IoT based monitoring and tracing of COVID-19 contact persons

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ABSTRACT

The difficulty of identifying the COVID-19 cases before the symptoms of the disease appear is the major reason behind the increase in the number of infected people. The symptoms take from one day to fourteen days on average to appear; thus, an asymptomatic person can transmit the disease to several individuals before realizing that. The existing solution currently used in Oman is epidemiological investigation teams that collect information from infected people. Those teams aim to put people that had close physical contact with a sick person in quarantine. The success of this method depends on the infected individuals' ability to remember people with whom they had contact within the last fourteen days before becoming symptomatic. Also, the infected person might be in a critical health situation. Therefore, this paper's goal is to provide a small device that makes a list of people that had contact with an infected individual. When two individuals have this device and get close to each other (within two-meter or less), each device will automatically record the data of the other device (name, day, and time) for fourteen days and upload it to the IoT platform. In case a person, who has the device, gets COVID-19, the health authority will use that list of people to inform them that they had contact with an infected person and advise them to self-isolate. Besides, the device has sensors to record three vital factors that are temperature, blood pressure, and oxygen levels in the blood since coronavirus affects these factors. The IoT platform is utilized to analyze these sensors' readings and predict if a user is likely infected by COVID-19. The device contains a GPS module (NEO-6M) that is connected to the programmed Arduino Uno to calculate the distance between devices. The devices are connected using a wireless connection by using an RF transmitter-receiver module (433MHz). Also, it has an oxygen sensor (MAX30100), infrared temperature sensor (MLX90614), and a blood pressure device (SUNROM 4118). Besides, a Wi-Fi module (ESP8266) is used to connect the system to the IoT platform.

Introduction

Currently, Coronavirus disease 2019 (COVID-19) dominates in all countries over the world. It is the sixth pandemic witnessed by humanity after the last outbreak of Pandemic flu (H1N1) in 2009. All governments over the world work to limit the increase in the number of infected people by COVID-19. This virus causes 3% of death of the total recorded cases, which reached more than 72 million until the beginning of December. The main problem of the COVID-19 virus is the fast ability to transfer from an infected person to a healthy one. Besides, the appearance of the COVID-19 symptoms takes few days to 14 days from the first day of infecting the body. Therefore, the sick person can transfer the virus to several people before knowing that he/she was infected with the virus. The idea of this project is to design a device that makes a list of people whom a person contacted within two meters or less. In case any person gets sick by COVID-19, the health authorities can return to the database to know all individuals in contact with the infected person and order them to stay self-isolated. The device contains three sensors (temperature, blood pressure, and Oxygen) that indicate the probability of being infected with COVID-19 by using an IoT platform to analyze the sensors readings.

Background information

Throughout history, several infectious diseases caused by viruses had appeared in different periods. The most popular diseases from the oldest to newest that killed more than one million people are Spanish flu (H1N1) from 1918 to 1920, Asian flu (H2N2) started in 1957 to 1958, Hong Kong flu (H3N2), which went on for two years (1968 and 1969), and Pandemic flu (H1N1) in 2009 (Liu, Kuo and Shih, 2020). Currently, COVID-19 or Coronavirus disease 2019 dominates in all countries over the world. It considers the sixth pandemic witnessed by humanity.

On 1 December 2019, Wuhan City in China registered a group of people suffer the same pathological symptoms which are dyspnea, fever, dry cough, and malaise. The health sector in china had rated this disease as pneumonia caused by a kind of uncommon virus. This disease is kept secret by the Chinese authorities without tells the World Health Organization (WHO). At the time, the Chinese press called this disease Wuhan pneumonia referring to the city that the disease appeared in. After the disease had spread more and been out of control, the Chinese authorities formally notified the World Health Organization (WHO) about the disease on 31 December 2019 (dos Santos, 2020).

