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An Affordable Internet of Things Solution for Health Monitoring Utilizing ESP32 Technology

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حل إنترنت الأشياء بأسعار معقولة لمراقبة الصحة باستخدام تقنية ESP32

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Abstract
The Internet of Things (IoT) technology has become inevitable in various fields due to its prominent role in achieving speed and accuracy in business performance. One of the most important fields in which IoT technology has contributed to its development and brought about a technological revolution is the field of healthcare. IoT technology has contributed to transferring patient data and displaying it to doctors remotely without the need for the doctor to be present next to the patient. In this paper, a healthcare system based on IoT technology was designed using an ESP32 board, an LM35 sensor, and a MAX30102 sensor, which is characterized by being inexpensive and easy to use. This system transfers a set of parameters specific to the patient's condition to a graphical user interface (GUI) designed on the Blynk platform, so that this interface allows the doctor following up on the patient's condition to review these parameters and then diagnose the patient's condition without the need to be with him. The system was tested and good results were obtained, as the parameters specific to the patient's condition were displayed on the GUI in real time.

Keywords: Healthcare, ESP32, Internet of Things (IoT).

الملخص
أصبحت تقنية إنترنت الأشياء حتمية في مجالات مختلفة بسبب دورها البارز في تحقيق السرعة والدقة في أداء الأعمال. ومن أهم المجالات التي ساهمت تقنية إنترنت الأشياء في تطويرها وأحدثت ثورة تكنولوجية فيها مجال الرعاية الصحية. حيث ساهمت تقنية إنترنت الأشياء في نقل بيانات المريض وعرضها على الأطباء عن بعد دون الحاجة إلى تواجد الطبيب بجانب المريض. في هذه الورقة تم تصميم نظام رعاية صحية يعتمد على تقنية إنترنت الأشياء باستخدام لوحة ESP32 ومستشعر LM35 ومستشعر MAX30102، والذي يتميز بأنه غير مكلف وسهل الاستخدام. ينقل هذا النظام مجموعة من المعلمات الخاصة بحالة المريض إلى واجهة مستخدم رسومية (GUI) مصممة على منصة Blynk، بحيث تسمح هذه الواجهة للطبيب المتابع لحالة المريض بمراجعة هذه المعلمات ومن ثم تشخيص حالة المريض دون الحاجة إلى التواجد معه. تم اختبار النظام وتم الحصول على نتائج جيدة، حيث تم عرض المعلمات الخاصة بحالة المريض على واجهة المستخدم الرسومية في الوقت الحقيقي.

الكلمات المفتاحية: الرعاية الصحية، لوحة ESP32، انترنت الأشياء (IoT).

