IoT based Resuscitation and Hypoxemia Diagnosis System using Embedded Microcontroller Architecture and IFTTT Implementation

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Abstract. In recent times, the World has taken a critical blow from the novel Coronavirus. Moreover, with its research ongoing and multiple variants emerging, uncertainty is on the rise. Lung damage and cardiac issues occur during and post recovery which is why there is a requirement to constantly monitor the patient’s vitals. This also applies to patients suffering from other lung diseases and heart conditions. They need immediate attention to avoid complications and further deterioration in their health. The proposed system aims to do so by observing the health parameters such as oxygen saturation in blood and heartbeat constantly and making the data available for the user by displaying it. In case of abnormality, it alerts the person related to the patient about the developments and relays the required information to help like symptom details and the patient’s location, this ensures that actions are taken quickly. Simultaneously, it provides assistance in breathing during the interlude till professional help arrives and the patient receives the necessary treatment. This is achieved with a combination of sensors, modules and other components integrated with a microcontroller as well as the implementation of Internet of Things (IoT) using a web service.

Keywords. Internet of Things (IoT), Remote Patient Monitoring (RPM), Pulse Oximeter, Resuscitators, Global Positioning System (GPS).

1. Introduction

For the normal functioning of a human being, it is suggested that the oxygen saturation in blood, otherwise commonly called the SpO2 levels lie in the 92-96% range [1]. This is often compromised in patients suffering from lung diseases, conditions like sleep apnoea and underlying heart illnesses. Reduced SpO2 levels is medically termed as hypoxemia. Although respiratory disorders have always been a cause of concern, lung damage in patients has increased owing to the virus during and post recovery also known as the long covid effect [2]. The World is facing a huge scramble in the oxygen supply due to the exponential increase in cases. With such load on the hospital infrastructures, many patients are being left unattended and don’t receive the prescribed treatment, which is why the usage of pulse oximeters, that recognize the measure of oxyhaemoglobin immersion (SpO2) which is a roundabout assessment of blood vessel oxygen immersion (SaO2), is advised to detect symptoms earlier and avoid mishap [3].
The demand for a patient-centric and commercially accessible health care setup has increased as technology advances and industries intertwine with each other. It is also partially due to the independent lifestyle approach in the unprecedented times of Covid-19 [4,5]. In the health industry, the development of IoT combined systems allow professionals to identify the best treatment processes for patients and has significantly led to reduction in cost, easier access, and effective long-term monitoring [6]. Remote Patient Monitoring (RPM) also enhances health services and makes it affordable which in turn makes it widely available [7]. Such systems are recommended for those who do not need heavy medical care until unavoidable hospitalization because there is a risk of misdiagnosis which may be fatal [8].

In this work, a resuscitation and hypoxemia diagnosis system is proposed. It is integrated with other facilities such as a text and email alerts, as well as location tracking using IoT and various modules. It centers around a manual resuscitator that operates on the application of pressure. This is automated to simulate a replica of inhaling and exhaling actions to assist a patient. Various existing literature and works related to the concept were studied to have a better understanding in section 2. Section 3 elaborates on the proposed system with subsections 3.1, 3.2 and 3.3 dealing with the hardware explanation, the system architecture and working of the model, respectively. The results obtained are discussed in section 4 while section 5 includes the conclusion and future aspects of the system.

2. Related Works

An IoT based health monitoring system is implemented in [9] where data is collected by the sensors attached to an Arduino and Raspberry Pi. The vital parameters are constantly monitored as well as stored in real time using an application on a smartphone or any device that can connect to the internet. This is attained using Bluetooth technology, Message Queue Telemetry Transport (MQTT) protocol and cloud computing for client-based approach.

In [10], the proposed system works heavily around monitoring health parameters of patients suffering and isolating due to the Coronavirus. It keeps track of the patient’s location to ensure that they are following the norms while visualizing their temperature, SpO2 levels and pulse in real time with the help of an IoT gateway to index and store the data of multiple such patients to be surveilled by the medical facility.

The system in [11] uses various body sensors to collect data. The data is correlated with various activities to calculate mean values that are unique to the user and Exploratory Data Analysis (EDA) approach helps identify the activity being performed by the user. It also makes it possible for real time monitoring of the parameters such as temperature and pulse, collected and recorded on a cloud for further analysis.

The work mentioned in [12] aims at reducing hospitalization of a patient by early detection of conditions by embedding a toilet seat with various modules like electrocardiogram, ballistocardiogram, and photoplethysmogram. This model is capable of clinical grade measurement and estimates blood pressure, stroke volume and peripheral blood oxygenation for analysis. The values collected were compared with those collected in a hospital centric system to validate the results.

Commercial off the Shelf (COS) sensors are used to obtain figures and evaluate one’s sleep cycle using random forest model in [13]. It is competent to analyze sleep and snoring patterns through the user’s bio status that includes physical movement, pulse, and oxygen saturation. The system accounts for the analysis in a statistical method and provides 95% accuracy when tested and compared thus making it an effective system for monitoring disturbed sleep at minimum expenses.

