BioSigMA
Bio Signal Monitoring Application

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Abstract: The aging of the population causes an increased prevalence of chronic diseases, such as cardiovascular disease (which is the leading cause of death in developed countries) and dementia. Because of the high morbidity and mortality rates associated with this group of diseases, it is necessary to continuously monitor the vital signs of people at risk. Nowadays this monitoring is carried out by a Holter monitor, which acquires electrocardiogram data for a long period of time, so that it can be analyzed later. However, this is not a real-time monitoring. There is another type of monitor, which stores the data and communicates with a remote server, allowing real-time continuous monitoring. The latter system requires a specific platform and, as result, the patients have to adapt to yet another device in their daily activities.

Information and communication technologies (ICT) have had a remarkable role in the management of health care distribution and social work, and can be applied on daily monitoring of patients, providing a timely opportunity for medical staff to intervene. In the ICT field we have witnessed the rise of smartphones as a gadget with great mobility, connectivity and processing capacities. They are the ideal device to take patient monitoring to the next level, replacing the need for specific platforms for each type of monitoring, and facilitating the daily lives of patients. This ability of smartphones becomes more and more apparent with the increasing number in new medical applications that profit from its characteristics.

Therefore, our goal is to create an application for smartphones which takes advantage of the portability and processing capacities of smartphones to assess cardiac function, using bio signals captured by a device with bluetooth interface and the sensors on the smartphone, and subsequent processing with a medical telemetry system.

1 INTRODUCION

The aging of the population, caused by the increased life expectancy and diminished number of child births, in the occidental population, means we have more and more elderly and less active people. Due to the difficulties of some of the elder people to live independently, there's a necessity to maintain a constant vigilance of their activities and their vital signs. With aging come various problems: a great part of this elder population have mobility issues, that can be the cause of falls. 70% of all the deaths caused by falls occur on the elder population (Edelberg, 2001); also, the high prevalence of dementia in this population can impair their orientation; a large number of people suffer from cardiovascular disease, which tends towards worsening with age. More than 30% of the deaths in Portugal (Instituto Nacional de Estatística, 2011) are caused by heart disease, that requires a continuous monitoring. This monitoring can be made using devices like the Holter monitor, that acquires electrocardiogram data from a long period of time to be evaluated by a doctor. However, this device does not provide real-time monitoring, which limits its usage to diagnosis. To address this gap, a monitoring system can be used that consists of three components: a network of sensors placed on users to get their vital signs; a Platform for Personal Monitoring carried by the user that obtains the data from the sensors and sends it to the third component; a remote server where there will be a caregiver to view the monitoring data. This type of monitoring is expensive and requires users to use another device in their daily living.

Our aim is to take advantage of the capabilities such as processing power, communication interfaces and sensors embedded in a smartphone, a device increasingly common, in order to investigate its poten-

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tial in the replacement of a specific Platform for Personal Monitoring.

This paper has 4 more sections: In section 2 we present the State of the Art, including examples of projects related to this work. In section 3 we describe the functionalities of this Application and how they were developed. In section 4 we present the results obtained in the tests made to this Application. In section 5 we draw conclusions about the work done in this project, and make some considerations about future work.

2 STATE OF THE ART

Related with this work we can enumerate projects that have specific goals and projects with a more broader scope. The Brickhouse Alert (BrickHouseAlert, 2011) consists of a device that connects to a home phone and receives data from a sensor wore by the user. This sensor sends an alert to the device in case of a detected fall. In this type of fall detection systems there is another project, SmartFall (Lan et al., 2009), that uses a modified crane to include accelerometers and gyroscopes for detecting falls and communicates alerts through Bluetooth. Both presented systems require specific hardware to be used by the user. To address this and provide a more comfortable solution, there are systems that use a daily device to implement this functionalities. The PerFallD (Dai et al., 2010) project uses the accelerometer in a smartphone for detecting the falls, by recognizing patterns of force. Today's mobile platforms also present an increasing number of mobile applications with medical use that are able to read the cardiac rate through the smartphone camera (Azumio, 2011). There are also applications that implement geofencing capabilities, and some of them, like the Reminders application of iOS, are already embedded in the operating system. These are all systems that take advantage of the functionalities provided by the smartphones, but they differ from BioSigMA in that they implement a system with only a specific use. In the group of projects that have a more broader scope we have the mobile monitoring systems that mainly use the architecture presented in 1. The Heartronic project (Rocha et al., 2010) consists of an array of sensors wore by the user that communicate, using Bluetooth, with a smartphone. This smartphone sends the raw data to a remote server where it will be processed, opposed to the presented solution in this paper where the data is treated on the smartphone itself, before being sent to the server. Some projects in this group have a specific population target, namely the elderly. Projects as the eCAALYX

Figure 1: Overview of a real time monitoring system.

(Boulos et al., 2011), still in development, and iCare (Lv et al., 2010), invest in the user interface of the application, because it will be used by the elderly, and needs to be simple and intuitive. The BioSigMA system also has the same elderly target and implements a simple user interface, but it also has advanced features that can be accessed by capable users.

3 IMPLEMENTATION OF THE BioSigMA App

To implement the Platform for Personal Monitoring on a smartphone it was necessary to investigate which development platform would bring more benefits to an application of this kind. We chose the Android platform, because it is an open system, which provides freedom to develop and distribute applications. For the purpose of this work it is important to have this freedom so we have access to the smartphone hardware without restrictions. Due to the nature of this application, which requires a continuous monitoring, we used Background Services, that consists in a process provided by the system that remains running in the background. This Service is the basis of the application and manages the communication and processing made by it.

