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HANDY HEALTH MONITORING AND ALERT TECHNIQUE USING PEAK DETECTION ALGORITHM

[1]Mrs. Niranjana A, [2]Mrs. Mithra S

[1,2]Assistant Professor, Department of Computer Science and Engineering,

Easwari Engineering College, Anna University, Ramapuram, Chennai, (India)

ABSTRACT

The main objective of this thesis is to design a health monitoring system, which can sense certain body parameters such as body temperature as well as heart rate and provide an alert if any abnormal condition, is detected. The need for a cheap and cost effective system led to the reduction in hardware circuitry by developing a robust peak detection algorithm. The proposed system focuses on being noninvasive, portable and ubiquitous. The entire system consists of two major sections. The first section consists of the hardware setup which comprises of the health sensors such as a temperature sensor and a heart rate detector. The Arduino board is used for signal acquisition as well as signal processing. A peak detection algorithm is developed to detect the peaks. There exists an interfacing module, the Bluetooth which is followed by the second section. The second section deals with alerting the patients as well as doctors, in case of abnormal conditions, using the mobile phones that run on the Android operating system.

Keywords: Health monitoring system, Heart rate detector, Photoplethysmography(PPG), Peak detection algorithm, non invasive and portable system, Arduino, Bluetooth, Android.

I. INTRODUCTION

These days, healthcare is supported by electronic processes and communication which is termed as e-Health. It involves e-Prescribing, electronic health records, telemedicine, consumer health informatics, healthcare information systems, virtual healthcare teams, mobile health etc. The recent trend followed is m-Health or mobile health. It includes the use of mobile devices in collecting aggregate and patient level health data, providing healthcare information to practitioners, researchers and patients. It involves real-time monitoring of patient vitals and also has direct provision for care via mobile telemedicine. It has its own pros and cons. With rise in mobile sales and open source application development, m-Health shows promising growth and development. Sensor technology has also developed with the advancement in the MEMS field, which gives rise to plenty of wearable sensors to measure body parameters.

Cardiovascular diseases (CVD) have been on the arise due to the current fast and sedentary lifestyle. Regular monitoring of the heart's metabolism is needed in case of elderly patients. ECG provides a great overview of various parameters but suffers from its own constraints. Thus arises the need to develop a miniaturized, portable device for self-assessment and monitoring of CVD patients. By measuring heart rate variability (HRV), the status of the heart activities can be estimated. HRV from PPG can be considered as a compromise for nonprofessional and daily monitoring. PPG is one of the non-invasive methods for measuring the amount of blood volume changes inside the blood vessel. A PPG device is easy to position for long term monitoring purpose and can monitor several CVD related parameters such as heart rate, respiration and oxygen saturation.

A portable biomedical health monitoring system, that monitors heart rate and temperature parameters is designed and implemented. The final results are displayed in an Android application, which is developed. The wireless communication is realized by implementing Bluetooth. Section II gives an overview of the system. Section III gives details of the functional parts of the setup. Section IV gives details of PPG signal processing design and section V is about temperature sensor output processing. Section VI gives the conclusion of the thesis work and section VII enlists the future work that can be done.

II. SYSTEM OVERVIEW

The overall design block diagram is shown in Fig. 1. It could be divided into two main sections. The first section involves the heart rate detector and temperature sensor whose output is acquired and conditioned by the Arduino. After signal processing and calculation, the result is transferred in a packet format via a Bluetooth to the Android application. The following sections give a brief idea of the operation of each block.

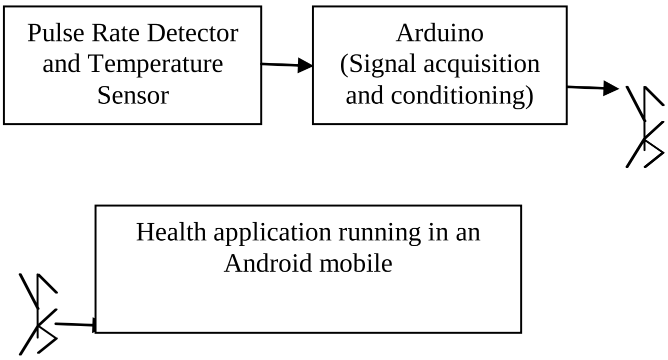


Fig 1.Block diagram of the proposed health monitoring system

III. FUNCTIONAL PARTS AND THEIR DESCRIPTION

In this section, the role and characteristics of each module within the system are introduced and described.

3.1 Pulse Rate Detector

The detector revolves around the photoplethysmography (PPG) technique of the plethysmography measurements for detection of change in the volume of blood flow. It is preferred for our system since it is simple to position and easy to design as well as use. Every time when blood pumps to periphery, blood vessels expand due to the blood pressure from the heart and a pulse is generated. Another pulse follows when the blood flows back. So the PPG pulse is the superimposition of a pumping pulse and a reflecting wave. Fig. 2 is a sample PPG waveform.

