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Research Article

An IoT-Based Healthcare Monitoring System for Infectious-Diseased Patients

Thanh Minh Vo[1,2], Thuan K. Tang[1,2], Duy P. Vo[1,2], Trung Kien Pham[1,2,*]

ABSTRACT

In recent years, there has been significant research in the healthcare sector and its advancements in technology. In particular, the Internet of Things (IoT) has displayed potential for connecting different medical devices, sensors, and healthcare practitioners. This connectivity enables the delivery of high-quality medical services in remote areas, leading to enhanced patient safety, reduced healthcare expenses, improved access to healthcare, and increased operational efficiency in the field of healthcare. The coronavirus pandemic (COVID-19) is a global coronavirus disease that causes various death and rapid infection across the population, especially in the urban area. However, many patients are infected without symptoms, that makes difficulty for quarantine campaigns. Therefore, it is very important to detect and monitor indication of the patient's health including body temperature, heart rate, and oxygen saturation. This motivates the concept named infectious-diseased patient monitoring system in this research. The system consists of three main parts: wearable devices used to monitor the medical status of the patient; Entrance door monitoring devices equipped with thermal infrared cameras to detect high temperature persons. The host server records all data from tracking devices for future analysis and treatment. With this system, medical staff can approach a patient's health record in real time and help patient immediately whenever needed. System will be very useful in the case of pandemic outbreak. The demonstration of the whole system with web interface confirms the success of the concept validation with details in operation and configurations of both software and hardware. The system prototype is implemented in the laboratory and with the ability of expanding in the hospital for various patients and monitored rooms.

Key words: IoT, healthcare, infectious-diseased patient

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INTRODUCTION

Healthcare monitoring system is preferred in recent years to determine the health status in various schemes. One of the impressive motivations is the devastating epidemics named COVID-19, also known as the coronavirus pandemic. Overall, Southeast Asia has the highest number of confirmed cases and ranks 15th in the world. People are easily inflected, and many of them do not exhibit symptoms. Infection with COVID-19 frequently causes the following symptoms: fever, muscle or body aches, shortness of breath, headache, etc. High fever, low oxygen saturation, and arrhythmia are typical signs. Low oxygen saturation and shortness of breath are named hypoxemia and hypoxia, respectively.

Patients with low oxygen levels and irregular pulse are vulnerable. They may be unaware of hypoxemia or a rapid pulse and misjudge that they are tired, and as a result, various patients died without any treatment. Therefore, it is very important to observe various aspects of the health of the COVID-19 patients, including body temperature, heart rate, and oxygen saturation. However, it is restricted space for on-site operation because during the pandemic, many quarantine places are in shortage of human resources for both observing infected patients and maintaining anti-epidemic efforts. With the development of embedded systems and IoT platforms, the system is developed in order that manual work is reduced, and the healthcare data can be provided to the medical centers with accuracy in real-time mode.

Many studies use monitoring technologies due to human needs and the invention of technologies. Remote health monitoring, safety monitoring, personal fitness monitoring, medication monitoring, and other IoT-based healthcare applications. They are designed and developed with the same goal of collecting vital information about the patient or elderly, such as heart rate, respiration rate, electrocardiogram (ECG), blood oxygenation, blood pressure, temperature, and blood sugar, to predict their current conditions. As A. Shanmugapriya used the SOAP protocol and Bluetooth module to capture body temperature, heart rate, and location of the patient or elderly person into the Android apps[1]. In emergency situations, physicians

