covIoT: Integrated Patient Monitoring And Sanitization System

Arushi Jain
Dept. of Computer Science and Engg.
Vellore Institute Of Technology
Vellore, India
arushijain1479@gmail.com

Janvi Prasad
Dept. of Computer Science and Engg.
Vellore Institute Of Technology
Vellore, India
janvi.prasad@gmail.com

David B.A. De V. Velho
Dept. of Computer Science and Engg.
Vellore Institute Of Technology
Vellore, India
davidvelho0603@gmail.com

2022 International Conference on Communication, Computing and Internet of Things (IC3IoT) | 978-1-6654-7995-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/IC3IOT53935.2022.9767863

***Abstract*—COVID-19 is a global pandemic afflicting our society. We propose covIoT, a novel Arduino-based automatic hand sanitizer dispenser, integrated with an oximeter, a heart rate monitor, a non-contact body temperature sensor, and voice assistant feedback. This system can be deployed as an end-to-end COVID patient monitoring system and also for automated sanitization. The system was tested on 100 people to evaluate its performance. The mean absolute error and root mean square error values were found to be 0.79 and 1.03 for the oximeter, 1.22 and 0.70 for the heart rate monitor and 1.07 and 1.28 for the body temperature monitor, respectively, compared to the industry-standard devices. These low error values indicate the high accuracy of our proposed system. We believe this is the first low-cost integrated patient monitoring and sanitization system with vocal feedback, to increase accessibility and ultimately helps combat the virus.**

***Index Terms*—Patient monitoring, Automatic hand sanitizer dispenser, COVID-19.**

I. Introduction

People throughout the world have been impacted by the pandemic. The virus is unpredictable and can mutate itself, due to which there can be a new variant of the virus that can result in a sudden spike in the number of cases [1]. The World Health Organization (WHO) suggests an approach that includes social distancing, wearing a mask, good ventilation and cleaning hands regularly using an alcohol-based sanitizer to stop the virus from spreading [2].

In the previous COVID-19 waves, it has been observed that a sudden rise in the number of cases causes staffing shortages in hospitals as healthcare professionals get exposed to the virus or other illnesses, or need to care for family members at home [3]. This increases the stress on the other healthcare professionals [4]. Hence, healthcare facilities must be prepared for potential staffing shortages in the future and have plans to mitigate these shortages. To help the frontline workers, an integrated patient monitoring system has been proposed by us. This was the motivation behind our problem statement.

covIoT is an integrated patient monitoring system that includes five major components: An automatic hand sanitizer dispenser, with a heart rate monitor, body temperature sensor, oximeter, and a voice assistant feedback. The primary focus is to design and develop an integrated patient healthcare system that works as a complete package for the healthcare of COVID-19 patients. covIoT helps patients monitor their heart rate, body temperature, and blood oxygen levels (SpO2) in an integrated manner. It has an automated hand sanitizer dispenser that patients can use before and after checking their vitals to ensure that the next patient utilizing the healthcare system gets a completely sanitized system. Using the automated hand sanitizer also reduces the chances of cross-contamination. Additionally, we have a novel voice assistant feature that makes the system more accessible, it gives feedback to the user based on the readings in the form of whether the user is at risk of getting COVID-19.

The automated hand sanitizer and voice assistant feedback can be used separately in public places. Most public places have a hand sanitizer dispenser that can be used manually, or a person specifically appointed to measure the temperature of every person entering a mall or a restaurant using a temperature gun and ensuring that everyone is sanitized before entering a store. As this system causes cross-contamination and increases the risk of spreading the virus, our automated hand sanitizer can replace the current system. A few automated sanitization systems already exist, but our system's novelty is the voice assistant feedback that works along with the automated hand sanitizer dispenser.

The rest of this document is laid out as follows: A survey of recent work done in developing patient monitoring systems is presented. Next, a detailed description of our system is provided. Our system's performance is analyzed by comparing its results with industry standard devices. Finally, the future scope of work has been identified.

