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Combining Non-Invasive Wearable Device and Intelligent Terminal in HealthCare IoT

Jui-Chung Ni[a**], Chu-Sing Yang[b], Jiun-Kai Huang[c], Liang Cheng Shiu[d]

[a] *National Cheng Kung University ,No.1, University Road, Tainan City 701,Taiwan*
[b] *National Cheng Kung University ,No.1, University Road, Tainan City 701,Taiwan*
[c] *National Cheng Kung University ,No.1, University Road, Tainan City 701,Taiwan*
[d] *National Pingtung University, No.51, Minsheng E. Rd., Pingtung City, Pingtung County 90004, Taiwan*

Abstract

In recent years, many studies have focus on health care. We designed a non-invasive wearable device that not only equipped with BLE to detect vital signals but also combining an intelligent terminal to develop healthcare IoT. In most studies, an electrode potential is used in ECG, while for PPG, heart rates are measured by the amount of reflected LED light. However, in this paper, we detect heart vibration signals based on radial artery vibration signals by the wrist PVDF piezo film sensor that the user wears to detect his/her heart rate. The device can also reduce power consumption. In order to promote Signal to Noise Ratio (SNR), we adopt filter circuit design and peak detection algorithm to eliminate noise by using the intelligent terminal, then we are able to achieve high accuracy heart rate calculation. Furthermore, the intelligent terminal will upload the data to the cloud, so not only the user can monitor self-vital information anytime but also medical institutions can access the data in case of an emergency.

Keywords: non-invasive, Wearable device, BLE, PVDF, intelligent terminal

[*] * Corresponding author. Jui-Chung Ni .Tel: +886-956801697
E-mail address:q38031013@mail.ncku.edu.tw

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1. Introduction

Normally, we measure heart rates on ECG and PPG. When applying ECG, we need to stick many electrodes on the user's skin which is not comfortable and convenient for the user [1]. As for PPG, it utilities LED to detect blood flow to measure heartbeat.

So the battery energy will be exhausted soon [1] [2]. In this paper, we will not only compare ECG, PPG and PVDF (please refer to Table1) but also adopt PVDF sensor to measure heart rates and can get slightly vibration which come from arterial wall's jumping of wrist[5]. In order to get heart rate easily, we add op-amp (operational amplifier) circuit and Butterworth filter circuit to enhance SNR. Moreover, we adopt PAN TOMPKINs algorithm [6] to peak searching when using an intelligent terminal device in order to eliminate noise and increase heart rate detection accuracy. Apart from having Wi-Fi and BLE functions, the intelligent terminal also equips with a powerful CPU to process raw data immediately and share the workload of the cloud server.

Table 1

	ECG (Electrocardiography)	PPG (Photoplethysmography)	PVDF (Piezoresistive sensor)
Principle	Measuring the electrical ions of the heart by placing electrodes on the skin[1]	Calculating heart rate by using the reflection and transmission of LED to detect blood volume changes in the artery of index finger [3]	Using vibrations generated by the contraction and relaxation of the heartbeat to calculate the heart rate[4]
Strength	1. No noise interference from movement 2. Power saving 3. The waveform is very complete which can know the user's heart condition.	1. Less power supply noise and EMI interference 2. Can be applyed on any fingers, toes, and ears. 3. Easy to use for sports	1. Power Saving 2. No interference from power supply 3. Flexible to wear on the user's chest and wrist.
Drawback	1. Susceptible to get the 50, 60Hz interference of AC power. 2. Measurement position limited to the user's chest and two hands 3. Conductive adhesive electrodes are prone to make the user have uncomfortable skin sensation.	1. Susceptible to noise caused by movement 2. Susceptible to background light 3. Lower power consumption Waveform provides less diagnostic basis	1. Heat rate signal is very small, and easy to carry noise. 2. Occupy a particular space 3. It is very sensetive

2. System structure

The paper is structured in the concept of how the healthcare IoT was designed (Fig.1). There are three layers: sensors layer, transmission layer and application layer. The sensors layer includes a PVDF sensor to measure heart rates, a 3-axis accelerator to detecct if the user falls down, GNSS receiver (Global Navigation satellite System) to get user's position and temperature sensor to detect the body temperqture. In the transmission layer, we adopt BLE 4.2 to transmit sensor data, to support PAN (Personal Area Network), and to integrate these components on the new designed PCBA as (Fig.4.a). In order to being able to quickly provide real-time information and transmit raw data of vital signals to the cloud server in emergency cases, we add an intelligent terminal[7] which acts as a gateway to supporting LAN/WLAN. When an emergency happens, the device can prioritize the process the even and notify the cloud server and the user. Last, the application layer focuses on healthcare. The cloud computing service will analyze the user's historical data and give appropriate advice to the user.