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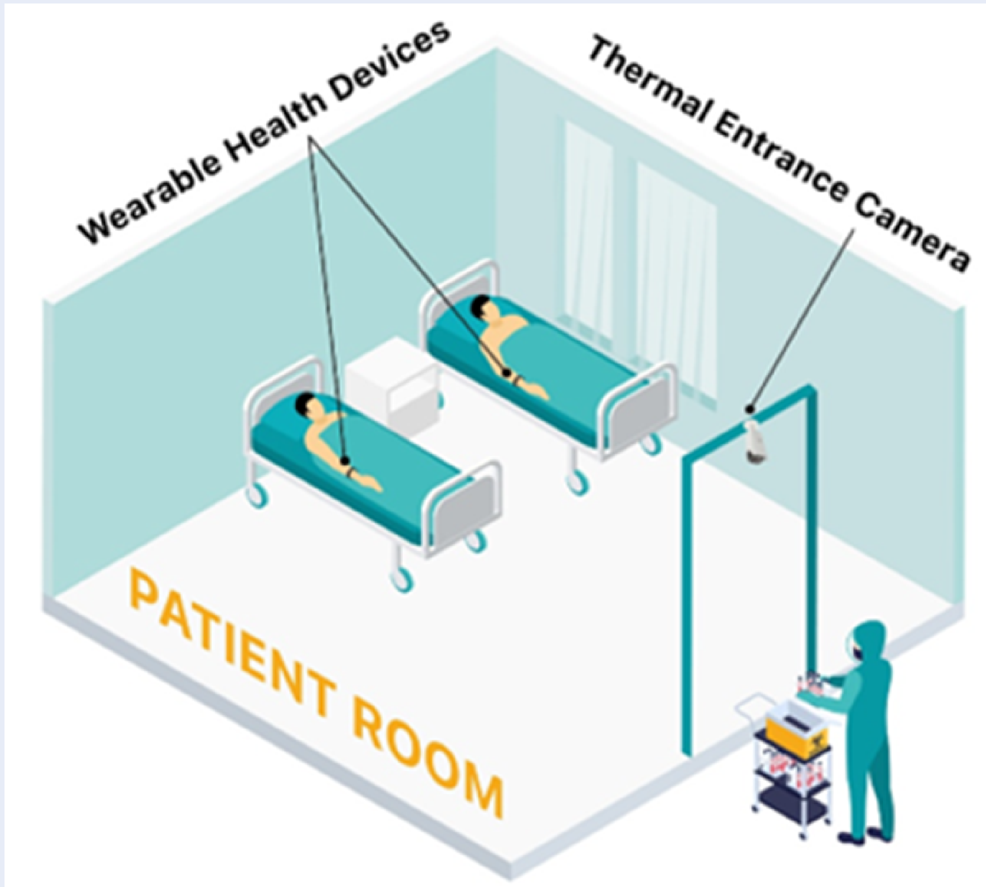

Figure 1: The scenario of patient monitoring system

can respond quickly. Project uses an Arduino and GSM module to collect data of edge devices and send it to the Raspberry Pi for visualization on the Thingspeak interface; besides, it also used buzzer for triggering[2]. The authors have developed a remote patient monitoring system based on IoT and WBASN technology that can be used for healthcare monitoring, according to study[3]. Although this project uses the same sensors and MQTT protocol, the webpage is made via NodeRed dashboard[4]. The webserver and Message Broker for the health care monitoring system is designed and implemented on Raspberry Pi embedded computer[5].

In this research, the overall objective is to assist the medical staff in better managing patients at isolation zone during treatment or quarantine period, as well as future outbreaks. The on-site system configuration is shown in Figure 1. The wearable devices, the entrance door monitoring devices, and the host server make up the system, which is designed and implemented to monitor Covid-19 signs and symptoms. MQTT communication protocol, node MCU sensor devices and the Raspberry Pi have been implemented in the Infectious-Diseased Patient Monitoring System. Each sensor device is worn at the patient's arm for updating on the state of health. With this system, medical staff can approach patient's health records and current conditions with convenience and time savings.

RESEARCH METHODOLOGY

In this research, An empirical research has been carried out, a prototype healthcare system has been designed. Some participants were invited to conduct the system test, and subjective evaluation was conducted at the end of the test. Through the tests, the operability of the prototype healthcare system was demonstrated.