Introduction

Previously, health care for patients depended on the doctor visiting patients in their places of residence, whether hospitals or homes [1], which leads to a delay in the diagnosis process of the patient's condition, which causes a delay in the patient's recovery, so it was necessary to search for ways to avoid the problem of delayed follow-up of the patient and diagnosis of his condition by the doctor by inventing smart technologies that allow remote follow-up of patients' conditions [2]. Modern technology has contributed greatly to the development of health care systems in terms of the ability to access data related to patients' conditions and monitor them remotely. Recently, what is known as Internet of Things technology has emerged, which has made this world a small network of electronic devices interconnected with each other. Through Internet of Things technology, it has become possible to monitor patients' conditions remotely, such as measuring heart rate, blood oxygen level, and body temperature [3][4]. The Internet of Things (IoT) technology is a process of merging the field of communications with embedded systems to form a system capable of connecting electrical and electronic devices with each other via the Internet and then monitoring and controlling these devices remotely [5]. In other words, it is a group of electronic devices connected to each other through different communication networks, so that this technology allows sharing different data for the purpose of monitoring and remote control, in addition to storing this data for the purpose of using it later when needed, as happens in healthcare systems in which the patient's condition is monitored and diagnosed remotely [6]. Where data related to the patient's condition such as temperature, heart rate, etc. is collected through a group of sensors located on the patient's body from points, and then this data is shared with the doctor supervising the patient for the purpose of diagnosing his condition [7][8]. In short, the concept of the Internet of Things (IoT) technology is the ability of all electrical devices to interact and communicate with each other to perform different functions [9]. IoT technology has contributed to the development of many fields, including: monitoring and controlling homes remotely, which have turned them into smart homes that the user can supervise via the Internet, healthcare and monitoring patients and diagnosing their condition remotely, designing and building cities, which have become known as smart cities as a result of facilitating life procedures in these cities, and the field of industry [10] [11]. It has also contributed significantly to the development of the field of healthcare and monitoring patients' cases remotely, as it has helped doctors monitor patients and diagnose their cases remotely using IoT technology, which allows these doctors to obtain data related to the patient's condition in real time and then diagnose the patient remotely without the need to visit the patient [12]. Thus, healthcare systems have become advanced smart systems that are available for continuous access in real time thanks to IoT technology [13]. The Internet of Things technology is characterized by the ability to facilitate and improve most of the work related to all industrial, agricultural, economic, social and other fields [14]. Thus, there will be a significant reduction in the time required to diagnose the patient by dispensing with visiting him, which may be in a remote and distant area. There will also be a reduction in the cost related to the process of moving to the patient, in addition to another important factor, which is the time required for the diagnosis process, as it will require less time to diagnose the patient through IoT technology [12]. Despite the advantages of Internet of Things technology in terms of rapid diagnosis of patients' cases and remote follow-up, there are risks that must be taken into account. These risks are represented by the risk of stealing patient data and spying on them because these smart systems are connected to the Internet, which in turn is vulnerable to hacking and theft. [15][16].

Evolution of healthcare monitoring systems

The methods used to follow up on patients and monitor their condition can be classified into several categories, including:

A. Traditional Healthcare Monitoring Systems

Traditional Healthcare Monitoring Systems refer to established methods of tracking and managing patient health primarily through in-person assessments, manual data collection, and centralized record-keeping, often involving paper-based documentation and standardized protocols. These systems typically emphasize routine visits and clinician-driven monitoring, lacking real-time data integration and patient engagement [17][18][19].

B. Remote Healthcare Monitoring Systems

These are systems that do not require the presence of specialists next to the patient, as a smart monitoring system located on the patient's body is connected to a Wi-Fi network or the Internet, so that it sends data about the patient's condition to specialists for the purpose of diagnosing the patient's condition.[20][21]

C. Mobile Healthcare Monitoring Systems

Mobile healthcare monitoring systems are characterized by the ability to track the patient anywhere by providing smart applications on the mobile phone, which allows the doctor to access the patient's data from anywhere in the world. [22] [23], [24], [25].

D. Wearable Healthcare Monitoring Systems

Wearable healthcare monitoring systems are systems that allow the user to wear them and move them anywhere, and thus the doctor can monitor the patient's condition continuously and anywhere.[27][26]

E. Implantable Healthcare Monitoring Systems

In these systems, precise sensors are implanted that take several images like capsules inside the human body through injection or ingestion by the patient, so that these sensors transmit precise data about the patient's body from the inside to the doctor. This data may be images, analyses, etc. [28].

Iot based healthcare systems architecture

The work of IoT-based monitoring systems depends on several stages illustrated in Figure (1) which are:[5]

i. Sensors: They work to convert physical quantities such as the patient's temperature into electrical signals and send them to the microcontroller.

ii. Data processing: In this stage, the electrical signals received by the microcontroller from the sensors are analyzed and converted into digital quantities through which the patient's condition is diagnosed.

iii. Data transmission: In this stage, data related to the patient's condition is sent to the doctor through wireless networks such as the Internet.