II. Literature Survey

There are multiple projects that have demonstrated an automatic hand sanitization technique using Arduino and ultrasonic sensors [5]- [13]. Sitompul et al. [5] proposed an Arduino UNO-based contactless sanitization system using an infrared sensor for detecting the person's hand. Long and Guangli [6] have proposed an infrared, non-contact human body temperature sensor that has a measurement error of less than 0.5°C. Sumbawati et al. proposed a system [7], in which the main control is an Arduino Nano microprocessor, with a human hand detection sensor and a servo motor acting as an actuator. Lee et al. [8] built an automated sanitization tool that works with a variety of sanitizer containers, thus users need not buy a new liquid container when they change their hand sanitizer. Wanarti et al. [9] proposed a system where the automatic sanitizer system will send an alert to the user's smartphone every time the liquid in the sanitizer dispenser runs out. The analysis reveals that the system operates with a low data transfer detection error. In [10], an Arduino Nano has been used as the microcontroller, a servo motor has been used as the motor, an ultrasonic sensor has been used to detect movement from the surroundings, and a rack and pinion system has been used to press the nozzle from the hand sanitizer. In [11], the researchers have implemented an automatic hand sanitization technique using Arduino and ultrasonic sensor. In [12], a cost effective system based on the Arduino Uno microcontroller with infrared sensor is presented. [13] exhibited an innovative design for a low-cost, touchless, automated sanitizer dispenser for use in public spaces.

Integrated patient monitoring systems have also been proposed by many researchers [14] - [21]. In [14], a tool that comprises of an Arduino Nano, MAX30100 sensor to measure SpO2 and heart rate has been developed. When compared with the standard devices, their system had a precision of 99.62% for SpO2 levels, 97.55% for heart rate, and 99.62% for body temperature. A portable pulse and temperature monitoring system based on an ATmega328 microcontroller has been described in [15]. Das, Alam and Hoque [16] have developed a pulse and body temperature monitoring device based on a microcontroller. Priyanka and Reji [17] developed a system which gave body temperature, heart rate using DS18b20 and pulse sensor as well. In [18], by using the LM35 temperature sensor, a microcontroller-based heartbeat and body temperature monitoring system has been built. [19] proposed an architecture leveraging low-cost real-time tool for measuring body temperature using the LM35DZ sensor. In [20], a portable device using IoT that can measure the patient's heartbeat, body temperature, blood pressure has been proposed. Taiwo and Ezugwu [21] developed a savvy home healthcare assistance system that allows users to monitor their vitals and get medications from doctors while staying at home.

III. covIoT: Detailed Architecture

Our system consists of the following components:

A. Automatic hand sanitizer dispenser

It is a device that dispenses a limited amount of hand sanitizer in a contactless manner. It conserves the quantity of sanitizer used and prevents infectious disease transmission. This contactless hand sanitizing machine is designed to nebulize alcohol or gel-based sanitizer that provides an automatic dosage of a drop, which enables easy hand disinfection. Also, it achieves optimal hand hygiene by eliminating cross-contamination.

B. Oximeter & Heart Rate Monitor

The oximeter is a device that monitors the oxygen level in a human body by having the patient place his / her fingertip on the oximeter. When the oxygen level goes below a threshold, medical attention is warranted. People impacted by COVID-19 can have irregular or high heart rates. Thus, patients are often recommended to measure their pulse rate on a regular basis to identify any aberrations from the normal heart rate.

C. Body Temperature Sensor

Non-contact temperature assessment devices have become a necessity during these times. These enable caregivers to read the body temperature of their patients while simultaneously maintaining a safe distance from the patients. Infrared rays from a body are focused on a detector by using a lens. Thus, the detector heats up and returns a temperature reading. These thermometers not only help in maintaining a safe distance from the patients but are also extremely accurate and faster in comparison to the traditional thermometers.

D. Voice Assistant and Feedback

A voice assistant feature is added to make the system more accessible. It provides guidance to users regarding the correct placement of their hands under the automatic hand sanitizer dispenser. It can read out the body temperature reading, heart rate reading and the oxygen level reading. Based on these readings, it gives feedback to the patient about the likelihood of having contracted COVID-19.

IV. System Description

A. Pin Configuration of the Arduino UNO

- Pin D9 is connected to the L and GND inputs.
- Pins D10, D11, D12, D13 are connected to the pins CS, SI, SO, SCK of the SD card module reader respectively.
- Pins SDA and SCL are connected to the SDA and SCL pins of the 128x64 OLED screen and the MLX90614 contactless temperature sensor.
- Pins A2 and A3 are connected to the ECHO and TRIG pins of the ultrasonic sensor.
- Pins A4 and A5 are connected to the MAX30102 sensor and the 128x32 OLED display as a shared connection.
- Pins D4 and D5 are connected to another ultrasonic sensor's ECHO and TRIG pins respectively.
- Pin D3 is connected to the IN pin of the relay.
- The 5V and GND pins are used to provide a common power and GND terminal.