3.1 Requirements

In order to implement a Platform for Personal Monitoring, the BioSigMA App needed to fulfill the following requirements: Maintaining a continuous execution; Obtaining values from the monitoring sensors; Storing the monitoring data; Configuring the monitoring parameters; Managing the connected sensors; Processing the received sensor data; Transferring the data to the remote server; Reducing the data transfer costs; Detection of falls; Location monitoring; Configuring notification alert limits; Sending alert notifications;

In the following subsections will be presented how these functionalities were implemented in the Application.

3.2 Sensor Communication

In order to communicate with the sensors available

(Zephyr HxM, Zephyr BioHarness and a platform for acquiring bio-signals developed by João Oliveira in his dissertation for the Master in Electrical and Computers Engineering (Pedro and Oliveira, 2012)), BluetoothSockets were used for the data transmission through Bluetooth and Threads were used to make the transmission asynchronous. Since each sensor has its own transmission protocol, it was necessary to create distinct classes to manage the transmission with each type of sensor.

3.3 Bio Signal Processing

The data received from the sensors, that includes heart rate, breathing rate and temperature values, is stored locally, in a SQLite database, for local consulting. The data is then verified against the caregiver's defined limits, and in case it is beyond the limits an alert is triggered locally, notifying the user, and remotely, on the server. The data is sent to the server organized in packages containing some seconds of information, so there is no constant data connection with the server. In case of alert the package with the last seconds of information is sent immediately. The remote server consists of a SOAP Web Service.

3.4 Geofencing

To implement the geofencing functionality in the application, we used the location data tools provided by the system. The Service registers itself as an handler for location events, and when it receives a location changed event it calculates the distance between the current location and the location defined by the caregiver as the center point. If the distance is bigger than the radius, also defined by the caregiver, an alert is triggered locally on the smartphone and remotely on the server.

3.5 Activity

Using the accelerometer data, it is possible to know the force acting on the smartphone, so we can know if the user is moving, and evaluate the intensity of the movement, allowing to correlate the monitoring data, such as the heart rate, with the activity level, reducing the triggering of false positives. The activity is evaluated using the mean of the last 30 values received from the accelerometer so we can ease the spikes.

3.6 Fall Detection

The fall detection algorithm uses the data provided by the accelerometer, like the activity algorithm, to detect a pattern as the one in the figure 2.

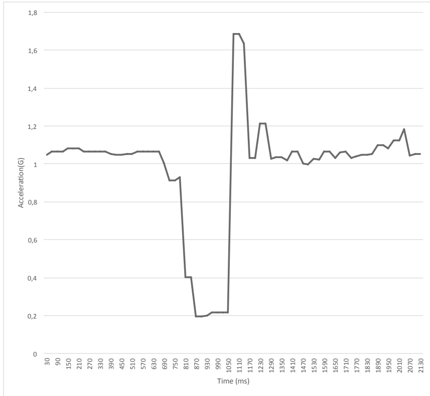

Figure 2: Force exerced on the smartphone in a fall.

When a pattern of a minimum (bellow a certain threshold) followed by a maximum (above a limit) is detected, it's possible that the user has fallen. To make the detection more robust this force pattern is complemented, in smartphones that include gyroscope, by the orientation of the device that will be different before and after the fall. After a fall the user activity will be monitored so we can know if the user recovered from the fall, or if he/she remained immobilized. In the case that he/she remained immobilized the smartphone will trigger an alarm. If the alarm is not cancelled, a text message will be sent to the caregiver with the location of the user.

4 INTEGRATION WITH KeepCare AND RESULTS

This mobile application was integrated in an already implemented solution (Sousa et al., 2012). This solution consists of a mobile application that provides the user interface for the BioSigMA platform, enabling the user to visualize his monitoring data, and also configure the monitoring parameters, as the limits for triggering alarms and the types of sensors connected to the device. The KeepCare application connects to a remote server (developed using the Wise Framework, by FreedomGrow) that receives the data from the smartphone and stores it, so the user is able to see the history of the monitoring on a website. The server also triggers alarms and shows notifications on the website.

We tested the functionalities implemented using as close to real-world examples as possible. The implementation of the bio signal data communication to the smartphone and from the smartphone to the remote server was straightforward, so the tests were

Figure 3: Monitoring data from Zephyr HXM.

simple.

In Figure 3 we can see the data as shown in the mobile application. This data is received and shown in real time. The alerts are also triggered in real time, sending a notification to the user. We also tested the activity levels by doing walks and runs, so we could adjust the thresholds at which we consider an activity a low level activity or a high level activity. For testing the fall detection, due to the nature of the tests, we could not use real falls, so we simulated falls. The simulation consisted on users walking slowly and tripping, falling on a mattress with the back facing up, down, left or right side. This simulated falls were all detected, by the application. The difficulty resides in not considering daily episodes as falls. Episodes as walking downstairs have force patterns similar to falls. So, if we have a smartphone with a gyroscope we can determine the orientation before and after a fall. In a fall the orientation differs within a value close to 90^o, while when walking downstairs the orientation variation is smaller. When a gyroscope is not available a timer is started when a fall is detected and, if the timer is interrupted by the user, there will be no notification of a fall, if the timer runs out there will be a fall notification.

5 CONCLUSIONS AND FUTURE WORK

With this work, a Platform for Personal Monitoring was developed in a smartphone that, taking advantage of the capabilities of this kind of device, implements functionalities that go beyond the transmission of the vital signs from the sensors to a remote server. Therefore, we can conclude that it is possible to use this kind of generic device in substitution of a specific Monitoring Platform. In terms of future work we will implement protocols for communication with new types of sensors and study the cost/benefits of using smartphones with included gyroscope that provide better results in the fall detection algorithm.

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