IoT-Based COVID-19 Patient Monitor with Alert System

Arjun Sharma, B. Nagajayanthi, A. Chaitanya Kumar, and Shirish Dinakaran

Abstract Lack of resources and proper infrastructure coupled with high population density has led to a sharp rise in the number of persons suffering from COVID-19 in certain regions. The situation continues to decline as the lack of proper enforcement of safety measures and precautions contributes even further to the spread. The system implemented by the team enables remote monitoring of a patient's condition over time while effectively keeping them isolated and also helping identify as whether they will need intense care in the foreseeable future. The set-up makes use of multiple sensors to measure the subject's heart rate, blood oxygen levels and temperature. This is accompanied by a trigger button that can send a text message to the desired recipient in case of mishappenings for immediate assistance. This system has been designed to be wearable as well. It can help save lives while limiting the effects of the disease on infected persons, while also helping improve national response to the situation by helping with efficient resource allocation.

Keywords COVID-19 · Temperature · IoT · Wi-Fi (ESP8266)

1 Introduction

Since the first case of COVID-19 in December 2019, the disease has continued to spread rapidly all over the world, with the World Health Organization (WHO) terming it a 'pandemic' in March 2020 [1]. COVID-19 has infected over 36 million around the globe, killing at least 1 million. Noticeable symptoms include fever, shortness of breath, coughing, abnormal heart rates and lower blood oxygen levels [2, 3]. Presently, a prominent concern is the effective containment of the disease and proper resource allocation to improve national response, especially in regions which lack the proper infrastructure and have a dense population because these circumstances serve as a fertile ground for community spread and worsen the situation at not just the regional level but at the international level, putting the general population at risk.

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In such circumstances, it is important to not just maintain a database that keeps track of COVID-19 case occurrences which has been carried out by several undertakings so far [4, 5] but also implement a means to track a patient's health condition over time while also being cost-effective. The system is designed for real-time on-site parameter reporting of the various health parameters which can be viewed by an official through the internet on common devices such as computers or smartphones. The system implemented by the team employs multiple sensors to measure the health parameters in real time, periodically recording all measurements for effective action through a cost-effective method which also requires less power, is accurate and also requires less manpower. In this paper, Sect. 2 discusses the literature survey on other undertakings that are similar to ours. Section 3 discusses implementation of the COVID-19 patient monitoring system, and the results obtained through the system are discussed in Sect. 4. Section 5 concludes the paper.

2 Literature Survey

COVID-19 has several effects on the respiratory system. In short, the breakdown of respiratory tissue leads to inefficient function of the lungs, which leads to lower blood oxygen levels, leading to shortness of breath. Fever and sometimes an irregular heart rate are also noticed. Below are some relevant examples of work previously carried out.

'Design of Iot based smart health monitoring and alert system' by Sivakanth and Sathish [6]. This paper describes a system that uses near field communication technology to receive information specific to the patient automatically as and when the designated medical professional approaches the subject. Bio-sensors which have been interfaced to the microcontroller will effectively help monitor the subject's health. If any of the sensors' pre-set threshold value is exceeded in any reading, a text message will be sent to the medical professional and the subject's caregiver. The monitor set-up consists of a web server part as well: the sensor network where sensor nodes are equipped with different biometric sensors. Data obtained from the sensors will be periodically transmitted to the database of the medical facility from where it is uploaded to the facility's web server. The subject's condition may be monitored remotely.

'An IoT Based Patient Health Monitoring System' by Krishnan et al. [7]. This paper describes a system that measures the subject's temperature and the heart rate and transmits them online onto a web server with their timestamps; these observations are also plotted graphically for easier observation of the data. The recorded data is also displayed on an LCD display to enable the patient and those around them to view the measurements of temperature and heart rate.

'Health Monitoring using Internet of Things (IoT)' by Saha and Auddy [8]. This paper describes a project that monitors multiple health parameters that are critical to the subject's well-being. Using the Internet of Things, the set-up is used to monitor the subject's temperature, heart pulse rate, eco level and also the pressure level. In the case of an abrupt change in the observations, the user is alerted mechanically of this change or occurrence in the subject's health condition so as to effectively attend to the patient. All of the observations are displayed over the internet.

