I J C T A, 9(41), 2016, pp. 381-389 ISSN: 0974-5572

Real-Time Heartbeat Rate Monitoring System using Raspberry Pi

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ABSTRACT

Today, with the ever-increasing pace of life and the intricacies associated with it, heart diseases have become very common in all age groups. For an early understanding of the problem, a continuous monitoring of the basic parameter i.e. the heartbeat rate of an individual can help in a big way. In this paper, a cost effective wireless monitoring system has been proposed. The concept helps in saving on human capital and error-free monitoring of the heartbeat rate. Not only is the monitoring necessary, there is also a need to store the data for future reference. The wireless transmission and updating of the data on the world wide web using a RaspberryPi(RPi) and the concept of "Internet of Things" aids this. The online, real-time graphs give an insight on the heartbeat rate trend of the patient, which becomes extremely useful for reference purposes; the major advantage being, the data can be accessed from all over the world on any basic computing system. Further, the proposed method becomes highly cost effective when applied for a number of individuals at a time and can, in turn, reach the relatively lower strata of the society.

Keywords: Photoplethysmographic heartbeat sensor, Arduino, Bluetooth HC05, RaspberryPi, Python programming, Cloud storage

1. INTRODUCTION

Heartbeat rate is an indicator of the soundness of our heart and helps in the assessment of the condition of cardiovascular system [1]. In a clinical environment, it is measured under controlled conditions like the blood measurement, heart voice measurement, and Electrocardiogram (ECG) [3] but it can also be measured at home environment [2]. The heartbeat is detected by a photoplethysmographic sensor, which works on the principle that he power transmitted by the LEDs is matched with the photo sensor in such a way that the resistance will vary within the range of the photo sensor afterattenuations through the index finger [8]. The change in blood volume when there is a beat is detected and transduced to an electrical signal. The reason behind choosing this sensor is it'scost effectiveness and a digital pulse as an output signal. An Atmega 168 microcontroller is used as a counter as it is easily programmable and has a considerable storage space. The data is transmitted using a bluetooth module to Raspberry Pi (a credit card sized minicomputer) module [9] for the comparison and uploading of the data. If the heart rate is beyond a certain limit, an online messaging service is used to generate a message and send it to a pre-fed number mentioned in the Python code of RPi.The storage of data is attributed to the url in the code which links to a site known as ThingSpeak, for cloud storage from which the data can be retrieved, anytime from all over the world on any basic computing system [10] The instantaneous graphical representation of the real time data is also recorded [11]. Many other methods to measure heart rates like Phonocardiogram (PCG), ECG, blood pressure wave form [4] and pulse meters [5] but these are clinical, bulky and expensive. There are other cost-effective methods that are implemented with sensors as proposed in [6] and [7] but they are susceptible to noise and movement of subject and artery.

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In the proposed paper, the RPi used is a mini credit card sized computer that is highly portable and user friendly. The major benefit of cloud storage is that it can be accessed worldwide using any basic computing system and provides mobility to the stay-at-home patients as well as the monitoring personnel. Also, it is a huge platform with practically unlimited storage space and the instantaneous graph plotting of the real-time data helps in monitoring the trend of that particular individual. The cost effectiveness will result in reaching out to the relatively lower strata of the society and connecting them with professionals, worldwide, a facility they are generally deprived of.

2. PROPOSED MODEL AND ANALYSIS

Fig.1 shows the proposed system consists of various components: Heartbeat sensor, Atmega 168 microcontroller, Bluetooth HC-05 and Raspberry Pi B and their linking to give a real time monitoring output and an alert (warning) message.

