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Software Implementation of a Smart Bracelet Prototype to Monitor Vital Signs, Locate, and Track COVID-19 Patients in Quarantine Zone

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***Abstract*— This paper describes the design and software implementation of a wearable prototype that allows users to monitor the vital signs of COVID-19 patients in quarantine areas. This prototype consists of two parts, the bracelet, andthe Base control unit (BCU). The bracelet is built with ESP8266 and sensors as main components, as well as the battery and other parts needed to fulfill the system's purpose (monitoring the vital signs of COVID-19 patients). At the same time, the Raspberry Pi (SCB) single board computer and GSM/GPRS/HAT are the main components of the Basic Control Unit (BCU). The current work describes the main parts of the pseudocode, as well as the activity diagram for the microcontroller and Raspberry Pi. This paper describes the mechanism of sending alert messages, whereby the system's ability to configure two types of alert messages; (1) *physician Messages* (these Messages will be sent to the physicianassociated with the patient if one or more vital signs reach a critical value; these messages contain all measurements of a patient's vital signs); (2) *Authorize messages* (these messages will be sent if the quarantine rules are violated; the patient's location will be sent to the authorized person as a Google Mapslink). Also, this paper describes the graphical user interface for communication, management, and interaction between the users of the system.**

Keywords—: Wearable devices, SBC, BCU, Smart bracelet, Healthcare, RSS

I. INTRODUCTION

Since early 2020, Coronavirus 2 "SARS-CoV-2" acute respiratory syndrome has caused an epidemic. To date, COVID-19 has caused more than ten million deaths worldwide and has destroyed individuals' physical and mental health [1]. People with mild to moderate symptoms are usually required to quarantine for at least 14 days to monitor their symptoms. If the situation reaches critical status, the patient should be transferred to hospitals full of patients, where there is a lack of medical staff [2].This research discusses the software architecture and execution of a wearable prototype that enables users to keeptrack of COVID-19 patients' vital signs while being quarantined. The prototype was built using an ESP8266 microcontroller, sensors, Raspberry Pi, and GUI [3]. This article describes the software environment that helps with the communication, management, and interaction between all components in the system, in order to achieveits purpose. The Cov-Care system sends an alert text message that includes the patient's vital signs measurements to their associated physician. In case one or more vital signs have reached a critical value, the patient's location is sent tothe authorized caregivers. The same happens in the case of quarantine rules violation [4]. GUI will display the information that contains several screens about a certain patient. This paper describes the main code with the system's activity diagram, pseudocode for each microcontroller, the Raspberry Pi, and user interface [5].

Section II describes the related work; section III discusses the methodology of the system; section IV talks about the software implementation; section V examines future work; and Finally, Section VI presents the conclusion of the work. about the software implementation, section V examines future work; and Finally, Section VI presents the conclusion of the work.

II. RELATED WORKS

Many studies have emphasized the potential benefits of using wearable technology to monitor a patient's condition in order to deliver timely health care [6]. Effective monitoring, processing, and analysis of COVID-19 patients' symptoms in quarantine zones or at home are now possible through electronic devices, wearable sensor technology, andthe Internet of Things (IoT) [7, 8]. In this part, we highlight a few examples of medical care solutions that include tools capable of tracking patients' vitals. We'll discuss the benefitsand drawbacks of each of these uses, as well as how they differ from our own proposed system solution.

Melad Mizher et al. [9] have proposed a wearable devicewhich is meant to decrease the spread of Covid-19 by remotely monitoring patients' blood oxygen, body temperature, and heart rate. The system is built with three distinct layers: the sensor layer, which collects data from sensors worn or carried by patients; the transfer layer, whichtransmits data from the ESP8266 to a Ubidots server; andthe application layer, which allows users to view data from the server and display all the measurements on a smartphoneor laptop connected to the server.

Jayantha al. [10] have thought about using a wearable gadget to track the patient's heart rate and notify medical staff of any anomalies to value. Patients will receive a vibrational alarm to remind them to take their prescription iftheir heart rate reaches a certain critical threshold, while their physician would be notified by email of any changes inthe patient's heart health. The heart rates of patients can alsobe viewed through a web-based interface. The HSF7051 sensor and ESP8266 microcontroller work together to track the user's heart rate in real-time.

Wei Jiang et al. [11] proposed a wearable chest-based device that monitors temperature, heart rate, blood oxygen saturation, respiratory rate, blood pressure, and cough for patients with COVID-19. The users can access the proposedsystem's information using a smartphone app and server.

