IoT based Wearable Health Monitoring System for COVID-19 Patients

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Abstract

Whenever the patient is admitted to a hospital, the doctors and nurses have to keep a regular check on each of them and also maintain a record of all the vital health parameters of patient. In a situation of pandemic like the one due to COVID-19 a huge number of patients are admitted at once which becomes very difficult for hospital staff to monitor each of them continuously. So, the model proposed here is a IoT based wearable system which is an assistive device for patient monitoring which will help the doctors, nurses and patient's relatives to keep a track of some vital health parameters like heartbeat, temperature and blood oxygen levels. All of these sensor data will be stored into the cloud platform "Thingspeak" and also to the mobile app "Blynk". And this system is made automatic so it will keep on monitoring and storing the sensor data at regular intervals which can be accessed from anywhere via the internet and even the alert system will notify about the emergency. Another part of the model which is separate from the wearable system is to monitor and store volume of drip or IV fluids is given to the patient.

Keywords 1

COVID-19, Wearable, Internet of Things, NodeMCU, Pulse oximeter sensor, Temperature sensor, Thingspeak cloud, Blynk App.

1. Introduction

Due to COVID-19 pandemic situation the number of patients admitted in the hospitals are increasing day by day and hospital staff which includes the doctors as well as nurses seems to be very less in front of such a huge population of COVID-19 positive patients. According to a survey considering the current population of India, the doctor to patient ratio is 1:1493 & nurse to patient ratio is 3:1777 (WHO recommends doctor to population ratio to be 1:1000 whereas nurses to population ratio to be 3:1000). With such a huge requirement for healthcare workers it has become a strenuous job to control the disease across countrywide. The system proposed here can help reduce the burden of monitoring patients regularly. This model uses sensors for taking different data from the patient which has to be accurate, and easy to integrate on a wearable device.

S. Joseph et al in [1] proposed a system for heartbeat monitoring. Stethoscope and Electrocardiogram are two major instruments to monitor heartbeat, but the former one requires expertise to use while the latter has high cost. So as an alternate solution, photo plethysmography (PPG) sensor is used instead. This sensor is low cost, easy to use and non-invasive. This sensor basically consists of a LED which emits light and a photo diode to absorb the reflected light. The sensor is usually kept in contact to the fingertip and whenever the blood volume changes, the light intensity absorbed by the photo diode also varies. O. Y. Tham et al [2] in the research used the

WAC-2022: Workshop on Applied Computing, January 27 – 28, 2022, Chennai, India.
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MAX30102 sensor which goes under the process of filtering and validation. This sensor also works on the same principle as PPG to measure heart rate but apart from that as a special feature of this sensor it also measures SPO2 in a similar way which is by using LEDs. IR/RED will help to get ratio of derived calibration curve empirically. In view of the approval results, the checking arrangement of SpO2 and pulse is fit to be utilized. The review done by Malasinghe et al [3] insights about the recent development in healthcare technology especially in remote patient monitoring. There are several sensors available in the market which can measure vital physiological data from the patients but the traditional systems were invasive and hence caused difficulty in terms of mobility for the patient and a patient's activities in daily living. Hence the recent development allows the sensors to be placed outside of the patient body to measure some vital sign such as body temperature, pulse rate, oxygen level etc. which implies that non-invasive sensors can also be accurate and provide reliable results. Sensor like MAX30102 works in a same non-invasive manner to measure the heart rate and the oxygen level in blood.

For the measurement of patients many sensors are available such as thermocouples, thermistors, resistance temperature detectors (RTD), and integrated circuit (IC) sensors, Alam et al [4] in the proposed model uses a LM 35 for temperature measurement as they are precision IC temperature sensor. The output voltage which is analog signal is linearly proportional to the temperature in Celsius or Centigrade. The reasons for using LM35 over other sensors is that it provides better accuracy of around ±¼°C at room temperature than others, also does not need any external calibration and has vey less self-heating of less than 0.1ºC.

