IoT based Heart Rate Monitoring System using Arduino and ThingSpeak

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Abstract*— Millions of people in the world are died due to the heart diseases because the ageing population and the costs for health care are rising. The quality health care devices from remote locations for patients are needed and demanded. Nowadays technologies in the medical electronics and communication have been advancing, which could support to decrease the cost of health care. Heart rate monitoring system based on Internet of Thing (IoT) by using Arduino UNO and ThinkSpeak is designed in this proposed paper. The pulse sensor is used for sense and detects the pulse rate from the body of the patient and send it to the Arduino in this system. It is designed to integrate the heart rate monitoring system controlled by Arduino to the ThinkSpeak through the ESP8266 Wi-Fi module. Thus, the heart rate of the patient can be automatically updated via the internet. This proposed system will display the Beat Per Minute (BPM) on the LCD. And this data is sent to ThingSpeak server via the internet as it is using ESP8266 Wi-Fi module and also display the heart rate data in the graph form in ThingSpeak. Therefore, heart rate can be monitored from anywhere in the world.

Keywords—IoT, heart beat, Arduino, pulse sensor, Wi-Fi module ESP8266, ThingSpeak

I. INTRODUCTION

Nowadays, The health problems such as, cardiac failure, lung failures and heart related disease are increasing day by day to a very high rate. Continuously health monitoring is very important to solve these problems. Health monitoring systems based on modern bioelectrical technologies can care the patient from the remote place wirelessly via internet. They are the essential roles in the improvement of the medical area. Cheap monitoring systems are providing more comfortable living to the people suffering from various diseases by using the leading technologies such as, wireless communications, wearable and portable remote health monitoring devices. Because of the information regarding patient's health directly displays to doctor's monitor screen from anywhere the patient resides, the visit of doctors to the patiently constantly can be decreased. Thus, the doctor can view the patient current pulse rate via web page using ThingSpeak.

IoT based heart rate monitoring system with Arduino and ESP8266 wireless module is designed in this proposed system. It is used ThingSpeak as the IoT platform. ThingSpeak is an open source Internet application and an API is used for HTTP over the internet or a local area network and required to modify the Arduino program. Wi-Fi module's name, password and IP address and the ThingSpeak's API key are mainly included in the Arduino program code for the security of that monitoring system. User name and password in the configuration system of the Wi-Fi module is important for safety the network. This IoT device could read the pulse rate and continuously monitor the pulse and update this rate on an IoT platform. It is integrated design the heart rate monitoring system controlled by Arduino and ESP8266 Wi-Fi module to send the heart rate data to ThinkSpeak server through internet. Thus, the heart rate of the patient can be updated automatically via the internet. This proposed system will display the heart rate of the patient in BPM on the LCD. And then this data is sent to ThingSpeak server via internet and the heart rate data in the graph form will be displayed in ThingSpeak, which is a greater source to display the data online as the user enable to access the data from ThinkSpeak at any time at any place. If the patient has any emergency cases, the doctor will contact to the person who takes care the patient.

A. The Objectives of the System

The main purposes of this system are the followings:

- to design and develop a device that continuously monitors the vital indicators as it periodically monitors and measures heart rate
- to design low-cost device which measures the heart rate
- to observe the heart rate singles in the present time by using the ATmega 328 microcontroller
- to reduce the dead rate due to the heart diseases
- to monitor the patient remotely over the internet

B. The Advantages of the System

- IoT monitoring proves really help when we need to monitor and record and keep track of changes in the health parameters of the patient over the period of time. In the IoT health monitoring system, doctors can take the reference of these changes or the history of the patient while suggesting the treatment or the medicines to the patient.
- Hospital stays are minimized due to remote patient monitoring.
- Hospital visits for normal routine checkups are minimized.

II. DESIGN METHODOLOGY

In the patient monitoring system based on internet of things project, the pulse rates of patient's health are sent to cloud using internet connectivity. These data are sent to a remote internet location so that user can view these details from anywhere in the world. Thus, Wi-Fi connection is needed to design IoT based heart rate monitoring system, so Arduino UNO is connected to the Wi-Fi module. In this system ESP8266 wireless module is used to configure the wireless network connection. The design of the heart rate monitoring by doctors is illustrated in Fig. 1.