3 Implementation

The set-up makes use of two sensors—a temperature sensor and a pulse oximeter sensor. The NodeMCU developer board in the system reads data from the sensor and transmits it to the IoT platform for real-time reception by the user. The NodeMCU is an open-source firmware that runs on the ESP8266 Wi-Fi module [9]. The data obtained can be monitored anywhere in the world by connecting to ThingSpeak or other similar platforms—for the system implemented by the team, ThingSpeak is used. The system also consists of an emergency button, which when triggered sends a text message to the selected recipient through If This Then That (IFTTT). The NodeMCU processes the data received from the sensor, and the processed data is then sent to the ThingSpeak webpage. The source code for NodeMCU is written using the Embedded C language. The set-up is represented by the block diagram as in Fig. 1.

Block Diagram
The system shown above in Fig. 1 shows the data input into the NodeMCU by the sensors mentioned earlier. The data here is processed and then sent to the ThingSpeak server through the ESP8266 Wi-Fi module embedded within the NodeMCU. The collected data is then analysed and processed in real time. The data can then be accessed by the authorized users on ThingSpeak by inserting the corresponding API

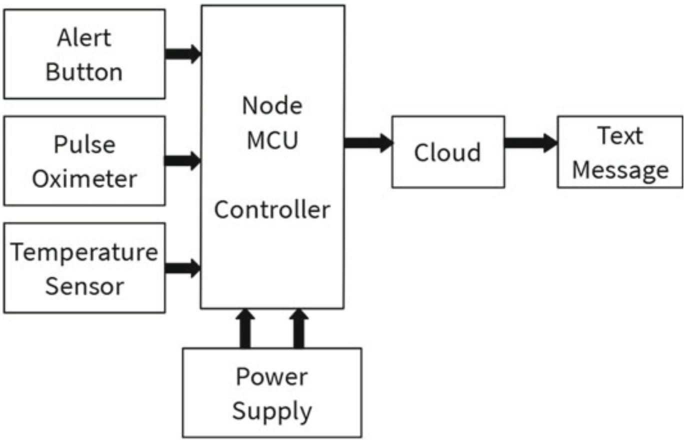
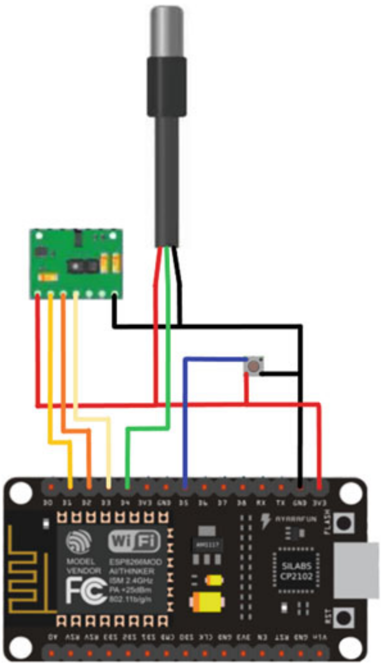


Fig. 1 Block diagram depicting workflow of the system

Fig. 2 COVID-19 patient monitor system



key. If the alert button is triggered, a text message is sent to the user using the IFTTT application, upon processing the received data in the NodeMCU.

The NodeMCU supports high-speed flash memory. It consumes low power, has a low form factor and a small size. It is suitable for portable applications, where small size is a key factor. The NodeMCU, represented in Fig. 2, is run by the ESP8266 module, which is a low cost, TCP/IP application, manufactured by the Espressif systems. The ESP8266 module uses a transreceiver to exchange data between the sensors and the server [10]. It uses the transmitter/receiver for transmission and reception of data between the sensors and the NodeMCU.

3.1 Working with ThingSpeak

The ThingSpeak platform is an open-source IoT tool for data visualization and analysis of the data which is collected by the system through said sensors [11]. The data can be visualized in the form of charts, gauges, plots and other means of visualization. ThingSpeak also enables users to send the data to the cloud, where the data can be stored and processed. The ThingSpeak tool provides a comprehensive platform to monitor and control data on the internet, using the channel and web pages provided by ThingSpeak.