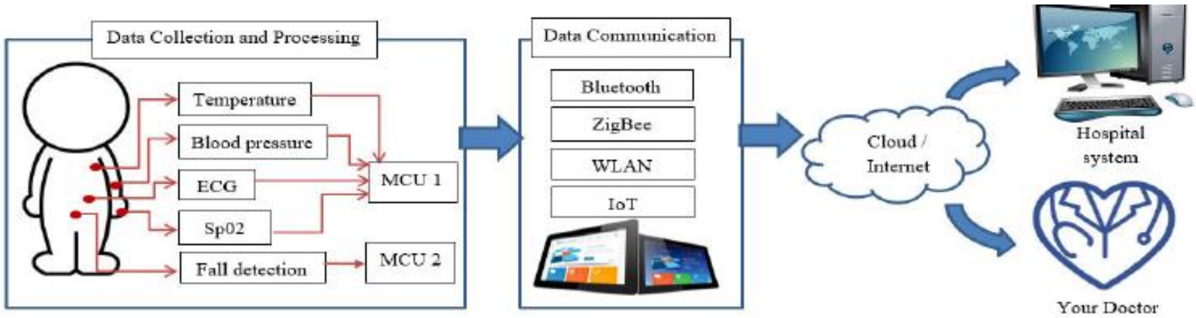

Figure 1: Architecture Of the Healthcare Monitoring System.

Literature review

Many studies have presented different designs for remote health monitoring systems, which generally depend on sending patient data to the doctor using wireless communication methods. Among these designs is what was presented by [29], where a health monitoring system based on the Internet of Things was designed using the Arduino board and the Nodemcu board as well as the GSM system, so that patient data is captured by sensors on the patient's body as well as sensors in the patient's environment, and then this data is processed and sent to the doctor.

The GSM unit was also used to send patient data to the doctor remotely [30]. A system for monitoring lung patients was designed to follow up on their health condition and send this data to the doctor [31]. A system for monitoring patients' heartbeats was also designed remotely and sending this data to the doctor through a smartphone application [32]. A design based on IoT was also designed to monitor the patient's condition remotely and send his data to the specialist doctor [33]. A remote health monitoring system was also designed that mainly depends on transferring patient data to the doctor via the Internet and the possibility of using the telephone network in emergencies to transfer patient data through text messages or voice calls [29].

Proposed healthcare system architecture

The healthcare monitoring system presented in this research as shown in Figure (2) has been built using three of elements that were taken into consideration for simplicity in addition to their low cost. These three elements are: the input elements, which are represented by sensors, the data processing element, which is represented by the ESP32 board, and the output element which is represented by GUI.

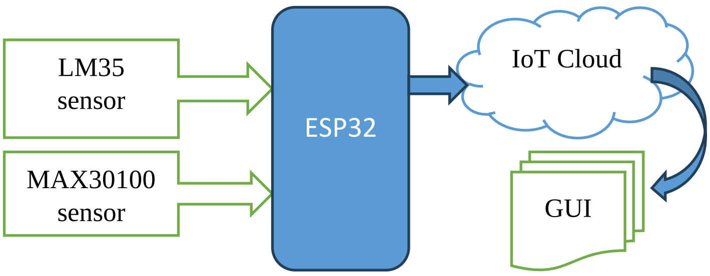

Figure 2: Block diagram of the proposed control system.

A. Sensors:

These are sensors through which physical quantities in the patient's environment are read. Two sensors were used for this purpose, which are:

i. Temperature senor (LM35)

The human body temperature varies from one person to another according to age, gender, and health condition. The normal temperature of the human body ranges from 36 degrees Celsius to 37.3 degrees Celsius [18]. There are several types of temperature sensors, the most important of which is the LM35 sensor due to its low price and ease of use, as shown in figure (3)[5].