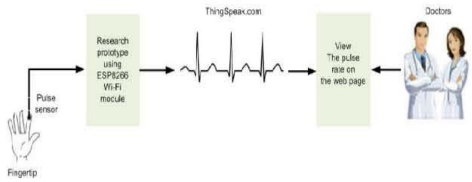

Fig. 1. The heart rate monitoring by doctors

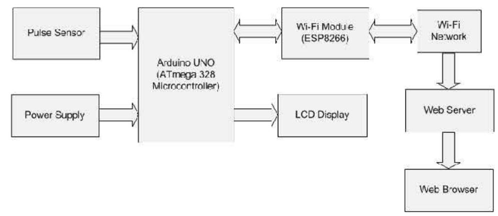

Fig. 2. Block diagram of the system

III. Background Theory

The heart is the main part of the human body. It is accountable for blood pumping throughout the body. Heart rate, HR is the rate at which the heart beats and is influenced with each beat by the development of the arterial wall. The most prominent pulse regions are wrist (Radial artery), neck (Carotid artery), elbow inside (Brachial artery), knee (Popliteal artery) and ankle joint (Posterior artery).

The HR shifts by era and the physical and psychological effects on the body. Higher pulse rate shows an abnormality in the body that can also be caused by other causes such as anxiety, rage, excitement, emotion and heart disease. An individual's pulse rate may help to determine different problems in the body, but it cannot be used alone to diagnose an abnormality.

The average heart rate for sedentary men is about 72 bpm and 80 BPM for sedentary women, but for qualified athletes these levels are often considerably different. The heart rate and respiratory rate for different ages are described as the following Table. 1.

Table I. Heart Rate and Respiratory Rate for Different Ages

Age	Heart Rate (BPM)	Respiratory Rate (Breathes/min)
0-5 months	90-150	25-40
9-12 months	80-140	20-30
1-3 years	80-130	20-30
3-5 years	80-120	20-30
6-10 years	70-110	15-30
11-14 years	60-105	12-20
14 + years	60-100	12-20

The cardiac monitoring system is one of the biomedical project models based on the IoT platform. The pulse sensor is used to detect and sense the human body's heart rate. AT Mega238 microcontroller in Arduino UNO controls the whole system. The patient's heart rate status is displayed on 16×2 LCD and Wi-Fi module, ESP8266 is used the web site, thingspeak.com, to connect this monitoring system to the internet. The block diagram of the system is described in Fig. 2.

In this system, ESP8266 is used to clarify the cardiac monitoring system based on IoT using Arduno. The Wi-Fi module ESP8266 is connected to Wi-Fi and the system will send the information about the heart rate of the patient to the IoT device server. ThingSpeak is used as the IoT server. Finally, the information from any portion of the world can be displayed to the ThingSpeak channel via internet. Arduino UNO, pulse sensor, Wi-Fi module ESP8266, 16×2 LCD display, 2kohm resistor, 1kohm resistor, LED are the components to implement the heart beat monitoring system. The primary elements of this system are Arduino UNO, pulse sensor and ESP8266 Wi-Fi module and 16×2 LCD display.

A. Arduino

Arduino Uno is one of Arduino's microcontroller boards based on the ATmega328 microcontroller from Atmel. "Uno" implies the latest in a series of USB, Universal Serial Bus, in Italian and UNO boards. Meanwhile, The Arduino panel is the reference system for the Arduino platform. Fig. 3 shows the development board of Arduino Uno.

Fig. 3. Arduino Uno development board

B. Pulse Sensor

The pulse sensor is an Arduino heart rate plug-and-play sensor. It can be used by learners, artists, athletes, game developers and developers of mobile devices who want to incorporate live cardiac information into projects readily. It is an integrated circuit of optical amplification and a noise suppression sensor. The heart sensor can be attached to the earlobe or finger of the human body and inserted into the Arduino.