The block diagram in Fig. 1 illustrates these connections.

B. Voice assistant module

This module consists of an 8 GB micro Secure Digital (SD) card, an Arduino SD card reader board, a PAM8403 amplifier board, and a speaker. The 8 GB micro-SD card is inserted into the SD card module and is also connected to the Arduino. Finally, the speakers are connected to the output of the PAM8403 circuit board, which is connected to the Arduino. The Arduino's 5V and GND are used for VIN and GND. A capacitor of appropriate capacitance between the L and GND of the PAM was inserted for volume control. With this reading provided by the temperature module, the Arduino

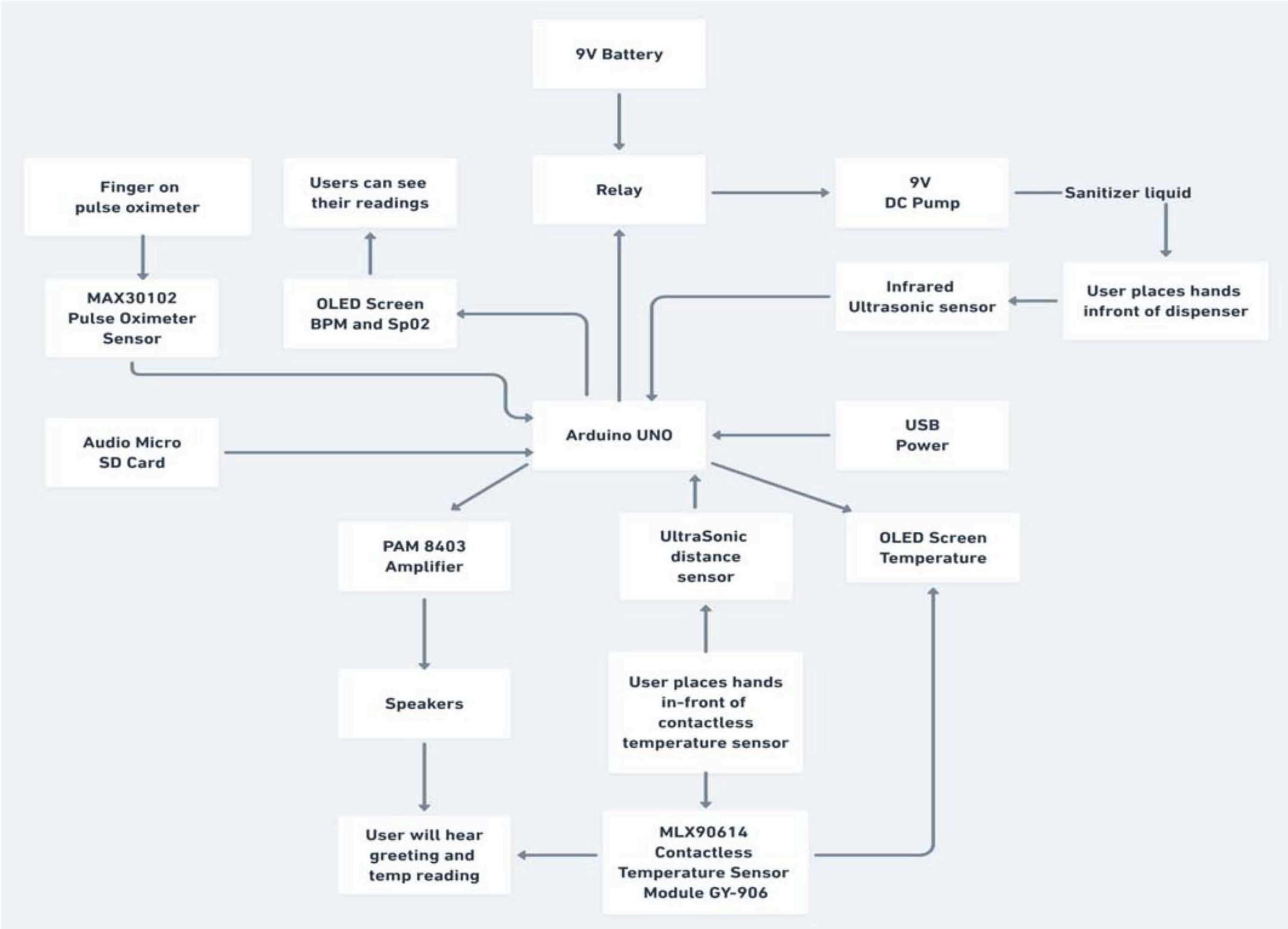

Fig. 1. Block diagram of covIoT

will use the SD card module to look for the file corresponding to the temperature reading of the user. These files are in 8-bit monotype waveform audio file format (WAV) and will be outputted as a waveform to the PAM chip, which amplifies it and plays it to a speaker. If the user's hand is farther than the minimum distance, we will hear, *"welcome to the temperature measuring system, please put your hand or forehead before the sensor about 2 cm"*. Once the user's temperature is read and is normal, they will hear, *"Your temperature is 36.5° C. Your temperature seems normal, so please keep healthy!"*

C. Pulse oximeter module

