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Smart Pre-Examination Health Care System for Doctors Developed on an ARDUINO Microcontroller †

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Abstract: At present, people and hospital management are wasting their time and wealth due to a lack of a smart system in the pre-examination process for patients. This paper discusses an approach to designing a healthcare system that collects necessary health condition data using a microcontroller-based smart system, the information from which is referred to an authorized device. The smart Health Care System is an economical healthcare device for a hospital; it obtains measurements of vital signs like temperature using a DS18B20 Digital Temperature Sensor, heartbeat and SpO2 level using pulse oximetry and a health rate sensor, and the height of a patient via an ultrasonic sensor, etc. The system contains a microcontroller, an Arduino UNO, and all the collected information from sensors is sent to the Arduino UNO. The LCD screen coupled with the Arduino UNO displays all measurements from the sensors. This project has an alert system that works according to the patient's condition; if there is an emergency, the RED LED will light up, and the system will generate an alert through a buzzer and send the information to the doctor using a Bluetooth system. This system can be placed before entering triage, used in the intensive care unit, or used as a personal device to monitor the health of a patient.

Keywords: Arduino UNO; pulse oximetry and health rate sensor; DS18B20 digital temperature sensor; LCD; buzzer; Bluetooth

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1. Introduction

Technological development has invaded all sectors and made them better and more at ease than before. Through novel tools, computer-based, convenient, embedded devices have occupied our healthcare field at another level; by utilizing these technologies, people may undergo regular checkups by themselves at a hospital. In addition, it is important to make continuous nursing available to people in non-clinical situations, especially during the COVID-19 pandemic; such self-health-examination systems offer more advantages that can be attained only through computer-centered monitoring devices with smart sensor technologies. With the state of technology today, there is a massive diversity of biosensors that are used to study signals such as blood pressure monitors, glucometers, and heart-rate regulators, including electrocardiograms, which allow patients to take essential measurements daily. Day-to-day readings are directed to doctors who will recommend medication and exercise actions that allow patients to improve their quality of life and overcome diseases. The use of the Internet of Things and wireless systems in the care of patients is becoming increasingly common in the field of health, which improves quality of life in the healthcare sector.

The combination of biosensors and Arduino technology is the finest way to carry out smart things in real time. These embedded systems can save data and convey an alert if there is any unexpected change in a patient's health. Arduino is one of the best hardware

environments that can be programmed easily, and it is a good open-source microcontroller platform that allows electronics enthusiasts to build rapidly, effortlessly, and for a small cost with minimal use. The Arduino Uno Board collects data like temperature, height, heartbeat, and pulse from biosensors and displays the measured data on an LCD monitor [1,2]. The system with the Arduino conjointly provides patient notifications on the screen and advises the patient about the next step to follow in the event of an associated nursing emergency. Also, the alert system works to notify an associate of any unanticipated situations for the patient. The project is certainly being established for parameters like pulse rate, vital signs, and pressure levels. This system saves time and money because it can measure heart rate and height without the need for an operator in the examination room in the hospital; it then sends the data to the doctor via Bluetooth. This system can also be made using the IoT, but to avoid complexity, reduce cost, and for proper management, the proposed system used a Bluetooth communication. Therefore, the system can be used as a portable device and can be carried to any place where it is needed regardless of whether the patient/medical person has a personal Internet connection (Figure 1).

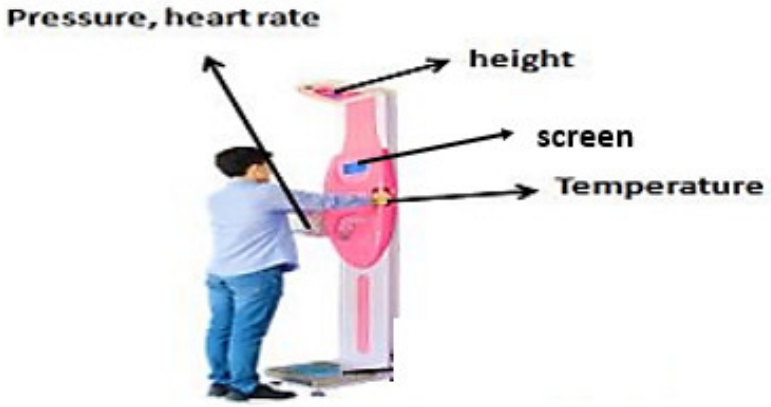


Figure 1. Patient health care unit.