Sheng-Wei Wang et al in [5] developed a model which can continuously measure the water levels by using a load cell and a floating pipe. In the model the floating pipe is suspended in the water with other end attached to load cell connect to a support system above water and the buoyancy force starts working on pipe therefore pushes the load cell vertically. Hence stating that the force acting on load cell is proportional to the water level. Rasheedha et al discussed about ADC HX711 which connects between microcontroller and load cell. HX711 converts analog signal from the load cell to digital signal for being picked up by microcontroller. It consists of two wires (clock and data) for communication between microcontroller. Any GPIO pins of NodeMCU will communicate easy to pass or read data from HX711 [6].

N. Deepak et al in [7] proposed a system which takes the input from the three sensors (temperature, pulse and MEMS tilt sensor) attached to the patient body and sends the data to the ARM7 controller. The MEMS tilt sensor basically is a tilt or inclination detection sensor which is for fall detection. The controller then collects and processes the data and transmits the output to the Bluetooth module which further sends it to the mobile application then ultimately to the cloud with the help of GPRS module. Also, the data can be seen on LCD screen attached to the ARM7 controller. Kumar et al [8] model consists of temperature sensor, respiration sensor, heartbeat sensor and accelerometer all integrated to a Raspberry Pi. Then the Raspberry Pi is setup in such a way that it can act as server for the website which will contain all the patient data and hence can be accessed from anywhere around the world.

N. P. Jain et al also proposed a model in [9] where a system is implemented consisting of temperature, blood pressure and heart rate sensor integrated using AT mega 32 microcontroller and the output is displayed on the LCD connected with the system allowing real time monitoring. In case of emergency situation, it can send alert SMS to the concerned doctor via the GSM module and will also allow them to control the flow of medicine remotely with GSM network and feedback motor attached to the saline.

Y. Xu et al [10] proposed a system uses temperature and heartbeat sensor connected to Arduino UNO for tracking patient's health. The micro controller is interfaced with LCD display and a Wi-Fi connection to send the data to the web server wirelessly. In case any abrupt change is recorded by the sensor an alert will be generated using IoT based notifications. This system also shows patients temperature and heartbeat tracked live data with timestamps over the Internetwork. Similar approach is done by Krishnan et al [11] wherein the proposed model uses LM35 and PPG sensor for temperature and heart beat detection. The sensors are connected to Arduino UNO which display the output on 16x2 LCD display and then to provide Wi-Fi connectivity to the circuit additional ESP8267 Wi-Fi module is used to help send the data to cloud.

Sohail Shaikh et al. [12] proposes an efficient way for transmitting the sensor data from the patients to the doctors reducing the usage of energy and transmission delay. The research is a comparative analysis between TDMA (Time division multiple access), CSMA (carrier sense multiple access), SMAC (sensor MAC) and 802.15.4 (ZigBee) MAC protocols. The analysis resulted in CSMA being much better than the other protocols.

S. Hossain et al [13] in this work discussed an inventive well-being observing frameworks are needed with a less human mediation which will be accessible for minimal price in the country just as in metropolitan regions. This work portrays a plan to give a savvy, solid and programmed saline stream observing framework that can be handily executed in an emergency clinic. The proposed framework gadget comprises of NodeMCU, IR sensor, ESP8266, keypad and LCD. By utilizing this gadget, the specialist or medical attendant can easily monitor saline level, drop rate.

The model proposed in this paper is focused on monitoring critical health parameters of a patient admitted to a hospital and is suffering from the Coronavirus. All the parameters are displayed on a small screen as well as uploaded on the cloud so as to keep a record and alert the concerned personnel immediately. The novelty of this model is that it is made to be a wearable system. Along with this, the model keeps record of how much drip bottle has been given to the patient and also alerts if the current drip bottle is about to end.