This module consists of a MAX30102 pulse oximeter and heart-rate sensor and an Adafruit 128x32 Organic Light Emitting Diode (OLED) display. The 128x32 OLED and MAX30102 are connected to the Arduino UNO and share the Serial Data (SDA) and Serial Clock (SCL) lines. The Arduino's 5V and GND are used for VIN and GND. The MAX30102 sensor works on the principle of photoplethysmography, which is an optical method to measure blood volume changes in tissue by illuminating the skin and measuring the changes in light absorption. It uses a reflective method where the Light-emitting diode (LED) and photo-detector are placed next to each other. The blood volume in the fingertip rises with each pulse, leading to an increased light reflection back to the sensor. A similar setup is used for detecting oxygen saturation. The sensor has two LEDs - a red LED with a wavelength of 650 nm and an infra-red LED with a wavelength of 950 nm. When a finger is placed on the sensor, the red and IR wavelengths change, and the sensor detects if a finger is present. It then calculates the heart rate and oxygen saturation per cycle and averages it out over a few seconds. These values are then displayed on the OLED screen.

D. Hand sanitizer module

This component, as indicated in fig. 3, comprises of an HC-SR04 ultrasonic sensor, a relay, a 9V pump, and the Arduino UNO. The Arduino is wired to the ultrasonic sensor, and the pump is wired to the relay. The battery's +ve terminal is connected to the relay's common (COM) terminal. The -ve of the battery and pump are connected. The +ve terminal of the pump is connected to the Normally Open (NO) relay terminal. The relay is then connected to the Arduino. The Arduino's 5V and ground (GND) are used for VIN and GND. The ultrasonic