On 10 January 2020, the disease started to spread outside China and registered four infections were registered in Thailand, South Korea, and Japan (Liu, Kuo and Shih, 2020). On 12 January 2020, WHO called the disease Coronavirus (2019-nCoV). On 11 February 2020, the official name has been adopted for this disease by WHO, which is coronavirus disease 2019 with shortcut COVID-19. Normally, the virus and the disease, caused by that virus, have different names. The International Committee on Taxonomy of Viruses (ICTV) is responsible for naming viruses depending on the genetic building. Therefore, it launched the name SARS-CoV-2 to the virus that causes COVID-19. The SARS name comes from the SARS virus that was found in 2003, which has the same genetic structure as the COVID-19 virus. On 11 March 2020, WHO was considered COVID-19 disease as a global pandemic (WHO, 2020).

Theories that state "bats are the reasonable cause of COVID-19 disease" are closer to the truth because bats are the natural host of several viruses, and SARS-CoV is one of these viruses. Also, the people of China are passionate about eating wild animals. The Bat-CoV virus was detected previously in bats in Yunnan Province, 1500km away from Wuhan City. This virus has a similarity percentage of 96.2% in genes with the SARS-CoV virus. Thus, this confirms the acceptability of this theory (Yesudhas, Srivastava and Gromiha, 2020).

The number of COVID-19 cases is still on the rise and is different from one country to another due to the population number, healthcare, and people's awareness. Currently, the United States, India, and Brazil top the list of the highest cases and deaths by COVID-19. Until January 2021, Oman registered more than 125 thousand cases and more than 1400 deaths (Worldometers, 2020). Scientists and researchers in the field of medicine are working to find a vaccine for this virus. Unfortunately, there are few expensive approved vaccines as of this period. Several types of research and innovations were done to reduce the spread of COVID-19. Tarasod application is one of these innovations that used to monitor the patient and ensure their involuntary commitment to quarantine. However, there is no device or application used to know all people in contact with the infected person before symptoms appear. Therefore, this paper is created to contribute to reducing the number of COVID-19 infections. Besides, it has three sensors (temperature, blood pressure, and Oxygen) used to predict likely individuals infected by Covid-19.

Methods

The methodology used in this paper is the V-Model method. This method was chosen because it fits projects that have software processes and hardware due to its flexibility. It will be more helpful in this project because of the number of components that need to be programmed. If any component does not work properly, V-Model allows the return to a previous stage in case a problem happened in the current stage (Tutorialspoint, 2020). Therefore, this advantage in V-Model will help to check any problem that occurred in the previous stages. Also, it is considered the best method for a project that is limited by time like graduation projects that have a strict deadline (Airbrake, 2020). Also, the testing process (designing and planning) occurs before the coding process as required in this project.

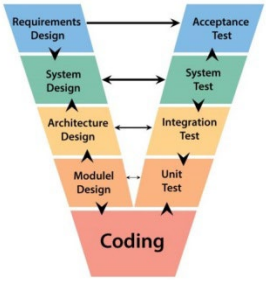

Figure (1): V-model Structure (Tutorialspoint, 2020)

Figure (1) shows the V-model, which is known as the Verification and Validation model. The verification phase locates on the left side of the V shape, which is started from the requirements design stage until the module design stage. The validation phase starts from the bottom right side of the V shape and ends at the top right side of the V shape. The validation phase contains the unit test, the integration test, the system test, and the acceptance test. Verification and validation phases are separated by the coding stage, which is used to choose the suitable programming language according to the project system requirements.

As referred to previously, the V-model methodology is used in this paper. Each stage shows the procedures and processes that are planned to complete this project as shown below.

- The verification phase.

- The requirements design stage: all basic requirements were chosen and analyzed. The project needs Arduino, GPS module, Wi-Fi module, temperature sensor, oxygen sensor, blood pressure sensor, a transmission module, and a receiver module. The information and the working principle of components were collected by using datasheets and internet websites.
- The system design stage: the communication setup between components and defining the inputs and outputs requirements were achieved with the help of a block diagram. Besides, a flow chart is used to explain the sequence of the processes flow when the system is running.
- The architectural design stage: the system was divided into two parts. The first part is devices to devices communication. It is used to make the device able to record the information of another device if the distance is within two meters or less. The second part is sensing some vital factors in the human body (temperature, oxygen, and blood pressure) that affected by the virus. All information will transfer to the IoT platform.
- The module design stage: the relations and connections between all modules are implemented by making the circuit diagram. Therefore, the circuit shows the order in which each component interacts with another component. Besides, it shows the role of each component in the project system.