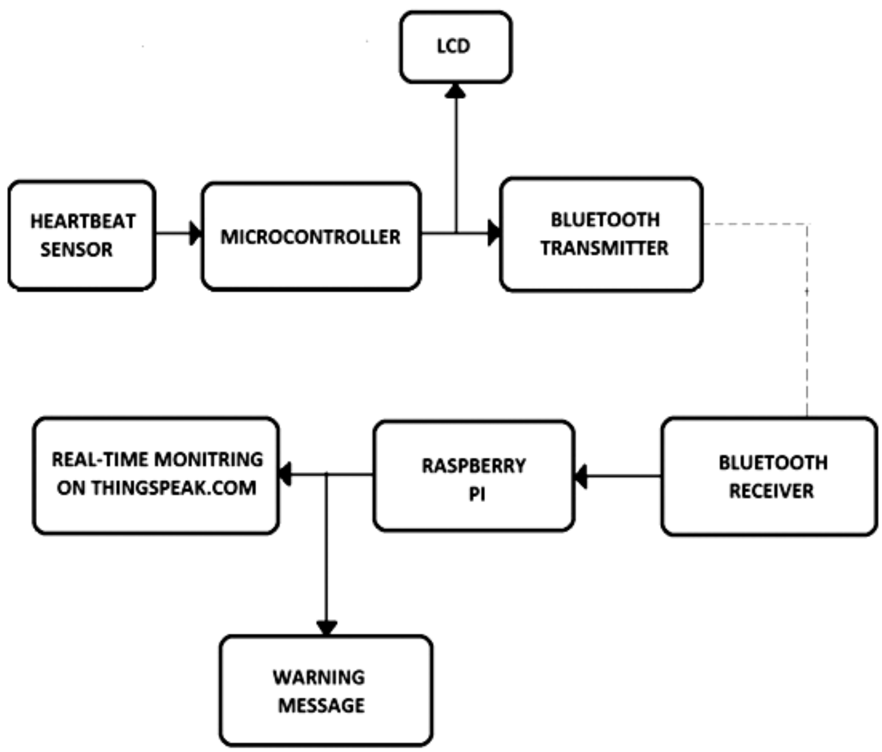

Figure 1: The proposed model of the heartbeat monitoring system

2.1. Heartbeat Sensor

A reflective optical sensor and is the main component of heartbeat sensor. The remaining part of the heartbeat sensor contains signal conditioning circuit. In the sensor both infrared light emitter diode and detector are placed adjacent to each other and thus helps in avoiding unnecessary surrounding lights which can affect the performance of sensor.The process of measuring heartbeat with the change in blood volume is known as photoplethysmography (PPG). In PPG signal AC and DC components are present. AC component gives the measure of change in blood volume which is useful information for determining heartbeat of a person and DC component gives information regarding average blood volume. AC component which is very small is superimposed over large DC component and thus DC component has to be eliminated. Output signal of heartbeat sensor is passed through RC High pass filter to remove the unwanted DC component. The signal is then passed through active Low Pass Filter (LPF). Two stage signal conditioning provides the advantage of removing DC component and high frequency noise while amplifying the useful AC signal. OP-Amp MCP 6004 is used as Active Filter. When observed on a CRO, whenever there is a beat, there is a spike in the signal. It is in the form of a digital signal as the sensor module uses an inbuilt A/D converter.This heartbeat sensor provides the voltage fluctuation from 0 to 5 Volt whenever a beat is detected and thus gives digital output and reduces efforts in coding.

2.2. Atmega 168

ARV microcontroller having 16KB programmable flash memory is used for computing the heartbeat from the output signal of heartbeat sensor and a compiler is used for compiling the code. A crystal oscillator is needed to generate frequency for the providing clock cycles to the microcontroller. The microcontroller's counter counts the pulses for 30 seconds and result is multiplied by 2 which give error rate of 2%.The computed result is displayed for 3 seconds on the LCD screen and the loop continues to count the heartbeat again until the stop button is pressed. Even after pressing stop button microcontroller will count the pulses for the ongoing loop and after then it will halt the system.

2.3. Bluetooth Module HC-05

Bluetooth Module HC-05 is employed for the wireless transmission of data from Microcontroller to Raspberry Pi. For wireless transmission one of the Bluetooth Modules must be configured as Master and the other one as slave. The transmitting module which is interfaced with the microcontroller is set as Master and the receiving module interfaced with the Raspberry Pi is set as Slave. The configuration for Slave is easier as compared to Master which is achieved using Arduino UNO Board. Since small amount of data is to be sent wirelessly to Raspberry Pi module, the Baud rate used for communication purpose is 4800.

