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Integrated System for Remote Health Status Monitoring and Analysis

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***Abstract* - With the emergence of new types of diseases and viruses that can affect the human immune system, different types of vaccines and treatments have been developed to combat the new threats. Various technical methods have been developed to monitor the health status of a patient suffering from a certain ailment in order to certify the efficacy of a given treatment scheme. A way to monitor the health condition of a patient is proposed, based on the Arduino platform. The prototype can transmit data collected from a sensorial system and store them to a web server. The system is designed to monitor human body temperature with three temperature sensors placed on the head, body and lower limbs to obtain the average body temperature; an oximeter sensor for simultaneously monitoring the heart rate and the blood oxygen level of a patient; and two sensors for measuring indoor air quality, namely a gas sensor and a temperature and humidity sensor. This last sensor determines if a given bacteria or virus can thrive in the environment. A specialized software program was used to create the remote health monitoring prototype, which was subsequently manufactured using a 3D printer. The prototype is resilient and efficient, being appropriate for long-term use.**

Cuvinte cheie: *monitorizarea stării de sănătate, comanda unui sistem de senzori, soluție IoT integrată.*

Keywords: *health status monitoring, sensorial system control, integrated IoT solution.*

I. INTRODUCTION

The literature in the area of health status monitoring offers a variety of solutions. Our capacity to solve problems, interact with one another, and handle everyday issues has undergone a paradigm shift as a result of new trending technologies like powerful industrial microcontrollers, Internet of Things (IoT), cloud computing, machine learning (ML), among others [1].

Temperature, breathing, and heartbeat (or pulse) are just a few of the human vital indicators that a remote health monitoring system can identify.

In [2] is suggested to use a mobile application-based health monitoring system. The suggested technology gives the patient's doctor and family members access to the patient's location and some current health parameters. With the help of graph tools, mobile applications may monitor their surroundings and connect to the internet via 3G or 4G wireless cellular networks.

A system that can collect patients' heart rates and body temperatures and save data in the cloud is provided in [3]. When compared to an electrocardiogram (EKG) equipment, the system underwent testing and displayed a similar accuracy.

The field of telemedicine has also advanced quickly, and the present research focus is on remote monitoring and the detection and analysis of human health status indicators [4].

II. HEALTH MONITORING SYSTEM COMPONENTS

An IoT-based patient health monitoring system using ESP8266 and Arduino is developed, able to process and transmit data collected from a sensorial system to a remote server. The system was designed with a dedicated program for a 3D printer, and the prototype was then realized to prove the usability of the proposed solution.

The proposed system is able to measure the heart rate/pulse (BPM), as well as the blood oxygen level (SpO2), using the MAX30100/102 pulse oximeter sensor. Some DS18B20 temperature sensors are used to measure the average body temperature. The temperature and humidity inside a room are detected with a DHT11 Humidity and Temperature sensor. The MQ-135 sensor is needed for monitoring the noxious gas levels that can affect the air quality inside a room.

The monitoring system is made of the components from Fig. 1. The IoT platform used for the data storage and analysis is ThingSpeak [6].

Arduino UNO is a development board based on the ATmega328 microcontroller. The Arduino UNO has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz oscillator, a USB connection, a power jack, an ICSP jack [7].

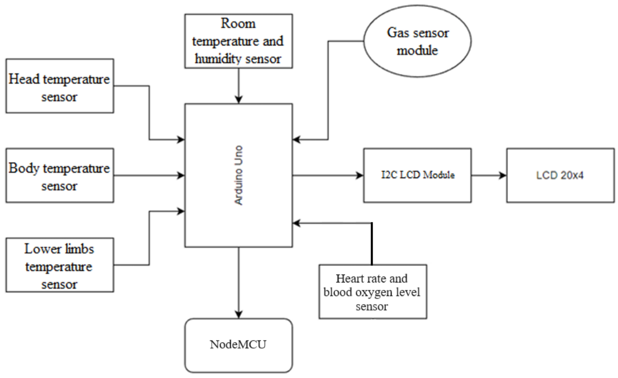

Fig. 1. The block diagram of the proposed health monitoring system.

