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Patient Health Monitoring System Using IoT

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Abstract:*People are careless about their health management due to heavy workload and financial issues which becomes a major factor causing various health issues. This project is based on Internet of Things (IoT) which aims to provide real time health monitoring for such people with ease and better facilities. This system measures Body temperature, Pulse rate, Pulse oximetry (SpO2) and Electrocardiogram (ECG) using respective sensors which are interfaced with controller Arduino Uno. These sensor readings are sent wirelessly to the cloud over the internet using ESP8266. ThingSpeak, IOTGeek, etc. are various IoT cloud platforms available on which the readings are displayed, visualized and stored securely. In this way, medical records are stored digitally and is easily accessed and analysed by the patient and the doctor remotely from any part of the world regardless of place, time and device. SMS/Mail alerts containing the patient information and location will be sent to the doctor during any critical condition.*

I. Introduction

In the age of wireless technologies, IoT has created a vast impact on various domains like manufacturing, healthcare, automation, retail sector, etc. With the help of IoT, different sensors will connect, gather and analyse real time data and communicate the information through the internet to collect, process, store the data remotely and provide context dependent alerts. With the growing role of IoT in healthcare industry, we will soon witness path-breaking innovations. Digital healthcare using IoT is one of the major trending technologies to serve patients with better treatment and allow medical centers to function more efficiently. According to a report, USD 250 billion dollars will be spent by 2020 on this technology out of which USD 15 billion dollars will be spent in the healthcare industry.

1.1 Problem Statement

Being a country with such a huge population count and large number of rural areas, availability of doctors in rural areas is only 2% whereas in metro cities and towns, it is 75% and 23% respectively. 15% of the population in rural areas have no access to healthcare facilities leading to many consequences, sometimes death. Large number of people monthly fall prey to many diseases due to their lack of care towards their own health. Various issues like clinical visits, costly check-ups, unavailability of medical instruments and medicines, lack of qualified and immediate assistance, lack of knowledge about one's health affects the patient's condition severely in numerous ways. Irregularity in check-ups because of a patient's daily work routine, unavailability of doctors, cost of clinic visits and consultation, expensive medicines does not lead to early pathology detection. Patient records are sometimes stored in various hospitals at different locations leading to unavailability of records to the doctors at the time of emergencies, when the doctors need to access the records immediately.

1.2 Objective

This system was proposed to overcome the possibilities of these problems so the patients can follow a cautious and healthy life and accessadvanced medical facilities. One of the advantages of the system is allowing the patient to have daily check-ups easily at home which will cut down the doctor fees, traveling to and fro and number of hospital visits. With real-time monitoring the doctor can access the patient's data from the cloud with ease from anywhere on a continuous basis. This helps doctor to keep a track of the patient's disease status and in case of emergencies provide immediate assistance. This helps to maintain healthy communication between the doctor and the patient. Since the data is stored on the cloud, patient can have his own digital identity and the patient records are stored online which are later accessed by both the doctor and the patient anytime immediately.

II. Methodology

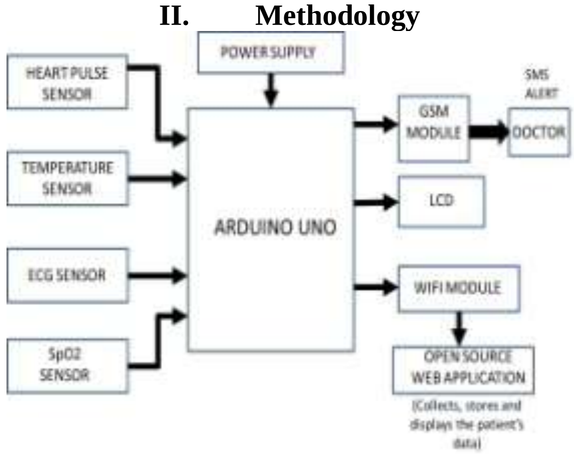

Fig. 2.1. Block Diagram

Fig. 2.1. illustrates the overview of the system. The medical sensors LM35, MAX30100, AD8232 and KG011 measure the body temperature, pulse oximetry, ECG and pulse rate of the patient respectively. LM35, AD8232 and KG011 are analog sensors that give the raw data in analog form as output which is later converted from corresponding voltage values to the desired readings for example temperature in degrees Celsius or beats per minute for pulse rate or oxygen percentage for SpO2.

