KeepSafe®
Wristband Device for Heart-rate Monitoring

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Abstract: The goal of this project is to meet efficient and technological management solutions that allow to increase life quality of elderly people and at same time reduce costs in the health sector. The KeepSafe® wristband device will increase the safety of users since it will be able to continuously monitor vital signs and it will generate dynamic alerts based on thresholds or manual alerts by pressing a SOS button. The device uses a reflective PPG (Photoplethysmogram) technique using two green LEDs and a photodiode sensor on the wrist to continuously estimate heart rate. Then this data is correlated with the activity data estimated by an accelerometer and gyroscope. All data is sent to a smartphone via Bluetooth® Smart. The future goal is to make the device autonomous by adding GSM communication capabilities.

1 INTRODUCTION

Nowadays, the ageing of population is one of the biggest problems of our society. It´s predictable that the number of elderly people will duplicate by the middle of century. This demographic change will cause an increase of health problems, in particular heart diseases. In Portugal the rate of deaths caused by heart diseases is above 30% (Instituto Nacional de Estatística, 2012) and often a life could be saved with a tele-monitoring system.

Continuously monitoring of vital signs and daily activity information can help to promote better healthcare and better quality of life. Clinical data is obtained by specific equipment, mostly available in hospitals, with several sensors, being necessary to put into practice the concept of proximity to be able to access in real-time health related information wherever the patient is.

IncreaseTime is a technology-based company whose activity is centred in ICT and wireless sensors solutions to promote people's life quality, especially focused on patients with chronic diseases and elderly people.

The KeepSafe® project intends to create a low-cost and non-invasive device for daily use to continuously monitor the heart rate and alert a caregiver in case of an emergency episode. The device is based on a wristband which is comfortable for daily use and the wrist is the suitable place to measure heart rate through the photoplethysmography method.

Figure 1: KeepSafe wristband monitor.

Our monitoring system has three main components: the KeepSafe® device, a mobile application and a web application. The device uses the sensor to measure the heart rate and sends it to mobile application through Bluetooth® technology that processes data locally and warns the caregivers if the data exceeds the thresholds. Furthermore, the device has an alert button on the wristband for emergency situations which immediately establishes

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the communication between the patient and the caregiver. This function could have a vital role in people lives. After process data, the mobile device is responsible for sending it to a remote server where caregivers can follow up the health status of users through a web application. This system takes advantage from the communication interfaces and processing power of handheld devices like a smartphone to create a low cost and user-friendly monitoring system.

The use of devices for personal health monitoring systems is an emergent area of research. Related to this work we can enumerate projects that have some common goals and projects with a broader scope. The eCAALYX project (Boulos et al., 2011) inserted in the AAL programme offers solutions for prevention and management of chronic conditions in elderly people. This project is based on a t-shirt with integrated biosensors and communication of bio signals into a smartphone application with a simple and intuitive interface. The accessible parameters in the application are respiratory rate, temperature and activity type (walking, standing or lying).

Other work based on a t-shirt is the VitalJacket (BioDevices S.A., 2008). This device uses wearable technology for continuously monitoring heart rate and ECG waves. The data is saved in the device attached to the t-shirt and then analysed by a physician. Another work with identical goals is the WIHMD (Kang et al., 2006). The wrist-worn integrated health monitoring device is a multi-parameter wristlet that includes 5 bio-signals and a fall detector. The bio-signals measured by WIHMD are ECG (single lead), blood pressure, SPO2, respiration rate, and body temperature. This device communicates with a mobile phone giving to the system tele-reporting functions to advise a caregiver in emergency situations. The Oxitone device (Oxitone Medical Ltd., 2013) is a wristband based device developed by an Israeli Company to monitor Heart Rate and oxygen saturation (SPO2). The Oxitone device uses a PPG sensor to perform these measures and has the ability of sending this data via Bluetooth® to a given application. The application performs data analysis and alerts the treating physician.

Related to mobile applications there are a lot of them in the market but the vast majority are focused on fitness activities and doesn't have the feature of monitoring multiple bio-signals. Recently, some of these applications are changing their focus for health records like TactioHealth (Tactio Health Group, 2014). This application has connectivity to several electronic health devices and is used to control a set of parameters like weight, blood pressure, lifestyle, heart rate, cholesterol and glucose.

