Algorithms for Gathering Wireless Wearable Sensors Information in Remote Healthcare Monitoring

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Abstract

The aim of this paper is to summarize recent developments in the field of wearable sensors and systems that are relevant to the field of remote healthcare monitoring. The major articles focused on the application of wearable technology to monitor elder people and patients with chronic diseases at home. Currently clinical applications of wearable technology are undergoing assessment. The home remote monitoring system derives from clinical monitoring system. The Patient Monitors are expensive and need special knowledge to use it. Patients need external help just to connect and disconnect from Patient's Monitor. As a result, wearable and easy to use sensors start to use not only in remote home monitoring, but in hospitals as well, such as floor sensor pad, chair sensor pad, bed sensor pad with heart rate detection.

Applications, such as heart rate detection, described in this review papers include those that focus on health and wellness, safety, home rehabilitation, assessment of treatment efficacy, and early detection of disorders. The integration of wearable and ambient sensors is discussed in the context of receiving vitals sign and activities of elder people and patients with chronic diseases. The main problem of home sensor like ECG still have to have knowledge how and where to put electrode as well as not very clearly the purpose of 1 Lead ECG sensor, it still complicated, but mostly used for Heart Rate detection. We believe that we may find easy way, like special algorithms, to get Heart Rate. Additional work is required to advance medical devices including wearable, portable and ambient sensors in a clinic.

Keywords: Wearable sensors, Home monitoring, Telemedicine, eHealth, mHealth

Introduction

As the manuscripts in this field is vast, we have limited the scope of this paper to include wearable sensors, portable and ambient sensors that measure health parameters such as vital signs for disease management and prevention health monitoring systems. In our project we concentrated the review on the following vital sign parameters: electrocardiogram (ECG), oxygen saturation (SpO2), heart rate (HR), Photo Plethysmo Graphy (PPG), blood glucose (BG), respiratory rate
(RR), and blood pressure (BP) [1,2]. Physiological monitoring could help in both diagnosis and ongoing treatment.

Wireless communication is relied upon to transmit patient’s data to a mobile phone or an access point and relay the information to the Center of Remote Healthcare Monitoring and Emergency Intervention (CRHREI) via the Internet or 3G Network. Emergency situations are detected via data processing implemented throughout the system and an alarm message is sent to an emergency service center (ESC) to provide immediate assistance to patients. Even cheap fall detector sensor or heart rate detector very helpful in most cases. Family members are alerted in case of an emergency but could also be notified in other situations when the patient requires assistance with, for instance, taking his/her medications. Attending doctor may monitor the patient's health remotely and receive reports of deviations from the normal state of the patient's physician for making decisions on the patient's treatment. Despite the potential advantages of a remote monitoring system relying on wearable, portable and ambient sensors as the one described above, there are significant challenges ahead before such a system can be utilized on a large scale. These challenges include technological barriers such as limitations of currently available battery technology (low consumption) as well racial prejudices to use of medical devices for household-based clinical monitoring system.

Wearable systems for patients’ remote monitoring contains of three main tasks:

- the sensing and data collection hardware and algorithms to collect physiological (vital signs) and movement data (accelerometer);
- the communication hardware and software to send data to a CRHREI;
- the data analysis algorithms to extract information from physiological and movement data.

Electronic chip manufactures, such as Analog Devices, Texas Instruments, Microchip technology inc have development and deployment of wearable, portable and ambient sensors systems for patients’ remote monitoring.[5]

Chip manufacturers have been producing chips even smaller and more complete functionality, such as specialized ECG-chip, have allowed researchers to develop miniature circuits entailing sensing capability, front-end amplification, microcontroller functions, and radio transmission. The ADS1293 from Texas Instruments is a highly integrated low-power analog front end (AFE) which features three high-resolution ECG channels.

We have own development of wearable 3-channels ECG [6]. The Wireless Heart Rate Monitor with Bluetooth low-energy (BLE) is intended as a reference design that researchers can use to develop end-products for battery-powered, 3-channel health and fitness electrocardiogram (ECG) applications. As a part of monitoring system we used a MicroElectroMechanical Systems (MEMS) accelerometer to monitor patients’ activities. The accelerometers are usually used in Medical devices as:

- Implantable medical devices (AXL)
Pacemakers, defibrillators, neuro-stimulators
Concussion detection in sports (high g AXL)
Helmets, patches, mouth guards
Motion detection and body motion reconstruction (AXL, GYRO, MAG, PS)
Man down, rehabilitation and training, personal emergency response systems (PERS), improved straight line motion, tilt detection for safety
Instrument guidance in surgery (AXL, GYRO)
Health care and wheelchairs/scooters (AXL, GYRO, PS)

The example shown in Figure 1 demonstrates how sensors can be embedded in a garment to collect, for instance, electro cardio graphic and electro myo graphic data by weaving electrodes into the fabric and to gather movement data by printing conductive elastomer-based components on the fabric and then sensing changes in their resistance associated with stretching of the garment due to subject’s movements.