Arduino Uno is the backbone of the system These sensors are interfaced to Arduino Uno board. ESP8266 is a Wi-Fi Module. ESP8266 is used for the internet connectivity with Arduino Uno. With the help of the above-mentioned sensors, vital parameter values are sent to Arduino Uno which are monitored and analog values are processed and later converted into a form that is displayed either on the serialmonitor or the LCD Display which is also interfaced to the Arduino Uno. ESP8266 is used to connect the Arduino Uno to the cloud platform on the internet. With the help of this Wi-Fi module, the monitored sensor data is sent wirelessly to the IoT Cloud platform where the data will be displayed, visualized, processed and stored. The health parameters have some defined values which determines if the patient is in normal conditions. If the monitored sensor values are not in the defined range, it indicates the patient's health is abnormal. This means he needs to be assisted immediately with proper instructions, precautions and medications by the doctor or other clinical staff as soon as possible. So, when the patient condition is critical, immediately an SMS or an E-mail containing the patient information, his location and the severe condition which is to be looked after is sent to the doctor. With this notification, the doctor is updated and he contacts the patient and provides the necessary assistance. The SMS is sent to the doctor with the help of the GSM Module SIM 900A. SIM900A is interfaced with Arduino Uno and it communicates serially. The message is updated with all the monitored values and then sent to doctor's mobile, clinic or hospital wherever necessary. The E-mail alert can be sent using the IoT Cloud platform which provides the facility of sending the e-mails automatically to the doctor's mail id. This saves a lot of time and effort and establishes a proper communication between the patient and the doctor which is of utmost importance.

There can be two portals on the cloud platform, one for the patient and other for the doctor. The patient and doctor will have their separate user ids and passwords to get logged in to access the patient information. The patient portal will display the various parameter values in numeric and graphical manner for easy analysis. The daily records will be maintained in the datasheet with the date, time and location. The doctor portal will have the records of all the patients so he can analyse the patient's status regularly and derive meaningful conclusions from the data. This data can be accessed anytime from anywhere which is really beneficial for both, the doctor and the patient.

III. Hardware

The system hardware has many units which are the medical sensors, the controller board, LCDdisplay to display the values, GSM module to send message alerts and the Wi-fi module through which the data is sent and received wirelessly over the internet. The list of hardware is as follows:

3.1 Arduino Uno

Fig. 3.1. Arduino Uno

Arduino Uno R3 is an ATmega328 based microcontroller board operating at 16 MHz, having 2048 bytes of RAM. Uno R3 has 20 input/output pins of which 6 pins are analog pins and 6 are PWM pins. Benefit of having Analog pins is that you don't need an external ADC to work with analog components. This was beneficial for this system since 3 of the sensors are analog sensors. Uno can be programmed using its easy-to-use Arduino IDE. It is USB-B compatible and the recommended input voltage is 7V-12V. Operating voltage is 5V. The sensors, LCD, GSM module and ESP8266 all are interfaced to Arduino at different pins.

3.2 LM35 Temperature Sensor

Fig. 3.2. LM35 Temperature Sensor

Fig.3.2. shows the LM35 temperature sensor IC. This is a semiconductor-based contact temperature sensor analog in nature. The output voltage of this sensor is linearly proportional to the temperature in Centigrade. It has a temperature range of -55℃ to+150℃. LM35 can be given an input supply within4V to 20V and it draws a current of 60µA from the input supply. LM35 has a linear output which means that with every single change in degrees Celsius, the output voltage changes by 10mV. We have used this sensor for measuring the body temperature. The normal body temperature range for an adult is between 36.5–37.5 °C (97.7–99.5 °F). If by measuring the temperature, the output is not within the defined range, it means the patient can have fever or hypothermia. Thus, an SMS/E-mail will be sent to the doctor indicating the patient's condition is not well.