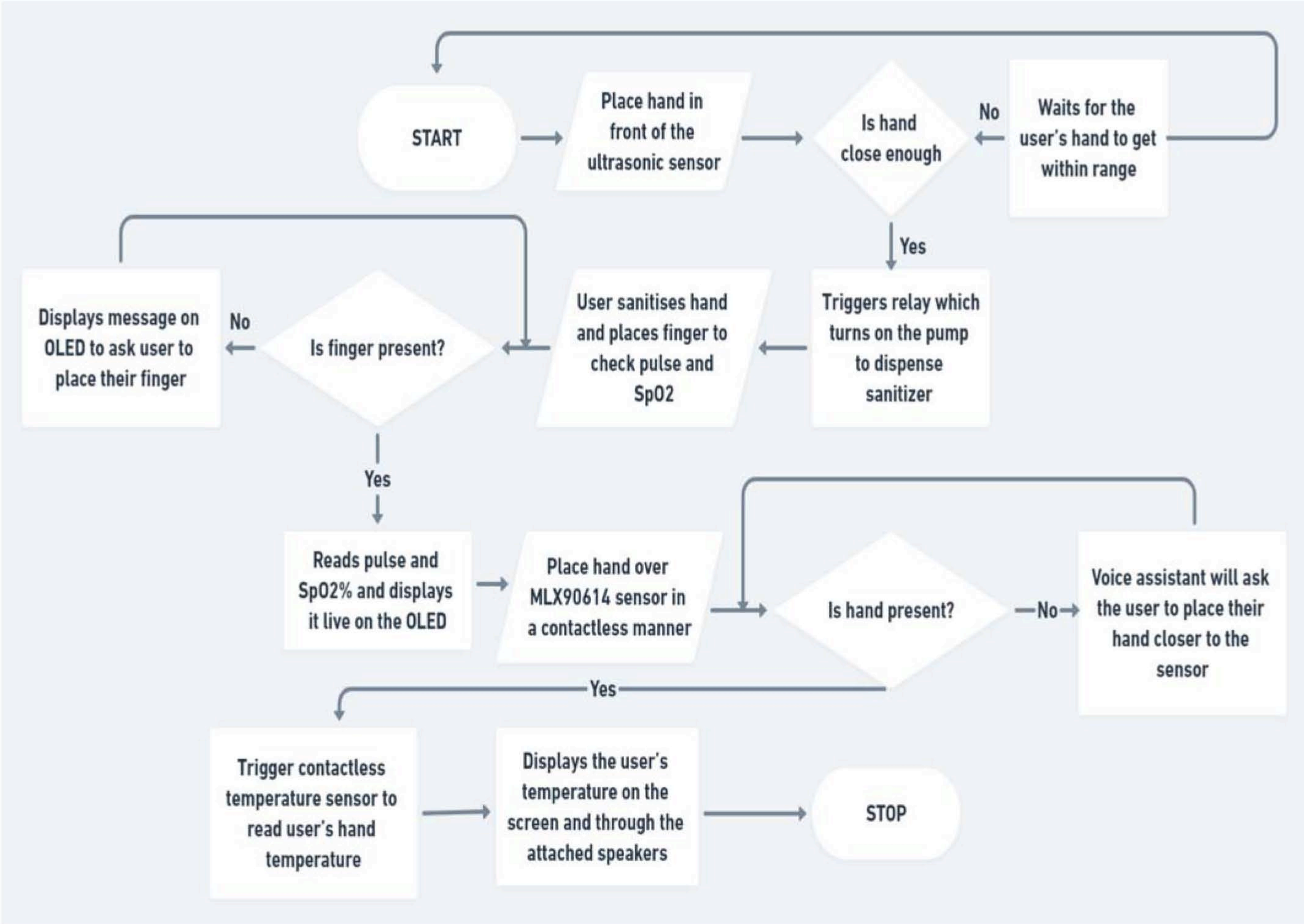

Fig. 2. Flowchart of covIoT

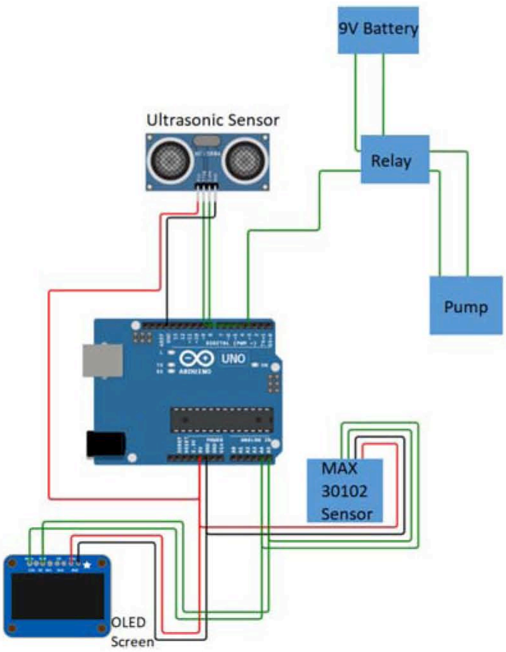

Fig. 3. Circuit Diagram of Hand Sanitizer Dispenser.

sensor will detect if the user's hand is closer than 5cm based on the time taken for an ultrasonic sound wave to travel back to the sensor after hitting the user's hand. If the user's hand is closer than 5 cm, the Arduino triggers the relay, which turns on the 9V pump to dispense hand sanitizer liquid. The relay is in the NO position, and the trigger from the Arduino causes the relay to close the circuit for 500ms, which causes the pump to run for 500ms, thus dispensing the hand sanitizing liquid.