SYSTEM DESIGN

Figure 2 describes the network design of the healthcare system which includes IoT sensor nodes, local MQTT broker and local webserver. There are three

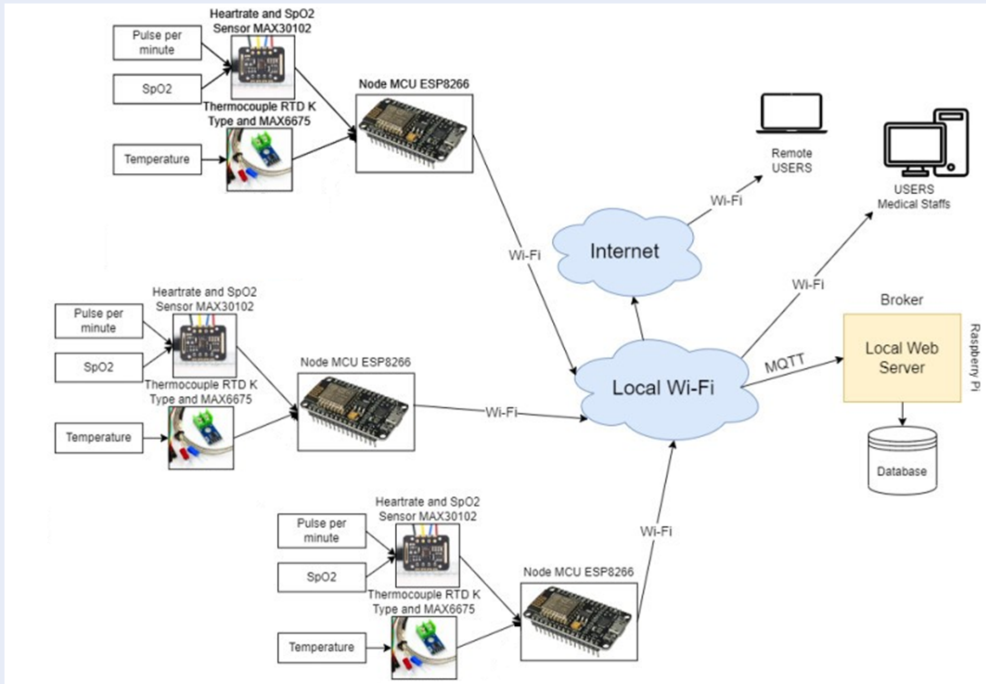

Figure 2: The network design of IoT Based healthcare monitoring system.

sensors (SPO2, heartrate, and temperature sensor) at each node and a thermal camera sensor connected to the IoT sensor Node (MCU ESP8266). The IoT sensor node converts analog values into digital data; the data then will be published to MQTT Broker which is installed in Raspberry Pi. The received data (subscribed data) will be stored and handled by a local web server built on Python flask Webserver framework implemented on the Raspberry Pi. The broker classifies data according to their corresponding topics and saves them to the database. The system uses Wi-Fi technology as standard data transmission. Remote users with authority can access data through the Web interface over the Internet connection.

HARDWARE DESIGN

The system uses three sensors: pulse oximeter (SPO2) and heart rate sensor MAX30102 [6], thermocouple type K (Kelvin) temperature sensor, MAX6675 [7] and thermal camera AMG8833 [8].

The MAX30102 is an integrated pulse oximeter that uses two LEDs that are visible and infrared light, a photo sensor, and low-noise analog signal processing to detect pulse oximeter (SPO2) and heart rate signal (BPM). The main task of the MAX30102 is to read the absorption levels of both red light and infrared light sources then store them in a buffer that can be read using the I2C communication protocol. The sensor uses Photoplethysmogram, which shines both lights onto the position where the skin is thin, where both lights can easily penetrate the tissue and detects the quantity of reflected light with a photodetector.

The MAX6675 thermocouple type K (Kelvin) temperature sensor can amplify K-type thermocouple readings, providing high accuracy and high stability during operation. The sensor transmits its value using the SPI communication standard. It is capable of measuring temperatures from 0°C to 700°C.

The sensor, AMG8833, measures temperatures ranging from 0°C to 80°C with accuracy of ±2.5°C. The range can be up to 7 meters away. This sensor uses I2C to communicate and can interpolate the 8-by-8 grid monitor. Instead of having a guard at the door to take body temperature, this process is automated by combining an AMG8833 sensor with a microcontroller to determine the temperature of the human body in a non-contact technique.

Figure 3 shows the connection of NODEMCU ESP8266 with SPO2 sensor, MAX30102 sensor and temperature sensor (MAX6675).