Oussama Ghorbel et al. [12] created a WSN-based smartmedical bracelet to track COVID-19 patients' core temperatures and heart rates. Data from temperature and SPO2 sensors is transmitted and stored in the cloud via the system's Waspmore gateway, which can then be accessed via desktop computers and mobile devices. When a user's vitals go above a predetermined level, the system will send out an alert through voice, light, and SMS to the authorized persons.

Table I II. RELATED WORKS

Title ,Ref .No.	Advantage	Disadvantages	What we bring new
" A Wearable Medical Monitoring and Alert System of Covid-19 Patients". [9]	• Monitors all vital signs • High accuracy	• Large Size • High Cost • Limited measurement area • Needs high Internet speed	• Acceptable size • Low Cost • Detects location
"Wearable Device to Measure Heart Rate using IoT" [10]	• Monitors patient heart rate • Sends alerts	• Measures only heartbeat • One-user monitoring	• Measures more vital signs • Multi-user monitoring
"A Wearable Tele-Health System towards Monitoring COVID-19 and Chronic Diseases" [11]	• Prevents the spread of the COVID-19 virus • Long-term monitoring	• A limited number of monitored patients • Build on Internet usage	• Works on more patients
"Design of a Smart Medical Bracelet Prototype for COVID-19 based on Wireless Sensor Networks" [12]	• Generates three types of alerts • Real-time monitoring of COVID-19 symptoms on time	• Not able to check the quarantine violation	• Allows doctors to monitor remotely • Commits patients to quarantine regulations

This paper tries to implement the software part of a suggested system Cov-Care that monitors patients' vital signs inside the quarantine area. The suggested approach helps medical professionals to continuously supervise, diagnose, and guide their patients while protecting their privacy and comfort. The software portion of the suggested system has been created to accommodate all its operations and activities. All system components, from sensors to the user interface that displays the vital signs, have had the system software procedures thoroughly defined.

III. THE METHODOLOGY

The main purpose of the prototype wearable device is to measure vital signs like body temperature, heart rate, and blood oxygen saturation through sensors, in order to continuously monitor the symptoms of COVID-19 in a comfortable manner, without interfering with the patient's freedom, while still meeting the medical staff's requirements. the (*FRs*) functional requirements and (*NFRs*) non-functional requirements are presented in [13]. One of the important aspects of the current work are the type and the model of the components that were used in the prototype. The proposed system consists of the following parts:

- Bracelet: This part collects data from the patient's sensors and transmits it to the central processing unit.
- The Base Control Unit (BCU): This part is the system's core and is in charge of receiving, analysing, processing, storing, and displaying data for each patient.
- Database: The system's measurements, users, and patients' data will be stored in tables in the Database.
- System Interface: In this section, pages will be designed to activate and organize system functions, inputs, and outputs under the user control.

IV. SOFTWARE IMPLEMENTATION

This section describes the software parts of the system per component.

A. *Bracelet*

In this part, an integrated development environment, "IDE", is used to set up the ESP software environment. This physical programming platform can connect and control multiple sensors by applications in real-time. The "IDE" works to set up the bracelet and can easily load a built-in program to initiate the ESP 8266 [14]. Esp8266 has an advantage over ESP32, because ESP8266 isa low-cost microcontroller. All tasks required in this system can be performed using ESP8266. Using Bluetooth (already built-in ESP32) doesn’t meet the system’s requirements regarding area coverage and the number of connected devices. Using Wi-Fi (already built-in ESP32), which is faster than Bluetooth, does meet the system’s requirements regarding wide area coverage and many connected users.

1) Activity diagram

In Fig.1 is represented the activity diagram for the bracelet. First, the system checks the ports and the connections between the bracelet and the base control unit. Second, the system verifies the vital signs compared to standard values and sends them to the base control unit via Wi-Fi. After that, "ESP" will enter for 15 minutes in a "*Deep Sleep*" mode. The sleep period can change based on the recommendation of the health care staff [14].