NodeMCU is an open source IoT platform used for adding networking capabilities to Arduino UNO. At first it included ESP8266 Wi-Fi SoC firmware from Espressif Systems and hardware based on the ESP-12. Later, support for the ESP8266/ESP32 was added [8], [9]. The NodeMCU development board is depicted in Fig. 2.

We use three DS18B20 temperature sensors to measure the average temperature of the human body, collecting data from the head, body and lower limbs.

Similarly, a patient needs to be kept in a room having a certain temperature and humidity level. Hence, the patient does not feel uncomfortable in the room. To do this we also need to monitor the room temperature and humidity. So we use the DHT11 Humidity and Temperature sensor.

The pulse sensor is an essential component of the system, allowing the user's heart rate to be constantly monitored [10]. The data obtained from this sensor provided valuable information about the person's cardiovascular health, as well as the level of physical activity and effort exerted during exercise. Detection of heart rhythm abnormalities, such as tachycardia or bradycardia, could signal serious health problems and the need for immediate medical intervention.

On the market are available many different types of health monitoring systems, including those based on Arduino and Zigbee technology for widespread health monitoring. The technology of the testing system should be optimized nonetheless, as there are now more health testing data available.

Systems that employ sensors, link gadgets, and the Internet to achieve a better level of automation can be created thanks to remote servers like ThingSpeak. IoT has the ability to completely change patient management and monitoring in the healthcare industry [5]. Silent monitoring is essential in an intensive care unit, as even a small delay in deciding how to treat a patient might result in death or lifelong health issues.

Emergency warnings may be delivered to medical personnel and caregivers in the event of changes in a patient's health, to enable timely intervention. This technique makes it feasible to identify medical emergencies before they become serious.

In Fig. 3 are gathered the main electronic components of the proposed system, along with the required supply voltage sources and the connections between them.

The Internet of Things (IoT) is a system of "connected things". Things generally include an embedded operating system and an ability to communicate with the Internet or neighboring things. One of the key elements of a generic IoT system that connects different "things" is an IoT service. An interesting implication of the "things" that comprise IoT systems is that the things themselves cannot do anything. At a minimum, it should have the ability to connect to other "things".

The real power of IoT is harnessed when things connect to a "service" either directly or through other "things". In such systems, the service plays the role of an invisible manager, providing capabilities ranging from simple data collection and monitoring to complex data analysis.

ThingSpeak IoT software allows users to create new and private channels to collect analyzed data. Analysts can read data from public channels and then transfer them to custom channels [6]. The platform allows users to write

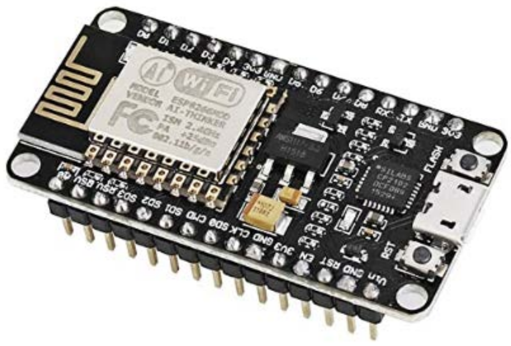

Fig. 2. Top view of NodeMCU [9]

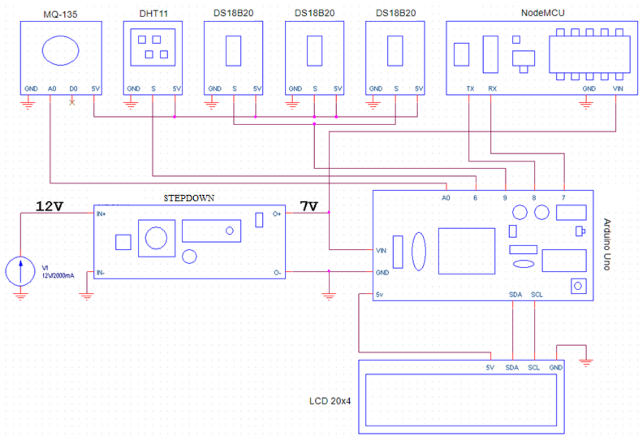

Fig. 3. Simplified electronic diagram of the proposed circuit.

data to their ThingSpeak channels in various formats such as REST API, MATLAB, MQTT or with third-party applications. These protocols allow experts to share telemetry information.