2. Literature Review

The earliest patient–physician encounter a patient has is with the triage nurse, completes a preliminary evaluation before transferring the patient's care to another area of the emergency department or a different department in the hospital. This indicates that staff are capable of differentiating the critically ill from the sick and, consequently, of segregating patients who may need admission from those who will not. Thus, health professionals need to be well versed in the concepts of triage. Functions performed by triage staff include initial assessments, physical examinations, initial diagnostic studies, documentation, and disposition [3]. The expansion of the tasks required by triage staff extends the time required to assess each patient and slows the patient flow; therefore, any smart system that is adapted must be designed to balance triage activity with patient flow. In addition, a portable physiological checking framework or self-examination system will be introduced which will reduce the time and cost of staff. In this paper, implementing a smart healthcare system with biosensors is proposed as a complete solution for these issues.

The proposed self-examination system is used for non-severe COVID-19 patients who wish to see a doctor. The most common symptoms of COVID-19 are an increase in body temperature, a high or irregular heart rate, a low oxygen level, dry cough, etc. [4]. This innovation permits patients to screen their key signs by themselves, using the smart system at a safe distance. And in times of a pandemic, the importance of the healthcare monitoring system is elevated even more than ever before.

Most of the studies in the literature presented a smart healthcare system with IoT which receives the biosensor information collected from patients using a Wi-Fi Module. In this system, only authorized personnel can access the data stored using Bluetooth, and based on these values received, diseases are diagnosed by doctors from a distance [4].

However, when designing for the concept of triage, due to the position in which one has to place the system and the distance from health experts in these cases, the IoT complexity is greater, so this system focused on the mobile application of Bluetooth.

3. Materials and Methods

The proposed smart health monitoring system was developed using an Arduino UNO microcontroller and sensors to measure the vital signs of a patient's body. In the Arduino-based smart Health Care System, there are sensors used as input devices which are a temperature sensor, an oxygen level sensor, an ultrasonic sensor, and a heart rate sensor, as well as a button, as shown in Figure 2.

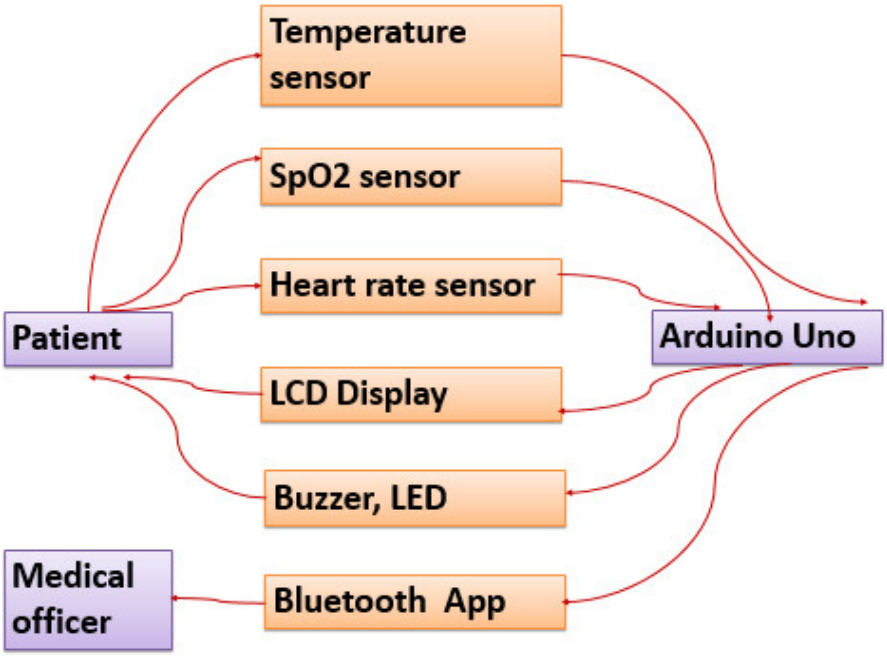


Figure 2. The basic structure of the Bluetooth-based health care monitoring system.

