International Journal of Electrical and Computer Engineering (IJECE)
Vol. 10, No. 2, April 2020, pp. 1239~1247
ISSN: 2088-8708, DOI: 10.11591/ijece.v10i2.pp1239-1247

Integrated healthcare monitoring device for obese adults using internet of things (IoT)

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Article Info

Article history:

Received May 23, 2019
Revised Aug 7, 2019
Accepted Oct 9, 2019

Keywords:

Blood pressure
Heart rate
Internet of things
SpO2
Storage of medical data
Temperature

ABSTRACT

Obesity is a global epidemic, often considered an impending disaster for the world's population. Healthcare organizations and professionals repeatedly emphasize the negative impacts on obesity in the development of cardiovascular diseases, hypertension and diabetes. The continuous monitoring of physiological parameters; namely SpO2, blood pressure, body temperature and pulse rate are imperative for obese adult patients. IoT is a dynamic field, used extensively in all fields: agriculture, automobile, manufacturing and retail industry primarily for automated remote real-time monitoring. This paper focuses on the implementation of IoT in the healthcare industry for monitoring and evaluating health conditions of obese adults, along with emphasis on the importance of medical data storage. Furthermore, a device is developed with a novel design and system, which not only allows real-time monitoring but also the storage of medical records for multiple patients simultaneously. The device facilitates measurements of these parameters using an Arduino environment and then transmits the data onto an IoT dashboard using a Wi-fi module for remote monitoring for healthcare professionals. The main aim is to provide a suitable device recommended by doctors for patients suffering from obesity, such that doctors can examine patient's health trends over a period from the stored data for monitoring any changes that could be a symptom of an underlying unnoticed health condition.

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1. INTRODUCTION

World Health Organization (WHO) stated in 2016, 650 million adults worldwide were obese. In 2016 in US 37.9% of men and 41.9% of women of their population were stated to be obese. Obesity is defined as a chronic disease due to abnormal amount and excessive distribution of body fats; it is diagnosed when the patient has a BMI (Body Mass Index) higher than 30kg/m^2 (mass in kilograms and height in meters). Obesity is caused due to various factors; lifestyle and dietary choices made by a patient. Obesity is prevalent in all age groups; however, the negative effects take a significant toll for obese patients over the age of 40 stated by the International Journal of Obesity [1]. Obesity mainly leads to a reduction of life expectancy due to the development of sudden heart stroke, and type II diabetes. These conditions and diseases can be directly linked to hypertension, stress and high blood pressure. Therefore, it is imperative for an obese patient over the age of 40 to go for regular check-ups and constantly measure their vital parameters; heart rate, blood pressure, SpO2 and temperature. They need to take daily measurements for analysis of their health parameters for symptoms that could potentially lead to a further complication of a stroke. Thus, the proposed device allows obese patients to check and record their health parameters while at home and then doctors to remotely monitor these patients [2, 3].

Internet of thing (IoT) provides a communication platform for all standard Internet enabled devices and non-internet-enabled devices through wireless or cable connections to sense, connect and share data. It consists of embedded systems; sensors, integrated circuits and microcontrollers, which create and assemble data, which is then shared and reciprocated to networking interfaces. This allows to data to quickly proliferate to a number of devices, accessed by a number of users with minimum human intervention. IoT simply makes devices smarter and users more informed [4]. IHS (Information Handling Services) Markit believes the number of connected IoT devices will increase 12% annually to reach 125 billion in 2030. IoT is used in healthcare monitoring, as it is fast, reliable and flexible, and that it provides a key aspect of data storage through cloud computing. Data storage and management in healthcare provides healthcare professionals a more holistic view of patient's treatment, and helps to monitor the patient's condition over a period [5].

Traditionally, vital health parameters were measured physically by a healthcare professional and mentioned in the patients report, which were stored in a hardcopy of the reports. This was further improved by health monitoring kiosks at hospitals and clinics; which allowed patients to independently measure vital parameters. Advances in technologies eliminated the requirement for patients to visit the nearest kiosk, with the introduction of portable health machines/systems for each parameter. These machines were bulky and only suitable for patient care at home. This shortcoming has been ruled out by introduction of health watches and smartphones. Health watches such as Fit Bit and smartphones with Infrared Rays (IR) sensors, allow patients to constantly monitor certain health parameters as per their convenience and ease [6].