Meteorologists can read temperature and humidity data from various weather channels and view the results on their private channels. Using MATLAB, they visualize trends, plot histograms, calculate dew points from raw data, and forecast changes in weather patterns.

ThingSpeak IoT helps users share analyzed data with public channels. The settings panel allows users to view more options on their channels. The tab shows sharing options that will allow the user to set their channel as private, public (everyone can see it), or shared with specific users. Professionals can also import or export data on their channels.

The DS18B20 from Fig. 4, a waterproof digital temperature sensor, is a reliable temperature sensor that provides an adjustable 9 to 12-bit thermometer using a 1-wire interface [11].

Fig. 4. The prototype of the DS18B20 sensor used for measuring the average body temperature [11].

Data is sent to/from the DS18B20 via a 1-wire interface, so only one wire (ground) needs to be connected from a central microprocessor to the DS18B20. It provides power for reading, writing and temperature conversions. The values can be derived from the data bus itself, without the need for an external power supply.

Because each DS18B20 contains a unique serial number on silicon, multiple DS18B20s can exist on the same 1-wire bus [12]. This allows temperature sensors to be placed in various places.

The MQ-135 air quality sensor from Fig. 5 is used to measure the air quality inside the room where the patient is placed [13]. Gas levels may be transmitted to an LCD screen or to a ThingSpeak channel, on which various warning messages may be displayed.

The air quality is constantly monitored with the developed system, so that the amount of toxic gas, smoke or alcohol cannot become dangerous for the patient. In case the gas level is exceeded, an alarm is triggered.

A thermistor is a sensitive thermal resistor that uses resistance values to determine temperature. It is comprised of a semiconductor, and when subjected to temperature changes, its physical resistance changes.

The DHT11 sensor from Fig. 6 is used for measuring ambient temperature and humidity, factors that decide whether the environment is conducive to certain bacteria or viruses [14].

The MAX30100 pulse sensor from Fig. 7 is a combined heart rate and blood oxygen sensor [16]. The sensor is meant to monitor blood oxygen levels and the pulse using photoplethysmography, a non-invasive technique.

The sensor is an integrated photodetector and LED emitter. Infrared (IR) and red light are emitted by the LED emitter, and the photodetector gauges how much light is reflected off the user's skin. For the purpose of detecting variations in blood vessel volume during the pulse, photoplethysmography is used. The sensor detects fluctuations in the absorption of infrared and red light as the pulsing blood moves through the arteries.

An oled display is used to display information about heart rate [bpm] and the oxygen saturation [SpO2] collected from the oximeter, as in Fig. 8.

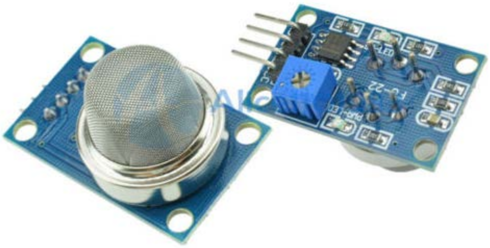

Fig. 5. MQ-135 gas sensor module [13].

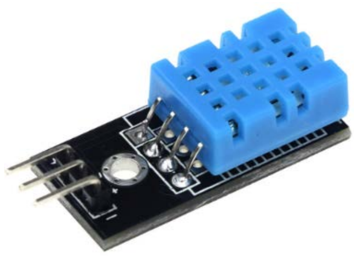

Fig. 6. DHT11 sensor module [15].

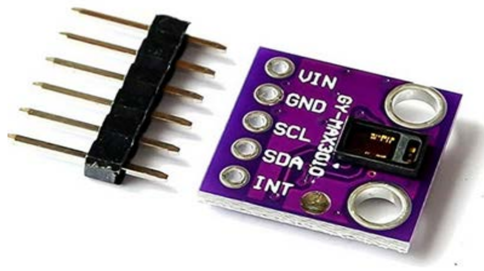

Fig. 7. The structure of the MAX30100 pulse sensor [17].