E. Body Temperature module

Fig. 4 represents this module that consists of the MLX90614 sensor, an Arduino UNO, an HC-SR04 ultrasonic sensor, and a 128x64 OLED screen. The OLED screen and temperature sensors are wired to the UNO and share the SCL and SDA data lines. The Arduino's 5V and GND are used for VIN and GND. The user will place their hand over the ultrasonic sensor, which is placed near the contactless temperature sensor. As soon as a hand is sensed by the ultrasonic sensor, the Arduino will trigger the temperature sensor to retrieve the reading. This reading is displayed on the OLED screen. It is also sent to the voice assistant module for an audio message to be played.

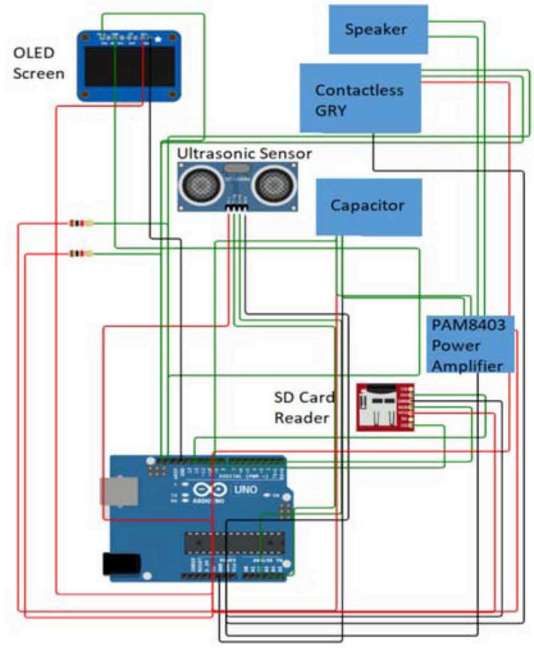

Fig. 4. Circuit Diagram of Temperature Sensor with Voice Feedback.

V. Results and Discussion

A. Testing the accuracy of the oximeter and heart rate monitor

To find the precision of the MAX30102 oxygen saturation and heart rate monitor, we compare its performance with the Zebronics pulse oximeter, an industry standard device. We tested our system on 100 users. The performance was analysed by evaluating the mean absolute error (MAE) and root mean square error (RMSE) values. While comparing the SpO2 levels, the MAE value for the MAX30102 sensor is 0.79 and the RMSE value is 1.03. While comparing the pulse rates, the MAE value for the MAX30102 sensor is 1.22 and the RMSE value is 0.70. These low error values depict the efficiency of our system. This shows that our system is highly comparable to industry standard devices. Fig. 5, 6 and 7 illustrate the results given by our system when compared with industry-standard devices, based on the tests carried out on 100 users.

B. Testing the body temperature sensor

The MLX90614 body temperature sensor was tested on 100 different people. These 100 patients' body temperature was also detected using Microtek IT-1520 contactless temperature gun, an industry standard device. Both of these values have been compared to evaluate the performance of our device. The performance is calculated by finding the MAE and RMSE values. The MAE value for the MLX90614 sensor is 1.07 and the RMSE value is 1.28. Both the MAE and RMSE can range from 0 to infinity. Hence, the low error values of our system indicates high accuracy. Thus, the performance of our device is optimal and is comparable to the industry standard device.

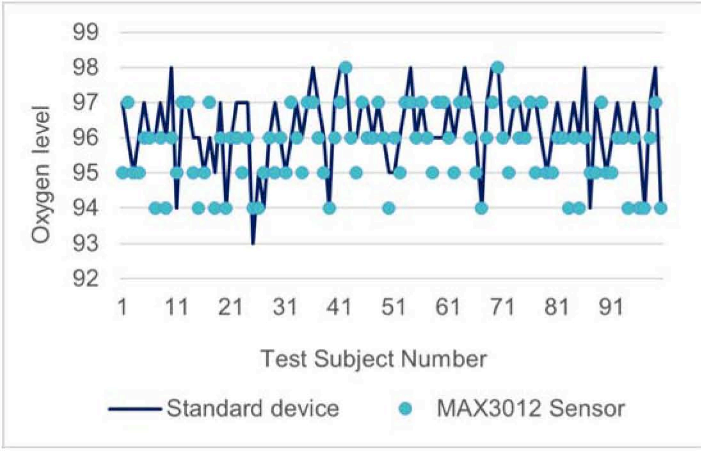

Fig. 5. covIoT oximeter vs Industry standard device.