SOFTWARE DESIGN

The system uses Python Flask [9], a lite web framework which aims to facilitate Python comprehension and

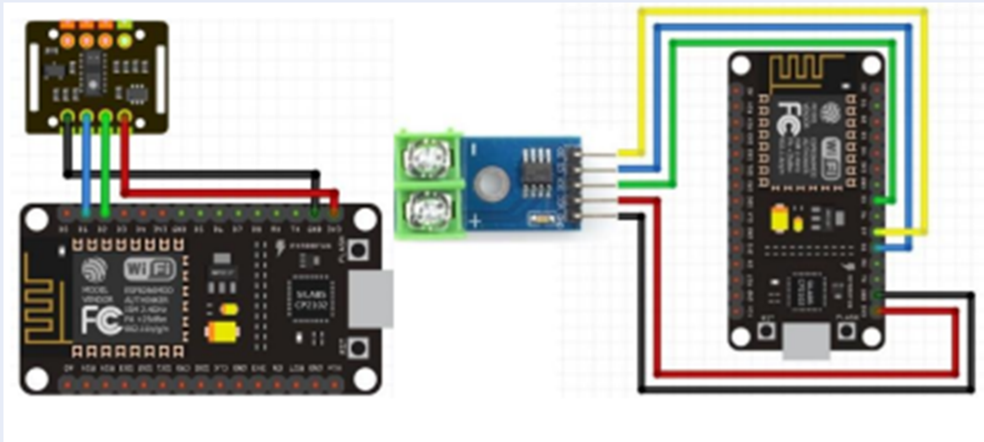

Figure 3: Interface of node MCU and sensors

website design for novice learners. Moreover, it has expanded its scope to developing intricate web applications. Flask leverages Werkzeug and Jinja2, two widely acclaimed Python libraries, which has established Flask's popularity as the leading Python web framework, superseding its counterpart, Django.

The data processing for Raspberry Pi is shown in Figure 4. When the data is received, they will determine the associated topics. Then, the data will be sent onto the web interface and stored into the database. At the same time, these data will be checked if they are in abnormal value. If the indices are out of normal range, the buzzer will be turned on.

Figure 5 shows how data is passed and received: the Broker functions as an open platform. The Node MCU ESP8266 (see [10]) can send and receive data, but in this case, wearable nodes or entrance nodes send data to a Web server through an intermediate MQTT broker where the data is classified according to the topics, the data will be stored in database and sent it to the web user interface whenever it is accessed. When a user logs in, authentication is required with password and account in the database to secure and manage the login session.

RESULTS

Figure 6 shows the hardware implementation of a prototype patient vital sign monitoring device. For mobility, the measurement device is connected to two 18650 lithium rechargeable batteries with voltage of 3.7V, and power of 2200 mAh. These batteries are charged every 3 or 4 hours. The batteries provide energy for the microcontroller and sensors for standalone operation at the patient location.

Some scenarios of testing including people at rest and people after sitting are recorded with around 25 students in the laboratory to validate the prototype operation. Table I shows the testing measurement results of data monitoring from SPO2 wearable device which can be compared with measurement results of a commercial product Oximeter- SPO2 Medel PO01 [11]. The errors among parameters are not significant and the agreement between the prototype and the benchmarked product is exhibited in Table 1.

Figure 7 shows an example of the webpage of patient data monitoring results. After successfully logged in, the home page will appear for interface. The navigation bar and the web page will be grouped by tabs for convenient usage. Each patient record displays pertinent demographic and clinical information, including the individual's name, age, gender, heart rate in beats per minute (BPM), blood oxygen saturation (SpO2), body temperature, and fetal heartbeat (FHB), where applicable. When the received value is out of the acceptable range, a noticeable alteration in color will occur and manifest as red. In the context of fetal heartbeats (FHB), it can be observed that the color designation of green corresponds to the presence of a fetal heartbeat, while the color designation of red corresponds to its absence.