At the output, there are LEDs, a buzzer, a Bluetooth device, and an LCD. When the code is uploaded to the Arduino and the commands are given, the green LED will turn on, and the temperature and pulse will be measured. If they are at normal levels, the LED will remain on. If the temperature and pulse measured are abnormal, then the system will produce an emergency indication: the green LED will be turned off, and the red LED will glow. When the red LED lights up, the buzzer will ring, and if the problem is resolved, it will return to normal and only the green LED will be on. While the red light glows, the wireless Bluetooth module refers the measured information to the smart devices of doctors, which are already paired with the system. If the button is pressed, the yellow LED will be on, which means the patient needs some help from a concerned person. When the button is off, it will return to normal, and only the green LED will be on. Also, real-time data from the sensors are displayed on the LCD screen. This is also useful for healthcare professionals who are actively monitoring the patient on-site or in intensive care units (ICUs); thus, the patient's condition can be protected and monitored with this project.

3.1. ARDUINO UNO

Arduino manufactures one of the most well-known microcontroller development boards that can be used in many embedded applications. Arduino Uno has six analog input pins, and these pins consist of 10-bit ADC as well as 14 I/O pins that can be connected to digital actuators such as LEDs or motors using PMW pins such as DC motors. Of the 14 pins, there are 6 pins (PIN 3, 5, 6, 9, 10, and 11) that can be used as PMW pins, or they can be used as normal I/O digital pins. The microcontroller used in this board is an

ATmega328P from the ATMEL company. This microcontroller works on an 8-bit principle with a CPU frequency of 16MHz, 32 KB of Flash, 1KB of EEPROM, and 2KB of SRAM. Moreover, Arduino Uno includes two pins for voltage that can be supplied to sensors or actuators which are 5 volts and 3.3 volts, as well as the (GND) to complete the electric circuit. For Bluetooth or Wi-Fi usage, there are two pins (pins 0 and 1) that are used to connect a separate extension to add this feature. Pin 0, called RX, is used to receive the data from the Wi-Fi or Bluetooth transmitter, and pin 1, called TX, transmits the signal to the transmitter. For Arduino programming, Arduino IDE v 2. was used for this project.

3.2. Pulse Oximetry and Heart Rate Sensor: MAX30100

This sensor is used to measure the pulse level and the heart rate of the human body, and it will interface with the ARDUINO microcontroller to display the measured quantities. The sensor has a pair of high-intensity RED and IR LEDs and a photodetector. It works by transferring both lights onto the finger or earlobe or an area where the skin is soft so both lights can easily enter into the tissue and measure the amount of reflected light using a photodetector.

The working MAX30100 can perform two different tasks, which are heart rate measurement and pulse oximetry, to measure the oxygen level in the blood. The oxygenated hemoglobin (HbO_2) in the arterial blood has the property of absorbing IR light, which is utilized in the sensor's action. The redder the blood, the higher the hemoglobin, so more IR light is absorbed [5,6]. As blood passes through the finger with each heartbeat, the amount of returned light changes, and it creates a varying waveform at the output of the photodetector. As it continues to glow, the light and the photodetector sense the heart beat (HR) pulse reading.

Calculating the ratio of IR and RED light received by the photodetector can determine the oxygen level (SpO2) present in the blood. To connect with the ARDUINO board, a supporting library is needed in the program for the MAX30100. This supporting library installed in the program gives most of the features of the sensor and provides defined functions to access and analyze the pulse rate and oxygen level. By using the serial monitor choice in the ARDUINO program, one can observe what the measured values from the sensors are, and the program will check with the threshold values set in the program. If the real-time data are above or below the threshold, the system will consider it an emergency. In an emergency that arises, the Arduino insists on transferring the information from the sensor to the wireless system for the doctors' reference, and the alarm works at the same time.