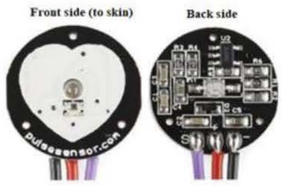

Fig. 4. Front and back side of pulse sensor

There are three buttons in the pulse detector: VCC, GND and Analog Pin. There is also an LED in the center of this sensor module that detects the heartbeat. Under the LED is a noise canceling circuit to prevent noise from affecting readings.

C. ESP8266 Wi-Fi Module

The ESP8266 is a user-friendly and low-cost tool for connecting your projects to the Internet. The module can function as both a point of access and a station. It can readily collect and download information over the internet, making Internet items as easy as possible. It can also extract data from the Internet using APIs, enabling your project to access all information on the Internet and make it smarter. Another interesting characteristic of this module is that it can be programmed using the Arduino IDE. The ESP8266 module works with 3.3V only, if we provide more than 3.7V would burn the module hence be cautions with your circuits. ESP8266 Wi-Fi module with pin diagram as illustrated in Fig. 5.

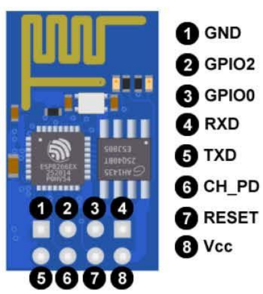

Fig. 5. ESP8266 Wi-Fi module

D. 16×2 LCD Display

LCD is a liquid crystal display. The LCD used here is 16 alphanumeric LCDs, which implies that alphabets and numbers can be displayed on 2 rows each with 16 characters. It is used to show the status of the gas leak. It can be used to show all the different alternatives and measurements stored in the EEPROM. Fig. 6 Shows 16×2 displays of liquid crystals.

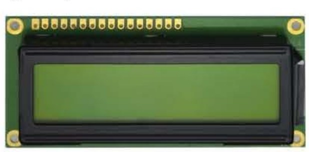

Fig. 6. 16×2 LCD crystal display

The Arduino Uno board is equipped with a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, a reset button, 6 analog inputs and also 14 digital input / output buttons. It utilizes the Atmega16U2 programmed as a USB-to-serial converter instead of a USB-to-serial FTDI driver chip used in all previous boards. The panel has a flash memory of 32 KB, the boot loader utilizes 0.5 KB, 2 KB SRAM, 1 KB EEPROM and a clock speed of 16 MHz.

IV. Implementation of the System

In this system, hardware implementation and software implementation are interfaced to design this heart rate monitoring system based on the embedded system. Fig. 7 described the flow chart of the heart rate monitoring system.

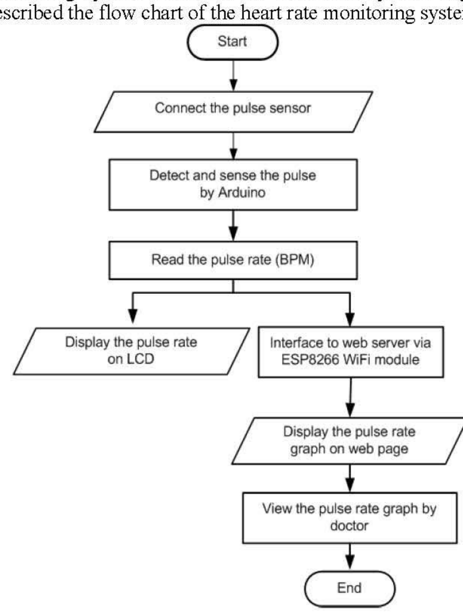

Fig. 7. Flow chart of the heart rate monitoring system

A. Hardware Implementation

Firstly, the pulse sensor is attached to any organ of body where it can detect the pulse easily like finger. Then the used sensor measures the change in volume of blood, which occurs when every time blood in the body is pumped by heart. The light intensity through the organ of body changes corresponding to the change in volume of blood in that organ. The software then converts this change into beats per minute (BPM). The LED which is connected at pin 13 also blinks per the heartbeat. Pulse sensor has three pins. Connect VCC and the ground pin of the pulse sensor to the 5V and the ground of the Arduino and the signal pin to the A0 of Arduino. A photoplethysmography (PPG) based pulse sensor is described in Fig. 8.