- The coding phase.

  The C++ language is the coding language used for programming the whole system. This language was chosen because it is commonly used for programming Arduino.

- The validation phase.

- The unit testing stage: The C programming is written for each module to connect them with Arduino. Besides, testing will take place in this stage to check if the function of each module is suitable as the project designed.
- The integration testing stage: connecting all modules in each part of the system together (detecting near people, and collect the data of temperature, oxygen, and blood pressure), and the coding is written to make all part works as a whole system. Also, the test is performed to investigate if both systems work properly.
- The system testing stage: write a code to make the two parts working synchronously. Besides, the whole system is tested several times to check if it works appropriately and compatible with the project target.
- The user acceptance testing stage: the whole system is tested practically and in a real work environment by giving this device to a group of people. The purpose of this step is to check if the device functions work under different environments and the device takes the required reading properly.

Literature review/theory

This section discusses five articles about paper and system that were designed to fight COVID-19 spread.

Title, author and year	Concepts, approach, methods, analysis adopted	Inconsistencies, gaps, contradictions, differences	Improvements
Role of IoT to avoid spreading of COVID-19 (Kumar, Kumar and Shah, 2020)	IoT was used to reduce the spreading of COVID-19 by connecting several sensors or devices (infrared, IR Sensor, smartwatch, optical camera, IP Camera) with a cloud gateway. All data collected from sensors or devices analyzed to identify the infected person. Besides, some devices were used to help with social distancing and reduce touching surfaces.	The infrared camera working method was explained in detail without mention the working principle of other devices and sensors.	The working method of IR Sensor, smartwatch, optical camera, and IP Camera in the suggested system is needed to mention in detail by providing a flowchart or circuits.
Real time Geolocation Tracking by using GPS+GPRS and Arduino based SIM908 (Koyuncu, Panahi and Meral, 2020)	The GPS module (SIM908) is used to identify and track the target every 30 seconds with the accuracy of positioning reaches from 2 to 4 meters. The target coordinates are displayed on the phone screen.		
IoT-based System for COVID-19 Indoor Safety Monitoring (Petrovic and Kocić, 2020)	The system depends on IoT is used to reduce the spread of COVID-19 in closed places. This system uses a thermal camera or infrared sensor to sense the temperature of the individuals and a camera to check the social distancing and wearing a face mask.		
COVID-19 knowledge-based system for diagnosis in Iraq using IoT environment (Nema, Mohialden, Hussien and Hussein, 2020)	A knowledge-based system is used to identify if the patient is infected by normal influenza or coronavirus. Besides, the system sends a notification to the health authority in case a patient has been infected by COVID-19. The patient data (name, location, and date of examination) is sent to the health authorities to get medical assistance.	The diagnosis process to check if a patient has normal influenza or coronavirus is done only by asking some questions. Therefore, this method is likely to be inaccurate to detect infections with Coronavirus.	The accuracy of the system can be improved to verify that the person has COVID-19 by adding some sensors.
Novel economical social distancing smart device for	The PIR sensor is used to monitor the social distancing by notifying the device user if	The PIR sensor detects any moving object, for example animals or cars.	Using a camera to detect human bodies

COVID19 (Nadikattu, Whig and Mohammad, 2020)	a person is less than six feet away from the user	Also, the sensor cannot detect individuals if they are stationary.	is more accurate than using a PIR sensor.