3.3. Temperature Sensor: DS18B20 Temperature Sensor

The DS18B20 sensor is used in the smart Health Care System to collect the body temperature of the patient. It is analyzed by the ARDUINO and provides information about whether the patient has a fever or not. The temperature sensor works on the principle of the direct conversion of temperature into a digital value via ADC. Its default bits value is 12, but it changes values according to the temperature change. The system reads the temperature, and if a fever is detected in the patient, the alarm sounds, and the value at that moment for the patient is displayed on the LCD screen. The wireless system is also attached to the Arduino and the measured data during the fever are referred to the doctor's smart device via Bluetooth mode. The temperature sensor's calculation is as follows [1]:

$$\text{Temp } (^{\circ}\text{C}) = (\text{analog Val}/1024) * 5 \text{ Volts} * 100 \text{ degrees/Volt}$$

3.4. HC-SR04 Ultrasonic

The HC-SR04 ultrasonic sensor uses SONAR to decide the distance between an obstacle and the sensor. It offers excellent non-contact range discovery with high accuracy. In the Health Care System, it is used to measure the height of a patient and it will display the value on an LCD screen paired with the Arduino. To determine the actual height of the patient, the sensor is placed on the top of the system as shown in Figure 1, and the measured value is subtracted from the actual height of the system, which was already measured before. The sensor produces an ultrasound wave at a 40,000 Hz frequency which is transmitted by the transmitter module. Then, it passes through the air, and if there is any obstacle in its path, it will travel back to the sensor and it will be received by the receiver module. Considering the travel time and the speed of the sound, you can calculate the distance.

3.5. Bluetooth Module: HM-10 Module with BLE

Bluetooth is a universally used wireless communication module which is easy to implement. Over the years, there have been many versions of Bluetooth standards to keep meeting the demand of customers and technology according to the needs of the time and situation. Bluetooth started with version 1.0 and currently, Bluetooth version 5.0 exists in the market. In recent, many things have been improved, including the data transmission rate, power consumption with wearable and IoT devices, and Security systems. The HM-10 is a popular Bluetooth 4.0 BLE module which is easily used with Arduino technology. The system uses a standard UART serial connection that communicates with the Arduino board.

3.6. LED, Buzzer, Button, and LCD Screen

In the smart healthcare system, there are three LEDs placed, and the green LED is on all the time when the situation is normal. If there is any problem in the situation, the green LED will shut off, and the red LED will switch on. In an emergency, the patient can press the button, and at that moment, the third LED will be switched on.

To connect the buzzer with the Arduino, the digital pin is used. One can use various electrical pulse frequencies with the Arduino, and a buzzer may be used to create noises. The Arduino must inform the Arduino which pin the buzzer is connected to, what frequency (in Hertz, Hz) of the electric pulse needs to be applied to the buzzer through the program, and for how long it is to continue producing the tone.

The system used a push button, which is connected to an Arduino digital pin, to notify staff of an emergency with the patient. The code instructs the Arduino to keep the LED off when the button is not being pressed and to turn the LED on as long as it is being pressed to complete the circuit and to keep the LED off when the button is not being pressed.