2.4. RaspberryPi

Raspberry Pi is a credit card sized computer. It provides us 512 MB RAM storage and 700 MHz microprocessor. The module used here is Raspberry Pi 2 Model B. The programming language used here is Python. The Pi modulecontains python scripts which performs monitoring and facilitate further functionality. puTTY is secure shell and telnet client developed for Windows platform. For connecting Pi and PC containing puTTY software, they must be connected to a common network which is provided by smart phone tethering.One of the script in Pi contains user name and password, which when provided by any hotspot, connects the Pi to that network. The IP address of Pi is provided to puTTY which is an interface where we can read and run the scripts stored in Pi. The Pi is password protected. In order to provide webpage accessibility to Pi, scripts are included in it which contains codes that contains link of the sites where data needs to be uploaded. Similarly for warning messages a script that provides access to online messaging service which is used in case recorded heartbeat go beyond a certain pre-defined range.The main script in Pi imports the above scripts. It reads the data received via Bluetooth. It contains line of codes that monitors and uploads the data and gives command to generate a warning message, if necessary.

2.5. Proposed real-time monitoring and alert message

Website used for real time monitoring is thinkpseak.com which is an open source API platform. This site is known for real time data collection, storage and its visualization. A channel is created which has a unique API (application programme interface) Key. This key is included in the respective python script through which Pi can send the data to this website. The channel can be set as private or public as per the requirement. In private mode, channel requires user name and password to access the data. In public mode, URL of the channel is shared with the people who need to access the channel. In each channel maximum 8 fields can be used for 8 different parameters. Since one physiological parameter, heartbeat is measured only one field is required.

The Heartbeat values sent by Pi are updated on this channel in every 30 seconds along with the time stamp. All the heartbeat values are represented graphically with respect to time. These values are stored and can be exported to the system in the form of tabular representation. An online message service portal is used for sending warning messages. The URL of website along with user name and password of the account created is specified in the respective python script. Along with this emergency number and message to be sent is specified in main script. When the system starts the Pi access the account and commands it to send message "System started" to the emergency number.

The Heartbeat values are continuously checked, whether they fall within the defined range. In case the value goes beyond the range, Pi commands the site to send warning message "Warning: Heart rate < XX" or "Warning: Heart rate> YY" where XX and YY are the lower and upper limit respectively.

3. Design Flow of Heartbeat Rate Monitoring System

Fig. 2 shows the flow of the complete circuitry and tethering with the worldwide web. The condition for generating the warning message is also depicted.

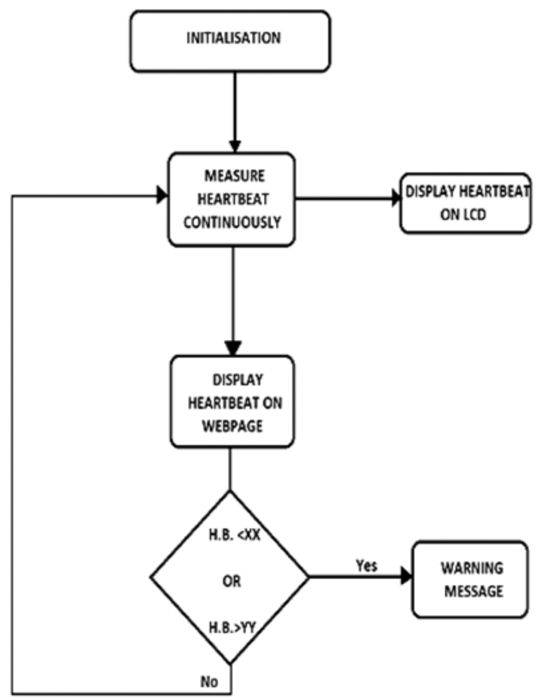

Figure 2: Design flow of the Heartbeat Rate Monitoring System

4. DISPLAY OF RESULTS

The proposed model of heartbeat monitor, the combined circuitry is shown along with different modules and connections in Fig. 3. The established connection between Pi and Laptop is done by tethering.The established connection between Pi and Laptop is done by tethering.

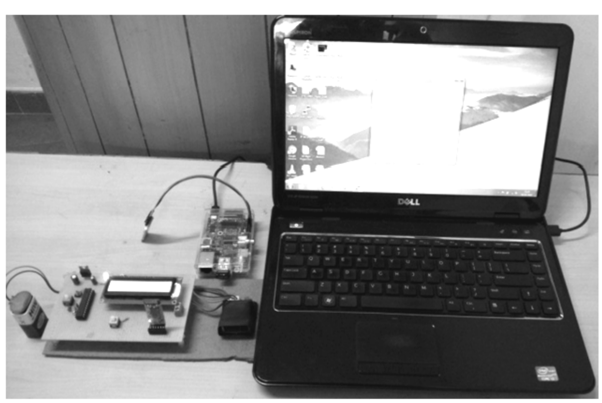

Figure 3: Design set up of the complete proposed model

Figure 4-10 show the stepwise working of the proposed model supported by the implementation pictures.