The measurement of health parameters is advancing rapidly, and there are certain features that require more focus. The data generated from healthcare services is voluminous in size and quantity and is generated at a rapid velocity, therefore has to be efficiently managed and stored. Conventional methods of data storage: hardcopy of documents in hospital archives or storage in portable devices: SD Card, CD and USB are redundant, and are preceded by cloud storage. Cloud storage not only is cost effective, but also allows long-term storage. Along with cloud storage, a decentralized platform is required, where data obtained from several sources is available in a single platform and with increased accessibility [7].

Fit Bits and smartphones (with health trackers) are expensive and only allow measurement of pulse rate and SpO2 [8]. Therefore, a more economical method, along with the measurement of other crucial parameters is required. These devices are suitable only for a single person, as irrespective of the number of patients that measure and use them; the data will be stored all together in a single folder in Cloud. Hence, there should be a device, which allows multiple patients to measure and store their data in their unique folder, independent of others. The cloud storage allows relatives and doctors access the patients' records in real time from any remote location, providing more accessibility. Finally, if these problems are overcome, it will benefit obese patients, as they have to regularly check their vitals. The disease obesity normally runs in the family, thus a single device measuring all the patients' vitals and storing the data uniquely, will be an optimal solution.

The previous studies conducted, have performed extensive research field of IoT implementation in healthcare and data storage. A basic patient monitoring system was designed to detect pulse rate and temperature and when these values are above the maximum threshold value, an SMS is sent via Wi-Fi to the caretaker [9, 10]. In addition to pulse rate and temperature as the vital parameters, blood pressure and SpO2 were integrated into the device [11]. This patient monitoring device was further enhanced by the usage of advanced communication technologies such as RFID (Radio frequency identification), Raspberry Pi, Bluetooth and Wi-Fi [12]. Furthermore, the complete function of this integrated system was applied to monitor patients remotely in the ICU (Intensive care unit) [13]. Techniques and tools that enable management of health through Electronic Health Records (EHR), analyzes the data generated from measurement of parameters using medical instrumentation [14]. Literature studies conducted establish the vital parameters to be measured as: pulse rate, SpO2, blood pressure and temperature. These four parameters are fundamental for diagnosis; therefore, through the application of IoT, a device has been designed for measurement of these parameters, along with usage of the dashboard iotgecko.com. The data is stored on the cloud permanently for a given period.

In order to make this device more efficient and effective for obese patients, certain features have been optimized. It is designed to be lightweight and portable. This device is economical, and allows multiple people to measure their data and store it uniquely. The data measured from each person is stored in his or her separate folder. It employs real time tracking, along with alerts and a buzzer sound alarming both the doctor and the patient. This device adds certain personalization as the doctor can enter the threshold values shown in the Figure 1 with respect to the obese patient being monitored, as obese patients have a higher blood pressure and pulse rate.

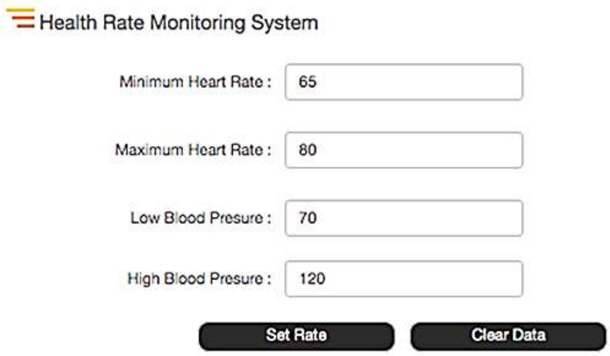

Figure 1. The web browser shows the parameters set by the doctor as per the patient condition

The system, which has been proposed for daily monitoring of adult obese patients, is shown in Figure 2. The integration of multiple sensors connected to the microcontroller, Atmega 328. These sensors are LM35 as the temperature sensor, MAX30100 as the SpO2 sensor and a wrist blood pressure and pulse rate monitor. The wristband is elastic band suitable for an obese patient. In addition to these sensors, a keypad and LCD (liquid crystal display) are also integrated into the microcontroller. The keypad allows the patient to navigate through the device and LCD screen, which allows the patient to view the instructions provided to ensure accurate measurements. Thus, this device is portable and cost effective.