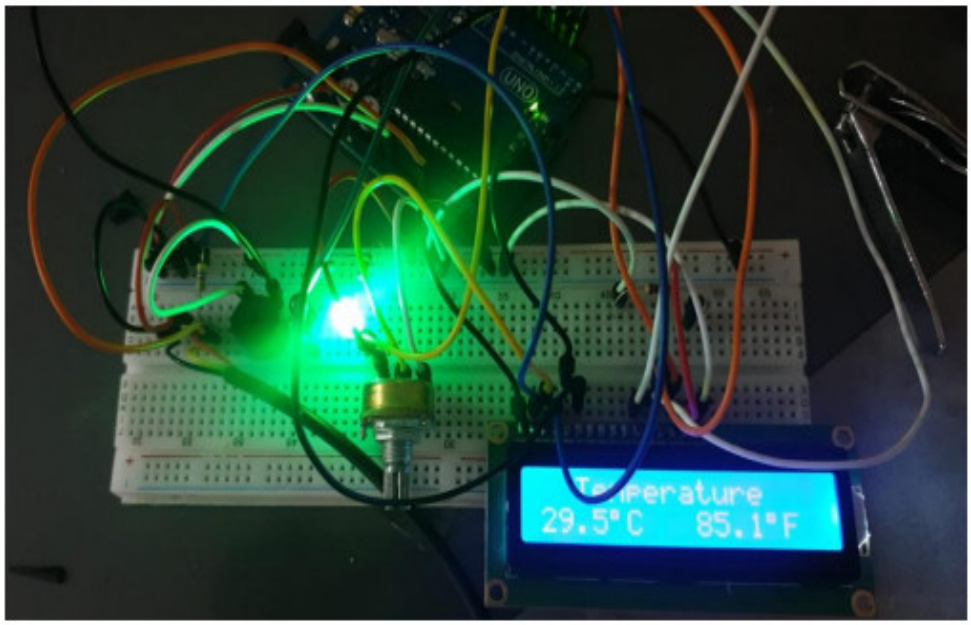
This display has a total of 16 pins. If 12 pins only are used except for the pins D0, D1, D2, and D3, it results in an interface with the LCD in 4-bit mode. To connect the LCD with the Arduino and the supporting library in the program, the measured data from all the sensors will be sent to the serial monitor in the Arduino and the LCD screen attached to the microcontroller.

4. Results and Discussion

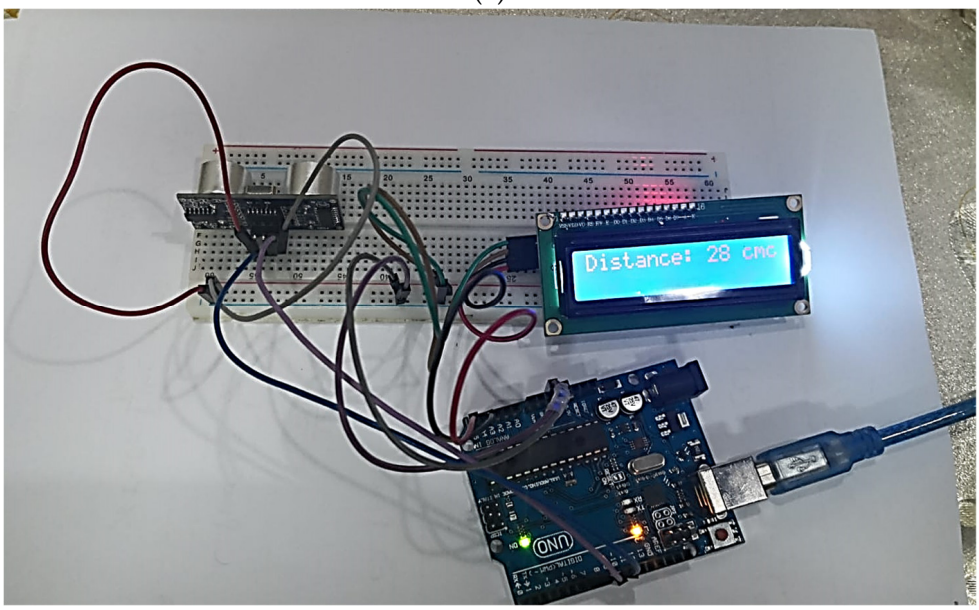
It is hard for people to notice the smallest change in their body, so using the Health Care System could be the finest solution to protect people and decrease the possibility of danger. This system will help protect the patient from heart attacks or abnormal increases in body temperature. Also, it will help doctors notice the smallest change in the patient's body and take the fastest action.