System design and analysis

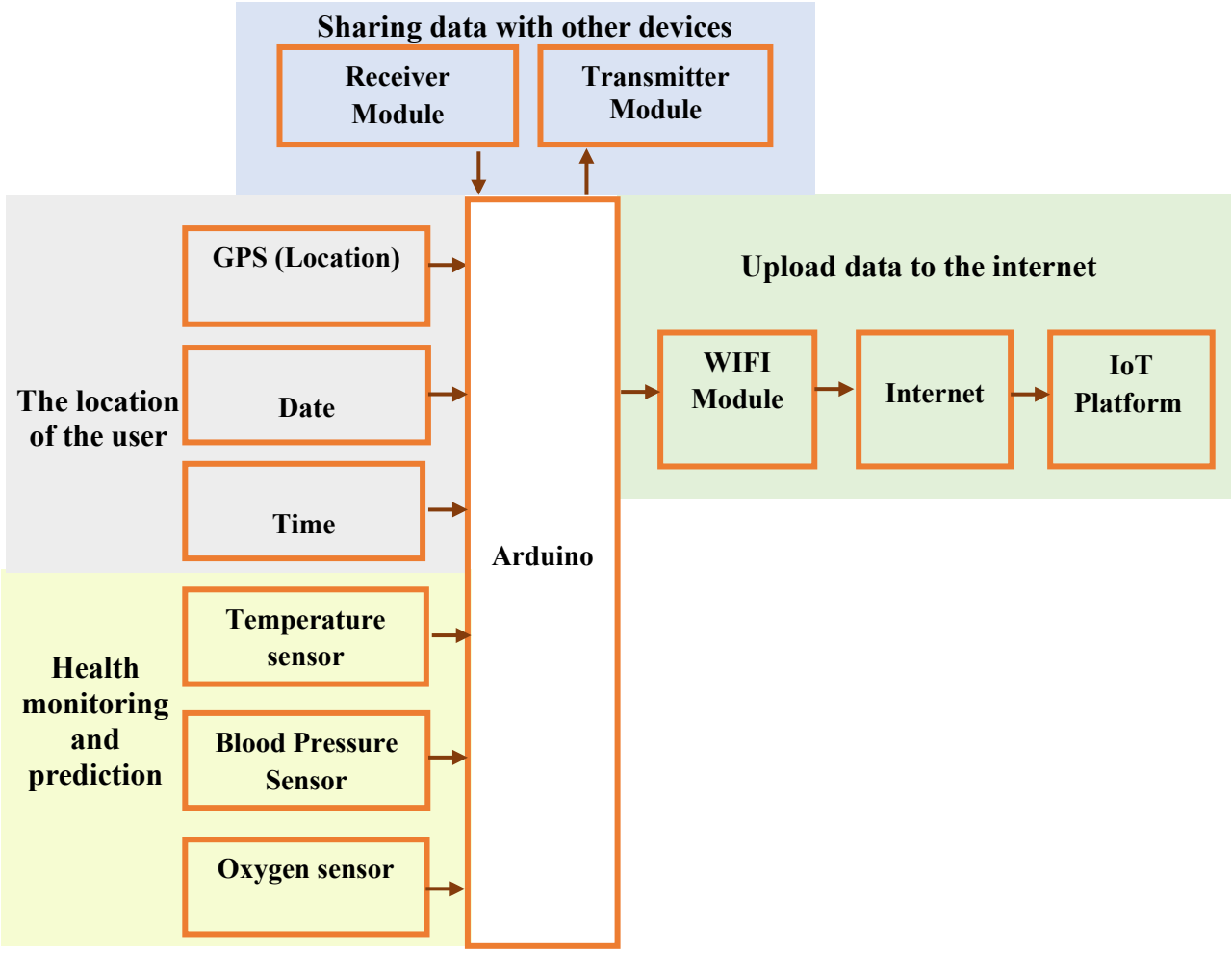

Figure (2): Block Diagram of the System

The Block diagram of this paper is shown in figure (2). The system contains five parts. The part of the location provides the location (coordinates) of the user in real-time by using the GPS module connected with Arduino. At the same time, each update in the user location will contain the date and time. The sharing data part will transmit the information recorded from the last part to other devices by using the transmitter component. Besides, the receive module that is connected to Arduino will receive the location data of other devices. This process aims to record the details (name, date, and time) of users' devices if the distance between them two meters or less (social distancing). The health monitoring and prediction part have three sensors (temperature sensor, blood pressure sensor, and oxygen sensor) that are connected to Arduino to detect three vital signs in the human body that the coronavirus affects. All collected data from sensors and any information of non-committing to a social distancing between the users of the device will upload to the IoT platform by using the Wi-Fi module.