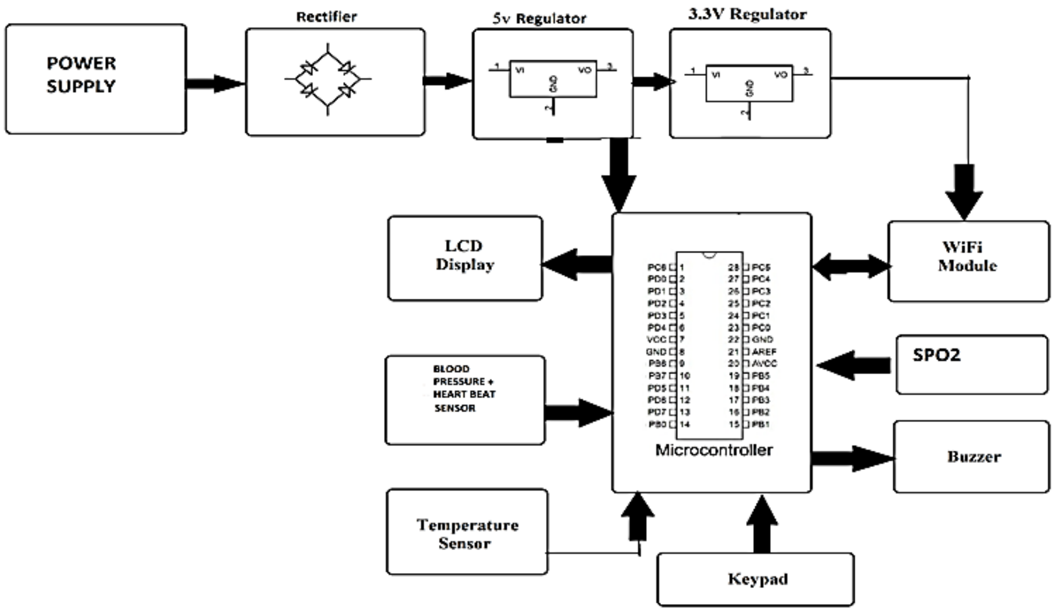

Figure 2. Block diagram of the monitoring system

The device is user friendly, and directly leads to a reduction in manpower in terms of hosiptal staff as the device is easy and simple to use. Once the system is switched ON and connected to a 12V power supply, the following procedure begins initially with the option of SpO2 measurement, then blood pressure and pulse rate measured simultaneously and finally body temperature. The parameters can be measured or skipped as per patient's requirement. Finally, the patients select the unique folder assigned to them for storage of their medical data. Therefore these steps involve gathering and sensing of information and can be collectively termed as Data Acquisition Step. After this step, all the information is received by the Wi-Fi module (ESP8266) and transmitted to the IoT gecko cloud server. [15,16]. The procedure displayed on the LCD screen can be seen in Figure 3. The patient can navigate through the device by the options displayed on the screen, which allows the patient to perform the desired measurements or skip the measurements.

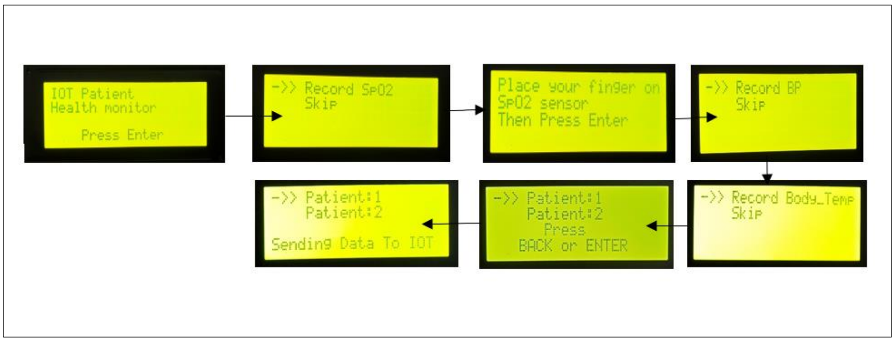

Figure 3. Menu preferences on LCD screen

Finally, it is crucial that the data collected is compared with the threshold values preset by the healthcare professional. This step is essential as threshold values of vital parameters vary among obese patients. This refers to the data processing as shown in Figure 4. Data processing refers to the device functioning and programming, for collection of data from the different parameters and transfer of data to the dashboard [17].