DISCUSSION AND CONCLUSION

A prototype of the IoT-based healthcare system has been designed and successfully implemented. In this system Raspberry Pi acts as a broker to receive and send data between the patient's wearable devices. There are three wearable IoT Nodes which integrated with a couple of sensors (temperature, SPO2, heart rate). In addition, a thermal camera is installed at the

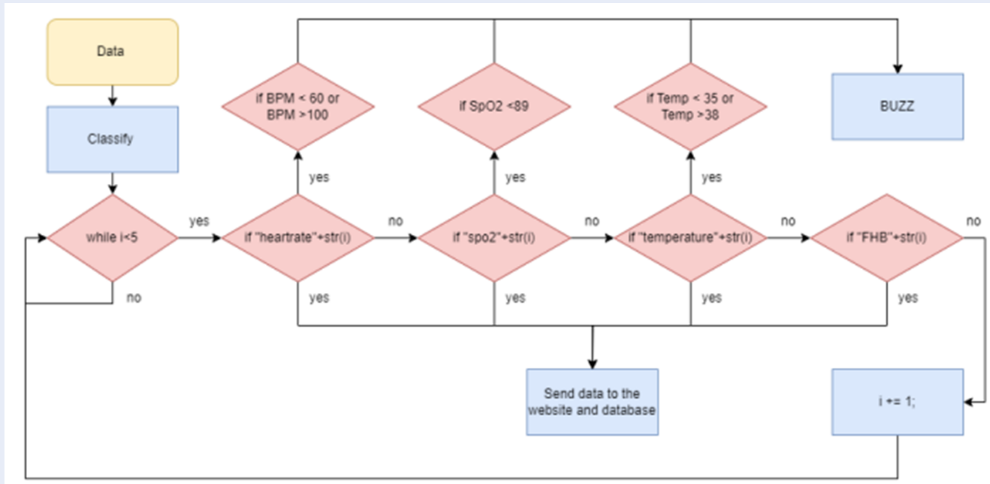

Figure 4: Data Processing implemented in Raspberry Pi

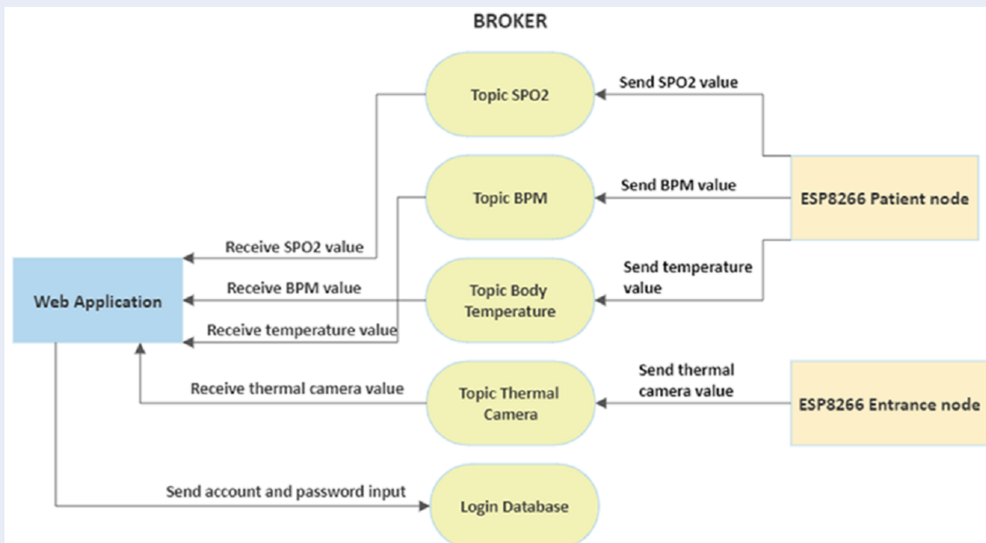

Figure 5: Data transmission diagram

Table 1: Scenarios on Wearable health devices

Testing case	Virtal sign variable	Prototpye	Market product
At rest	Temperature(^{o}C)	36.75	36.5
	SPO_2(%)	97	97
	Heart rate(bpm)	89.5	93
After sitting	Temperature(^{o}C)	34	34.2
	SPO_2(%)	96	95
	Heart rate(bpm)	111	119