2. Proposed Methodology

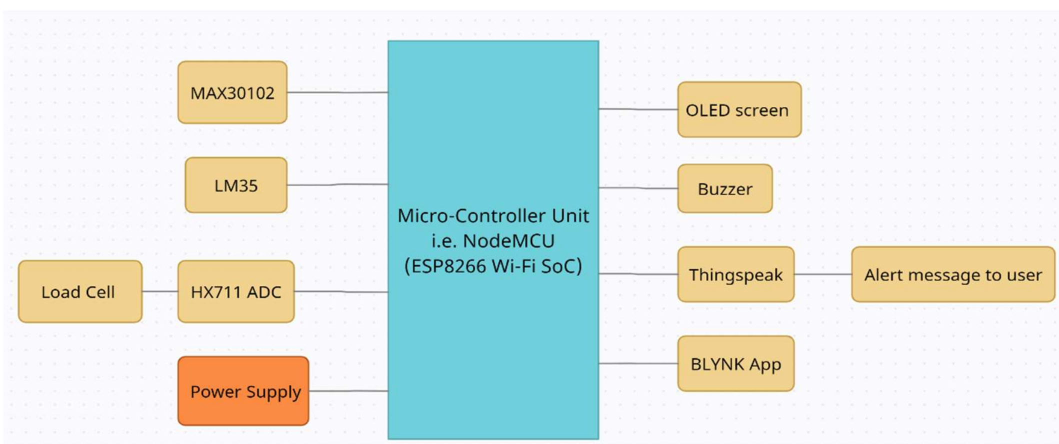


Figure 1: Block diagram of the proposed system

The figure-1 depicts the proposed system model discussed in the proposed work. As seen from the figure-1 that the input side of the model consists of sensors to measure some of the vital health related parameters like temperature, pulse rate and blood oxygen levels. The sensors include LM35 for temperature detection, MAX30102 for heart rate and SPO2, MLX90614 for non-contact temperature detection and load cell transducer to monitor the quantity of IV (Intravenous fluids) given to the patient.

The output side of the above fig-1 consists of an OLED screen SSD1306 (128x32), buzzer, Cloud Platform – Thingspeak and Blynk (Mobile application). The OLED screen is used to continuously display all the output achieved from the sensors i.e., temperature, heart rate, SPO2 of the patient. The buzzer is connected so that whenever any sensor data crosses the threshold value then in that case buzzer or alarm will go off indicating the emergency to the hospital staff. Unless the data fall under the below given range alarm will not be triggered.

- Heart beat measured by MAX30102 is less than 100 BPM greater than 60 BPM,
- SPO2 measured by MAX30102 is greater than or equal 95%
- Temperature measured by LM35 is less than 101ºF

The above data range is defined considering the patient is at rest. The Thingspeak cloud platform then takes the real-time data from the NodeMCU via the internet and keeps updating the values of temperature, SPO2 and heart beats in separate fields. At last, the BLYNK app will allow user to view the real-time sensor data in mobile phone.

The major advantage of this model is that the whole system shown in fig-1 is integrated on a shirt or more specifically on the costume which is given by hospital staff to a patient when they are admitted, hence making it a wearable and convenient to use. As once initialized the system will automatically take the data, upload it on the cloud and display on the OLED screen as well. The doctors and nurses can benefit from this system as they have to take care of a lot of patients in a given time so this system can help in keeping a record of the data and also will alert them before patient's health becomes worse. Especially during the current COVID-19 pandemic many of the families of the patients are worried as they do not get updated about their health conditions where this system can help as their family can themselves observe the health conditions from anywhere through internet.

3. Hardware Specification

As it can be seen from fig-1 that the core of the proposed system is **NodeMCU**. It is a development board which includes firmware that runs on the **ESP8266** Wi-Fi SoC.

The **MAX30102** is High-Sensitivity Pulse Oximeter and Heart-Rate Sensor. This sensor module has internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection.