With each heart beat the volume of blood at the finger tip changes. This change plays a role in reflecting different intensities of the infrared light emitted by an IR (infrared) emitter and the intensity of the infrared light received at the IR detector too. If the volume of blood increases, infrared light has to travel a larger area and less infrared light is received at the detector and vice versa. Fig. 3 (a) and (b) show the positioning of the device on fingertip in a reflecting setup of the IR emitter and detector, where both operate at a wavelength of 940nm. The infrared circuit setup used in the thesis is shown in Fig.4.

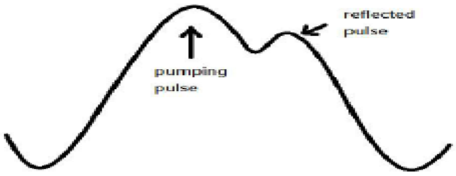
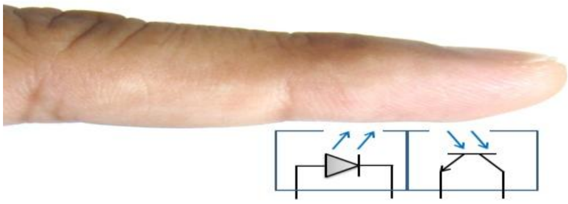
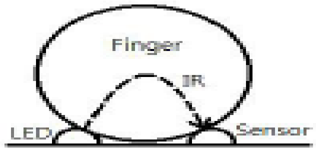


Fig 2.Sample PPG waveform



(a)



(b)

Fig 3 Illustration of PPG sensor schematic

The setup consists of the side looking IR (infrared) emitter as well as the detector of a matching wavelength (940nm) placed beside each other which constitutes the reflecting setup as seen in Fig.4. Both are supplied with a voltage of 5 volts via resistors. The anode of the infrared emitter is provided with the power supply and the cathode is grounded. The collector of the infrared detector is provided power supply via resistors and the emitter is grounded. The base acts as the region where the infrared light falls upon. The output is obtained at the collector and the pulses obtained are of very small amplitude. This signal has to be amplified for further processing. Hence it is passed through a sound amplifier LM386. The amplified signal contains noise and it has to undergo filtering.

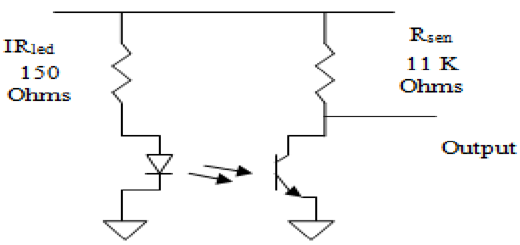


Fig 4.Infrared circuit setup

3.2 Temperature Sensor

The temperature sensor LM35 is used to detect the body temperature. It is seen in Fig.5. LM35 is a precision IC temperature sensor with its output proportional to the temperature (in ^{o}C). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. The operating temperature range is from -55°C to 150°C. It requires a supply voltage of 5 V.

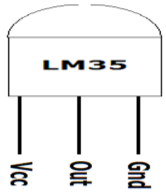


Fig 5.LM35 pin diagram

3.3 Arduino Microcontroller

The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). It is an open source. It is preferred since it has multiple analog and digital I/O pins. It has an inbuilt analog to digital convertor. This board acquires and conditions the data received. Thus this block performs signal acquisition as well as signal processing and transfers data to the Android application. The Arduino Mega 2560 board is used since it has a crystal oscillator of 16 MHz, 54 digital I/O pins, 16 analog pins and 4 UARTs.

3.4 Bluetooth Module

A cheap Bluetooth module, the JY-MCU V1.05 (Linvor) is used to send the data from the Arduino to the Android side wirelessly. Its' baud rate is set to transmit at 115200.

3.5 Android application

The Android application is developed using the Eclipse software which came along with the Android SDK. The coding is carried out in Java language. The Bluetooth APIs of Android supports the cable replacement protocol RFCOMM which provides serial port RS-232 emulation. It displays the heart rate and temperature received as well as alerts the user of the prevalent condition and the necessary action to be taken. The application's layout and result are shown in Fig.6. A real time graph can be plotted after accepting data from the Arduino side to show the heart beat waveform.

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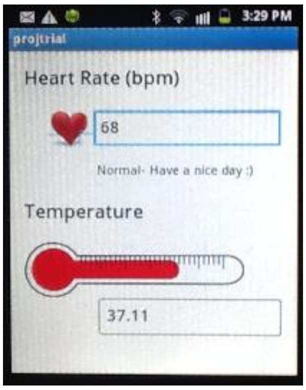


Fig 6 Android Application Layout and Result

IV. PPG SIGNAL PROCESSING DESIGN

The PPG (photoplethysmography) waveform has a lesser complex morphology when compared to the other waveforms such as ECG and EEG However, there always exist high-frequency noises as well as the low-frequency baseline drift, derived from either the measurement itself or respiration and motion artifacts.