Fig. 8. The OLED Display used to monitor the pulse sensor [18].

III. Design of the Health Monitoring System

The proposed system is based on two Arduino boards and a NodeMCU, and has four different components that act as a whole for the health monitoring.

Each subsystem was previously developed and tested with Fritzing, an open-source hardware package that makes electronics available to anybody as a creative environment [19].

After developing and testing each subsystem, they were added together as parts of the health monitoring system.

A. Body Temperature Sensor Subsystem

In Figure 8 is depicted the 2D schematic of the body temperature sensor, consisting of:

- the Arduino UNO development board;

- 16x2 LCD display. An I2C was used to save pins. By using it, only two pins to power the display were used, and opened up the possibility to connect other sensors to the display. To use I2C, it was necessary to use the related library in the code;

- the DS18B20 sensor, to which a 4.7kΩ resistor was connected. This resistor was used to enable the sensor's internal pull-up resistor to ensure proper communication between the sensor and the microcontroller.

The body temperature sensor is an important component of the monitoring system. It allows the detection and monitoring of fever, a significant indicator of infections and other conditions.

By monitoring the body temperature in real time, the system can provide early alerts if the temperature rises above the normal limit, signaling possible respiratory infections or systemic diseases. Thus, it can contribute to prompt intervention and initiation of appropriate treatment.

A pull-up resistor is a resistor connected between a signal line and a positive voltage source (VCC) for the purpose of providing a logic high (HIGH) level on that line in the absence of an active command.

B. Ambient temperature sensor subsystem

The subsystem used for monitoring the ambient temperature and humidity, based on a DHT22 sensor, is depicted in Fig. 9. As with the subsystem used to determine the body temperature, in addition to the sensor itself, a switch powered from digital pin number 8 of the Arduino UNO board was added, aiming to reduce the waiting time for the sensors to display on the LCD, making it more practical to select any sensor and use it as long as needed.

The ambient temperature and humidity sensor brings an extra dimension to the health monitoring. It was designed to measure the level of humidity and air pollution in the environment. Air quality and humidity levels can affect a person's respiratory health and overall well-being. By detecting and monitoring high levels of humidity or the presence of air pollutants, the system can provide warnings or recommendations related to improving air quality and preventing respiratory ailments.

C. Gas sensor subsystem

The subsystem of the gas sensor MQ-135 from Fig. 10 was designed to display the gas level on the LCD. An LED was also added to digital pin number 5 of the Arduino UNO board. Pin 5 was defined as an output pin, to which a 1 kΩ resistor was added, in order to limit the current that passes through the led and to protect it against any overvoltage.

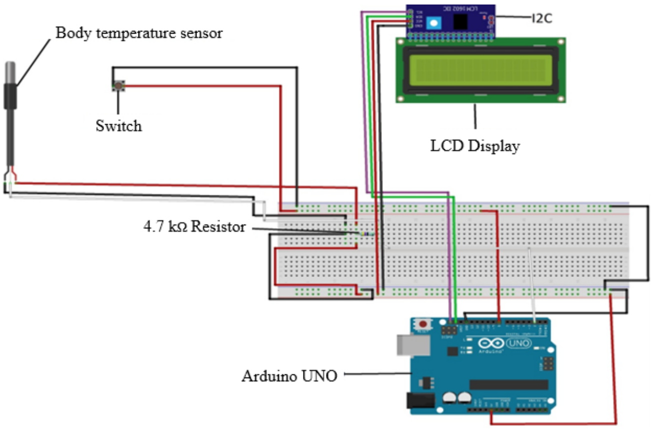

Fig. 9. Diagram of the body temperature sensor subsystem.