The **MLX90614** is an Infra-Red thermometer for non-contact temperature measurements. It can measure the temperature in range of -20 to 120 ˚C, with an output resolution of 0.14 ˚C.

The OLED screen in the discussed model uses **SSD1306** which is a single-chip CMOS OLED driver. Consisting of 128 segments and 32 commons.

The above-mentioned sensors and OLED screen use I2C protocol so they have their own 7-bit address which by default is set as:

- MLX9061x IR temperature sensor - (0x5A)
- MAX3010x Pulse & Oximetry sensor - (0x57)
- SSD1306 monochrome OLED - (0x3C)

The **Load cell (TAL220B)** is a straight bar transducer that can translate up to 5 kg of pressure (force) into an electrical signal. The load cell uses **HX711** which is 24-bit analog-to-digital converter (ADC).

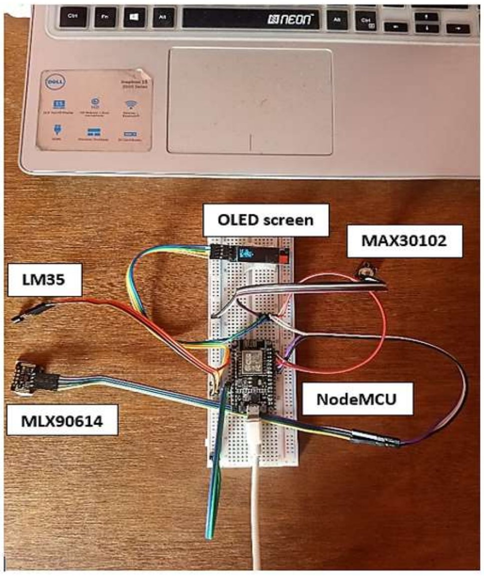
4. Software Specification

Thingspeak is an IoT analytics platform that allows to aggregate, visualize and analyse real-time data streams in the cloud.

Blynk is an IoT based application responsible for communication between Hardware and software.

Both of the above-mentioned platforms are useful as they provide secure and easy to access services for displaying output data from sensors connected to patients from anywhere just by having access to the internet.

5. Proposed Model Implementation



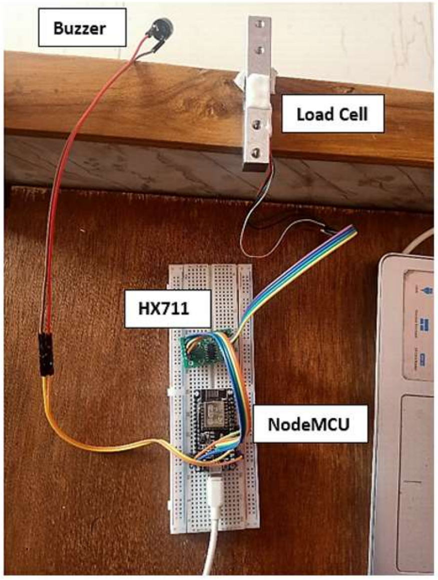


Figure 2: Proposed model circuit for wearable system
Figure 3: Proposed model circuit for drip monitoring system

The figure-2 shows the circuit for wearable system consisting of sensors MAX30102, LM35 and MLX90614, buzzer and OLED screen are directly connected to NodeMCU which is given a power supply of around 5V from the laptop via USB to micro-USB cable. The three devices (which are OLED screen, MAX30102, and MLX90614) support I2C protocol for communicating with microcontroller so they require SCL (Serial Clock) and SDA (Serial Data) pins. As the NodeMCU only has two pins which support I2C which by default are GPIO5 (D1) and GPIO4 (D2) which are assigned as SCL and SDA respectively. So, all the three devices mentioned above were connected to D1 and D2 pins. The LM35 sensor which gives the analog output in terms of voltage so it was connected to analog pin of NodeMCU.