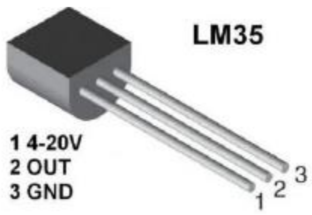

Figure 3: LM35 temperature sensor**.**

The LM35 temperature sensor has a high reading accuracy of +/-0.4°C and a measuring range of 0 to 100°C. This sensor can operate at a voltage ranging from 4V to 20V.[34]

ii. MAX30100 sensor

The MAX30102 sensor shown in Figure (4) is used to measure heart rate and blood oxygen levels together, it is characterized by a high accuracy of up to 95%[34]. It need for a small operating voltage ranging from 1.8 volts to 3 volts.

Figure 4: illustrates how MAX30102 sensor.

iii. ESP32 Board

The ESP32 board is responsible for receiving signals from sensors in the patient's environment, processing these signals, sending them via IoT technology to the doctor, and displaying them on a GUI on the doctor's phone. Figure (5) shows the ESP32 board, which is an advanced board with a larger memory capacity than the Arduino board, and Wi-Fi and Bluetooth technology have been integrated into this board
.[5]

Figure 5: Indecates the ESP32 board.

The remote health monitoring system was programmed using Arduino IDE, which is an open source program that writes the code in C language. [35]. A graphical user interface was also designed using Blynk platform, where the graphical user interface allows remote monitoring and control of control systems by exchanging control signals between the control systems and the graphical user interface, which saves a lot of time and effort for the user in the monitoring and control processes. Figure (6) shows the graphical user interface of the health monitoring system presented in this research, which includes readings of the temperature sensor, heart rate, and blood oxygen level
.[36]