A smart healthcare system can place a triage unit in the hospital to collect vital body information from patients without any time lag. To know the basic condition of a patient, one must examine their heartbeat, temperature, fever height, etc., at the beginning, before the doctor's consultation. To carry out these responsibilities, in this project, three sensors were used, and more sensors will be used in the future. The temperature sensor is provided to measure the patient's body temperature and determine whether they have a fever or not,

and the second sensor is used to measure the heartbeat; the third is an ultrasonic sensor which is used for measuring the height of the patient. Three LEDs were placed; there is the green LED, which indicates that the temperature and pulse are stable (Figure 3), and the red LED, which indicates that there is a problem, after which the buzzer will ring. Also, the temperature and heart rate can be viewed on the LCD screen and will send the data via the wireless Bluetooth system. This system is essential for patient comfort and even more imperative for protection in medical services and other critical contexts like the COVID-19 pandemic.

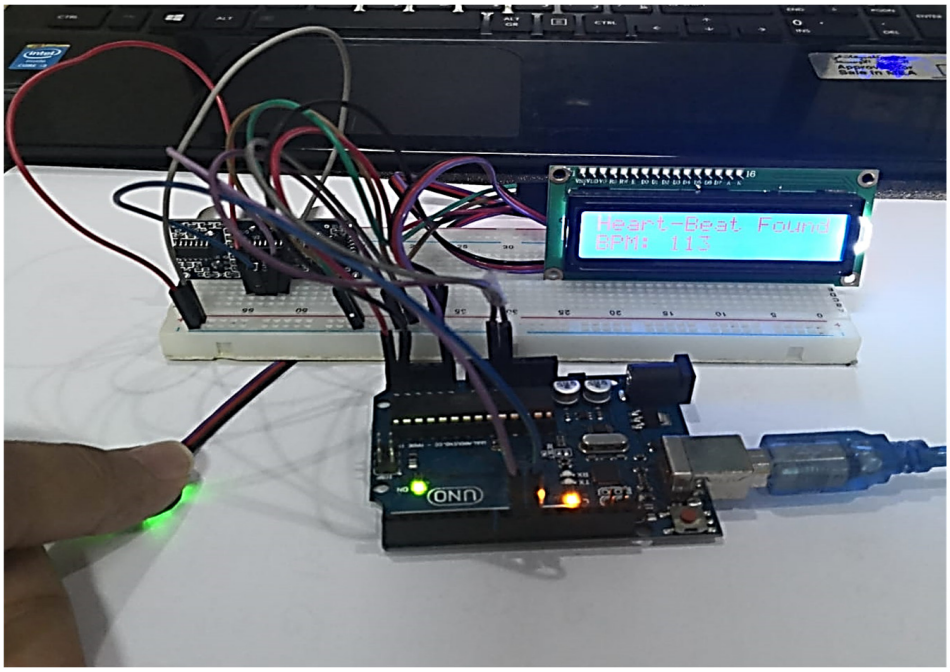


(**a**)



(**b**)

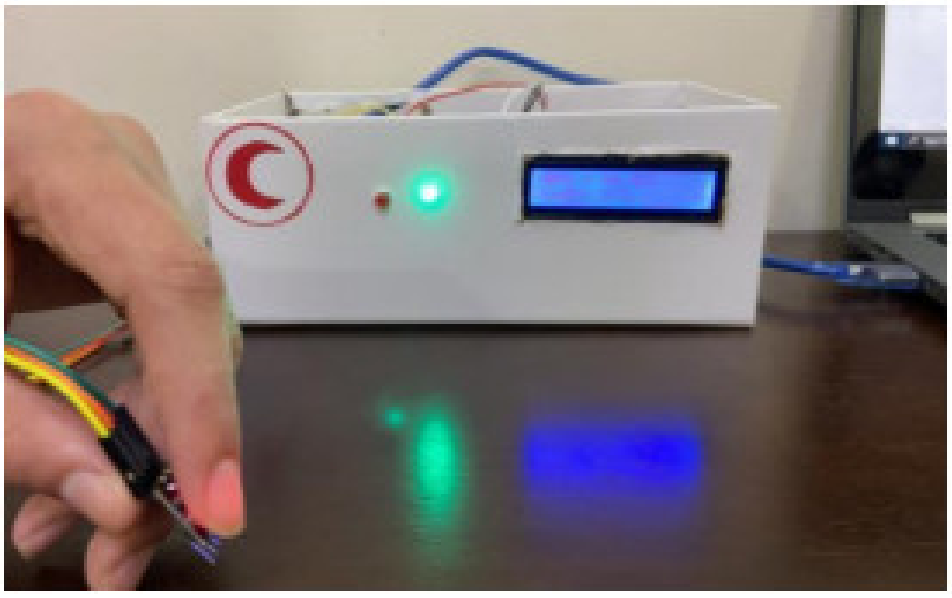
Figure 3. *Cont.*



(**c**)

Figure 3. Figure (**a**–**c**) shows the circuit's connection to the Health Care System.