The fig-3 shows the implementation of drip monitoring system using load cell and NodeMCU. The load cell is setup in such a way that on one end of the device a drip bottle can be hung. Since the load cell has strain gauges attached to it so it will measure the amount of strain applied at the location where the bottle or bag is hung. From there the corresponding analog voltage is sent to HX711 (24-bit ADC) and then the signal is acquired by NodeMCU where the weight is calculated. Usually, the IV solutions are available in 100 ml to 1000 ml bags and the load cell used in this model can easily measure that with proper calibration. So, when the weight of the bottle or bag goes below the threshold a buzzer will alert the doctor or the nurse about the bottle getting empty. The data of weight of bottle, is stored in the cloud so that when needed the doctor can see how much volume of IV fluid was given to the patient and at what date and time.

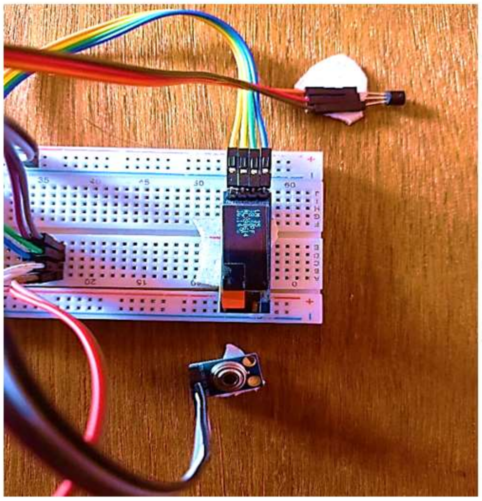
For the software implementation a dedicated Thingspeak channel with separate fields for temperature (in ºF), pulse rate, SPO2 (in %) and amount of IV fluids (in litres) were created. Then a unique API write key is generated by the channel which is used for updating the values on the channel fields.

Next for the BLYNK app, a dedicated project was created under which required widgets were chosen for the proposed model. The widgets used were value display and gauge display for displaying the senor data. Then for receiving the sensor data to the app, a unique auto-generated authorization token was used which allows to update value in the corresponding widgets in the app. To print output data in Blynk, select the same port which allows the microcontroller to take the sensor values and then by using the port number publish the values directly onto the application.

6. Results and Discussion

Figure 4: Wearable system model

The system has been designed with the primary controller being NodeMCU. This whole system is modelled as such so that it can be integrated on the patient's shirt making it a wearable device as shown in the figure 4.



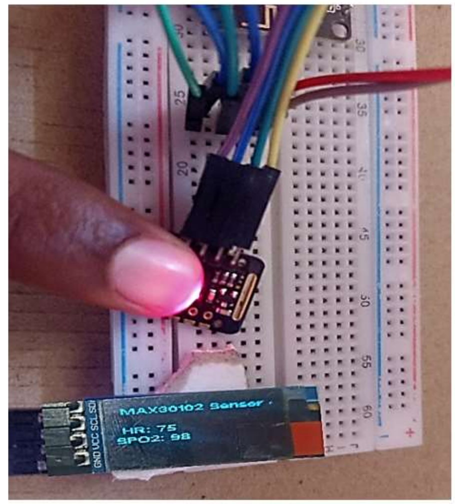
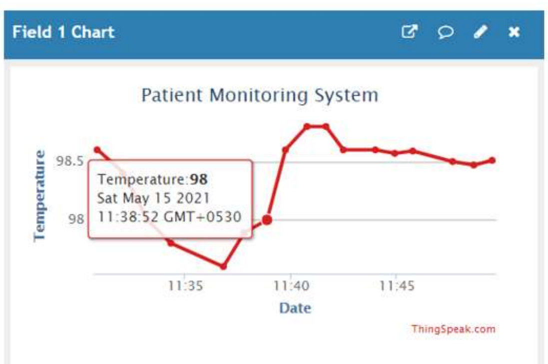


Figure 5: OLED screen showing temperature of the patient.