The flow diagram of the PPG signal acquisition and processing is given in the Fig.7. It ranges from a series of steps ever since the pulses are read, detected, amplified, processing and mapped to give the final heart rate value.

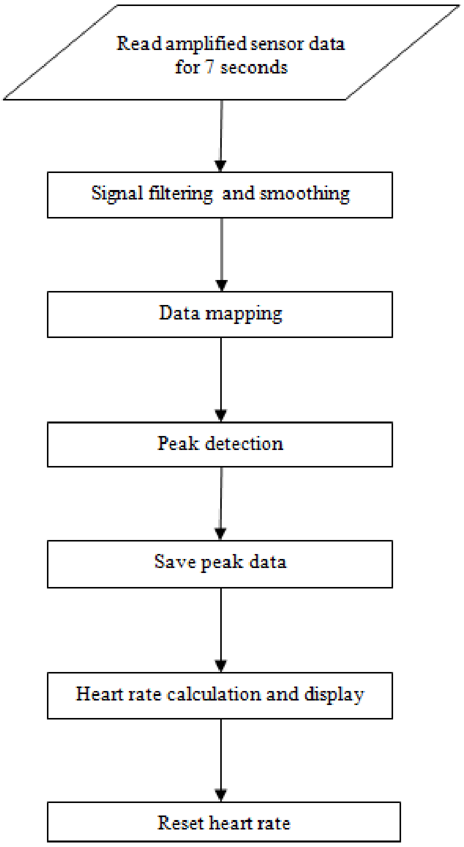


Fig 7.PPG Signal Acquisition and Processing Design Algorithm

4.1 Signal acquisition

The amplified sensor data from the audio amplifier's output port is read into an empty definite array by the Arduino. The received signals are analog in nature and are saved after they are converted as voltage values. The values are observed in Processing 2.0 as shown in Fig.8 and are read for a period of seven seconds for better accuracy.

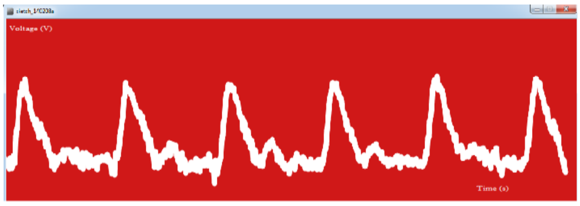


Fig 8.Raw signal in Processing 2.0

4.2 Signal filtering and smoothing

The main idea of the health monitoring system developed is the portability of the device. Hence software filtering had to be opted for filtering processes instead of hardware filters. The software filtering is generally preferred because of its accuracy and portability.

Filtering is required to smooth out the raw sensor data of any noise and jitter. The pulse waveform obtained has a lot of noise due to d body anatomy, movement and even respiratory activity. The pulse waveform with input values marked is shown in Fig.9.

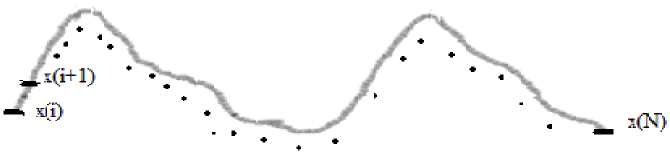
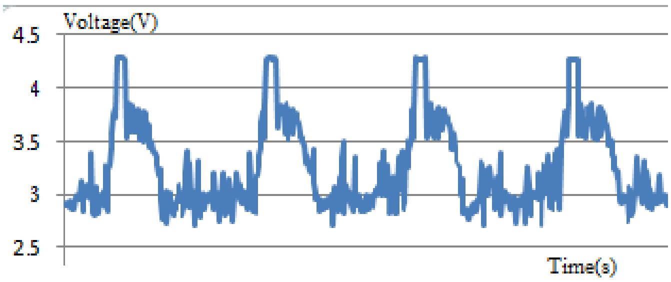


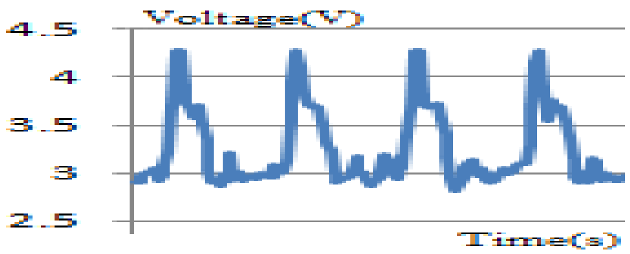
Fig 9.Raw input waveform

An averaging filter, which is a low pass filter, is implemented. A factor of four is chosen, with respect to the array size, to filter out the raw sensor data. If a factor greater than four is selected, the signal shall be lost and if a factor lesser than four is selected, averaging the data didn't provide a better result. N is the total number of values in the array (even). 'z' is the increment factor that varies as 0,4,8,12 …in terms of multiples of 4 till the final value, for each iteration. 'x' from (i) to (i+3) represents the four consequent points of the sensor input values. 'y' yields the output of the average of four consequent input values and varies from 0 to N/4.