3.3 MAX30100 Pulse Oximetry Sensor

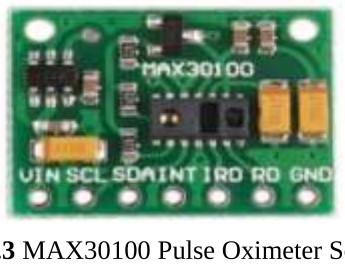

Fig.3.3 MAX30100 Pulse Oximeter Sensor

MAX30100 is a pulse oximeter and heart beat sensor module. This sensor is interfaced to Arduino Uno using I2C protocol through SCL and SDA pins of the sensor. The sensor comprises of 2 LEDs of different light emission wavelength, one being a red LED and other an IR LED. It has a photo-detector which senses the blood flowing through the fingertip placed on the sensor module. A low noise analog processing unit then processes this signal and an internal microcontroller then converts it into a digital output which makes this sensor a digital sensor. It has an inbuilt voltage regulator so it operates on 5V. It has an ultra-low power operation and provides high sample rates. This sensor is used for the purpose of calculating the oxygen saturation levels of the human body. The normal oxygen level of a human being is between 95 to 100%. If the measured output is below 95% then an alert is sent to the doctor indicating the situation of the patient.

3.4 AD8232 ECG Sensor

Fig.3.4.1 AD8232 ECG Sensor

Electrocardiogram (ECG) can be used to diagnose health conditions. An ECG kit available with doctors at clinics or hospitals is very bulky and expensive. It is not feasible for a common man to use that kit for daily monitoring. For that purpose, compact and low-cost ECG module AD8232 is used shown in Fig.3.4.1.AD8232 operates on a supply voltage of 2V to 3.5V consuming 170µA current. It can be used in 2 or 3 electrode configurations. The 3 electrodes or sensor pads are connected to the right arm, left arm and right leg of the body. This module is interfaced with Arduino Uno to one of its 6 analog pins. The output can be displayed either on an OLED, or a visual processing software or directly can be observed on the IoT cloud platform being used.

3.5 KG011 Pulse Rate Sensor

Fig.3.5 KG011 Pulse Rate Sensor

The KG011 pulse rate sensor allows the patient to monitor his/her pulse rate just by placing the tip of the finger on the LED in the sensor module. This sensor gives an analog output and it is interfaced with Arduino Uno on one of its analog pins. This sensor operates on 5V supply and draws a current of 100µA. The heart rate then can be observed on the LCD display or the serial monitor of Arduino IDE or the cloud platform on the internet. The normal pulse rate of a human being is between 60 to 100 beats per minute (bpm). If the observed pulse rate of the patient is above or below the range then the doctor is notified by the alert notifications and he can get in touch with the patient immediately.

3.6 SIM900A GSM Module

Fig.3.6. SIM900A GSM Module

Working on 900/1800 MHz frequency, this GSM/GPRS modem is built with dual band GSM/GPRS engine. It can be interfaced with the PC or the microcontroller kit with the help of RS232 interface. Or simply get interfaced to Arduino Uno through serial communication pins TxD and RxD. The GSM modem works by giving AT commands. Using AT commands, we can make voice calls, send and receive text messages and access the internet. This modem is thus suitable for voice, data and SMS transfer. The modem operates on 12V regulated supply. Sole purpose of this modem in this project isto send the text messages to the doctor and even receive messages from the other side.