The KeepSafe® system has similarities with the presented works but we intend to differentiate it by creating an innovative and complete system that works autonomously (no other device or application) and automatically alerts formal or informal caregivers.

This article contains 3 more sections. In section 2 the method is explained describing the KeepSafe® device, signal acquisition and required processing to compute heart rate. Section 3 presents experimental results and discussion. Finally, section 4 refers conclusions and future work.

2 METHOD

In this section we will describe in detail the KeepSafe® device and signal acquisition.

2.1 KeepSafe® Device

The device is composed mainly by 5 blocks: accelerometer/gyroscope, a PPG sensor combined with an analog front-end (AFE4490, Texas Instruments, USA) for pulse oximeter applications, a processor unit, an emergency button and a Bluetooth® unit.

The selected accelerometer (MPU9150, InvenSense, USA) has an integrated gyroscope too, this component allows to perform activity recognition tasks through patterns analysis. This was important to correlate heart rate measurement with activity level and it provides extra information about user daily life. The accelerometer could also be helpful to estimate the error in PPG signal. This information makes possible to use adaptive filtering techniques to improve signal-to-noise ratio.

The PPG sensor and front-end is one of the central features once heart rate is the critical factor to monitor. The analog front-end allows controlling LEDs (Light-Emitting Diodes) to pulsate light, periodically, through the wrist. Then the sensor will capture the reflected light which is quantified by the front-end. All the data is sent to the mobile application using the Bluetooth® smart unit. Figure 2 illustrates the PPG sensor with the LEDs placed at each side. The SOS button is an extra safety for the user: in case of an emergency episode, users can press the button and the alert will be sent by Bluetooth®. All alerts (manual or dynamic) are forwarded to the caregiver through the mobile application. The work is still in progress and the next step is to add new features like GSM communication and GPS antenna. These new features will eliminate the smartphone requirement. The mobile application (Sousa et al., 2012) is responsible to collect, process and send data to the remote server and it allows users to configure parameters like personal data, thresholds for heart rate and has an interface to visualize data in real-time. The mobile application connects to a remote server developed using the PlugThings® Framework (FreedomGrow, 2011) which is very useful to remote monitor users and follow up their health status based on history monitoring data.

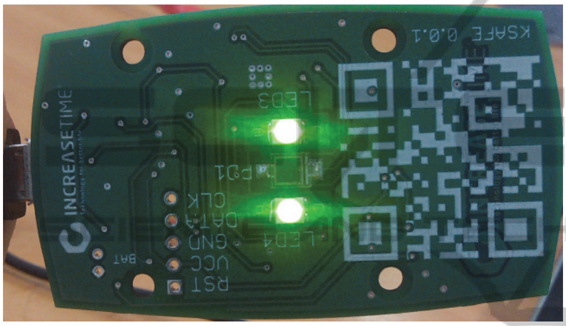

Figure 2: Heart rate sensor in KeepSafe device.

2.2 Bio-signal Acquisition

PPG is one of pulse wave detection methods which consists in emitting light through vessels or arteries and measure the amount of light that crosses the tissue (transmissive PPG) or the amount of light that reflects back (reflective PPG) (Tamura et al., 2014). This technique uses as principle the variation in light absorption when the blood is flowing to calculate the pulse rate. In this particular case, we use the reflective technique because it is more suitable for measurements on the wrist. We use two LEDS for emitting light (operating in the green wavelength – 520nm) and a correspondent wavelength photodiode sensor. That wavelength is proved to be suitable for PPG acquisition at wrist. Studies about different wavelengths in reflective PPG have been done (Lee et al., 2013). For the signal acquisition we use a sample rate of 100 Hz once is good enough to get pulse rate frequency and at the same time doesn't overload the processor leaving more processing power for signal filtering, heart rate compute algorithm and other tasks.

2.3 Bio-signal Processing

Since PPG signal is a low amplitude and noisy signal it's necessary to add extra signal processing in order to improve signal quality and heart rate estimation.