The user is first required to sign up and create a channel on the ThingSpeak website. Then, the user is to create a new channel on their registered account and create an API key for setting up and visualization of real-time data obtained in the system. The user may then input the required fields (in this case, temperature, heart rate and blood oxygen levels) to the axes and select ‘Public’ for other users to be able to access the obtained data in real time. The API code received above in the ThingSpeak portal is then initialized in the source code for effectively linking the real-time data obtained to the cloud server and subsequent visualization of the data.

By clicking on ‘channels’ next, one can visualize the real-time data obtained through the sensors and view it online, after choosing the ‘View Charts’ option. The serial monitor on the ThingSpeak website automatically displays the values obtained and produced on the website.

3.2 Sensors

A sensor is a transducer that detects and responds to relevant changes in the environment. A sensor has different parameters for detection and measurement of stimulus that includes precision, resolution and speed. Calibrating a sensor would help reduce the percentage error (difference between the actual value and obtained value). Real-time observation of data using ThingSpeak enhances the system, by compensating for the errors caused by individual measurements of the stimulus. In the implementation of this system, the following sensors were used:

3.2.1 DS18B20 Temperature Sensor

The DS18B20 temperature sensor is a low-cost sensor that consumes low power and owing to the integrated digital to analogue converter, directly produces a digital output based on the temperature sensed at the input [12]. The output signal received from this sensor ranges from 9 to 12 bits, depending on the temperature value read by the sensor, which can range from −55 to 125 °C, it is observed to have an error range of ±0.5 °C. The set-up makes use of a waterproofed implementation of the sensor where the cable is actually covered by a layer of poly vinyl chloride (PVC).

The sensor consists of three pins—supply voltage (Vcc), ground (GND) and a digital output pin. Interfaced with the NodeMCU, it transmits the resulting output signals of a reading to the NodeMCU. Its small size and cheap cost facilitate its use for remote IoT applications.

3.2.2 Pulse Oximeter Sensor

The pulse oximeter sensor uses a non-invasive method, a light detector, to measure the changes in blood volume under the human tissue [13]. The source of light is placed on one side of the tissue which is typically the finger, and the light detector is placed on the other side of the tissue. The variation in the light received and transmitted through the blood tissue is then measured using the detector. Haemoglobin that is oxygenated well causes the absorption of more red light and allows the passing through of infrared light, which results in higher oxygen levels being reported. Blood that is not oxygenated will absorb less red light, leading to a lower level of blood oxygen level being reported.

By measuring how much light reaches the detector, it is possible for one to determine the amount of haemoglobin in the blood. The amount of light absorbed linearly varies according to the length of the light path through the finger and the concentration of the light-absorbing substance. The light absorbed is linearly proportional to the amount of haemoglobin in the blood.

3.3 Alert Button and Text Message Using the If This Then That (IFTTT) Applet

The IFTTT is a web application that enables clients to create user-defined conditional statements that can be triggered by third-party resources [14]. It provides a seamless experience by connecting devices over the internet. The triggers stand for the 'this', and the action stands for the 'that' part. Applets are predicates formed from the triggers and actions that are defined by the user. One can add text message functionality to their work as shown below:

1. Sign up and login to the IFTTT application through an account on other selected platforms,
2. Create a webhooks applet from the Applet window,
3. Give an input option,
4. Select the webhooks services to get the http request,
5. Select 'To send notification',
6. Select 'Action'.

An alert button is integrated within the system in case of emergency. When triggered, it sends data to the IFTTT application, which further sends a text message to the user's selected contact alerting them about the emergency.

3.4 Self-charging Mechanism

A self-charging mechanism has also been implemented by the team to help sustain the effective use of this set-up even in the absence of a continued supply of electricity [15]. Three Li-Po cells, where each cell has the capacity—3.7 V and 200 mAH, can be connected to the set-up in the absence of a proper supply of electricity, or they may also be used as the primary source of electricity as well. This battery is charged by the self-charging mechanism described as follows. The self-charging circuit employs piezoelectricity which can effectively convert mechanical stress into electrical energy which charges the battery and is usable by the set-up to sustain itself. The self-charging circuit is placed in close proximity to the set-up to keep it portable.