The Patient Health Care System was implemented, and it was tested on various persons with normal to abnormal health conditions (Figures 4 and 5). The observed data and normal range are given in Table 1.



(**a**)

Figure 4. *Cont.*

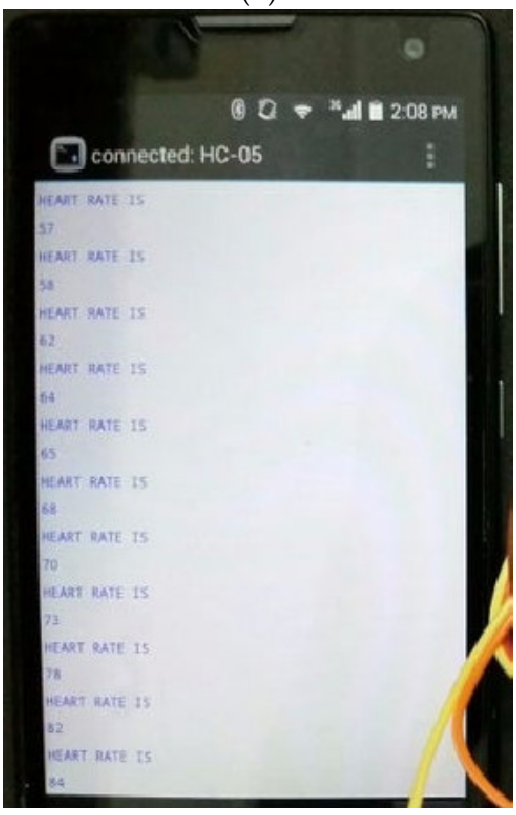
(**b**)

Figure 4. The green LED light will glow when the sensor reads normal body condition data from the patient (**a**), LCD display (**b**).

(**a**)

Figure 5. *Cont.*

(**b**)



(**c**)

Figure 5. The red LED light will glow when the sensor reads abnormal body condition data from a patient with a fever (**a**) and it will display od LCD screen (**b**), the buzzer makes an alert. Figure (**c**) shows the collected information displayed on the doctor's smart device through Bluetooth.

Table 1. Collected data from different patients.

Data from Sensor	Observed Data in the System	Normal Range
The oxygen level in the blood	98—normal 99%—normal 90%—low	96% or more
Heart rate	95.77—normal 90.12—normal 135.35-high	40–100 bpm
Height	178.3—normal 162.12—normal 156.4—normal	150–180cm adult
Temperature	37.21 (normal temperature) 36.9 (normal temperature) 39.53 (patient with a fever)	36.6–37.5 °C

5. Conclusions

Overall, the Health Care System is a smart system that helps and ensures that the patient is safe at all times and helps all patients take care of themselves without any delay via a low-cost method. The system measures the body's condition in real time and takes necessary action according to the data; additionally, the device can operate in any place. More sensors that examine the condition of the patent in more detail can also be added. Future work in the unit can be used and developed by adding more sensors that aid in better monitoring the health and condition of patients and integrate with robots. The system is now specially designed for pre-examination rooms before a doctor's consultation as triage; further, the system can be used as a monitoring unit for patients in the intensive care unit or as an alert system for bedridden patients and patients in ambulances. Also, there is a possibility of integrating a machine-learning-based decision model via Advanced ZigBee [7] or IoT connectivity [4,5] into the monitoring of the physiological parameters.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Written informed consent has been obtained from the patient(s) to publish this paper. Data are contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

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