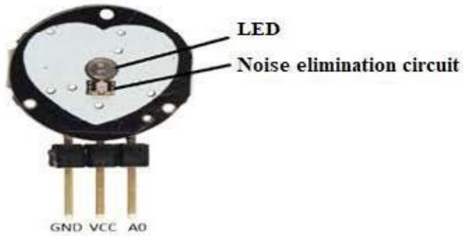

Fig. 8. Pulse sensor

The ESP8266, which is shown in Fig. 5, communicates with the Arduino and sends the data to ThingSpeak. This data on the ThingSpeak is displayed in a graph form showing the past readings too and can be accessed from anywhere over internet. The LCD connected also show the BPM.

ESP8266 requires 3.3V and if the Arduino Uno board provides it with 5V then it will not function properly and it might get damaged. Connect the CH_P D and the VCC to the 3.3V pin of Arduino. The RX pin of ESP8266 requires only 3.3V and it does not respond to the Arduino when it is connected directly to the Arduino. So, a voltage divider for it is made which converts the 5V into 3.3V. This can be done by connecting three resistors arranged in series. Connect the TX pin of the ESP8266 to the pin 9 of the Arduino and the RX pin of the ESP8266 to the pin 10 of Arduino through the resistors.

Fig. 9 shows the overall schematic diagram of the system that has been designed in this project to monitor the pulse rate of the patient.

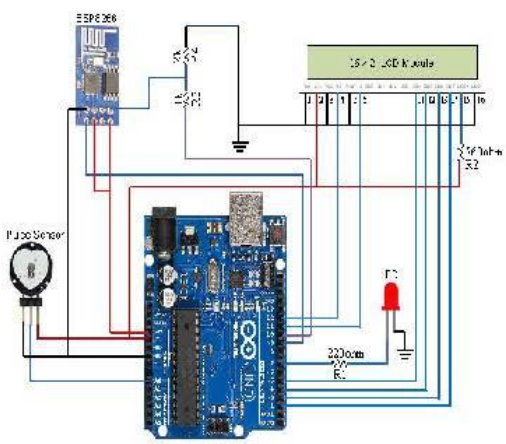

Fig. 9. The schematic diagram of the heart rate monitoring system

The output pin of the pulse sensor is connected to A0 from Arduino and the other two pins to Vcc and GND. LED is connected to Arduino digital pin 7 via a 220-ohm resistor. Pin 1,3,5,16 of the LCD screen are connected to GND and pin 15 of LCD is connected to resistor R1 (560-ohm) which limits the current through the back light LED. Pin 2 and 15 of the LCD is connected to Vcc. 4,6,11,12,13,14 pins of the LCD display are connected to the Arduino 12,11,5,4,3,2 digital pins respectively. The ESP8266's RX pin will operate at 3.3V and it will not communicate with the Arduino when it is directly connected to the Arduino. A voltage divider will be created that will convert the 5V to 3.3V. This can be done by connecting a 1k-ohm and 2k-ohm resistor. Thus, the RX pin of the ESP8266 is connected to pin 10 of Arduino via the resistors. Pin 9 of the Arduino is connected to the TX pin of the ESP8266. The ESP8266 Wi-Fi module connects to Wi-Fi and sends the data to the IoT device server. In this system ThingSpeak is used as the IoT server. Finally, by connecting to the ThingSpeak channel with Wi-Fi module, data can be monitored from any part of the world.

B. Software Implementation

The simulator Arduino IDE, 1.8.7 and Proteus 8 is used to implement software. Arduino IDE, 1.8.7 is used to write the Arduino c program to the Arduino UNO interface. Before the hardware circuit is implemented and this circuit is interfaced with the system software program, proteus 8 simulator is used to simulate the system layout of this interface circuit. The BPM value will show on the LCD.