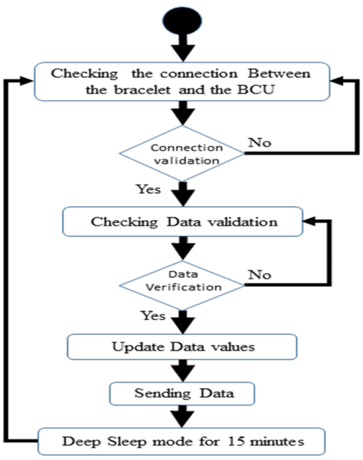


Fig. 1 ESP8266 Activity diagram

2) The pseudocode

The activity diagram in Fig.1 is detailed in the following pseudocode from Fig.2. In the step Data Verification, body temperature sensor will check whether it is between 35°- 41° degrees Celsius; the oxygen level sensor will check whether the blood oxygen saturation is around 50-100 percent, while the heart rate should be between 60-120 bpm.

```
Begin:
  0: Checking connection
  1: If connection valid
       Goto 2
     Else
       GoTo 0

  2: Checking data validation
  3: If 35 < Body Temperature < 41
        Get Body Temperature from the
sensor
          Goto 4
     Else If less than three consecutive
readings
            GoTo 3
          Else
           Goto 6

  4: If 50 < Oxygen saturation < 100
        Get Oxygen saturation from the
sensor
          Goto 5
     Else If less than three consecutive
readings
            GoTo 4
          Else
           Goto 6

 5: If 60 < Heartrate < 120
        Get Heartrate from the sensor
          GoTo 6
   Else If less than three consecutive
readings
         Goto 5
      Else
        GoTo 6
 6: Update data values
 7: Sending Data
 8: Deep Sleep mode for 15 minutes
 Goto Begin
```

Fig. 2 ESP 8266 pseudocode

The "Body Temperature, Oxygen Saturation Level, and Heart Rate" ranges for those measurements are considered to be the normal values for a living person [16]. Even if the probable values are out of range, the system will try again for three consecutive times, which means that the bracelet might get a value in the normal range.

Otherwise, if the datais out of range, it will be prepared and sent, while the patient will get an alarm. The data is prepared to be sent (in both cases: normal andout-of-range values), a matrix is made, and the old valuesare replaced with the new ones. If the sensor values are out of range, the system tries again until it gets a value in the normal range Fig.2. However, after two tries, the system will compose an alert message ready to be sent to the authorized personnel to determine the error. When the conditions are fulfilled, the dataset is accepted, and the old values are replaced with the new ones [17].

B. *The base control unit (BCU)*

In this part of the system, "Virtual Network Computing" (VNC) was used as a tool to run the "RaspberryPi" software environment. This software is a physical programming platform that can receive, process, and store data, and then display it at runtime.

VNC Editor works with the Python programming language; it can easily load an internal application on "Raspberry Pi"[20]. The Raspberry Pi 4 has built-in Bluetooth and Wi-Fi, as well as multiple USB ports and ethernet, which offer the possibility to facilitate the communication with many bracelets simultaneously.

1) Activity diagram

The Fig.3 presents the activity diagram for the BCU. The activity begins with the detection of the connection between the values of vital signs that should not be more or less than the chosen values. If out of range, an alert text message containing the patient's vital signs will be sent automatically to the associated physician. If the connection is open for bracelets and the base control unit, data will be received from the system's bracelet.

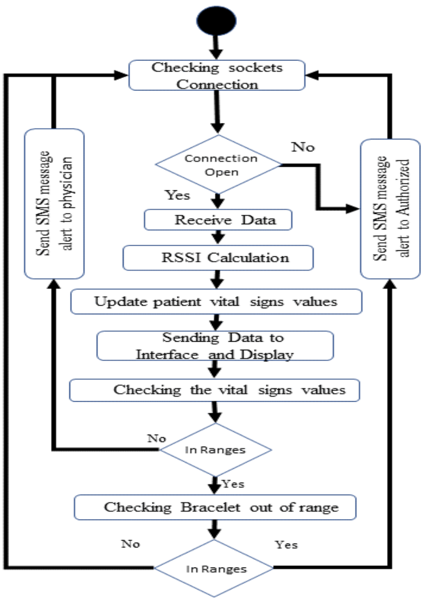


Fig. 3 Raspberry Pi Activity diagram

This step will be repeated until the connection is detected and the system receives the data. The system will calculate the RSSI value, enter all the data into the MYSQL database,and update the patient's vital signs. Next, it will export the data from the database to the interfaces. The following aspects should be noted:

- The values of vital signs should not be more or less than the chosen values. If so, an alert text message containing the patient's vital signs will be sent automatically to the physician [22].
- In case of disconnection between the bracelet and the basic control unit, an "URL SMS" message will be sent automatically to authorized persons containing the patient's location on "Google Maps"[22].
- The "Raspberry Pi" in the BCU also added the measurements of the bracelet and the "RSSI" computations in order for them to be compared and find the **distance** between the bracelet and the BCU.
- If the bracelet cannot detect any measurements in the three-time patient, the system will send an alert to authorized persons to find the error [14].