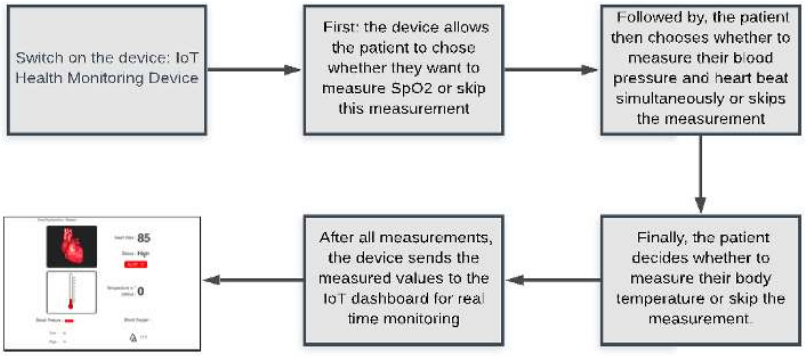

Figure 4. Data processing

Figure 5 the health monitoring devices are shown; namely:
- Temperature sensor
- Heartbeat and blood pressure sensor
- SpO2 sensor
- Arduino Atmega 328 microcontroller
- Wi-Fi Module
- LCD Display

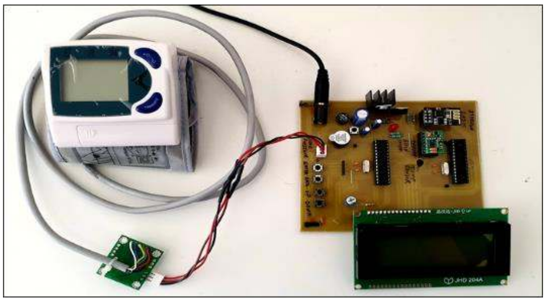

Figure 5. Health monitoring device

The hardware components, which are all non-invasive techniques:

Temperature Sensor: Figure 6 displays the LM35 sensor is a precision integrated-circuit temperature instrument, with an output voltage linearly proportional to the Centigrade temperature. The sensor has a major advantage over linear temperature sensor, which provides the corresponding voltage in Kelvin, and therefore it is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range [18]. The LM35 sensor is easy to use and can be used by slightly pinching the sensor

Heart Beat/Pulse Rate and Blood Pressure Sensor: The sensor used is an easy to use and flexible, as it can be worn around the wrist, shown in Figure 7 It is suitable for thick wrists in case of obese patients. It measures upper blood pressure, lower blood pressure and pulse rate. Heart rate varies depending on a person's age, fitness and genetics [19]. Heart rate is measured by measuring the pulse rate: the amount of blood flowing through the arteries due to contractions in the ventricles of the heart. Pulse rate is traditionally measured by placing a finger over a superficial artery on the neck or wrist pulse rate, in beats per minute (bpm). In this study, the pulse rate sensor is integrated with the blood pressure sensor worn on the wrist. Therefore, the sensor measures pulse rate by measuring the beats per minute. It doesn't require any pumping, like the traditional sphygmomanometer and displays the values on the LED screen provided on this wrist sensor and also on the main screen of the health monitoring sensor. It provides reading in mm of Hg [20, 21].

Figure 6. LM35 sensor

Figure 7. Blood pressure and pulse rate sensor

SpO2 sensor: the MAX30100 sensor is used to measure pulse oximetry; Oxygen saturation in the blood. It is very sensitive, and can effectively measure how oxygen is carried to the ends of the body, arms and legs. It measures the amount of oxygen saturation in the blood. It employs an IR sensor and a photodetector, which measures the amount of oxygen bound to haemoglobin It works on the principle that oxygenated haemoglobin (oxy Hb) and deoxygenated haemoglobin (deoxy Hb) absorb light at different wavelengths. Such that oxy Hb absorbs red light (650nm) and allows IR (950nm) says to pass, whereas deoxy Hb absorbs IR rays and allows red to pass. In the MAX30100 sensor, a finger is placed on the sensor, source of light and below there is a photodetector which produces a voltage proportional to the light absorbed by both Oxy Hb and deoxy Hb. A ratio is obtained for red light to IR light and then converted to a percentage of the available haemoglobin that carries oxygen [22].

