Patient Monitoring based on Mobile Sensor Network

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Abstract: Mobile sensor networks offer opportunities to monitor state of health without constraining the activities of a wearer. These mobile systems are now realizable due to miniaturization of integrated circuits, low power microcontrollers and wireless communications. This paper presents a design of mobile sensor network patient monitoring system based on several health status and movement monitoring sensors including ECG, GPS and accelerometer. Key functionalities of the software include calculating and displaying the values of heart rate variability parameters and movement patterns. Detection of QRS is based on Pan-Tompkins algorithm. Algorithms detect non-standard situation and in case of emergency sends an SMS to a selected number. System uses Android smartphone as a gateway to forward patient electronic health record to medical web server, where data are available via graphical web-based user interface.

1 INTRODUCTION

Medical professions and practitioners in health care as well as engineers in the area of the information and communication technology have shown recently great interest in body sensor networks (BSN) or WBAN(wireless body area network).

A WBAN consists of one or more wearable network nodes, each of them capable of sensing, and processing one or more physiological signals (e.g., heart rate, blood oxygen saturation, physical activity (e.g., body orientation, type and level of activity), and environmental parameters (location, light, atmospheric pressure). These nodes are placed on the human body as tiny patches or attached to users' clothes (Jovanov et al., 2005; http://ieee802.org/).

There are several examples of commercial systems based on WBAN. The most common application is monitoring of cardiac patients. Corventis System (Corventis, 2012) consist of wearable device that captures ECG data and a mobile transmitter. It offers continuous surveillance of symptomatic and asymptomatic cardiac abnormalities to help physicians diagnose and treat cardiac arrhythmias. When an arrhythmia is detected, system automatically transmits the ECG via a wireless data transmitter device to the Monitoring Center. Another example of cardiac monitoring system is CardioNet (CardioNet, 2012) which monitors the patient via the small sensor during normal daily routine. As events occur, patient activity is automatically transmitted to the Monitoring Center for analysis and response. CardioNet is focused on helping physicians diagnose and treat patients with arrhythmias.

This paper presents a WBAN-based health monitoring system which integrates wearable and battery-operated ECG, movement (accelerometer) and GPS sensors which send data to mobile phone via wireless Bluetooth network. Algorithms were developed that process and analyze signals in real time in order to calculate heart rate and locate the patient. The main advantage of the system is algorithms optimization for real time data processing.

The rest of the paper is organized as follows. Section 2 overviews the system design. Section 3 presents hardware used to build a prototype. Section 4 describes principles of vital signal processing. Section 5 discusses the paper and describes ideas for the future work. Section 6 concludes the paper.

2 SYSTEM DESIGN

The architecture of the proposed health monitoring system consists of a mobile wireless ECG, acceleration activity(ACC) and GPS sensors that is

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placed on the user body and a monitoring gateway.

The sensor samples, processes and sends the information about user ECG, ACC signals and GPS location to the monitoring gateway via Bluetooth. Received data is analyzed by custom built algorithms and forwarded to Internet database, where medical data is accessible to a doctor. Figure 1 presents the system design.

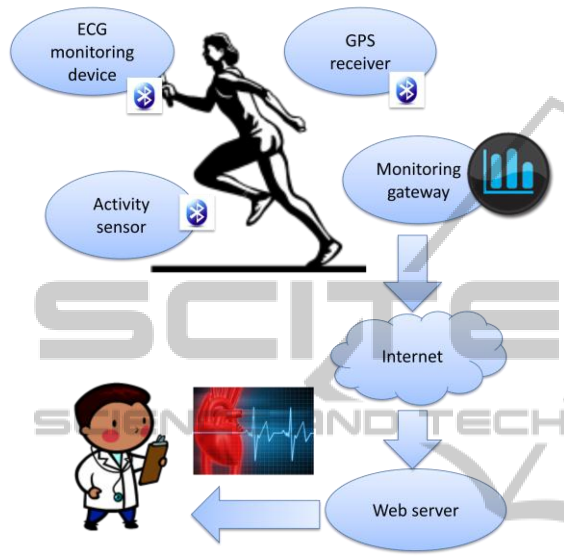

Figure 1: System design.

System was designed to face the following requirements:

- wearable,
- use miniature and low power sensors,
- wireless communication using Bluetooth,
- battery operated,
- allow monitor patient ECG signal,
- easy to use,
- automatic fall detection,
- calculation of heart rate,
- low-cost,
- secure,
- data remote access interface.

3 MOBILE SENSORS AND MONITORING GATEWAY

Monitoring system integrates Aspel Aspekt 500 ECG signal transmitter and Android based smartphone with GPS used as monitoring gateway to perform analysis and forward data to dedicated medical web server. Aspekt 500 (Fig. 2) is a digital unit designated for wireless ECG signal transmission. It is equipped with a ten electrodes cable. ECG signal is sampled at the frequency of 500 Hz. The transmitter allows a free patients movement up to 10 m from monitoring unit. Aspekt 500 is a portable sensor (dimensions 130×96×30 mm).

Figure 2: Aspel Aspekt 500 ECG signal transmitter

The MMA7341L is a low power, miniature (3mm x 5mm x 1mm) capacitive micromachined accelerometer featuring signal conditioning, low current consumption (400uA), temperature compensation and self test. The typical application is tilt and motion sensing.