3.7 ESP8266 W-Fi Module

Fig.3.7. ESP8266 Wi-Fi Module

The unit that makes this project Internet of Things compatible is ESP8266 Wi-Fi module. This module is a self-contained SOC having an integrated TCP/IP protocol stack which gives any microcontroller-based board an access to the internet. It comes with a pre-programmed AT command set firmware. The maximum operating voltage of ESP8266 is 3.6V. But to make the Arduino Uno and ESP8266 communicate, a Logic Level Converter is needed since ESP8266 is not capable of 3-5V logic shifting. The Rx and Tx pins of ESP8266 are connected to the logiclevel converter which is connected to the Arduino Uno. With the help of this module, we can set up the Arduino board to the cloud platform and the transfer of data can be done wirelessly.

3.8 16x2 LCD Display

The LCD module is a basic output device that displays alphanumeric and special characters. It can display up to 16 characters per line and it has 2 such lines or columns. Each character is displayed in a 5x7 pixel matrix. This LCD display is used to display all the sensor readings and other parameters to let the patient, know about the ongoing process of the system.

IV. Software

4.1 Arduino IDE

Arduino IDE is a platform used to write, upload the code and communicate with the Arduino board. Arduino IDE is most compatible and user-friendly software. The program here is written in C/C++ language which is converted into binary code to compile the program and load it into the board using a USB cable. Arduino IDE consists of a feature called libraries added at the start of code which makes sketch easier to debug and also saves the memory. Libraries comprise of at least header file (with extension .h) and source file (with extension.cpp). Header file contains commands and functions while Source file contains the code which is used to make the library work. Wire.h, LiquidCrystal.h, Max30100_PulseOximeter.h are some of the libraries available in Arduino IDE. By selecting the appropriate board and port from tools, the program can be uploaded on the board. Later by using Serial Monitor the output can be displayed on Arduino IDE itself.

4.2 ThingSpeak

ThingSpeak is an IoT analytics platform used to collect the data from sensors and turn it into useful information, analyse and visualize the data, and control the system using Internet. Using ThingSpeak the data can be sent to cloud from any Internet enabled device. Channels, tools, webpages are features provided to control the system. Channel is where all data of application is stored and each channel contain 8 fields to contain information, URL field to link webpage, location field, etc. Once the channel is created the data can be accessed by a read key if it is kept private(default). But if the channel is set to public, read key is not required. Real time data is obtained from the sensors which is received and transmitted in the form of Hypertext Transfer Protocol (HTTP). Then the data is uploaded on the cloud from where it can be used for various purposes. The data is stored and updated on Google sheet. Triggering levels can be set and alert messages are sent using SMS/Mail to the contact number/E-mail id mentioned. By using commands or certain options messages are sent to the objects to perform various tasks. Using visual tools, the real time data can be visualized in form of graphs, statistical distribution etc.

V. Readings

These are some of the sensor readings tested on Arduino IDE Serial Monitor.

Fig.5.1. Output of LM35 on Serial monitor of Arduino IDE.

Fig.5.2. Output of MAX30100 on Serial monitor of Arduino IDE

VI. Conclusion

The proposed systems help in availing regular health monitoring from any place, limiting in expenditure, immediate access to doctor for treatment during critical condition, maintaining records in form of digital identity. Thus, system helps in creating a friendly communication between the doctor and the patient and can also improve patient's health in home environment. By using IoT to connect different sensors to the cloud and visualizing, processing and storing the data, real time statistics are made available to the user and can be later accessed by both doctor and patient through any device. But since the system is limited to few sensors in future many more sensors can be added using different controller, technologies as such as Artificial Intelligence and making the system more compatible in terms of technology, size and cost. Security related threats in IoT network can be minimized in future and applying different security algorithms. Since the sensors used target the condition of heart, this system can help the doctor predict the heart related diseases by analyzing the data weekly or monthly and comparing the results, doctors can derive meaningful conclusions and detect what type of disease or illness the person is facing.

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