Figure 6: OLED screen showing output from MAX30102 sensor.

The OLED screen in fig-5 shows the output achieved from the temperature sensors LM35 and MLX90614 in units of ºC and ºF. In fig-6 the OLED screen shows the output from the MAX30102 sensor. The OLED displays the message instructing the user to place the finger on the sensor so that heart rate and SPO2 can be measured. Then after the finger is placed the OLED display the output as shown in figure 6.

As in the proposed model single OLED screen is used so the sensor values displayed on it changes after 5 seconds delay for example after displaying the temperature values for 5 seconds the display then switches to displaying the heart rate and SPO2 then again back to temperature.



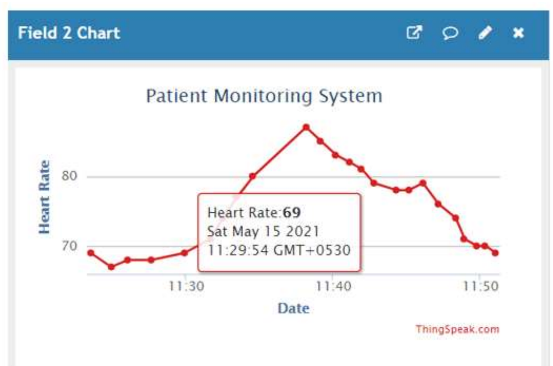
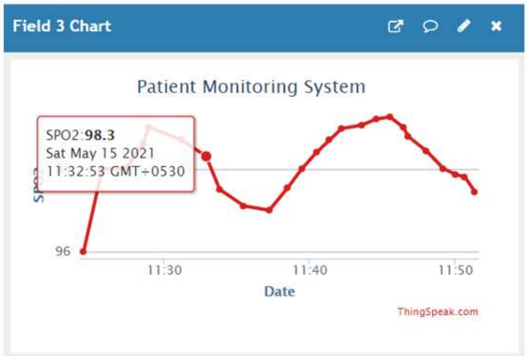


Figure 7: Temperature field in Thingspeak
Figure 8: Heart rate field in Thingspeak

The figure 7 is the graphical field created for visualizing the temperature data of the patient which is obtained from the LM35 sensor. As it can be seen that the graph shows the heart rate and also time, date, day along with it which can be very helpful to track down the data.

Figure 8 shows the graphical field created for visualizing the Heart rate of the patient. The values are obtained from the MAX30102 sensor which is then updated to this field.



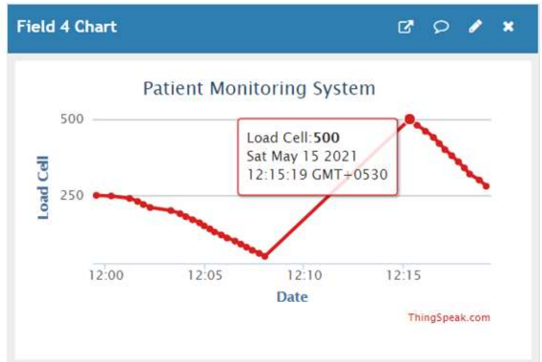


Figure 9: SPO2 field in Thingspeak

Figure 10: Load cell field in Thingspeak showing millilitres of IVs given to patient.

The figure 9 shows the graphical field created for visualizing the SPO2 data of the patient obtained from the MAX30102 sensor.

The fig-10 shows the graphical field created for visualizing the data obtained from the load cell. The purpose of showing this sensor data on the cloud is because it can help keep a track of amount of drip (Intravenous fluids or IV) given to the patient.

Now if any of the sensor data values goes above or below the set threshold (i.e., heart beat goes above 100 BPM and below 60 BPM considering the patient is at rest or SPO2 of goes below 95% or temperature goes above 101ºF) the Thingspeak will generate an alert message in the form of email which will be sent to the concerned doctor or nurse or any of the patient's relative.