4.1. Sensor Initialisation

The sensor module shown in Fig.3 (black, box-like structure) requires a minimum 5V power supply. Once the supply is given, LED glows and the initialisation message "Heart rate Monitoring Sys" is displayed on LCD screen as shown in Fig. 4

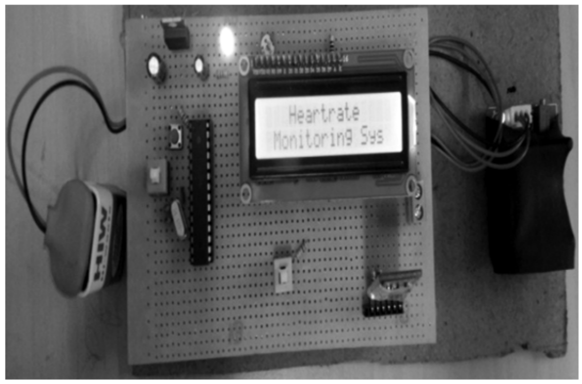

Figure 4: Sensor Module Initialisation

4.2. Module Ready for Monitoring

When the module is ready, a new message "Press To Start" is displayed on LCD screen as shown in Fig.5

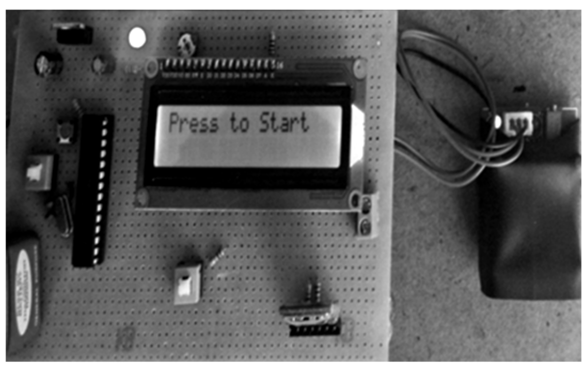

Figure 5: Module ready for monitoring

4.3. Heartbeat Detection

Then a finger is placed on the sensor. Continuous blinking of LED indicates detection of change in blood volume which gives heartbeat reading. The push button is pressed and the message "Heartbeat…" is displayed on the LCD as shown in Fig. 6.

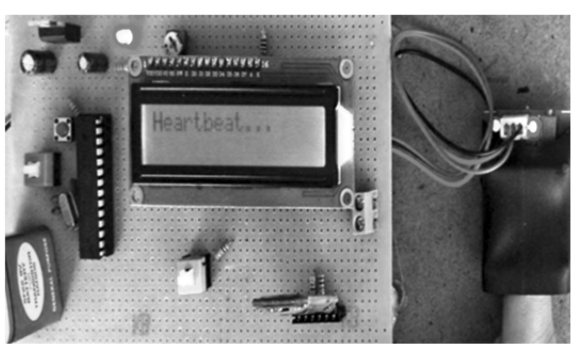

Figure 6: Heartbeat detection

4.4. Display of the Heartbeat Recorded on LCD

Heartbeat is detected and computed. After that a message indicating heartbeat is displayed on LCD for 3 seconds as shown in Fig. 7

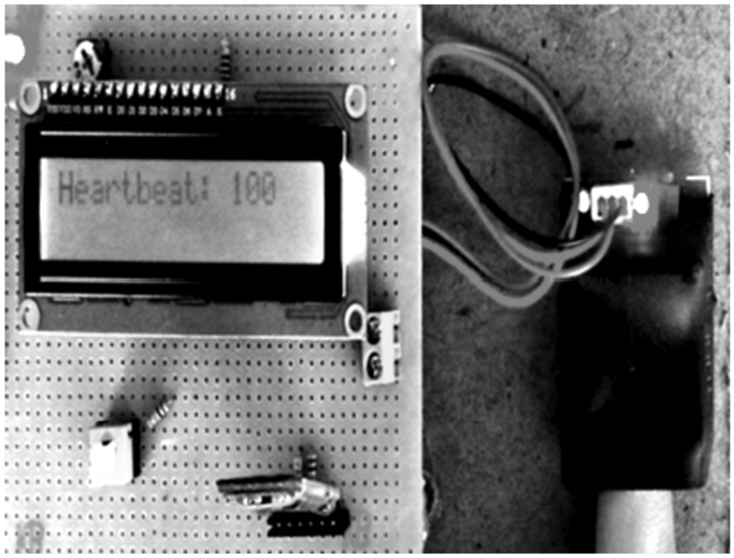

Figure 7: Heartbeat detected displayed on LCD

4.5. The Running of Python Script

The puTTY software interface displays the heartbeat data transmitted wirelessly by the Bluetooth module to the RPi module; updating it continuously. Figure 8 shows a snippet of the script.