The pseudocode from Fig.4 details the activity diagram from Fig. 3.

```
  Begin:
  # Checking sockets Connection
  1:  If connection valid
          Goto 2
       Else
            If     less     than     three
consecutive readings
                GoTo 1
          Else
            Send Alert to Authorized
       Goto 1
  2: Receive data
  3: RSSI calculation
  4: Update Patient Data
  5:  Sending  Data  to  interface  and
display
  #  Bracelet  number,  Distance,  Body
Temperature, Heartbeat, Oxygen , (date,
time).
  # Checking the vital signs and Sending
SMS Alert
  6:  if {(Body Temperature > 37.8) or
(Oxygen < 90) or (120 < Heartbeat < 60)}
           Send SMS message by GSM with
all vital signs to physician
              Goto 1
       else
  7:  if Bracelet out of range
           Send  SMS  message  by  GSM  the
location information
         Goto 1
```

Fig. 4 Raspberry Pi pseudocode

Fig. 5 shows the output of the Cov-Care system, with vital signs, patients' names, the RSSI, Distance, the number of the bracelet, and the date and time for each patient measurement in the system.

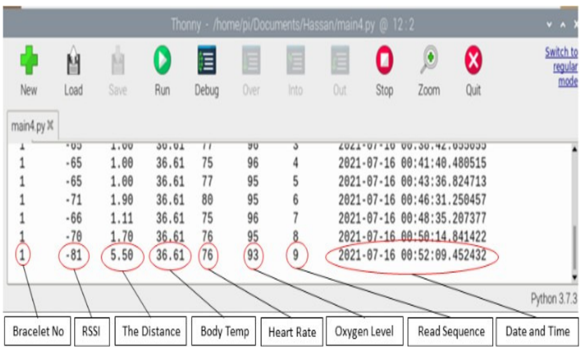


Fig. 5 System Output

C. Database

The database contains the following tables. Each table contains specific data :

- User: The data related to the users (who can be physicians, data managers, or administrators)
- Patient: The demographic data of all patients
- Record: The data of vital signs, and other relevant information for each patient.
- Roles: The roles of all users of the system.

Fig.6 depicts the pseudocode for creating the patient's table.

```
Begin
from application import db
class Patient(db.Model):
  P_id=db.Column(db.Integer,
   primary_key=True)
  P_name=db.Column(db.String(50))
  P_age=db.Column(db.Integer)
  P_gender=db.Column(db.String(10))
  P_braclet=db.Column(db.Integer)
  P_distance=db.Column(db.Float)
  P_indate=db.Column(db.DateTime)
  P_outdate=db.Column(db.DateTime)
  P_enable=db.Column(db.Boolean)
  P_state=db.Column(db.String(50))
  P_username=db.Column(db.String(50))
  P_password=db.Column(db.String(50))
END
```

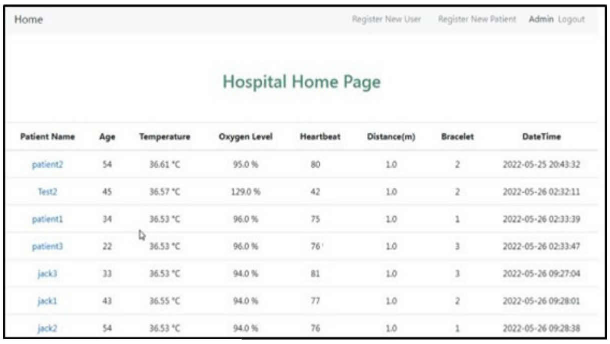
Fig. 6 Part of Pseudocode Patient Registration

D. Graphical user interface

The GUI is made up of a storyboard interface builder,a set of actions, and processes to interactively display and process the data between the system and the user[23]. The system interface has several pages, including registration, login, patient registration, and home page. There is also a sub-page that will graphically display the patient's vital signs, as well as Pop-up information, where the user can select one or more vital signs to display individually for the patient. In the following sections, we will describe interface pages according to the selection[23].