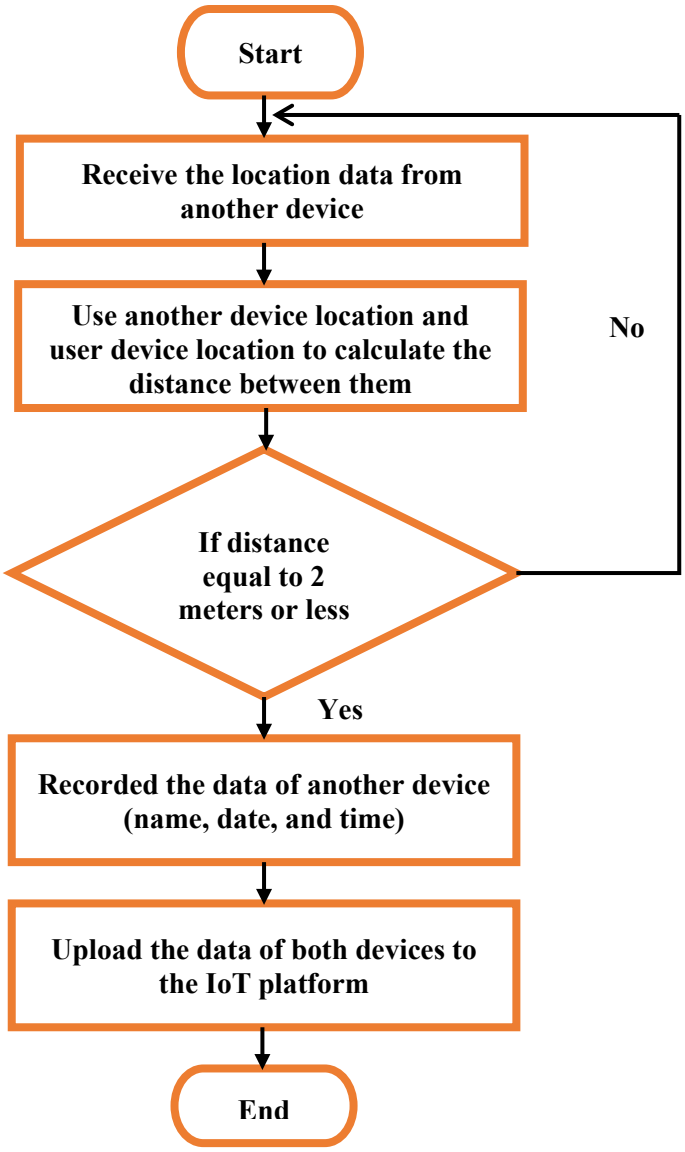

Figure (3): Flow Chart of Registering the People That the User Has Contacted within 2 Meters or Less

Figure (3) shows the processes sequences of the system. This part responsible for making a list of people that the user contacted within two meters or less. When another device enters a user's device connection field, the location (coordinates) of the other device will send automatically. The received device will count the distance. If the distance between two devices two meters or less, the data of both devices (name, date, and time) will upload to the IoT platform directly. Otherwise, if the distance is higher than two meters, the system will not upload the user's data.

