Smart Heart Rate Monitoring System

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***Abstract*— Heart rate that is given by the number of times heart beats per minute is a crucial health parameter that indicates the soundness of the human health. In this project, a real-time heart rate measurement technique called Photo-Plethysmography (PPG) is implemented using simple infrared transmitter and receiver circuit. Arduino Uno board has been used for calculating the heart rate from the fingertip. The obtained heart rate values are initially displayed on a Liquid Crystal Display (LCD) and sent serially to Raspberry Pi which is used as an Internet of Things (IoT) gateway. The values are then sent to the cloud through Message Queuing Telemetry Transport (MQTT) protocol. The designed system updates the user with their heart rate through electronic mail (email), Short Message Service (SMS) and real-time plots and provides name and address of a nearby prominent hospital in case of an emergency.**

Keywords— MQTT, PPG, IoT, Raspberry Pi

I. INTRODUCTION

Proper functioning of a human body depends upon various parameters which also includes the heart rate[1]. Health status of an individual can be determined with the help of observing heart rate levels. The cases of unavailability of proper equipments at the time of cardiac arrest have been increasing, especially in the remote areas that do not have doctors in their immediate vicinity. Due to lack of awareness, people of remote areas are at very high risk of major health problems as they might ignore a heart attack, or they might be incapable of a suitable treatment. In order to avoid such cases of cardiac arrests, there needs to be a regular heart rate check-up. The most common way to measure heart rate is by placing a finger on the artery to feel the pulse and counting it for about 30 seconds and then double that result to get the heart rate. However, this method of measuring heart rate is not accurate and surely does not provide precise results. Later, more technologically advanced devices that determine the heart rate were designed, like the ones that consist of monitoring set-up with a pair of electrode leads that are attached to the chest. These methods for measuring the heart rate utilize electronic techniques such as Electrocardiography (ECG)[2]. But the issue here is that these heart rate measuring devices are not only costly[2] but also most of them require experts to operate them[2].

In today's world, everything surrounding us is able to communicate with each other and this process of making things to communicate with each other is fancied by a name called Internet of Things (IoT). IoT has evolved the world in a whole new manner by creating a sort of network between things such as vehicles, home appliances, and other embedded systems that gave birth to many intelligent inventions like smart grids, smart homes, smart cities etc. In this paper, we have intended to create an intelligent/smart heart rate monitoring device which will measure the heart rate of the patient and will send the calculated value to a cloud platform. The main component that is used to detect heart rate in this device is an infrared (IR) sensor. Arduino board is used to interface the device with computer for analysis. The concept used for fabricating such a cost-efficient and easy to use technology is Plethysmography [4,5]. Plethysmography[4,5] is the volumetric measurement of an organ, resulting from fluctuations in the amount of blood or air that it contains. The change in blood volume is synchronous to the heart beat, so it can be used to detect heart rate levels. The intensity of the reflected light varies with the volume of blood in the fingertip, which in turn varies in accordance with heart beat. Specifically, lower intensity of reflected light from the fingertip indicates higher volume of blood and vice versa.

We are using Node-RED platform which is an open source visual editor by IBM that allows programmers of any level to rapidly interconnect physical input/output, cloud based systems, databases etc. It is a very flexible and powerful tool for implementing IoT. It updates the measured heart rate values on thingspeak.com and also sends the same to mobile phones via SMS or email using Message Queuing Telemetry Transport (MQTT) protocol which is a publish/subscribe based messaging protocol. This protocol is superior to Hyper Text Tranfer Protocol (HTTP) as it has additional IoT supporting features such as faster delivery speed, last will which means that in case of unexpected disconnection of a client all subscribed clients will get a message from a broker, retained message means that a newly subscribed client will get an immediate status update. HTTP has none of these features.

II. COMPONENTS USED

A. IR Transmitter and Receiver

The IR transmitter comprises an LED that emits the infrared radiation which, in turn, is received by the photodiode, which acts as IR receiver at the receiving end.

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Since the IR radiation is invisible to human eye, it is perfectly suitable for wireless communication. An electronic remote device mainly comprises IR transmitter and receiver. A remote-control emits a flash of invisible light which is transformed into an instruction and is received by the receiver module. Here, the IR transmitter/receiver is used to transmit and receive the reflected radiation from the fingertip of the user.