Based on Healthcare IoT (Fig.1) which system architecture is divided into four units, Unit 1 is sensing function; Unit 2 is BLE communication; Unit 3 is intelligent terminal, Unit4 is cloud computing unit.

2.1. Unit 1.Sensing function

Mainly to detect the user's heart rate by PVDF sensor _CM-01B [8] (Fig. 4.a) which is contact microphone, it uses sensitive but robust PVDF piezo film combined with a low-noise electronic preamplifier to provide vibration pick-up with buffered output. The arterial wall's jumping of wrist is transformed into an acoustic wave to touch the film inside CM-01B, it can produces a low voltage signal about 0.3mV (Max), then through an amplifier circuit (Gain= 600) to amplify, because heart rate signal is analog signal which is very easy to be gotten crosstalk by noise, in order to increase SNR value, we adopted 2 order Butterworth low pass filter circuit which cutoff frequency is set at 200Hz, to eliminate high-frequency noise, then convert to digital signal by MCU of BLE, according to Shannon sampling principle, its sampling rate is setting to 480Hz which must over heart beat rate frequency two times, it can keep original vital signal which also don't have any distortion and clearly appeared heart rate waveform.

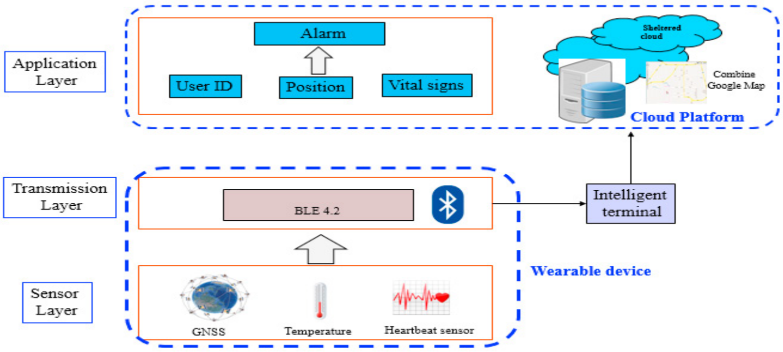


Fig.1 system architecture

2.2. Unit 2. BLE communication

For this unit, it used Nordic BLE4.2 to transmit data, which is low power consumption, and support short range's wireless solution[9] , it is very suitable for Body sensor network application; In existed BLE profile, it only support ECG/PPG, so we designed a particular profile (Fig.2) for PVDF sensor, there are four items, heart rate raw data, EMG message, position and USR ID, the length of each item has 20Bytes, it based on the importance of items to define transmission period, EMG item means heart rate is over threshold value and threaten with his/her life, it will adjust high priority to process and inform intelligent terminal immediately.

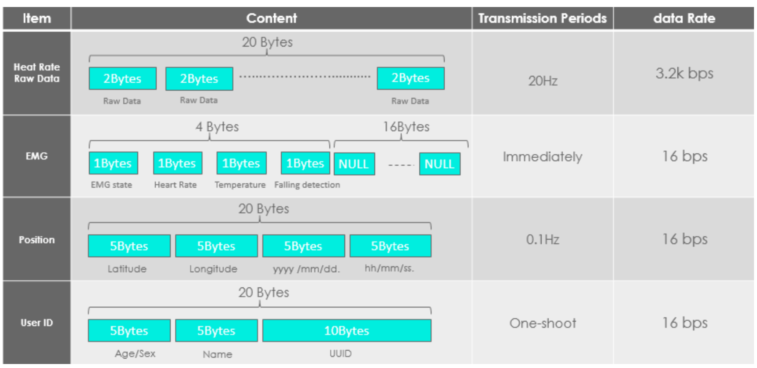


Fig. 2 BLE package format

2.3. Unit3. intelligent terminal

In IoT applications, we always collected all of sensors data and send to cloud server [10]. The finally cloud server will do statistics and analysis to make a decision; But emergency process, it can't deal with the event immediately; In order to improve this issue, we added an intelligent terminal with edge computing in this healthcare system, the intelligent terminal accessed sensors information frequency from wearable device, and processed raw data which come from PVDF sensors, then base on Fig.3 to calculate heart beat rate and get real-time heart rate information, once heart rate is over setting threshold value, it will enable emergence mechanism to inform user and send a message to cloud server, let cloud server to call to hospital or 911; For the intelligent terminal, it not only process data timely, but it also can share the loading of cloud server.