Wi-Fi module's name, password and IP address and the ThingSpeak API key are mainly included in the Arduino program code for the security of that monitoring system. This system uses the user name and password for safety and API keys are required to modify the program. Arduino code is programmed to read the pulse rate and sense the pulse rate data to ThinkSpeak via ESP8266 wireless module. The baud rate per ESP8266 is either set in the program at 9600 or 115200. Connection of the ESP8266 Wi-Fi module is programmed to build a Wi-Fi network to send system information to ThingSpeak.

Some of the key abilities of ThingSpeak and it can

- configure a device to send data to Thing-Speak easily by using required IoT protocols
- develop and apply Internet of Things technology that is not needed to set up servers or develop any web software
- update on the data and communicate automatically by using ThinkSpeak

C. ThingSpeak Setting

ThingSpeak is a nice instrument and offers system equipment based on IoT. The information can be tracked and controlled via the Internet using the ThingSpeak website's channels and web pages. Firstly, a registration is needed to create a ThingSpeak account on the ThingSpeak site, https:/thingspeak.com, as described in Fig. 10. A ThingSpeak account was created, channels were clicked, and as described in Fig , a new channel and field name was created in Fig. 11. Do the check mark in the check box at the bottom of the form to choose "Make public" and save the channel and generate the new channel. The new channel has been created, the API keys in ThingSpeak site as illustrated in Fig. 12. Then select the API key to duplicate the Write API key. It will be needed in the program. API keys are required to modify the program and they are necessary to set the information.

Fig. 10. ThingSpeak site

Fig. 11. Creation a new channel in ThingSpeak

Fig. 12. Creating the API key in ThingSpeak

V. Result and Conclusions

Heart Beat Monitoring System is used in hospitals and wherever the ThingSpeak is used. The sensor of the pulse is linked to the human body. It is possible to detect the pulse, the pulse sensor measures the changes of the blood volumes. Arduino transforms heart beat per minute and display the text about the heart rate "BPM" on the LCD. The ESP8266 will configure with Arduino and send the information to ThingSpeak to obtain the code and display the outcome using the Arduino-connected graph and the outcome (BPM) will also be displayed. The prototype of the system is illustrated in Fig. 13. The heartbeat taken is shown on the LCD monitor at ThingSpeak and displayed on the internet as shown in Fig. 14.

Fig. 13. Prototype of the heart rate monitoring system

Fig. 14. Displaying the heart rate data in the graph form in ThingSpeak and on LCD

Output over the internet can be viewed by searching the particular channel at the public channel section of the ThingSpeak website by searching for tags such as Heartbeat monitor, Internet of things or Photo- plethysmography over the link (https://thingspeak. com/channels/public). The LED also blinks as per the corresponding heartbeat. The Wi-Fi module in this device can be automatically connected to only that Wi-Fi network, whose Wi-Fi network name and password is known and present in the program embedded in the Arduino Uno. If the user's Wi-Fi network is needed to change, the user name and password of the network have to change, the Wi-Fi network can be changed in the main program and embedding it again into the Arduino Uno board. This proposed system can be improved by interfacing various other biomedical sensors with Arduino and other advanced MCU boards. The heartbeat of the patient obtained from this prototype and then it can be sent via ThinkSpeak to any personal cloud storage or the cloud storage of a hospital for easy access by the doctors. Thus, it is more effective than keeping the records on printed papers stored in the files. Even the digital records which are stored in the personal computer or laptop or memory storage devices can be got corrupt and data might be lost. Whereas, this IoT based system is more reliable to use the cloud storage and has a few chances to loss the data. This proposed system is very useful for the doctors just by visiting website or URL they could continuously monitor the heart rate of the patient.

VI. Further Extensions

The heartbeat GPS module can be added in this IoT based heart rate monitoring system. It can search the location of the patient with the position of the longitude and latitude. Then GPS module will send this location of the patient to the web server on the cloud as it is used the Wi-Fi module. Then doctors enable to know the location of the patient when they have to need any preventative actions.

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