B. Arduino Uno

The Uno board comprises a microcontroller based on the ATmega328P. The various factors considered to choose and work on Arduino include its minimal cost, clear and easy programming and the extensive availability of the hardware as well as the software. A single Uno board is used for controlling the entire mechanism therefore it acts as the brain of the working structure. The board has taken various controls in the entire process to serve the purpose of the system which includes the process of collecting the data from the user and further working on that data to give the desired results.

C. Raspberry Pi

It is a credit card-sized computer which was originally designed for education, inspired by the 1981 BBC Micro. Due to its small size, it was quickly adopted by tinkerers, makers, and electronics enthusiasts for projects that require more than a basic microcontroller (such as Arduino devices). The Raspberry Pi is a complete Linux computer and can provide all the expected abilities that implies with effective results, at a low power consumption level. Here, we have employed Raspberry Pi3 model.

D. USB to TTL

The USB TTL driver provides USB to serial conversion. It further provides connectivity between USB and serial UART interfaces. A range of cables, such as 5V, 3.3V or user specified signal levels, are available offering connectivity with various connector interfaces.

III. WORKING

The project uses simple and low-cost IR transmitters and receivers for the calculation of heart rate.The user is required to place his fingertip gently on the IR transmitter and receiver. The sensors values acquired through photo plethysmography is sent to Arduino Uno .The Arduino performs Software filtering of the signal to make the signal within the desired frequency range (1 Hz-3 Hz).

The signal is scaled so that it can be visualized with more ease. The filtered signal values are then used to calculate the heart rate. We have used peak finding method (i.e. the number of systolic peaks obtained in 60 seconds) to determine the heart rate of the person. PPG signal values within a period of ten seconds are stored in an array and the number of peaks are calculated.

This value is then multiplied by six to obtain beats per minute. The calculated heart rate is sent serially to Raspberry Pi. Raspberry Pi is used as an IoT gateway that sends the heart rate values to a Node-Red cloud platform through the MQTT protocol.

The MQTT protocol works on publish/ subscribe mechanism. Pi publishes the heart rate values at a specific “topic”. On the Node-RED cloud, we subscribe to that topic and receive the heart rate values.

The cloud can be used to perform initial level analytics and for visualization using graphs and charts. For example the user will be able to know what his heart rate was on a specific day at a specific time. Through the cloud, an SMS and email notification is sent to a doctor or any registered person informing the heart rate of the person.

In case the heart rate of the person is above or below the normal limits, the system also informs about the name of nearby hospitals along with the directions to reach to the hospital. The entire dashboard (with graphs, charts, nearby hospitals and directions to reach hospitals) can be seen on the Node-Red dashboard or on an android app.