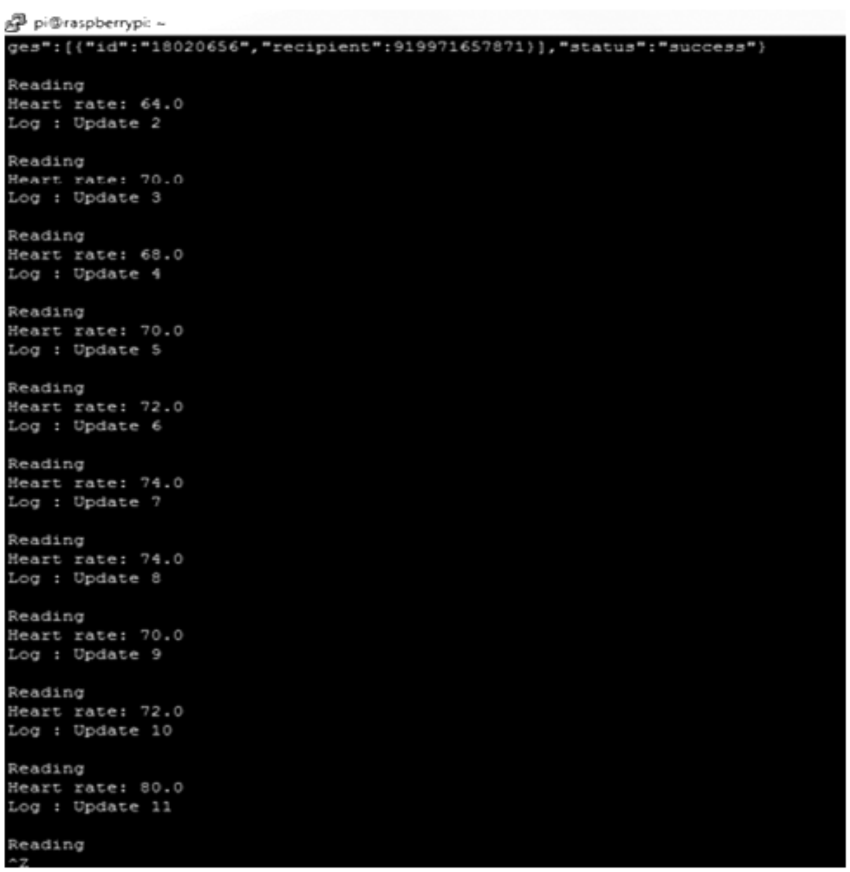

Figure 8: The Python script running

4.6. Message sent to pre-fed phone number

A message delivered from an online messaging service shows "System Started" (shown in Fig. 9) as soon as the puTTY software starts executing the Python script.

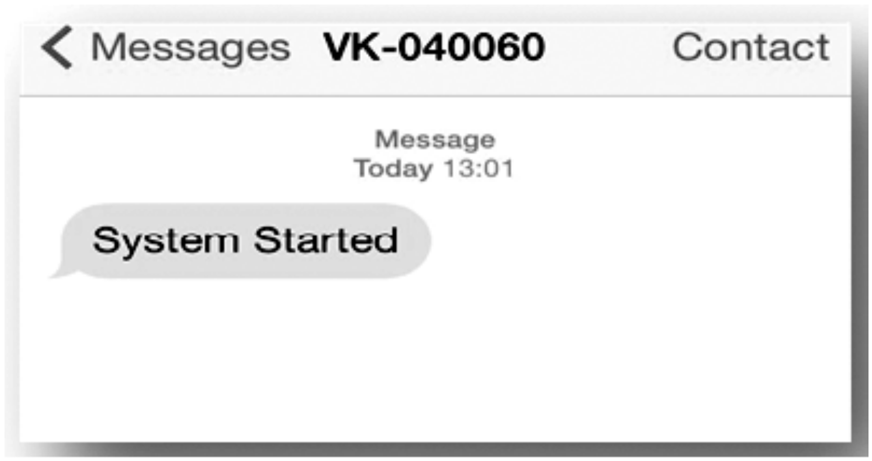

Figure 9: Message sent to the pre-fed number

4.7. The Tabular Form of Data

The following table shown in Table 1 shows the readings taken over a time period, that are uploaded on the website