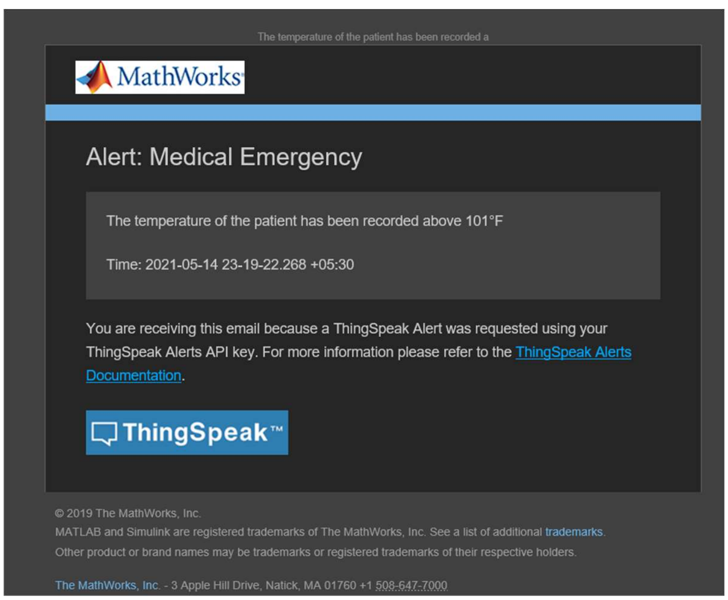


Figure 11: Alert message sent via email service

Figure 11 is of an alert mail which was received when the temperature of the patient was recorded above 101ºF. Similar mail as in fig-11 is generated for the heart rate and SPO2 when values cross the threshold.

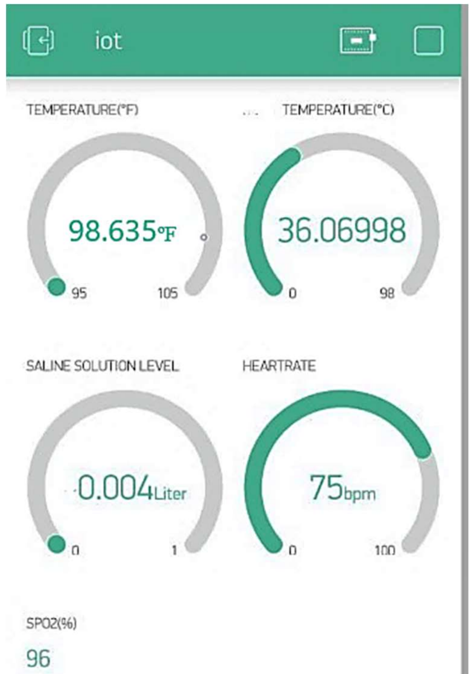


Figure-12: UI of BLYNK App

Figure 12 is of BLYNK application showing the UI for the proposed model. As it can be seen that the app shows all the data from the sensors like temperature in both ºC and ºF from LM35 and MLX90614, Load cell whose out in Kgs in converted to corresponding Litres, then heart rate and finally the SPO2 %.

7. Conclusion

A patient monitoring system has been implemented into a wearable device which will measure the heart rate, SPO2 and temperature of the patient continuously and will display the output on the OLED screen one by one. The amount of drip or IV is also measured to keep a track of how much it is consumed and when the bottle is about to get empty. The data is also updated and stored in the Cloud platforms Thingspeak and the mobile application BLYNK which allows doctors, nurses and patient's relatives to monitor the health from anywhere via the internet. Also, if the sensor records any value going beyond the set threshold the Thingspeak will generate a alert Email and send it to concerned person stating about the medial emergency.

Also, further Blood pressure measuring sensor, if possible, blood sugar level sensor could be added to the model. And these sensors should be such that it should automatically acquire the data without the need of patient to interfere with system.

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