In [14], the system proposed is an automated ventilator that is implemented using a programmable logic controller that runs the mechanical ventilation process of a bag-valve-mask-based emergency
ventilator. It uses a human-machine interface to check on the vital parameters, keep a record of the values and identify when the patient needs oxygen supply and carries out the process accordingly.

The system in [15] is an automated bag valve mask (BVM) compression system that is based on the Arduino Controller and 3-D printable parametric component-based structure. It provides flexible adjustments in breathing modes by possessing the ability to alter breathing rates, tidal volumes and inspiratory to expiratory ratio thus making it an efficacious system.

Various testcases in [16] helped infer that Personal Emergency Response System (PERS) spread a sense of security within the users and make them feel independent. However, the systems need to be compact to have a greater impact in the market which was backed by [17] in which a study was conducted in order to compare the thoughts of PERS users and non-users. Likewise, [18] suggests that research and approaches must be expanded in the field of wireless technology to be incorporated in the health industry as technology continues to strive.

These works provided the inspiration to work and extend on the existing literature thus making a system that can monitor the health of a patient, alert a health personnel or a relative in case of an emergency to avoid negligence, contribute by providing the patient’s location and keep their condition stable till they receive proper care. This system is extremely helpful since it helps cope with the shortage of ventilators and supply chain disruptions as well as heavy load on the hospitals in general.

3. Proposed System

In this work, a resuscitation system is combined with IoT technology and implemented to monitor a patient’s health condition with reference to their SPO2 levels and pulse while simultaneously cautioning the concerned person about the situation in case of an emergency since low SPO2 levels imply that the patient needs to be hospitalized. As mentioned, the system can be segregated into its offline working and online working where the hardware model observes vitals and contributes in keeping the patient stable until they have access to better medical equipment in case of deteriorating health. It also establishes a connection with the internet in order to alarm the person related, about the crisis and providing them with essential details such as the patient’s location and health, so that they can take necessary actions to help the patient.

3.1. Experimental Setup

Shown in figure 1 is the implementation of the model. With an uncomplicated configuration, the system is user friendly and easy to work with. The Arduino Uno which is a microcontroller-based development board, is the heart of the model with all the processing done within it. MAX30102 is a pulse oximetry and heart rate sensor which is connected to sense the pulse and SPO2 levels. The Direct Current (DC) motor and BTS7690 43A motor driver combination is employed to enable the resuscitator with the help of Infra-Red (IR) sensors. The ESP8266 Wireless-Fidelity (Wi-Fi) module is attached to establish a connection with the internet while the GPS module is used to retrieve location coordinates. The Liquid Crystal Display (LCD) helps visualise the values and situation.
3.2. System Architecture
The ATmega328P within the Arduino processes the code for the entire model by being interfaced with the components to receive input and provide output while the board also acts as a power supplier to most of the components attached to it.

The pulse oximeter reads the patient’s vitals by using the method ‘photoplethysmography’. The patient places their finger on the sensor where a Light Emitting Diode (LED) along with a photodiode measures the perfusion of blood that helps deduce comprehensible data as required.

The resuscitation system is built using a Bag Valve Mask (BVM) that works on the application of pressure. This is achieved with the help of a DC motor and IR sensors. A rod is linked to the motor by the means of a nylon thread to govern the inflation and deflation of the bag. This is made possible by altering the motor’s rotation between clockwise and anticlockwise directions to push and pull the rod thus exerting force on the resuscitator. The motion is switched according to the readings collected by the IR sensor that are placed in appropriate positions to detect the state of the BVM. It is administered if the SPO2 and heart rate don’t lie in the normal range thus causing hypoxemia, to assist the patient with breathing. Since this is effective for a short time, the system essentially works on forcing air supply to the patient, but an oxygen reservoir can be fixed for high-risk patients.

It also connects to the internet so as to trigger a predefined Short Message System (SMS) and an email to alert about the patient’s condition using web services. At the same time, the GPS module acquires the patient’s location in terms of latitude, longitude and altitude in real time using satellites to help navigate to them. Figure 2 showcases the design of the model proposed.

![Diagram](image_url)

**Figure 1.** Hardware setup of the proposed model.
3.3. Workflow

Patients often lose their ability to comprehend the state that they are in, which makes it difficult for them to take control of the situation. They become incapable of helping themselves and need support immediately. Hence, the main goal of the model is to avoid the requirement of applying pressure manually on the bag valve mask in order to operate it as a resuscitator till the patient receives proper medical attention which is made possible by automatically letting people related to the patient know about the situation through messages to ensure prompt response. Figure 3 elaborates on the working of the proposed model.

Figure 2. Block diagram of the proposed model.
The ATmega328P is fed with the values collected by the sensor and displays the same on the LCD while comparing the values obtained with a set condition to check if the patient’s health is stable. If it is not, then the dc motor runs to create pressure on the bag valve mask to assist the patient in breathing. The bag is inflated and deflated at regular intervals to mimic respiration using IR sensors to control the rotor of the DC motor.