Table 1
Data Recorded Over a Period of Time

created_at	*entry_id*	*field 1*
2016-03-16 13:28	1	70
2016-03-16 13:28	2	64
2016-03-16 13:29	3	70
2016-03-16 13:29	4	68
2016-03-16 13:30	5	70
2016-03-16 13:30	6	72
2016-03-16 13:31	7	74
2016-03-16 13:32	8	74
2016-03-16 13:32	9	70
2016-03-16 13:33	10	72
2016-03-16 13:33	11	80

4.8. Graphical Representation of Data

The data uploaded on the site is represented graphically, continuously, over a period of time as depicted in Fig. 10. This shows the trend of the heartbeat rate of the individual.

4.9. Warning Message Sent and Displayed on Phone

Figure 11 shows the warning message that is sent to the pre-fed phone number when the heartbeat rate goes beyond the pre-defined healthy range.

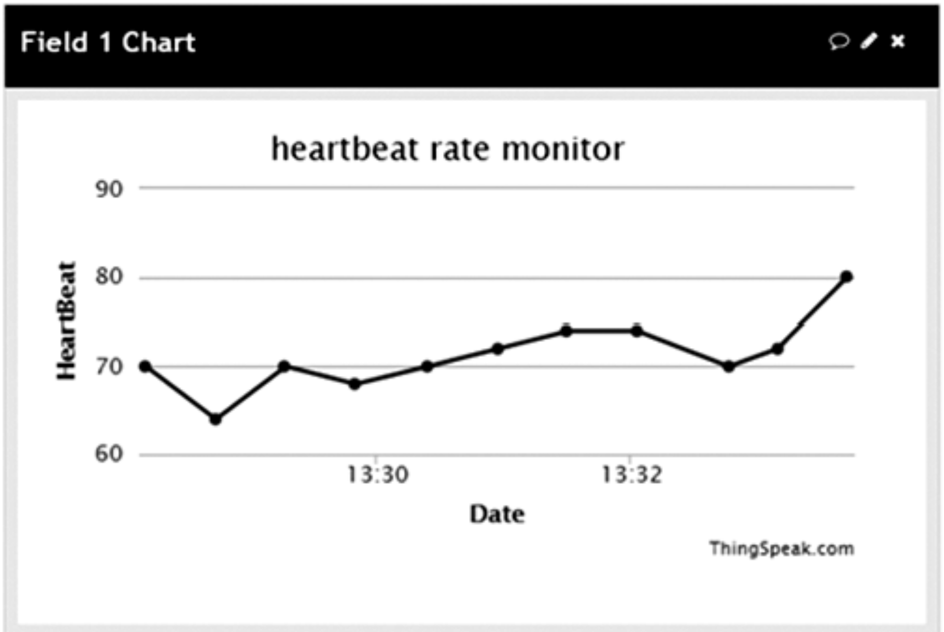

Figure 10: Graphical representation of the data

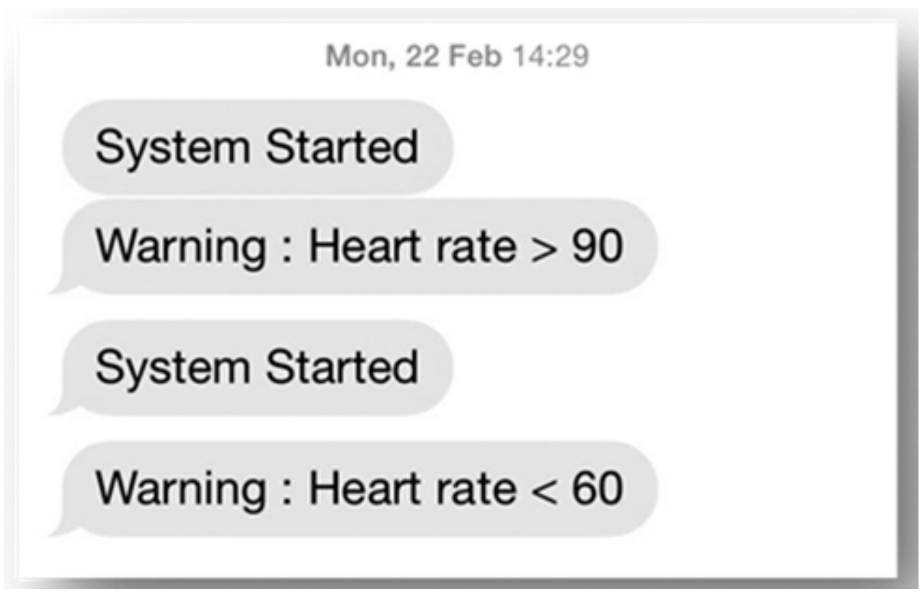

Figure 11: Warning Message Sent to Phone

5. CONCLUSION

Heartbeat is one of those physiological parameters which changes whenever a person suffers from any disease. The proposed system is cost effective and allows real time monitoring of heartbeat of a person which can be accessed from anywhere on any device. The real time monitoring can reduce the workload of manual monitoring and can still be as effective as earlier because of the messaging service employed for the warning purpose. The recorded heartbeat is uploaded on a website and represented graphically. The data can be exported from the website in tabular form which will be helpful for doctors in analyzing the patient based on his abnormal heartbeat timing on a particular day. Further the proposed system sends warning message whenever unusual heartbeat is monitored which helps in seeking attention of the concerned personnel.

This system can be designed for more than one patient using different sensors for different patients, using a mesh network created by ZigBee for the wireless communication but using single RPi for monitoring with some modification in the programming and creating separate channels for each patient. This will reduce the overall cost of the system.

REFERENCES