It helps to remove the high frequency noises as well as jitter and reduces the raw data present in the defined array to about one-fourth of the total data. This helps to smooth out the data as well as increase the efficiency of the processor. The raw and filtered data graphs are shown in Fig.10.



(a)



(b)

Fig 10.Raw (a) and filtered (b) waveforms after using averaging filter

4.3 Peak detection Algorithm

Peak detection and its techniques play a vital in signal processing which require the presence of peaks and its count. If wrong or faulty, the entire system can yield faulty and erroneous results. The values of the filtered waveforms are mapped in certain defined ranges. This helps in defining the values which are to be considered for peak detection and the values that are to be neglected. It helps in making the peak detection process easier.

This was done by determining the maximum value in the array of input values and determining other factors to be added or subtracted to split the range (based upon the voltage of the signal obtained) into three different ranges as in the algorithm below in Fig.11. Then each input in the averaged array is checked with the limits set, to see whether it falls within the particular range. If they do, they are represented by an equivalent value. Three values represent three different zones. Only the upper (highest or last) range is considered for the peak detection process. The lower ranges are avoided.

1: **let** P =: max(y(i), y(i+1),….y(N/4));

where,

i varies from 0 to one fourth of the total number of values, N;

'P' gives the maximum of the averaged values y;

2: **let** $y_{n(0 \text{ to } N/4)}$ be a new array;

3: **let** n =: 0;

4: **for** i = 0 till i < N/4

5: **if** a value of y, say y[i] < (P – X_1)

then y[n] ← P1;

else if y[i] >= (P--X_1) and y[i] < (P—X_2)

then y[n] ← P2;

else if y[i] >= (P – X_2)

then y[n] ← P3;

where X_1 , X_2 are the selected factors and

P1, P2 and P3 are allocated values

Fig 11.Algorithm for mapping input values

The other issue that poses a problem is the existence of multiple peaks. The existence of a current peak and a subsequent peak in the same range was solved by making the current peak as a value that belongs to some other range. Thus, the subsequent peak shall be considered. This helps to reduce consecutive multiple peak problem to some extent.

The state of nonconsecutive, multiple peaks within the same range were still present. Hence, another method was required to remove the multiple peaks in order to obtain local maxima points in the range. Every value is checked for a high peak, from the beginning till the end of the upper range. After checking all the peaks in each and every individual range shall be counted and the complete set of high peaks shall be replaced by a single high peak value which represents a local maxima point.

1: let hb =:0

2: for i = 0 till i < N/4

3: if y[i] == y[i+1]

4: if ((y[i] != P1) and (y[i] != P2))

then y[i] = P2;

5: if (y[1] == P1)

then let r =i+1 and y[r] != 0 and r shall be incremented

if (y[r] == P3)

then let counter = counter + 1 ;

and let c = r

c = r;

6: if counter > 1 or counter == 1

then increment the hb counter variable

and counter = 0

Fig 12.Algorithm for the removal of consecutive double and multiple peaks

These local maxima points can be counted and multiplied by the corresponding time factor to give the pulse rate.

V. TEMPERATURE SENSOR OUTPUT PROCESSING

The output values which are obtained from the LM35 temperature sensor are analog in nature. They are converted into voltage values and are displayed.

VI. CONCLUSION

A cheap, efficient and portable heart rate detector for the patients suffering from cardio vascular diseases is designed and built. The main idea of developing the system was a reduction in hardware circuitry by developing a robust peak detection algorithm and thus reducing the cost. It is a suitable system for monitoring the heart beat at any location and time which is very useful for the elderly. The readings could help in the detection and diagnosis of various heart diseases. The system also has a temperature sensor which could help in health monitoring. With the development of mobile technology and increasing usage of mobile phones by various sections of the society, there has been a great development in the field of mobile health (m-Health) technology. Android being the most commonly used mobile operating system worldwide, various health applications are developed for health monitoring. The application developed for this thesis, obtains the readings from the sensors and displays them in the android health application.

VII. FUTURE DEVELOPMENTS

In the future development, more tests shall be conducted on many subjects and compare the results obtained with the standard medical equipments for accuracy evaluation and improvement. The heart rate detector can be carried onto the next level by developing it to measure and evaluate oxygen saturation in the blood. The Android programming can be extended to transmit the PPG obtained data over the Internet for personal and hospital health history databases via 3/4G networks.

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