1) Home page

The "Home Page" allows to display all the necessary information for all patients and users provided by the system(such as patient's name, age, etc.) [23]. In addition, the system can provide a separate display feature for each patient [24]. By clicking on the name of a particular patient, an interface will display the name of a specific patient and the last reading of his vital signs, as shown in Fig. 7



Patient Name	Age	Temperature	Oxygen Level	Heartbeat	Distance(m)	Bracelet	DateTime
patient2	54	36.61 °C	95.0 %	80	1.0	2	2022-05-25 20:43:32
Test2	45	36.57 °C	129.0 %	42	1.0	2	2022-05-26 02:32:11
patient1	34	36.53 °C	96.0 %	75	1.0	1	2022-05-26 02:33:39
patient3	22	36.53 °C	96.0 %	76	1.0	3	2022-05-26 02:33:47
jack3	33	36.53 °C	94.0 %	81	1.0	3	2022-05-26 09:27:04
jack1	43	36.55 °C	94.0 %	77	1.0	2	2022-05-26 09:28:01
jack2	54	36.53 °C	94.0 %	76	1.0	1	2022-05-26 09:28:38

Fig. 7 System Home Page

2) User Registration

Users' personal information is typically gathered via a series of screens, forms, and profiles upon registration [23]. When registering for a new account, the user is often required to enter a username and a password, and to answer some security questions. Complete identities, usernames, passwords, and roles in the system are needed for registration in the system as shown in Fig. 8.

Fig. 8 User Registration

3) Patient Registration

The patients will be registered in the system with all needed information like full name, age, gender, bracelet number that will be given to the patient, and the entry date, as shown in Fig 9.

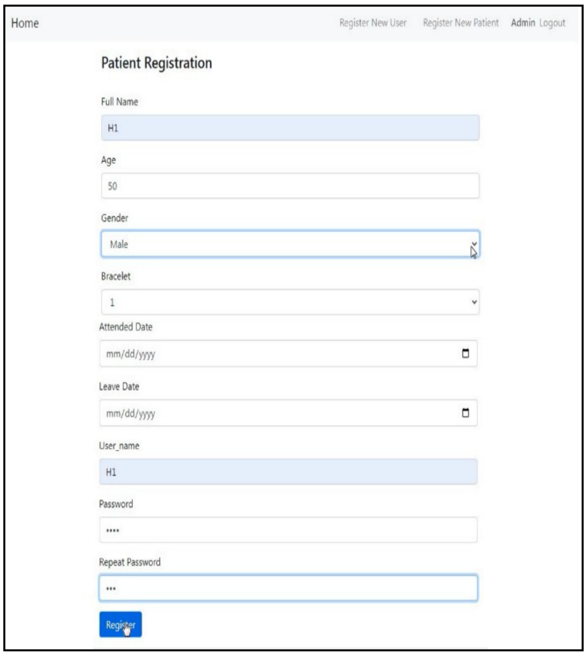


Fig. 9 Patient Registration

4) Display the vital signs

This page displays the vital signs measurements graphically, for each patient separately [24]. By clicking on the name of the patient, a graphical vital signs measurement will display all the vital signs that are measured by the system for the patient.

In the Fig.10 the measurement starts with the date of entry into the system until the day of the report.

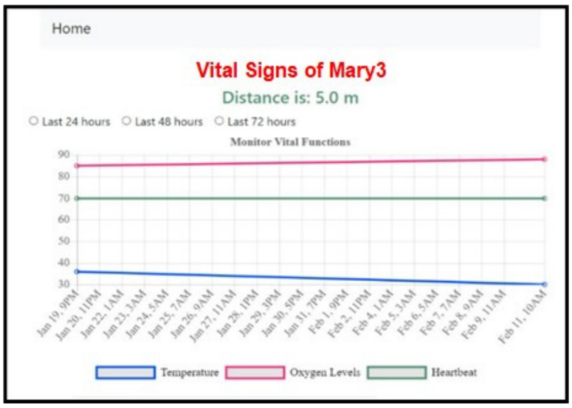


Fig. 10 Display Vital Signs

Moreover, the user can choose the specific vital signs they want to display by clicking on the button at the bottom of the vital signs page. That will determine which vital signs will disappear. By clicking on the virtual button for a certain vital sign atthe bottom of the page, the user can isolate the graph of vitalsigns and display only the selected vital sign. Fig. 11, and Fig.12. are captures of the system.