[1] R.G. Landaeta, O. Casas, and R.P. Areny, "Heart rate detection fromplantarbioimpedance measurements", 28th IEEE EMBS Annual International Conference, USA, 2006, pp. 5113-5116.

[2] P. F. Binkley, "Predicting the potential of wearable technology", IEEE Eng. Med. Biol. Mag., Vol. 22, 2003, pp. 23-27.

[3] H. Shim, J.H. Lee, S.O. Hwang, H.R. Yoon, and Y.R. Yoon, "Development of heart rate monitoring for mobile telemedicine using smartphone", 13th International Conference on Biomedical Engineering ICBME 2008), Singapore, 2008, pp. 1116-1119.

[4] C. C. Tai and J.R.C. Chien, "An improved peak quantification algorithm for automatic heart rate measurements", IEEE 27th Annual Conference on Engineering in Medicine and Biology, China, 2005, pp. 6623-6626.

[5] Y. Chen, "Wireless heart rate monitor with infrared detecting module," US2005075577-A1, 2005.

[6] T. Usui, A. Matsubara, and S. Tanaka, "Unconstrained and non-invasive measurement of heartbeat and respiration using an acoustic sensor enclosed in an air pillow," SICE 2004 Annual Conference, 2004, vol. 3, pp 2648-2651.

[7] S.Rhee, B.H.Yang and H. H. Asada, "Modeling of finger photoplethysmography for wearable sensors," 21st Annual Conference and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc. BMES/EMBS Conference, 1999.

[8] M.M.A. Hashem, Rushdi Shams, Md. Abdul Kader and Md. Abu Sayed, " Design and Development of a Heart Rate Measuring Device Using Fingertip", ICCCE 2010, Kuala Lumpur, Malaysia.

[9] A. Swapna, Mr. Md. Ammeenuddin, "Implementation of Sensor Data Monitoring and Transmitting using Raspberry Pi with reference to healthcare industry", International Journal & Magazine of Engineering, Technology, Management and Research, Vol. No. 2, Issue No. 7, ISSN No. 2348-4845, July 2015, pp. 1849-1853

[10] Mehta Karankumar D., Mehta Shreya B. and Raviya Kapil S., "Analysis of TOI(Thing of Internet) Industrial Monitoring System on Raspberry Pi platform", International Journal of Computer Science and Mobile Application, Vol. 2, Issue 11, ISSN No. 2321-8368, November 2014, pp. 33-40

[11] Mohamed Fezari, Mounir Bousbia-Salah and Mouldi Bedda, "Microcontroller Based Heart Monitor", International Arab Journal of Information Technology, Vol. 5, No. 4, October 2008, pp. 153-157