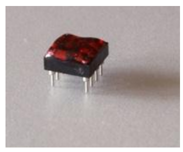

Figure 3: Accelerometer MMA7341L.

Smartphone HTC Desire (119 x 60 x 11.9 mm) - monitoring gateway is used to acquire monitoring signal and forward it to the medical web-server. It is equipped with 1 GHz Scorpion CPU, GPS and has 576 MB RAM, what makes it very powerful processing unit. Smartphone runs Android OS v2.2 (Eclair).

Figure 4: HTC Desire.

All this data are forwarded using the Internet via UMTS or GSM network to a purposely-designed medical web server where it is accessible to a doctor or selected people through easy to use web-based graphical interface. In case of emergency an action is automatically taken.

4 VITAL SIGNAL PROCESSING

The most challenging task was to design the software that will cope which huge data flow from the monitoring device and real time signal analysis at the same time. As a result algorithms were designed and implemented.

Key functionalities of the software include calculating and displaying the values of heart rate and locating patient based on GPS data. All data can be saved in the file for further statistical analysis.

One of the most popular and often cited QRS detection algorithms that works in the time domain is the Pan and Tomkins algorithm that was proposed in 1985 (Tompkins and Pan, 1985). The QRS detection algorithm is based on analysis of the slope, amplitude and width of the QRS complex which refers to the depolarization of the right and left ventricles.

First, in order to reduce noise, the ECG signal passes through a digital bandpass filter composed of cascaded high-pass and low-pass filters. The next process after filtering is differentiation, followed by squaring, and then moving window integration.

Algorithms were implemented in Java. Therefore, they can be used by a wide range of smartphone devices and operating systems. One of the project goals is to locate the patient. Tracking is based on GPS data that are forwarded to a server and accessible through web based interface which uses Google Maps API(http://code.google.com/) in order to mark patient location on the map (Fig. 5).

Positionning data (longitude, lattitude and height above the sea level) are used to calculate the speed and inclination and with assumption of active motion and knowing the subject's body weight determine the total energy required. This value is then correlated with the heart rate variability in order to determine the correctness of its acceleration in response to a physica load and deceleration in the rest phase. The respective factors, although not yet widely accepted by cardiologists are provided by the system when everyday activities are used as a safe alternative to a regular stress test.

Fall detection is perform by algorithm is responsible for analyzing data from accelerometer.

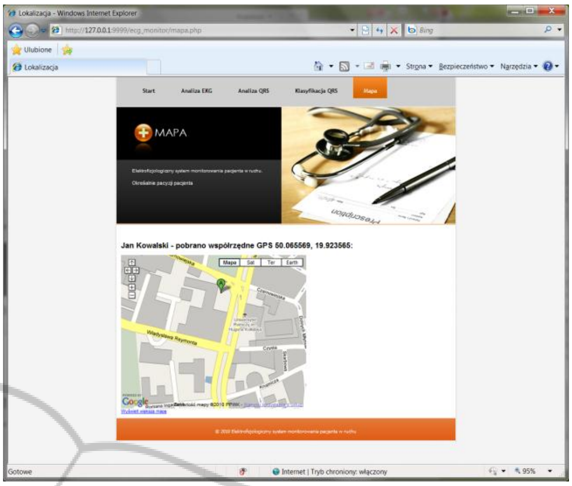

Figure 5: Localization of patient via web page interface.

The absolute sum of tree axis accelerometer data is calculated. If obtained value is higher than experimentally set trigger point, the alarm module is switched on.

Existing fall detection solutions analyzes acceleration to detect falls. In Ref. (Mathie et al., 2001) a single, waist-mounted, tri-axial accelerometer is used to detect falls. Lindemann (Lindemann et al., 2005) integrated a tri-axial accelerometer into a hearing aid housing, and used thresholds for acceleration and velocity to decide if falls happen. In Ref. (Jantaraprim et al., 2010) a fall detection algorithm utilizing two thresholds for the resultant acceleration in 1.5-s window segments was presented. The results, tested on 300 sequences show that falls can be distinguished from activities of daily living with 100% sensitivity and more that 93% specificity.

5 DISCUSSION AND RESULTS

Testing the QRS detection with MIT/BIH Arrhythmia Database resulted in 94.50% sensitivity. Through analysis of the 20 recorded simulated falls, 85% were correctly identified.

WBAN is one of the key components of the future e-health initiative that could make significant improvements in patient care and monitoring. The application of the WBAN technology could make some of the specialist treatments more accessible and efficient as well as cost-effective for the service delivery point of views (Otto et al., 2006; Yang, 2006).

Sensor-based measurements and monitoring techniques have been widely used in electronic patient care systems for a long time. The concept of sensor-based patient monitoring using wireless body area network (WBAN) will bring revolutionary changes in health care systems. WBAN allows flexibility in providing location independent and seamless patient monitoring without affecting the lifestyle of patients.

6 CONCLUSIONS

This paper presents an overview of wearable WBAN-based patient monitoring system. Potential applications include early detection of abnormal conditions and supervised cardiac rehabilitation. Automatic integration of collected information and user's inputs into research databases can provide medical community with opportunity to search for personalized trends and group patterns, allowing insights into disease evolution, the rehabilitation process, and the effects of drug therapy.

The achieved results are satisfactory for the monitoring purposes. However, more tests are needed to develop system that will focus on prevention and early detection of health conditions.

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