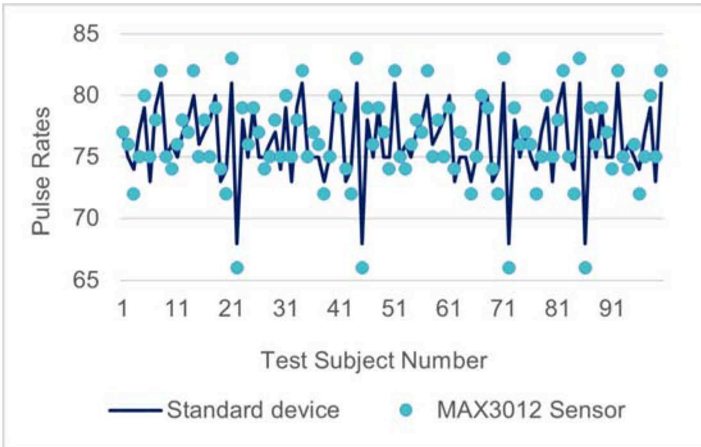

Fig. 6. covIoT heart rate monitor vs Industry standard device.

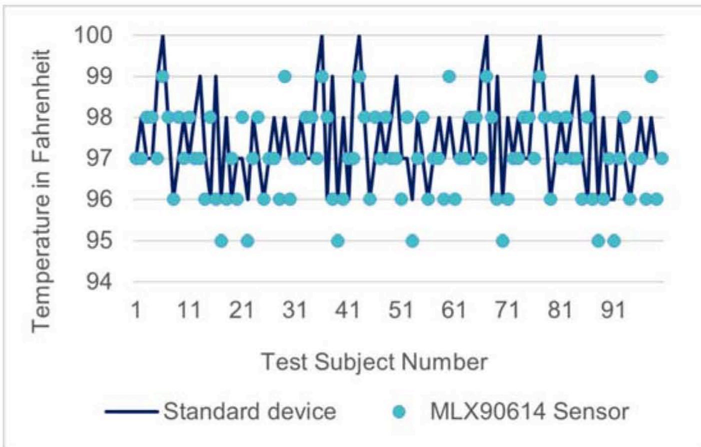

Fig. 7. covIoT temperature sensor vs Industry standard device

VI. Conclusion and Future Scope

This paper presents covIoT: an integrated patient monitoring and contactless hand sanitizer dispenser system with voice feedback. The system also includes an oximeter, heart rate monitor, body temperature sensor to measure a patient's vitals. The primary purpose of covIoT is to assist health care professionals and the frontline workers. This remote patient monitoring system has several use cases: It enables healthcare professionals at COVID treatment centers to measure and keep track of patients' vitals in an easy and contactless manner. Our hand sanitizer model can be used in public places, as it provides a contactless sanitization solution which makes it much safer. The system was tested on 100 people to evaluate its performance. The MAE and RMSE values were found to be 0.79 and 1.03 for the oximeter, 1.22 and 0.70 for the heart rate monitor and 1.07 and 1.28 for the body temperature, respectively, compared to the industry-standard devices. These low error values indicate the high accuracy of our proposed system. We believe this is the first low-cost integrated patient monitoring and sanitization system, with vocal feedback to increase accessibility, and ultimately helps combat the virus.

The system is designed with a focus on automation and high-accuracy. Storing the patients' data, with their consent, can enable the training of Machine Learning models to predict if a patient is safe or not based on their vitals. Leveraging IoT to connect covIoT with other internet-enabled devices can enable communication between various devices and help establish a much more comprehensive IoT-based healthcare system. This can also be used to build web-based dashboards for curating statistical evidence for reporting, monitoring, and analysis purposes. Ultimately, such a mechanism is critical in countering the virus' propagation.

References

[1] "SARS-CoV-2 Viral Mutations: Impact on COVID-19 Tests". Accessed on Jan 30, 2022. Available on: https://www.fda.gov/medical-devices/coronavirus-covid-19-and-medical-devices/sars-cov-2-viral-mutations-impact-covid-19-tests.

[2] "Advice for the public: Coronavirus disease (COVID-19)", Oct. 1, 2021. Accessed on Jan. 30, 2022. Available on: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public.