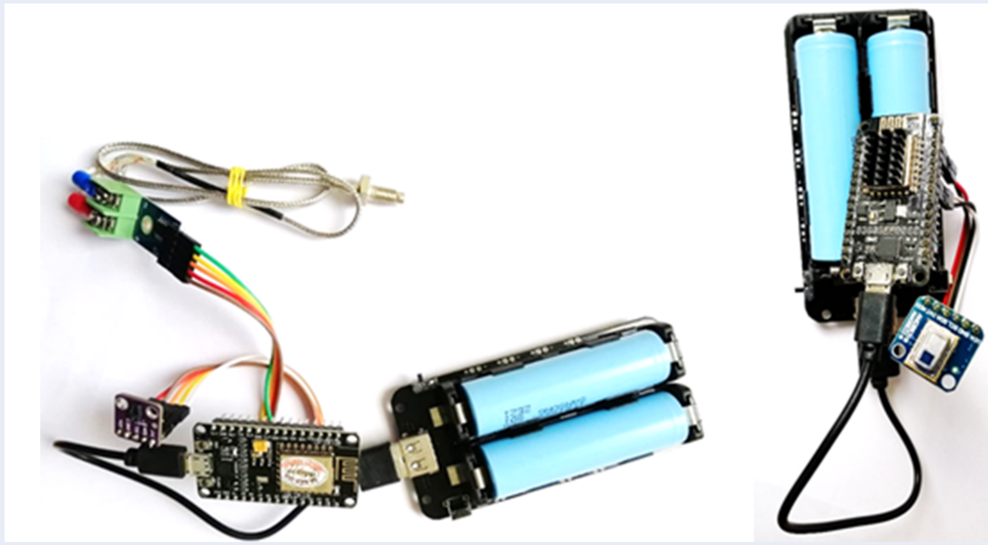

Figure 6: Hardware Implementation Modules

entrance sensor IoT node. If the monitoring data is lower or higher than the safety threshold, a buzzer informs the monitor (doctor/nurse) so that he/she can act in time. The hardware utilizes a microprocessor, specifically the NodeMCU ESP8266, which has been programmed within the Arduino integrated development environment. The NodeMCU is equipped to facilitate data transmission from the sensor to Broker using the MQTT protocol as its primary method of communication.

The current initiative is developed with the objective of providing pertinent assistance to healthcare staff, thereby alleviating their workload. Based on this system, healthcare professionals can continuously monitor the condition of their patients without encountering any issues, especially infectious cases. Despite the existence of certain shortcomings and challenges associated with its usage, including the need to carefully consider multiple scenarios in practical implementation, the current prototype constitutes a significant advancement in the integration of Internet of Things (IoT) technologies within the healthcare domain. The user interface of the system is user-friendly, while simultaneously ensuring the continuous updating of data.

For future development, the system will enable healthcare personnel to draft medical records, make diagnoses, specify treatments, and archive this data to a database. Moreover, the integration of blood pressure and ECG sensors is envisaged to provide enhanced diagnostic support. The emergence of machine learning (ML) will result in a noteworthy advancement in the accuracy of measurement and estimation of diagnoses.

The successful design and implementation of this prototype IoT-Based Healthcare Monitoring System for infectious-diseased patients will be very useful for healthcare monitoring applications especially applied for patient caring in the case of pandemic outbreak.

COMPETING OF INTERESTS

The authors declare no competing interests.

AUTHOR'S CONTRIBUTION

Thanh Vo-Minh: Conceptualization, Formal Analysis, Writing - Original Draft.

