used for monitoring systems [9] [10]. With the technical improvements in mobile technologies, such as multithreading or wireless standard support (i.e. Wifi, Bluetooth, zigbee), monitoring multiple vital parameters of individuals, is now a reality [9] [11].

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A good example is the Vital Jacket®, a wearable vital signs monitor [12] that was developed by an high-tech company named Biodevices S. A. (http://www.biodevices.pt), together with researchers at the University of Aveiro. The Vital Jacket® aggregates a suite of non-intrusive wearable technologies, as inconspicuous as a t-shirt. It combines textile and microelectronics providing a reliable physiological data for sports, clinical and emergency scenarios [12]. Vital Jacket® is compliant with the EU directive 42/93/CE for medical devices and produced with an ISO9001 and ISO13485 certified manufacturing process.

In this paper, we present an Android based application – the DroidJacket. It relies on mobile devices to support real time monitoring vital signs of a team of individuals. This work is a proof of concept of a broader context within the VitalResponder project (http://www.vitalresponder.pt). The objective of this project is to support first responder teams in operational scenarios (e.g.: open field, forests and urban scenarios) in order to access and measure changes in the stress and fatigue levels. Vital Responder’s ulterior objective is to provide a first responder team monitoring solution supported in reliable markers of stress and fatigue, that can be used both in the real time decision and in long term follow up of the individuals (e.g.: clinical follow up). The project involves IEETA/University of Aveiro and has several partners from academia/research (IT/Porto and IT/Aveiro, Carnegie Mellon University), companies (BioDevices S.A., Petratex) and firemen associations (Companhia de Sapadores de Vila Nova de Gaia and B. Voluntários de Amante).

II. DROIDJACKET

The DroidJacket is an Android application running on a smartphone that gathers vital signs such as ECG stream, and relays it to external clients. The DroidJacket (Fig. 1) is composed by the Vital Jackets® and their embedded VJ boxes where the storing and wireless link are located, the VJ Server (Fig. 2), the Android smartphone and a running application (Fig. 3). We select Android operating system for the opening and well documented SDK to develop new applications. It supports multitasking and background services, storage, where it abstracts the hardware and network resources, and has effective data share mechanisms [15]. The DroidJacket is able to process the incoming ECG data to extract the pulse information, and the characteristics of individual heart beats to support a simple arrhythmia detector. It relies on BIOSal (Fig. 4), as a component of the application, which allows access and management of data flows to provide both the user interface and the processing facilities. The architecture decouples the data provider (in our case the VJ Server Fig.2 – VJ Server communication network) from remote clients (e.g.: other Vital Responder nodes – the VR communication network) as depicted in Fig. 4. Note that in an operational scenario the connection between Vital Jacket® and DroidJacket can be made directly (Fig. 1).

A. BIOSal

BIOSal is a modular framework for a Bio-Signal Stream Session implemented in Java. In BIOSal the Session Manager is the entity responsible for managing all running sessions and for providing an interface between entities who want to create, start or close a session. It also is responsible for dealing with communication to our data providers (the VJ Server or the VJs). BIOSal integrates our simple and compact plugin solution – the Light Java Plugin Framework [16]. Using the definition of specific Java interfaces, and relying on Java dynamic binding and classpath mechanism, it is possible to integrate new features in runtime through plugins. To incorporate a new plugin, one only needs to provide a handle to the plugin (as a Java object that implements a given interface). There are four main types of plugins in BIOSal:

- **DataSources**: abstracts and supports a simple connection to a data provider, encapsulating the complexity of the connection to the outside of the system. An example is VJDataSource in Fig. 4.
- **Parsers**: enable data parsing, where each parser has to handle the data type generic input stream (e.g.: VJParser in Fig. 4).
- **Processors**: are responsible for handling and performing the processing algorithms. They can be specialized depending on the input data type. Currently, the input can be ECG and RR Intervals.
- **Alarms**: analyze collected or processed data, and through well defined rules for event recognition, are able to sense specific events and notify the user or
interested observers (e.g.: Arrhythmia Detector in Fig. 4).

B. Droid Jacket as a Data Gatherer and Provider

DroidJacket relies on the Vital Jacket® as the main (current) data provider. Vital Jacket® enables acquiring individual data, including: ECG, location (GPS) and physical activity (3 axis accelerometer). Besides being able to store the data in an SD card, Vital Jacket® is also able to stream this data to clients through Bluetooth connections. For development purposes, the point of access to Vital Jacket® data is through the application called VJ Server running on a PC. As proof of concept, the VJ Server provides the simulation of human units, since it combines the output of several Vital Jacket® devices (at the moment a maximum of four) [12] and allows online and offline access to the acquired physiological data to external applications. The offline mode relies on previously acquired/recorded/stored data on a SD card [12]. Note that we can implement new applications without always using the Vital Jacket® for testing; taking advantage from using the previously acquired data that running on VJserver emulates a “live” Vital Jacket.