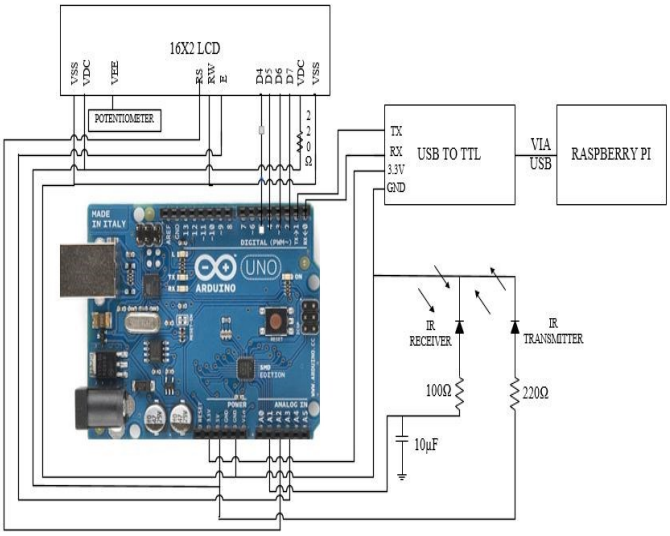

Fig. 1. Circuit Diagram

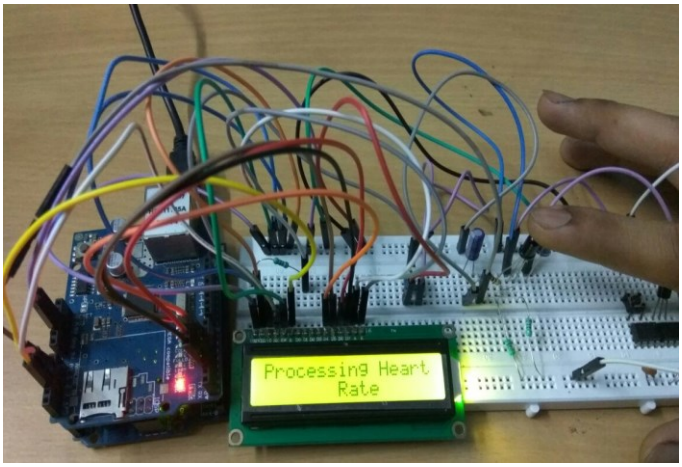

Fig. 2. Device processing the information after fingertip is placed

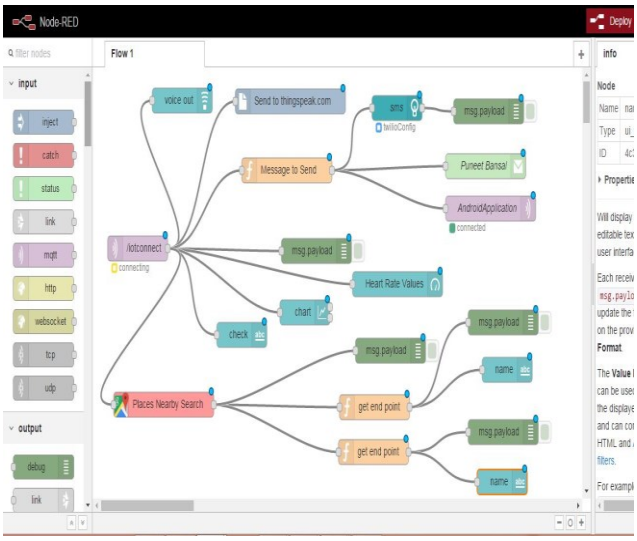

Fig. 3. Node-RED platform

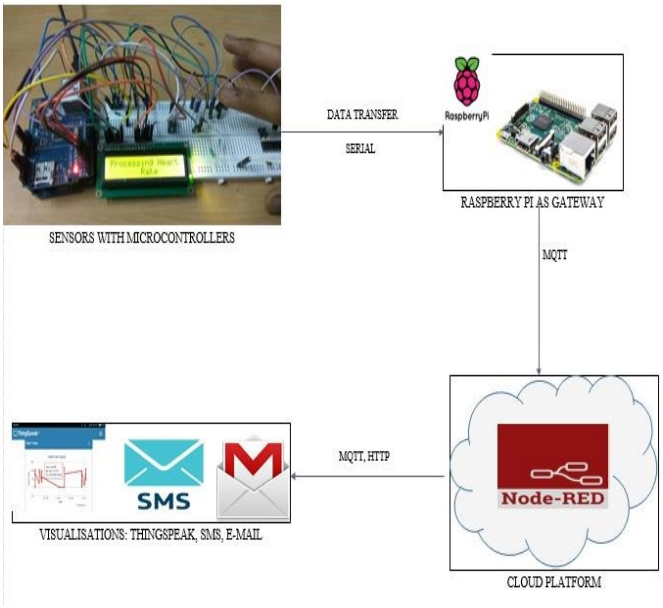

Fig. 4. Block Diagram of working procedure of the device

IV. COMPARISON WITH EXISTING DEVICES

The developed system enables patients to access the whole history of their check-ups along with time stamps and dates, which was not implemented in [6,7] and thus helping them to keep a track of their health on a regular basis. In contrast to other devices which have used conditioning and amplifying circuits [8], our device uses software filters ,thereby reducing the complexity of the hardware circuit. In most of the analog devices present, the patient needs help from another person to measure heart rate. Whereas, this device can be used without any need of assistance from others. Moreover,the device is very easy to use. The user only needs to place a fingertip ons the sensor, as opposed to enclosing fingertip inside a cap or wearing a cuff. Existing systems such as [14] have implemented Internet Of Things on Heart rate monitoring system where the data is sent to thingspeak.com which takes places through HTTP. The proposed system however, not only plots graphs and charts on thingspeak but in addition also updates the registered users through email and SMS services over the Node Red cloud. In addition to this , the system also shows nearby hospitals in case of emergency. MQTT protocol has been implemented to connect to the cloud which provides faster connectivity and lower battery consumption.