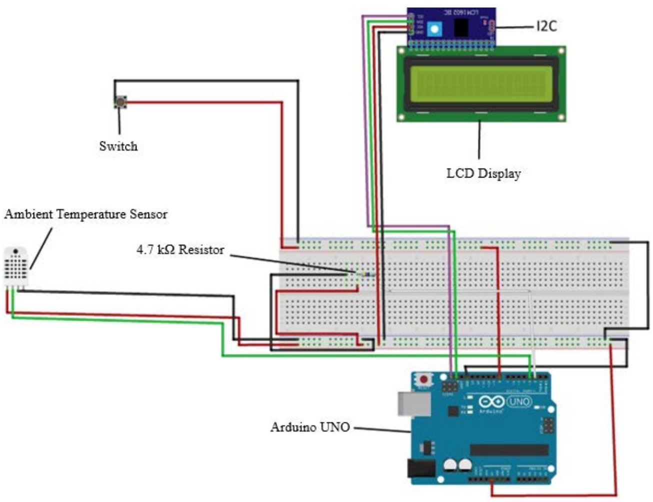

Fig. 10. Diagram of the ambient temperature sensor subsystem.

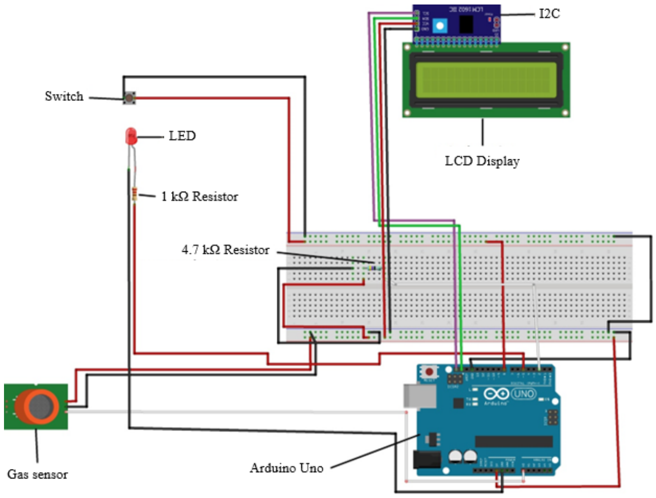

Fig. 11. Diagram of the gas sensor subsystem.

The use of the gas sensor is an important measure to prevent and manage the increased levels of polluting gases in the air. This sensor can detect the gas level in the room and issue warnings or alerts if the detected value is above the permissible limit. This aspect is of particular importance in preventing accidents caused by gas leaks, as well as in promoting a responsible and healthy approach to the quality of the air breathed by the patient.

D. Pulse monitoring subsystem

The pulse monitoring sensor subsystem from Fig. 11 differs from the other subsystems, as it could not be implemented on the same Arduino Uno board. With a second board available, a separate circuit was implemented, due to the limited memory capacity of the first board, which started to create interference between the pulse sensor, ambient temperature sensor and the LCD display.

The new Arduino board offers enough space to implement an OLED display that would display the desired information separately from the other sensors, as in Fig. 12 An OLED display was chosen due to its additional functions, such as creating an animation. The second Arduino board is powered from the first board with a 5V voltage.

E. The Whole Health Monitoring System

The main components of the whole health monitoring system are depicted in Fig. 13. These are a pulse monitoring sensor (MAX30100), three body temperature sensors

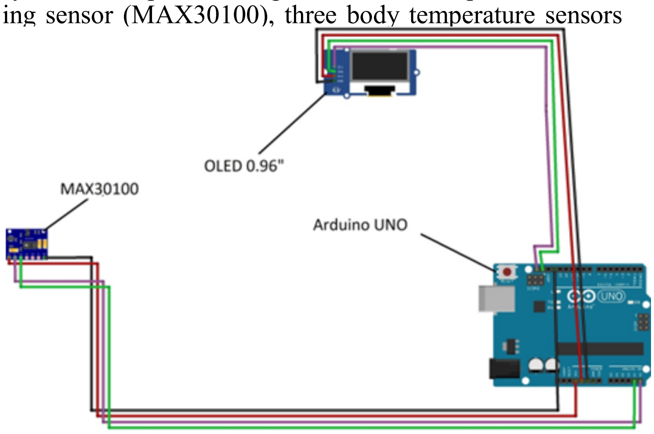

Fig. 12. Diagram of the pulse monitoring subsystem.