Arduino Atmega 328 Microcontroller: This is an open-source prototyping platform, the Atmel ATmega328P is a 32K 8-bit microcontroller based on the AVR architecture. The ATMEGA328-PU is a PDIP 28 pin package and is used on 28 pins AVR Development Board. It is executed in a single clock cycle at 20 MIPS at 20MHz and 131. Instructions most of which are executed in a single clock cycle. It has a memory of 32KB of programmable FLASH, 1KB of EEPROM and 2KB SRAM. It allows data retention for 20 years at 85°C and 100 years at 25°C. ATmega32 has 32 pins (4portsx8pins) configurable as Digital I/O pins. It has 3 Inbuilt timer/counters, two 8 bit (timer0, timer2) and one 16 bit (timer1). It has one successive approximation type ADC in which total 8 single channels are selectable and on-chip analog comparator is available. Arduino boards are relatively inexpensive compared to other microcontroller platforms.

Wi-Fi module: ESP8266 is used as a Wi-Fi modem, allowing the data to be stored with the IoT interface. It is a low-cost Arduino compatible modem, with full TCP/IP coverage and also has MUC Integration, to control I/O pins. Its specifications are 32-bit RISC CPU. A 64 KiB of instruction RAM, 96 KiB of data RAM and WEP or WPA/WPA2 authentication, or open networks [23].

LCD Display: An LCD Display is provided which is connected to the Arduino with pins, it displays the data after each measurement is taken, allows the patient to skip parameters and allows the patient to successfully store the data for the patient as per the folder.

The software components include:

Arduino IDE programming: Most microcontroller systems are limited to Windows but Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Arduino Software (IDE) provides easy programming software, which is open source and extensible [24]. The language can be expanded through C++ libraries. The programs developed are installed in the Arduino Atmega 328 Microcontroller through digital and analog pins provided.

IoT system: The software is stored on the Cloud and is accessed by web browser iotgecko.com, on which all the data is stored for both patients. The web browser can be acceded from anywhere and provides necessary alerts. The web browser also allows the doctor to set the threshold values as per the obese patients' conditions [25].

2. RESULTS AND DISCUSSION

The previous studies concluded with the measurement of several parameters for a patient in the Intensive Care Unit (ICU) through a device, monitored through a mobile application, allowing the doctor to remotely monitor the patient [26]. In this device however, storage wasn't developed as, constant analysis in real- time and alerts were the fundamental focus. The other approaches focused primarily on monitoring the vital four parameters and sending SMS to the doctors for alerts, using Raspberry Pi and Zigbee technology for close range short distances [27, 28]. Therefore, by understanding previous studies, this device allows monitoring of vital parameters for obese patients and storage of data for medical analysis for multiple patients. The sensors operate when the device is connected to a Wi-Fi router. Figure 8 shows the processing that takes place after measurements are taken, then sent to the IoT dashboard.

In the Figure 9, the dashboard is displayed after the readings have been taken. When the measured values are higher or lower than the pre-determined threshold value, an alert with a buzzer noise is set off. In this scenario, as the lower blood pressure threshold value is set as 70, and the measured value is 67, an alert with buzzer sound has been set off. Therefore, this feature allows the doctor and the patient to be alarmed in abnormal situations for all measured parameters.

In case the patient skips a measurement, then the value displayed on the IoT interface is zero, shown in Figure 10. The doctor selects the patient's folder and can view all the previous measurements and the most recent, which is denoted by the first Serial ID. In this figure, values for two separate patients are observed: Person 1 and Person 2, and the most recent readings out of the monthly readings stored are displayed. Thus, the values get stored onto a Cloud platform, for a long-term examination. The stored values are fundamental to this device, it allows data analysis and provides statistical reasoning.

The graph shown in the Figure 11 indicates a monthly trend for two parameters: blood pressure and heart rate for an obese patient. This patient has been regular with checkups with their doctor, and faces headaches and sweating on a weekly basis. The obese patient's parameters were measured daily using this device, and their values were subsequently stored on the Cloud platform. The doctor through the analysis of his parameters can get a better understanding of the medical condition and potential medical threats that the patient might face. The values for a given month (Jan 2019) were integrated together and a graph indicating the patient's health trend was developed, to provide a statistical analysis. Finally, the doctor/healthcare professional can continuously remotely monitor obese patients for any disturbance in their health conditions, to prevent a potential catastrophe.