[3] "Strategies to Mitigate Healthcare Personnel Staffing Shortages", Jan. 21, 2022. Accessed on Jan. 30, 2022. Available on: https://www.cdc.gov/coronavirus/2019-ncov/hcp/mitigating-staff-shortages.html

[4] N. Salari, H. Khazaie, et al. "The prevalence of stress, anxiety and depression within front-line healthcare workers caring for COVID-19 patients: a systematic review and meta-regression." Human resources for health 18.1 (2020): 1-14.

[5] B. Sitompul, S. Solikhun, et al. "Design and build of automatic hand sanitizer using arduino." Eduvest-Journal Of Universal Studies 1.3 (2021): 119-127.

[6] G. Long, "DESIGN OF A NON-CONTACT INFRARED THERMOMETER." International Journal on Smart Sensing & Intelligent Systems 9, no. 2 (2016).

[7] M. S. Sumbawati, H. A. Chandra , et al. "Design Automatic Hand Sanitizer Microcontroller Based using Arduino Nano and Ultrasonic Sensors as an Effort to Prevent the Spread of Covid-19." International Joint Conference on Science and Engineering (IJCSE 2020). Atlantis Press, 2020.

[8] J. Lee, J. Y. Lee, et al. "Design of automatic hand sanitizer system compatible with various containers." Healthcare Informatics Research 26.3 (2020): 243-247.

[9] P. Wanarti, N. Nurhayati, et al. "Automatic Hand Sanitizer Container to Prevent the Spread of Corona Virus Disease." International Joint Conference on Science and Engineering (IJCSE 2020). Atlantis Press, 2020.

[10] J. Lesmana, A. Halim, and A. P. Irawan, "Design of automatic hand sanitizer with ultrasonic sensor." IOP Conference Series: Materials Science and Engineering. Vol. 1007. No. 1. IOP Publishing, 2020.

[11] P. Janga, M. S. Khan, L. Suneel, and M. A. Reddy, "Design and implementation of automatic hand sanitization technique using arduino and ultrasonic sensor." In AIP Conference Proceedings, vol. 2358, no. 1, p. 050029. AIP Publishing LLC, 2021.

[12] A. P. Ramadian and L. Marlinda, "Design of Automatic Hand Sanitizer Based on Arduino Uno Microcontroller." Sinkron: jurnal dan penelitian teknik informatika 6.1 (2021): 157-167.

[13] A. Das, A. Barua, et al. "Development of a Novel Design and Subsequent Fabrication of an Automated Touchless Hand Sanitizer Dispenser to Reduce the Spread of Contagious Diseases." Healthcare. Vol. 9. No. 4. Multidisciplinary Digital Publishing Institute, 2021.

[14] E. A. Suprayitno, M. R. Marlianto and M. I. Mauliana, "Measurement device for detecting oxygen saturation in blood, heart rate, and temperature of human body." Journal of Physics: Conference Series. Vol. 1402. No. 3. IOP Publishing, 2019.

[15] V. R. Parihar, A. Y. Tonge and P.D. Ganorkar, "Heartbeat and temperature monitoring system for remote patients using Arduino." International Journal of Advanced Engineering Research and Science 4.5 (2017): 237161.

[16] C. K. Das, M. W. Alam, and M. I. Hoque, "A wireless heartbeat and temperature monitoring system for remote patients." International Conference on Mechanical Engineering and Renewable Energy. 2013.

[17] R. Priyanka, and M. Reji, "IOT Based Health Monitoring System Using Blynk App." International Journal of Engineering and Advanced Technology (IJEAT) 8 (2019).

[18] B.O. Oyebola, M.E. Anih and Odueso, "Development of a Microcontroller Based Temperature and Humidity Controller for Infant Incubator." Journal of Industrial Technology, 2 (4): 78 - 89. 2017.

[19] F. Sudhindra, S. J. Annarao, R. M. Vani, and P. V. Hunagund, "Development of Real Time Human Body Temperature (Hypothermia & Hyperthermia) Monitoring & Alert System with GSM & GPS." Int. J. Innov. Res. Sci. Eng. Technol 5, no. 6 (2016): 9355-9362.

[20] P. Bharathan, V. Nadar, and S. Wayal, "Remote health monitoring using iot." International Journal of Advance Research, Ideas and Innovations in Technology (2017).

[21] O. Taiwo and A. E. Ezugwu, "Smart healthcare support for remote patient monitoring during covid-19 quarantine." Informatics in medicine unlocked 20 (2020): 100428.