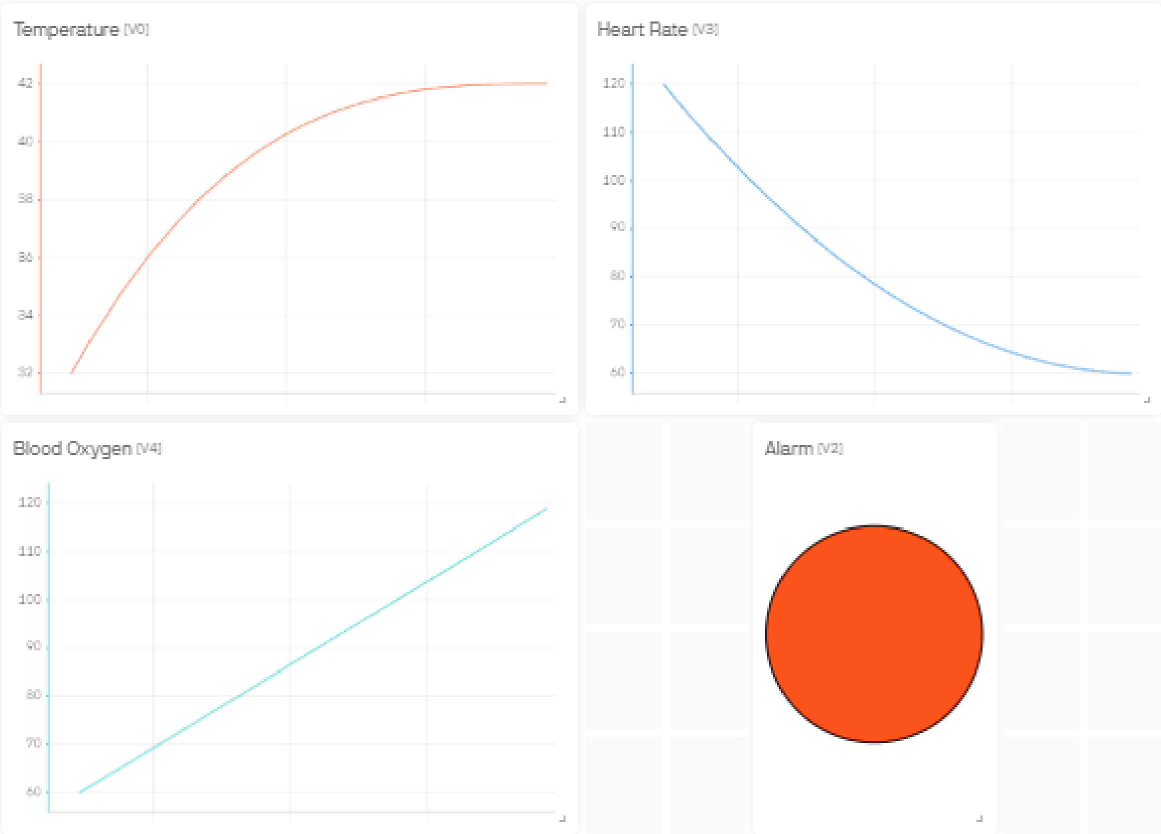

Figure 6: The graphical user interface.

The mechanism of the presented healthcare system

The proposed healthcare system in this research works by sensing physical quantities such as the patient's temperature, heart rate, and blood oxygen level, then converting these values to the ESP32 board, which processes these values and converts them into digital values that can be displayed and manipulated. The digital values that express the values of the physical parameters are transferred via the Internet of Things technology to the graphical interface on the Blynk platform so that the doctor can view them remotely wherever he is and diagnose the patient's condition. The proposed system in this research was designed and implemented as shown in Figure (7). The focus in its design was on its low cost and high performance.

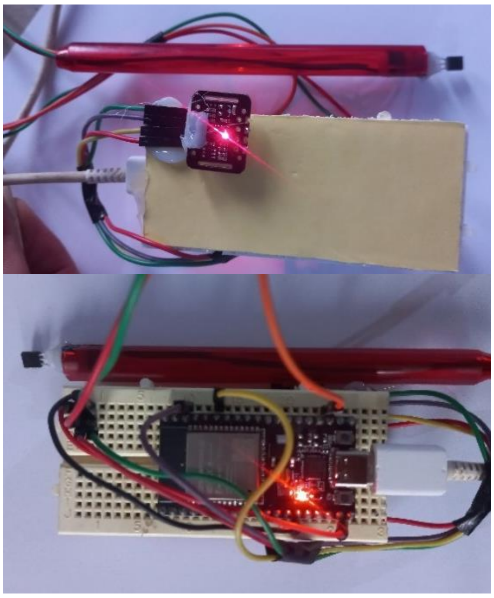

Figure 7: The healthcare monitoring system presented in this research.

Results

The system presented in this research, shown in Figure (8), was tested to measure three parameters which are: temperature, heart rate, and blood oxygen levels on two people aged forty years, person A and person B.

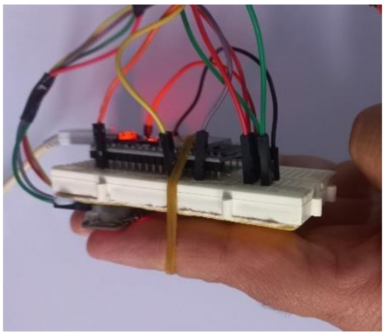

Figure 8: Indicates how to test our healthcare system.

As the normal human body temperature ranges from 30 to 36 degrees Celsius, while the normal heart rate for an adult range from 84 to 90 beats per minute [29], and if it rises above 90 beats per minute, this indicates that there is an increase in the heart rate [37].

And the normal value of blood oxygen (PaO2) is between 75-100 mm Hg. Therefore, any value of PaO2 outside this range indicates a malfunction in the human body [38][39].

The system was tested in two cases as follows:

1- person A was healthy with good parameters as shown in Figure (9).