The first processing stage begins in the front-end when the signal passes through a transconductance amplifier. After that the signal is submitted to a second stage amplifier and ambient light cancellation and the final step is to submit the signal to ADC converter to get a digital form signal. All that processing is performed in the front-end.

The digital signal is then read from the master processor and digital filters are applied to get the desired frequency range and improve signal quality eliminating some of the noise caused by movements.

The selected processor (ATXMEGA128A4U, Atmel, USA) is a 16 bit processor which is characterized by being low-cost and low power consumption at sleep mode. Besides, that processor provides enough computing power to deal with all the tasks and signal processing.

The selected digital filter was a pass-band IIR butterworth filter. The selected type was IIR since the FIR type requires a high order filter to get the desired behaviour which would demand more processing power. An eight order IIR filter was used and the selected range frequency was 0.6-4.5 Hz. That frequency is enough to get pulse rate range between 36 and 270 bpm without attenuation.

3 RESULTS

In this section it will be presented experimental results regarding to PPG wave and heart rate calculation.

The signal showed in figure 3 is an example of the signal after applying the filters described in previous section.

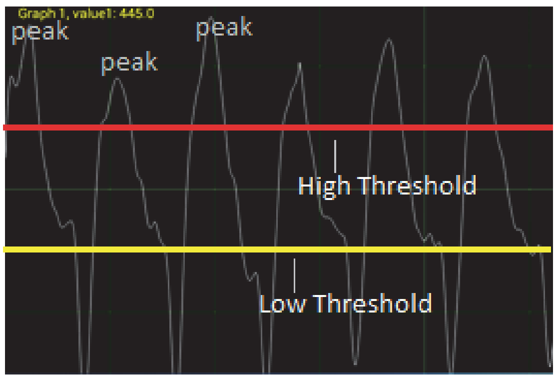

Figure 3: PPG signal obtained with KeepSafe device.

Heart rate estimation is calculated by extracting information from the filtered wave. We can clearly identify the wave peaks in the image. The developed algorithm is based on the peaks detection to calculate the distance between each peak. In order to detect peaks were used two adaptive threshold based on the last two seconds of data. One high threshold and a low threshold to avoid fake peaks. Each time the wave crosses high threshold we are facing a possible peak. At this time the value in x-axis (the time axis) corresponding to local maximum is stored. As soon as the wave crosses the low threshold that peak is confirmed and the algorithm starts looking for the next peak. Furthermore another verification condition was to set a minimum distance of 200 milliseconds between peaks.

The computed heart rate is sent to mobile application where information is shown as illustrated in the picture below. All user information can also be consulted through the Web Application.

Figure 4: Main screen of mobile application.

Heart rate measurements obtained with the KeepSafe® device were evaluated in comparison with a conventional pulse oximeter (CMS50E, Contec, China) which has an accuracy of ±2 bpm according to manufacturer. The results were very close, showing a deviation of ±2 bpm between both devices which implies that KeepSafe® has a maximum error of ±4 bpm. Tests were performed in stationary conditions. It was observed that a significant movement affects the PPG signal making harder to get precision measurements. That will be an aspect to improve in future with adaptive filters bearing in mind the person movement.

4 CONCLUSIONS

During the project development we conclude that it is possible to develop a user friendly and low-cost mobile monitoring system. Reflective PPG at wrist provides a good method to develop a comfort heart rate monitor. However, it implies to have efficient algorithms and a considerable processing power.

There is other similar wrist monitors but with focus on sports activity. KeepSafe® intends to be mostly used by elderly people and works as an emergence device to increase user's safety.

The future work involves the development of an activity recognition algorithm to correlate this data with heart rate monitor. This information will be useful to apply adaptive filtering techniques that leads to higher signal-to-noise ratio during motion. The battery autonomy is another aspect to improve. The use of management power techniques like sleep mode of peripherals whenever they aren't operating will allow extend autonomy to encourage continued use of KeepSafe® monitoring device.

Regarding hardware, a GSM and GPS modules will be integrated in order to transform the KeepSafe® bracelet in an autonomous device.

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