V. RESULT

The heart rate values for 25 different people from various age groups was obtained and can be seen in table 1. From the table it can be inferred that the obtained heart rate values for the various age groups was within the normal heart rate range. The obtained PPG signal was plotted using the processing software and the obtained waveform can be seen in Fig. 5.

TABLE 1. HEART RATE VALUES

Age (Years)	Calculated Results (beats per minute)
7	98
8	70
10	75
15	96
15	88
18	78
19	77
21	110
25	72
25	70
27	65
28	70
31	109
33	69
35	73
36	103
39	65
42	68
45	75
47	78
47	77
50	88
70	62
72	102
75	104

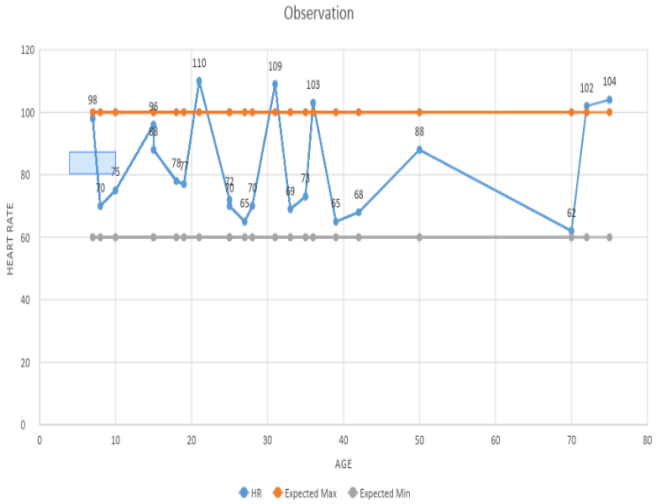

Fig. 5. Chart representing calculated values

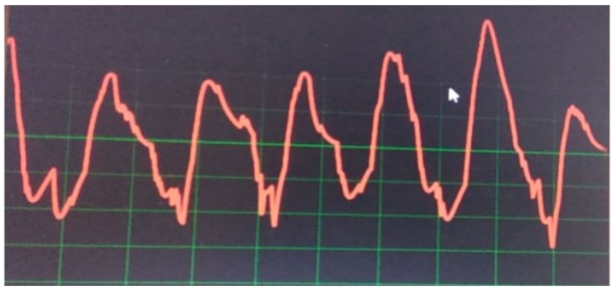

Fig. 6. PPG signal

VI. CONCLUSION AND FUTURE WORK

Using Raspberry Pi as an IoT gateway, the developed device could not only calculate the heart rate accurately but also enable real time monitoring of patient's heart rate signatures. A cloud based infrastructure has been developed for convenient visualization of the heart rate trends through graphs and charts and for data analytics. The major goal was to predict and avoid any heart based emergency by detecting an anomaly and immediately updating the registered user through email and SMS services over the cloud.

With this one-time investment patient can do regular check-up without the necessity of visiting doctors or needing professionals to operate it every time. This device is usually useful in rural areas as a doctor can remotely monitor health condition of a patient in a remote village area as he/ she receives updates via email, SMS and thingspeak visualization.

The obtained heart rate values are in the acceptable range. However, while measuring the heart rate, the fingers need to be kept very still over the transmitter and receiver assembly as even a slight movement will cause variation in results.

As a further extension of this device, Photoplethysmography could be used to measure oxygen saturation, blood pressure and respiratory rate. The entire device can be voice controlled using Amazon Alexa voice service and an authentication system can be incorporated using facial recognition. As this is the initial prototype, future research will aim to improve the power efficiency, scalability and cost efficiency of the device.

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