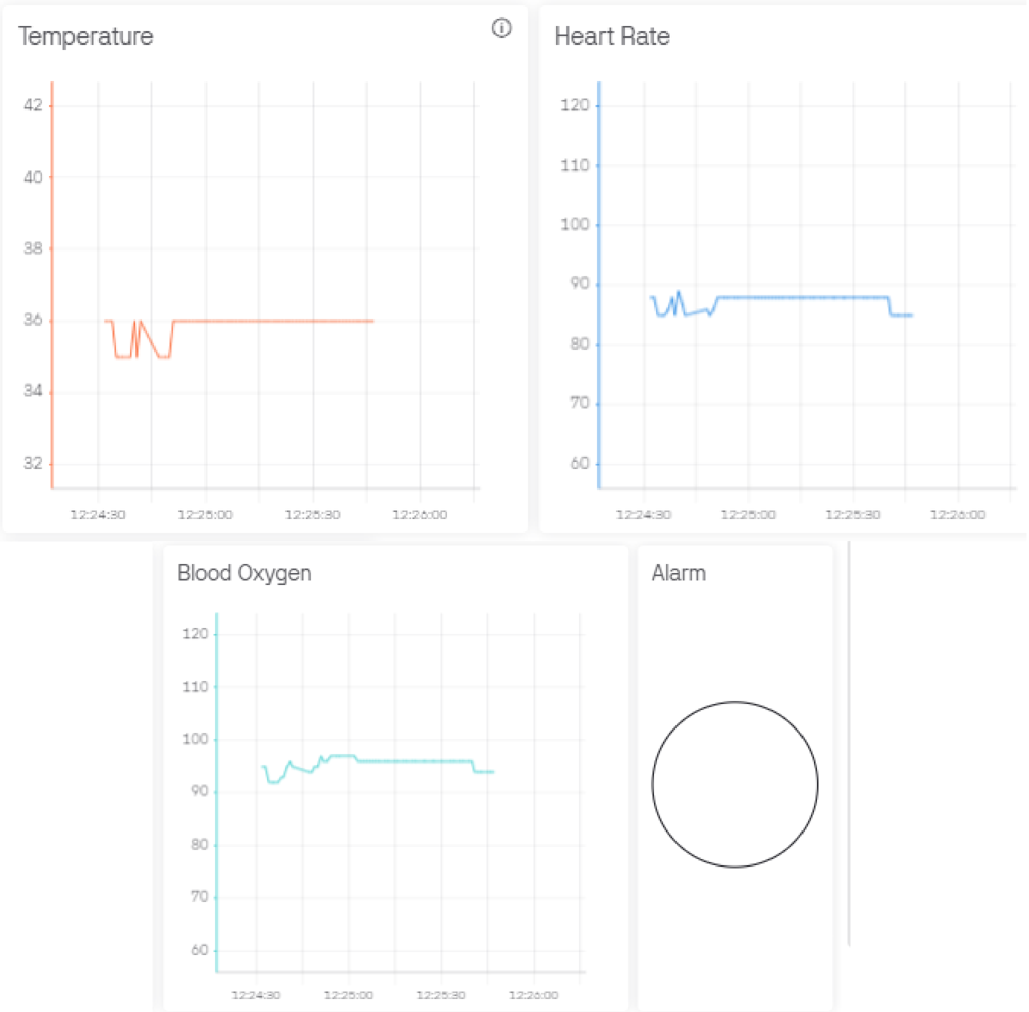

Figure 9: The experimental results of person A.

2- person B had pneumonia and fever with bad parameters as shown in figure (10).

Figure 10: The experimental results of person B

Conclusion

In this research, a remote healthcare system was designed using IoT technology. This system aims to assist doctors to follow up and diagnose patients remotely without the need to be present with them. The system was implemented and tested and the results were very good, as the required parameters were displayed in real-time on a phone application designed on the Blynk platform. The system presented in this research was characterized by the accuracy of its results, its low price and ease of use, in addition to the possibility of carrying it and moving it anywhere, which would give the patient more moral energy because the patient is not obligated to be in one place.

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