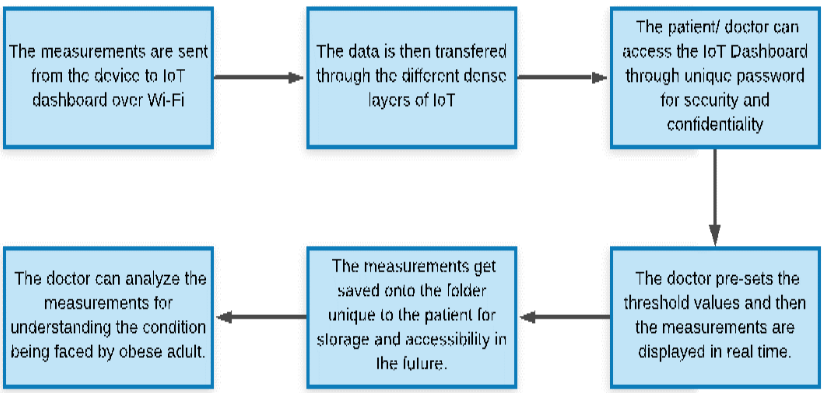

Figure 8. Software processing of measurements

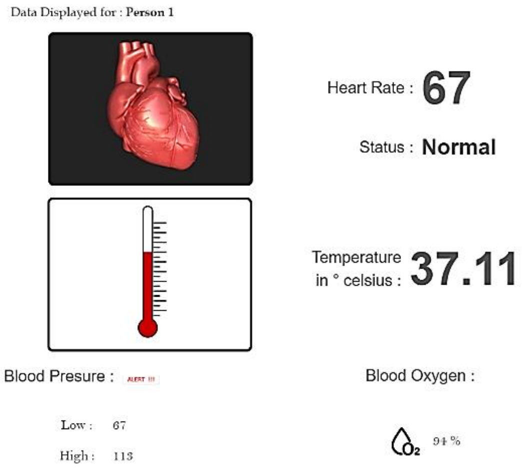

Figure 9. Real-time monitoring: display of web browser including alert shown on the web browser

Person : Person 1 ▼

ID	Heart Rate	Temperature	BP Low	BP High	Oxygen %
1	0	36.62	0	0	94
2	83	0	82	128	0
3	81	0	87	134	94

Person : Person 2 ▼

ID	Heart Rate	Temperature	BP Low	BP High	Oxygen %
1	0	0	0	0	95
2	77	0	82	121	0
3	64	35.64	85	145	94

Figure 10. Readings for multiple patients on the dashboard

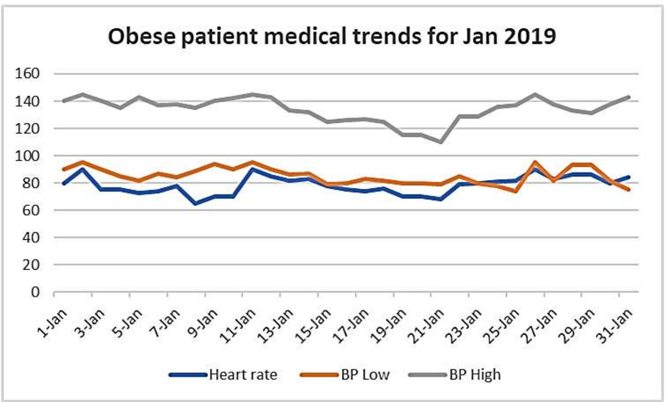

Figure 11. Monthly trend for an obese patient

3. CONCLUSION

The study provides a suitable device for daily analysis of health parameters for obese patients. This research paper establishes the requirement for obese patients over the age of forty for constant monitoring as their body physiological state varies from the normal. The prototype is a fully functioning device, to measure the body parameters and store these medical records. This device is efficient, portable and user friendly. Therefore, this device is of a suitable use for regular tracking of body's conditions and also allows the doctor to be notified for development of any severe health condition. The patient and the doctor can analyze their historical medical data on the IoT server, which will help them keep track of their body's physiological condition on a daily basis.

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