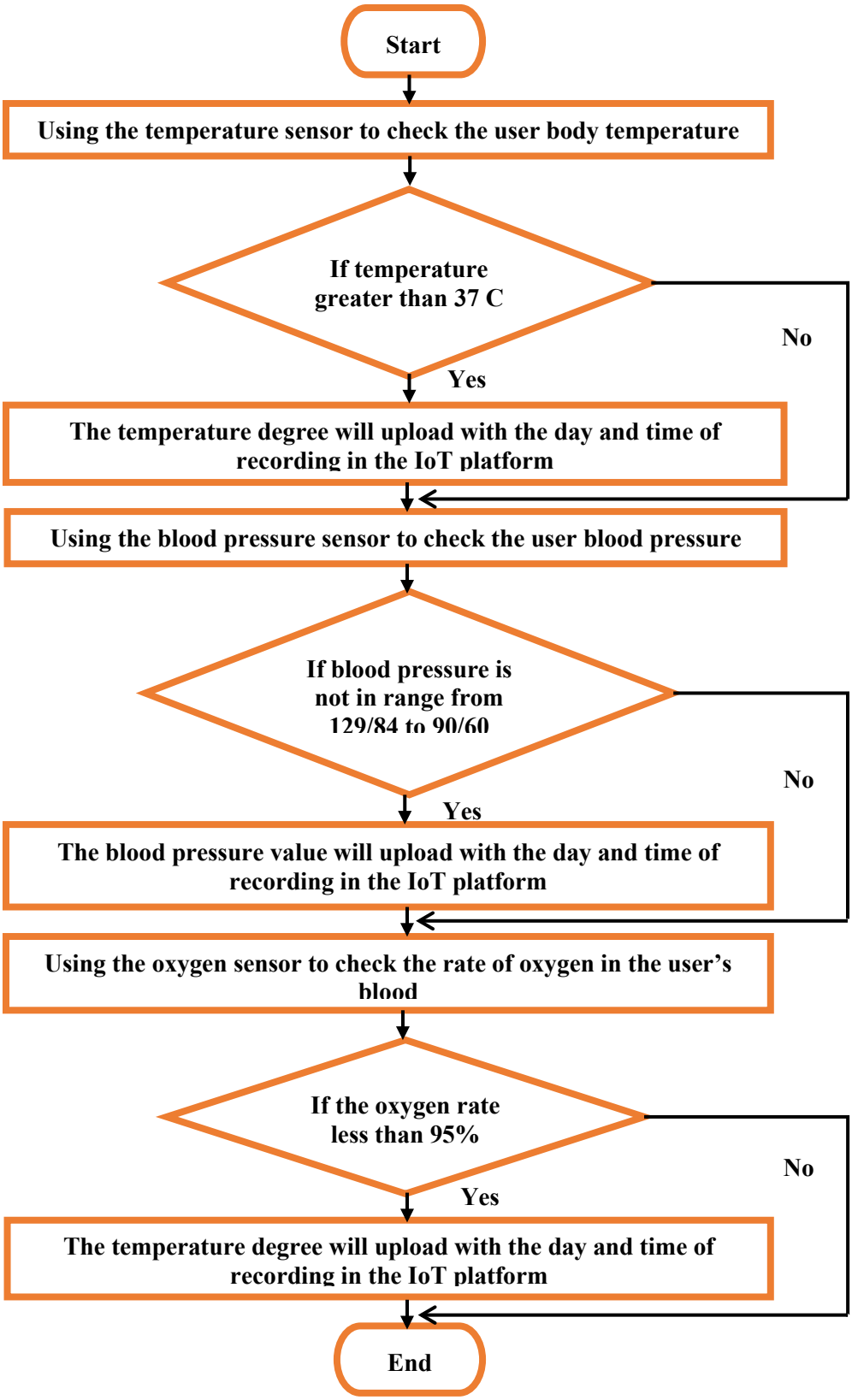

Figure (4): Flow Chart of Reading the Vital Signs Values in the User's Body That the Coronavirus Affects

The flow chart shows the process sequences of reading vital signs in the human body that COVID-19 affects in figure (4). This part of the system contains three sensors which are a temperature sensor, blood pressure sensor, and oxygen sensor. Any user of the device can use this part when feels the symptoms of flu or to monitor his/her health condition for any cases. This subsystem starts by check the user's temperature body by using the temperature sensor. If the body temperature is above 37°C, the temperature data will be uploaded to the IoT platform with the date and time of checking the temperature. Otherwise, the system will leave the next stage, and it will go to the blood pressure sensor stage without upload any data to the IoT platform. The next stage contains a blood pressure sensor to check if the blood pressure is normal or not. In case the blood pressure is not in the range from 129/84 to 90/60, the value of blood pressure will be recorded automatically in the IoT platform. However, if the blood pressure is in the normal state, the system will go to the oxygen sensor stage. The oxygen sensor stage will check the oxygen percentage in the user's blood. The oxygen in the blood is considered a non-normal value when the oxygen in the blood is less than 95%. Therefore, the system will record this value in the IoT platform. But if the oxygen in the blood is equal to or greater than 95%, the system will end the process. In the IoT platform, all readings of the sensors will be analyzed to decide if the user likely has COVID-19 or not.