Thuan K. Tang: Synthesizing and Performing the Experiments

Duy P. Vo: Synthesizing the Experiment Results

Trung-Kien Pham: Synthesizing, Writing – Review and Editing, and Supervision

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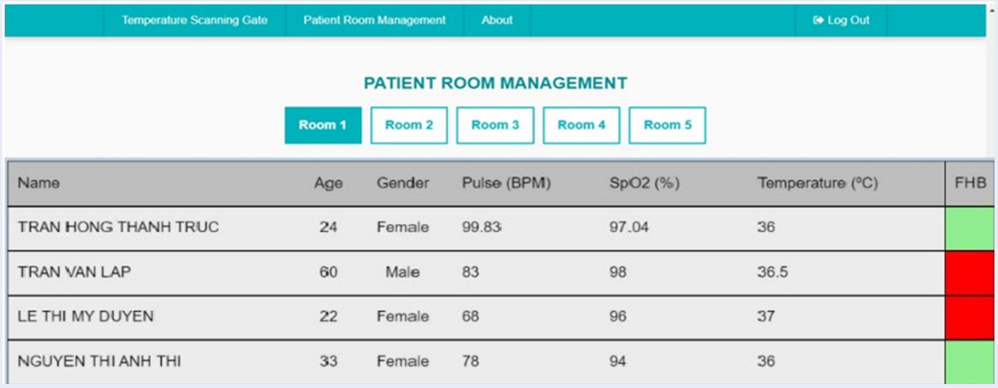

Figure 7: Web interface of the monitoring system

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Bài nghiên cứu

Hệ thống giám sát chăm sóc sức khỏe cho bệnh nhân mắc bệnh truyền nhiễm ứng dụng công nghệ internet vạn vật

Võ Minh Thạnh[1,2], Tăng Kim Thuận[1,2], Võ Phước Duy[1,2], Phạm Trung Kiên[1,2,*]

TÓM TẮT
Trong những năm gần đây, đã có những nghiên cứu quan trọng trong lĩnh vực chăm sóc sức khỏe và những tiến bộ về công nghệ. Đặc biệt, công nghệ Internet vạn vật (IoT) đã cho thấy tiềm năng kết nối các thiết bị y tế, các cảm biến khác nhau với các bác sĩ chăm sóc sức khỏe. Sự kết nối này cho phép cung cấp các dịch vụ y tế chất lượng từ xa, giúp nâng cao sự an toàn cho bệnh nhân và cả nhân viên y tế, giảm chi phí chăm sóc sức khỏe, cải thiện khả năng tiếp cận dịch vụ chăm sóc sức khỏe và tăng hiệu quả hoạt động trong lĩnh vực chăm sóc sức khỏe. Đại dịch vi-rút Corona (Covid-19), là một đại dịch toàn cầu do vi-rút Corona gây ra nhiều trường hợp tử vong và lây nhiễm nhanh chóng trong cộng đồng, đặc biệt là ở khu vực thành thị. Tuy nhiên, nhiều bệnh nhân nhiễm bệnh không có triệu chứng đã gây khó khăn cho các chiến dịch cách ly. Vì vậy, việc phát hiện và theo dõi các dấu hiệu sức khỏe của bệnh nhân bao gồm nhiệt độ cơ thể, nhịp tim và nồng độ oxy trong máu là rất quan trọng. Những phân tích chính là nguồn động lực cho nhóm nghiên cứu nghiên cứu giải pháp: thiết kế và phát triển hệ thống theo dõi bệnh nhân mắc bệnh truyền nhiễm ứng dụng công nghệ Internet vạn vật. Hệ thống bao gồm ba phần chính: thiết bị đeo dùng để theo dõi tình trạng sức khỏe của bệnh nhân; Thiết bị giám sát cửa ra vào được trang bị camera hồng ngoại nhiệt để phát hiện người có nhiệt độ cao và máy chủ lưu trữ ghi lại tất cả dữ liệu từ các thiết bị theo dõi để phân tích và xử lý dữ liệu bệnh nhân và phát hiện kịp thời những người có nguy cơ nhiễm bệnh . Với hệ thống này, nhân viên y tế có thể tiếp cận hồ sơ sức khỏe của bệnh nhân theo thời gian thực và trợ giúp bệnh nhân ngay lập tức. Hệ thống sẽ rất hữu ích trong trường hợp đại dịch bùng phát trong tương lai. Việc triển khai toàn bộ hệ thống với giao diện web khẳng định sự thành công của ý tưởng với các chi tiết về vận hành và cấu hình cả phần mềm và phần cứng. Nguyên mẫu hệ thống được triển khai trong phòng thí nghiệm và có khả năng mở rộng trong bệnh viện cho nhiều bệnh nhân và phòng theo dõi khác nhau.
Từ khoá: Internet vạn vật, Chăm sóc sức khỏe, Bệnh nhân mắc bệnh truyền nhiễm

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