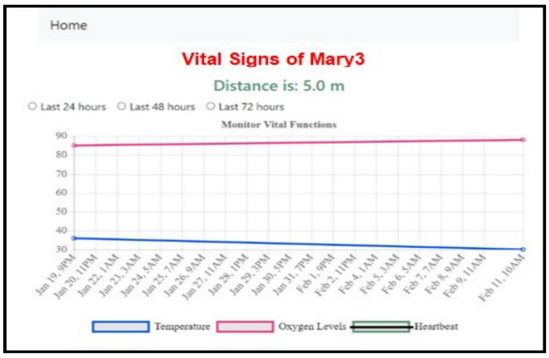


Fig. 11 Oxygen and Body Temp.

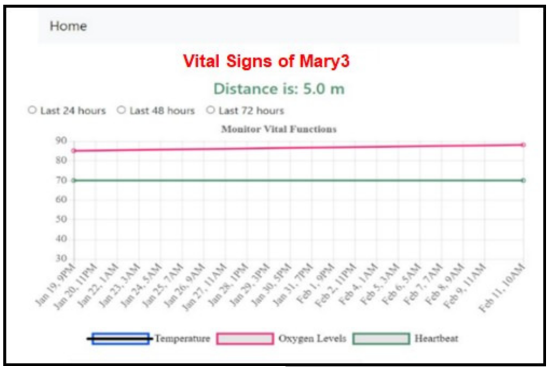


Fig. 12 Oxygen and Heart Rate

The system can arrange the vital signs as periods of (24, 48, and 72 hours), by choosing radiobuttons (shown in the upper side of the figure), to give the physicians and the medical staff a clear image of the patient's status for that period, as shown in Fig. 9.

a) Pop-up information

A short description of a particular vital indication will appear in a pop-up window by pointing the mouse to a specific position on the graph line in the vital signs interface. This will show "the value, its time, and the date," as shown in Fig. 13

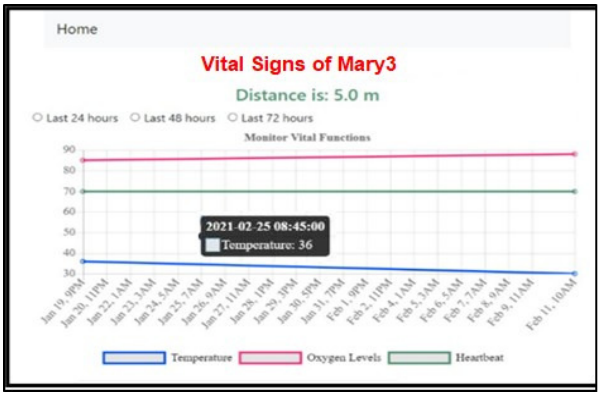


Fig. 13 Pop-Up Message

V. CONCLUSION

In the coming years, "IoT" technology will certainly evolve, and many additional systems will appear, especially wearable equipment. As a result, this prototype reviewed the software aspect of a health monitoring system which was built based on "IoT". This paper discussed the software component of a proposed system that monitors patients' vitalsigns within the quarantine zone Cov-Care. The proposed system assists healthcare practitioners to continuously monitor, diagnose, and direct their patients while ensuring patient privacy and comfort. The software side of the proposed system has been designed to satisfy all functions and operations of the system. The steps of the system software have been explained in detail for all parts of the system, beginning with sensors and ending with displaying the vital signs by the user interface. The proposed system could automatically configure and send text messages using GSM technology to:

- **Physician**, when one or more vital signs reach a critical condition.
- **Authorized personnel,** if a disconnection occurs between the bracelet and the base control unit, or one of the quarantine conditions has been violated.

In this paper, we try to implement a program that uses synchronous programming languages, physical operating systems (microcontrollers, sensors), and networks to provide basic frameworks that enable us to transfer data in real-time. A database was created to store and organize patient information, and user interfaces have been designed to manage user interactions. The system is energy efficient, easy to use, fast, with acceptable accuracy, and efficiency. Finally, a field test will be conducted to verify the reliability and validity of the system, as well as to prove that the system can generate medical data with readings like those generated by conventional medical equipment. This paper concentrates on healthcare deployed in real-time in the Iraqi medical health environment, specifically remote monitoring of COVID-19 patients. The system will be tested on a real sample of patients within the Iraqi environment to demonstrate its effectiveness in comparison with calibrated medical equipment, in order to become a scientific method that ensures credibility for the obtained results.

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