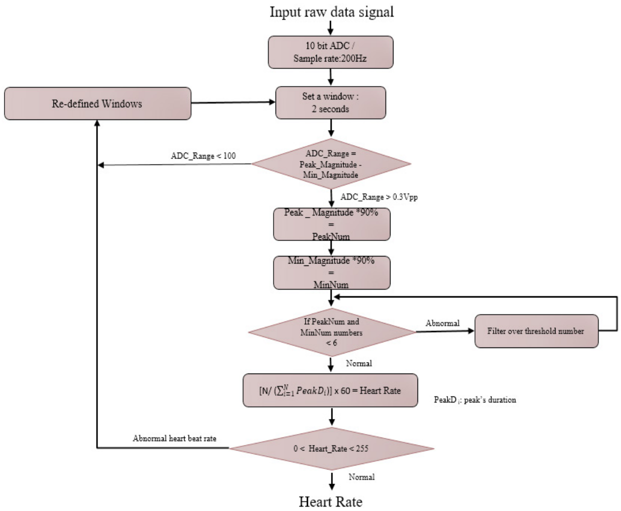


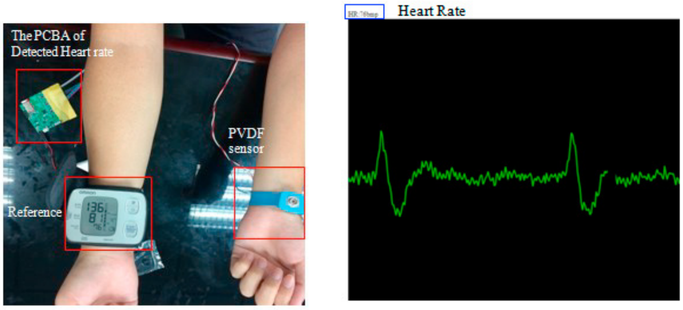
Fig. 3 Heart beat detection

2.4. Unit 4. Cloud *computing*

The cloud computing system receive all of information which come from intelligent terminal, it record user's the raw data of vital signal, location information, user ID and Emergency information, it also can based on location data to combined with LBS (Location-Based Services), it is more easily to know user's location and share these data to hospital and doctor, then can save medical resource and time.

3. Result

Per this experiment, we put detected PVDF sensor with PCBA on the left wrist and use OMRON (HEM-6221) wrist blood pressure monitor on the right wrist to be a reference as follow Fig.4.a; It also can show real time heart rate and waveform, refer to Fig.4.b. In Table 2, there are 6 people who are 4 males and 2 females to join this trial, besides record heart rate, and also check its SNR; The heart rate detection system can achieve 98% accuracy.



a b

Fig. 4. (a.) measured location on wrist (b.) Heart beat rate waveform

Table.2

	Gender	Age	OMRON(BPM)	DUT(BPM)	SNR(dB)	Error rate
1	Male	20-30	76	76	18.4	0.00%
2	Male	20-30	69	70	12.6	1.45%
3	Male	40-50	73	71	11.1	2.74%
4	Male	40-50	84	82	11.1	2.38%
5	Female	20-30	69	68	13.1	1.45%
6	Female	40-50	68	65	8.9	4.41%
	Avg					2.07%

4. Conclusion

In this paper, we presented a new heart rate detection method which combined intelligent terminal and edge computing to realize a healthcare IoT system; In this trial, based on these experiment data, once the SNR is lower to 8.9dB, it can be caused to increase the error rate of heart rate calculation and got inaccurate heart rate, because its heart rate signal is too low.

For future work, we can add more sensors to implement sensor fusion which can eliminate the same background noise and promote SNR, then the heart rate calculation can more accurate.

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