The schematic for the self-charging circuit in Fig. 3 constitutes a series and parallel combinations of a total of nine piezoelectric discs to supply and maintain the adequate voltage to charge the battery. The equivalent final voltage of the combination has been shown below:

$$1/C_{eq} = 1/C1 + 1/C2 + 1/C3 \text{ [for a combination in series]},$$

where

C_{eq}	is the equivalent capacitance of the orientation in series.
$C1$, $C2$ and $C3$	are capacitance values of the discs when considered individually.

$$\text{Also: } Q = CV,$$
$$\text{Thus: } C = Q/V$$

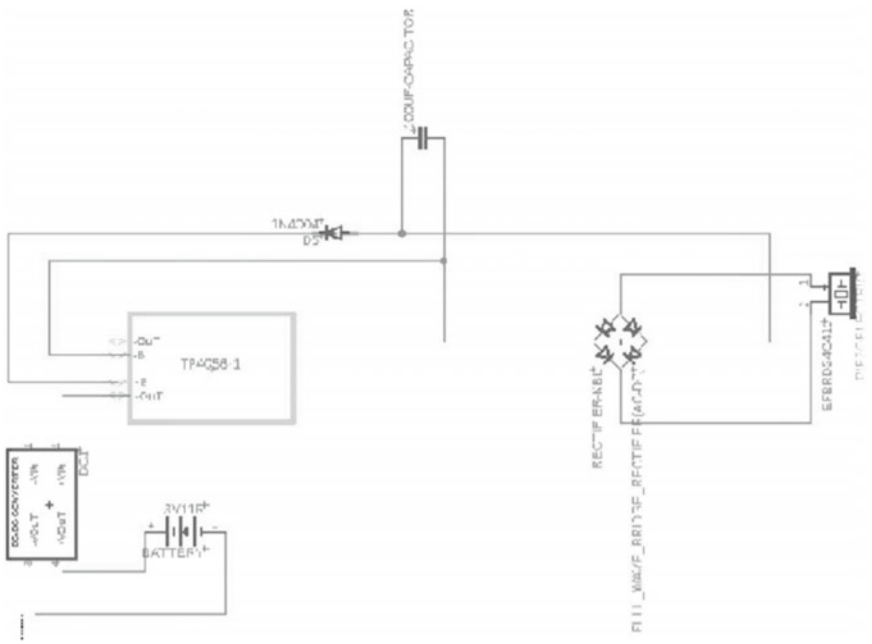


Fig. 3 Schematic of the self-charging mechanism for the set-up

where

Q charge on the capacitor.
V voltage across the capacitor.

$$V_{eq} = V1/Q + V2/Q + V3/Q$$
$$\therefore V_{eq} = V1 + V2 + V3,$$

$V1$, $V2$ and $V3$ are voltage values that were measured across each disc.

The output voltage across each piezoelectric disc is 3 V

$$\therefore V_{eq} = 9\,\text{V}$$

4 Results

After completing the set-up, the person(s) authorized to view the health status of the patient may do so by authentication on ThingSpeak. The measurements of heart rate, blood oxygen levels and temperature will be displayed in real time, on three different fields, to graphically display the measurements over time. These measurements may be inspected by a medical professional to observe the patient's condition over time and also make relevant recommendations remotely, thus also reducing the movement of person(s) and in one way, helping contain the spread of the virus.

5 Conclusion

Internet of Things and the products and services that arise from this concept are now an integral part of life in the twenty-first century. So much so that there is extensive research being performed towards accommodating the optimum functionality of connected 'things' in the upcoming generations of internet services.

A life-function monitor specifically designed for patients suffering from COVID-19 has been implemented to effectively monitor patients remotely. The system developed by the team is cost-effective and is also observed to be less power consuming. This set-up, if implemented on a larger scale, can enable remote monitoring of multiple patients by a single professional which allows medical professionals to assist the patients at the medical facility in a more efficient manner. The set-up will also facilitate a more efficient approach towards the utilization of resources including financial resources, medication and accommodation. With the medical condition parameters such as temperature, heart rate and the blood oxygen level being monitored over short periods of time, it becomes very simple to identify the possibility of an uneventful circumstance; in such cases, the alert button may be triggered to alert authorities.

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