To allow receiving several data sources from the VJ Server, a multi threaded design was used in order to handle each individual data stream from TCP/IP sockets. Droid Jacket uses the same approach for external communications. DroidJacket uses a SQLite database to store the team unit’s information, namely personal information (Fig. 6).

C. Online processing

In DroidJacket, BIOSal supports data gathering of several first responders and the integration of simple plugins: VJ DataSource (DataSource), VJ Parser (Parser), QRS and Beat Detector (Processors), Out of Perimeter and Arrhythmia Detector (Alarms) (Fig. 4). Through orchestration of these simple processing algorithms and alarm, we can implement different processing pipeline and alarm generation. For example the QRS workflow, part of the arrhythmia alarm workflow (presented in Fig. 5) processes the incoming data from VjDataSource that provides the InputStream abstraction (encapsulating the communication details) to the VJ Parser that will filter the incoming data. After the VJ Parser filters the data (ECG) and updates the observing entities (activities and services from the DroidJacket). At this point, the BIOSal identifies the QRS Detector as a processing plugin that receives the ECG as input and, once this processing has ended, the listeners are updated again (e.g.: user interface that provides heart rate visualization to the user). The same logic is applied again to Arrhythmia detector (Alarm, but using the R-R Interval as input). Every time an arrhythmic episode is identified, an alarm is triggered and a notification is sent to the Android mobile device status (Fig. 6).

D. The Pulse and Arrhythmia Plugin

We implemented pulse and arrhythmia detection modules to process incoming ECG data. To extract the pulse from ECG we implemented a QRS detector based on the Hamilton - Pan Tompkins method [17]. The QRS detector enables the identification of the R-R intervals that were used to extract the pulse and for segmenting each beat from ECG waveform. The arrhythmia algorithm that we used, proposed by M. G. Tsipouras et al. [18], applies a classification algorithm based on a state machine to identify rhythm abnormalities. Both algorithms were first implemented and tested in Matlab using WFDB Toolbox for Matlab [7], that supports reading signals and annotations directly via HTTP from Physio Toolkit. [7] The Matlab implementation was used as reference to validate the Android OS implementation.

III. THE APPLICATION

The initial DroidJacket screen presents to the user (a team coordinator or a person with monitoring role, such as a nurse or MD) a group of options: Users, Monitoring, and Start as Server Mode and Configurations (Fig. 6) are available. The Users option allows user management, showing firstly the user (team unit) list of the system. This list is presented by the user name and photo, followed by a jacket icon that indicates the user state by its color (off, on, alarm - respectively for black, green and red). We can add new users, and by selecting a user, update and remove it. From the monitoring view, a map was displayed, providing visualization of spatial position, representing each team unit by a jacket icon. The jacket icon uses the same logic as the one we previously described (Fig. 6). Mobile device is represented by the commander/firefighter icon. We can visualize distance between each unit and receive notifications if a unit is out of a defined range. By clicking info button, we can visualize vital signs and other relevant
Selecting Android allowed us to implement modules in Java that can be reused in any Java environment – implement once and deploy many times. A good example was the BIOSal framework and respective analysis modules that were initially developed in a standard workstation and deployed easily to the Android mobile application. By defining conceptual software entities such as bridges, drivers, detectors and data stream providers that are directly mapped into Java interfaces and/or reference implementations without platform specific concerns, our solution is highly extendable and flexible. This was a successful way implementing reusable modules from data acquisition to processing capabilities, independent from Android specific features. An example is the pipeline presented in Fig. 5.

The current DroidJacket setup still lacks specialization to be applied in operational environments but already demonstrates its broad concept: acquiring a team status in a distributed environment, monitoring and determining relevant vital conditions in real time, either visually or automatically – in our case using ECG, beat classification and arrhythmic episode detection [18].

As future work we are already addressing open issues identified in DroidJacket: managing storage namely keeping an historical record of data and events more efficiently, be able to propagate urgent information and support for offline analysis of the ECG to support more thorough analysis (e.g., more complex algorithms, use other computational resources). Considering ongoing evolutions of the Vital Jacket® it is our goal to integrate other physiological measures in the system alarms and processing. Examples are oxygen saturation by pulse oximetry (SPO2), respiration, temperature, movement, posture, galvanic skin response (GSR) and blood pressure, which are already being integrated in a new wearable prototype. With these improvements, we plan to extend the DroidJacket from a proof of concept to an operational solution, namely by extending the simple detector for cardiac abnormalities to more specific and high level services. That will allow detecting more complex mental and physical status, to be used as indicators of stress and fatigue [23]. Another approach is to use DroidJacket as a distributed computing node. At Vital Responder we are studying new forms to use Android OS at ad-hoc network configurations. This will enable to have a network composed by the Android smartphones nodes communicating among them, enabling dynamic, decentralized auto-routing network.

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