On the other hand, the Wi-Fi module attains the IP address of the patient by connecting to the internet. This helps in implementing the IF This Then That (IFTTT) web service where the ‘this’ condition is to connect and trigger an event through a Unique Resource Locator (URL) using a unique Application Programming Interface (API) key and the ‘that’ condition is to send a text to inform about the patient’s condition and an email that expatiates on the same respectively as two different events. The GPS also gains and sends the live coordinates of the patient to ensure that they receive proper medical attention within crucial time.

4. Results and Discussions

The working and results of the system can be measured at the patient’s end where the resuscitation as well as hypoxemia detection system is implemented and at the receiver’s end where the alert system is accomplished. The working of the system at the patient’s end mainly involves data retrieval and hardware functionality while most of the work on the receiver’s side is processing of the data and implementing online features.
4.1. Patient’s end

Figure 4 displays the values recorded by the MAX30102 pulse sensor. It senses the amount of light reflected back and calculates the SPO2 and heart rate level accordingly. The validity of the acquired values are also taken into consideration while observing them by returning Boolean values to indicate the same. It is displayed on the serial monitor which is set at a fixed baud rate.

![Serial monitor display when Arduino runs the program.](image)

The system primarily concentrates on the monitoring hypoxemia and maintaining the dropping values of oxygen saturation in blood. If the values are valid, only then are the figures compared with the conditions set and while being shown on the LCD persistently. Figure 5 exhibits that the system constantly monitors the SPO2 levels and displays the same thus making it available at the user end.

![SPO2 levels being monitored using the LCD.](image)

Figure 6 provides insights on how the resuscitation system operates in the unfortunate event of alarmingly low levels of SPO2 detected to assist the patient until emergency service arrives. It indicates that air is forcefully being supplied to the patient but with enough gaps to exhale. This is done in order to restore SPO2 levels. As a test case, the value conditioned to be compared with the fed values of SPO2 was set high enough just to operate the system when assessing it with people whose SPO2 levels were normal.
Figure 6. Deflation and inflation of the BVM.

4.2. Receiver’s end

Figure 7 exhibits the coordinates received from the GPS module that is then displayed in real time on a developed webpage that refreshes the coordinates continuously. It also links google maps in order to map the position hence helping in comprehending the exact location of the patient to commute to them as soon as possible and treat them as required.

![PATIENT TRACKING](image)

|          | 90.4125 |
|----------|---------|
| Latitude |         |
| Longitude| 28.8103 |
| Date     | 25/06/2021 |
| Time     | 07:01:28 PM |

Click here To check the location in google Maps

Figure 7. Coordinates and mapping of location received.

Figure 8 describes the working of the IFTTT web service where an event in defined and so are the ‘this’ and ‘that’ conditions. For this system, two such events are established. One to send an SMS to notify about the sudden drop in SPO2 values and another to email a detailed description of the situation and possible deductions of the same. On establishing a connection with the web, the webhooks condition is satisfied which triggers the latter part of the service - text and email. Both of them have a predefined format along with values picked up from the program such as the time the event got triggered and the location obtained by the GPS.
Figure 8. IFTTT implementation of an event.

Figure 9 presents the outcome of the text event once triggered. An SMS is sent from the registered mobile number to the provided mobile number. SMS is the most effective way to relay a message since it is the most accessed form of communication in present day. Although, it only mentions the occurrence of the worrisome event with values, the time of the event and the measures to be taken since there is a limit on character count.

Figure 9. Resultant SMS sent to provided mobile number.

An email, however, allows us to pass on more information thus making it a better carrier. Similar to the text event, the email is sent from the registered email address to the email address opted for. It provides all the details to be sent for reference including the location of the patient as well as an inference of the circumstances such as other symptoms that the patient might experience and the likely conditions that could have caused it. Figure 10 presents the email sent once the event is set off.
5. Conclusion and Future Aspects

With heavy load on hospitals due to the increasing cases of Coronavirus, it is important to adapt to Remote Patient Monitoring (RPM) in the long run. Contributing to RPM, a resuscitation, hypoxemia detection and alert system is implemented and analysed. The main aim of the proposed system is to keep a check on a patient’s levels of oxygen saturation and heart rate since hypoxemia makes a patient highly vulnerable. Conceding that the SPO2 levels drop more than the level that is considered safe, the system activates the automated BVM that functions to provide assistance in respiring thus avoiding further collapse of health till they receive professional medical support. It also alerts health workers or people associated with the patient about their condition and plausible reasonings of the same so that timely measures are taken effectively. This is achieved using a microcontroller-based development board along with few models and components attached. The location identified by the GPS ensures that the patient receives timely attention. To implement IoT, services from IFTTT were utilised since the application is easy to grasp and available to all as it is an open platform. Overall, the system is reliable, user friendly and economical. Both, the software, and hardware components were tested and debugged to achieve the results.

The current system focuses on oxygen saturation whose readings fluctuate due to multiple reasons, it is difficult to narrow down the cause of concern and provide targeted treatment without investigation. To overcome this, other biomedical sensors can be integrated within the system to detect other symptoms that can be coupled to identify probable conditions. To provide better user experience, an application can be developed to monitor the vitals of the patient which also implies that the data is stored and can be revisited for analysis.

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