Simulation

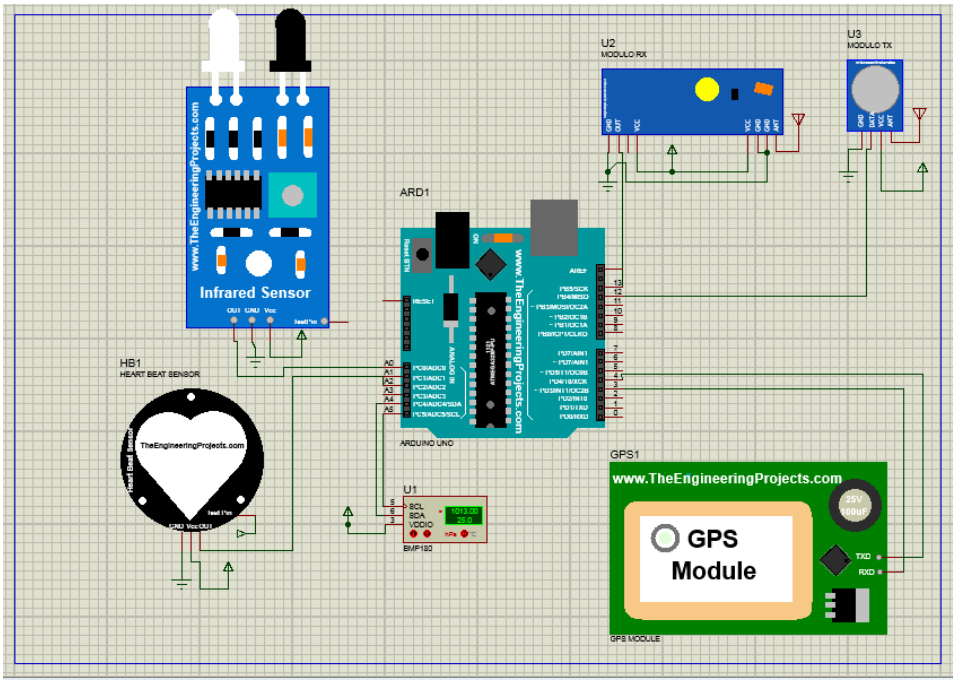

Figure (5): The System Circuit Simulation

Figure (5) shows the simulation of the paper circuit by using the Proteus program. In the simulation, the IR sensor is used to detect motion was used rather than the infrared temperature sensor due to unavailability in this program. Also, the IR sensor has the same working principle as the infrared temperature sensor that depends on infrared. Furthermore, it consumes the same voltage (5V) and provides an analog signal. The blood pressure sensor (SUNROM 4118) is not available in the software. Therefore, it was replaced by the BMP sensor which measures the atmospheric pressure. However, the BMP sensor provides an analog signal, which is not the same as the blood pressure sensor which provides the digital output signal. The oxygen blood sensor (MAX30100) is used also for measuring heartbeats. Therefore, it is labelled by heartbeats sensor in the simulation. The Wi-Fi module (ESP8266) was not used in the program because the designers of this program did not design the Wi-Fi module (ESP8266) due to its operation complexity. All connection between the circuit components was created as explained in the initial condition and input and output parameters parts. However, applying the testing on all components is challenging because some components (infrared temperature sensor and blood pressure device) are not available in this software and the replaced components give different outcomes than required results in this paper.

Conclusion

Scientists, and engineers around the world work on innovating solutions to reduce the impact of COVID-19 on societies. Therefore, this paper was designed to contribute to limiting the spread of the disease. This paper provides a device that identifies people with whom an infected person contacts within two-meter or less before the symptoms of the disease appear. The device contains Arduino Uno programmed to calculate the distance between devices depending on the coordinates provides by a GPS module. Besides, it has sensors that sense three vital factors, which are temperature, blood pressure, and oxygen levels in the blood. All data collected by the device are analyzed using the IoT platform to predict if a device's user has COVID-19 depending on sensors' readings. The V-Model method was used to achieve the objectives of the paper which is characterized by testing the system after each stage of the project. Five articles were studied in the literature review section to overview previous projects in order to develop and enhance the outcomes of this paper. The block diagram and flowchart were applied to show the principal functions of each component and describe the sequence flow of the system's process. Finally, the system was simulated using Proteus software.

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