Most wearable, portable and ambient sensors is not invasive sensors, but for individuals with type 1 diabetes for real-time continuous blood glucose data we have to use invasive sensor for now, there are some non invasive glucose meters in clinical trials. Glucose levels were determined every 30-60 s and Bluetooth transmission signal with glucose data occurred every 5 minutes. This sensor was to be combined with an implantable insulin pump, which will be control of blood glucose levels via the delivery of variable amounts of insulin.

An example of this technology is the MIThril system [4]. Such systems by design were not suitable for long-term health monitoring. One is the promises technologies is Bluetooth Low Energy (BLE), the low consumption and easy established paring communication - the key why BLE became more popular now. Mobile operating systems including Windows Phone, iOS, BlackBerry, Android, and as well as OS X and Windows 8, natively support Bluetooth low energy. The Bluetooth SIG predicts more than 90 percent of Bluetooth-enabled smartphones will support the low energy standard by 2018.
Figure 1. Example of e-textile system for remote, continuous monitoring of physiological and movement data. Embedded sensors provide one with the capability of recording electrocardiographic data (ECG) using different electrode configurations as well as electromyographic (EMG) data. Additional sensors allow one to record thoracic and abdominal signals associated with respiration and movement data related to stretching of the garment with shoulder movements. (Courtesy of Smartex, Italy).

Sensors and Algorithms

Electrocardiography has been used for many years as a key, non-invasive method in the diagnosis and early detection of coronary heart disease. For interoperability standard in healthcare systems usually used ISO/IEEE 11073 (73X) Medical / Health Device Communication Standards is a family of ISO, IEEE, and CEN joint standards addressing the interoperability of medical devices.

The ISO/IEEE 11073 standard family defines parts of a system, with which it is possible, to exchange and evaluate vital signs data between different medical devices, as well as remote control these devices. This modular approach makes it relatively easy to add support for a new type of device. More device specialization standards are on the road, including:

- IEEE P11073-10406 - Device specialization - Basic ECG (1 to 3-lead)
- IEEE P11073-10413 - Device specialization - Respiration rate monitor
- IEEE P11073-10418 - Device specialization - INR (blood coagulation)
- IEEE P11073-10419 - Device specialization - Insulin pump

Modification of existing standards:

- IEEE Std 11073-10404 - Device specialization - Pulse Oximeter (revision)
- IEEE Std 11073-10417 - Device specialization - Glucose Meter (revision)
IEEE Std 11073-10441 - Device specialization - Cardiovascular fitness and activity monitor (revision to add 3D accelerometer / physical activity monitor data)

One-lead ECG recorders may be used for monitoring the heart rate in association with regular exercise, workouts, and sports activities. The actual recordings need to be done while the body is not moving, to avoid artifacts from the muscles. However, "resting" measurements can nonetheless be done during exercise and while the heart is responding to the exercise by briefly interrupting the activity long enough to obtain a recording or immediately after finishing the activity. In most cases, we need not ECG signal for aggregation, we just need signal from sensor good enough to get Heart Rate for monitoring purpose.

The basic functions that we deal with the sensors:
- Monitors physiological data;
- Capture raw data;
- Process raw data;
- Communicate data;
- Display data.

The most important step is Process raw data, because it very noisy and have some artifacts. The actual sensors send information to the micro-controller. The software is designed to handle the following activities:

- Data acquisition
- ADC Lead off detection
- DC signal removal
- Multi band pass filtering
- ECG lead formation
- QRS (HR) detection
- RR Detection
- Bluetooth communication

Thus, QRS (HR) detection is an important part of many ECG signal processing systems.

QRS detection algorithms
Differentiation forms the basis of many QRS detection algorithms. Since it is basically a high-pass filter, the derivative amplifies the higher frequencies characteristic of the QRS complex while attenuating the lower frequencies of the P and T waves. An algorithm based on first and second derivatives originally developed by Balda et al. (1977) was modified for use in high-speed analysis of recorded ECGs by Ahlstrom and Tompkins (1983). Friesen et al. (1990) subsequently implemented the algorithm as part of a study to compare noise sensitivity among certain types of QRS detection algorithms. Figure 4. shows the signal processing steps of this algorithm.[7]
Figure 3. Various signal stages in the QRS detection algorithm based on differentiation.
(a) Original ECG. (b) Smoothed and rectified first derivative. (c) Smoothed and rectified second derivative. (d) Smoothed sum of (b) and (c). (e) Square pulse output for each QRS complex.

Conclusion

Low noise 1-Lead ECG with 24 bit analog to digital conversation and robust algorithm against noisy environment, artifacts etc. and relatively easy computation are one of the benefits proposed solution for HR detection problem. There are a lot of various algorithms based on ECG signal averaging used for High-Resolution ECG (HRECG) e.g. [9, 10].

Proposed 1 Lead ECG, method and algorithm are effective for relatively quick ECG Heart Rate detection as well as preprocessing stage for searching R pointers. The described HR detection algorithm is also robust against artifacts and non-stationary degradation factors.

Acknowledgement

The work was carried out with the financial support of the Ministry of education and science of the Russian Federation (the contract № 02. G 25.31.0033)
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