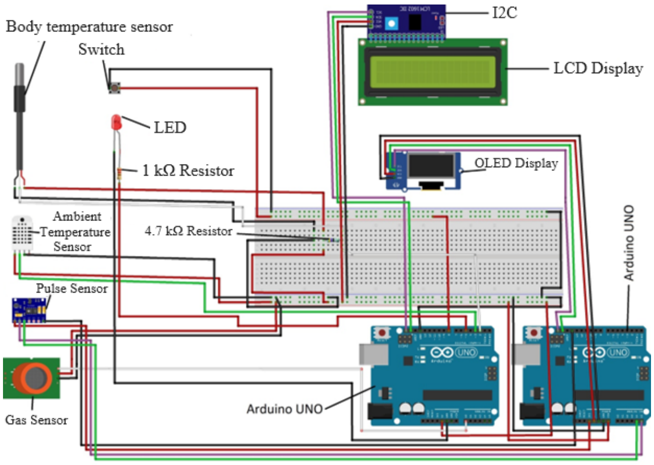

Fig. 13. Main components of the health monitoring system.

(DS18B20), an ambient temperature and humidity sensor (DHT22), a gas detection sensor (MQ-135), two Arduino UNO development boards, one LCD display (16x2), one I2C circuit, one OLED display, one Switch, some LEDs and some 4.7kΩ and 1kΩ resistors.

IV. Development of the Panel and Preparation for 3D Printing

The designed health monitoring system was further developed, in order to integrate all the components in a prototype, with the aid of a 3D printer.

At first, a sketch with the panel size of 200x200mm was created. Then the mounting holes with a diameter of 5mm and the holes for the temperature sensors and the MQ-135 sensor, as in Fig. 14, were added.

The extrude function was used to raise the wall by 3mm. The sketch was designed using the Fusion 360 software package, as in Fig. 15.

In Fig.16.a) is depicted the final design, while Fig.16.b) depicts the sketch imported by the 3D printer software package.

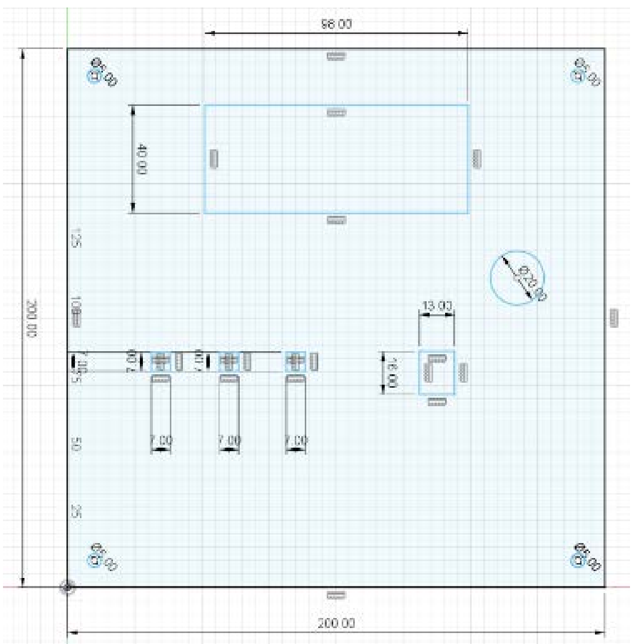

Fig. 14. 2D view of the panel in Fusion 360.

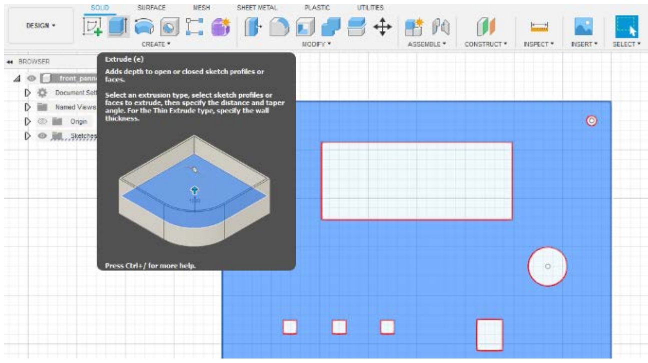

Fig. 15. Sketch design steps.

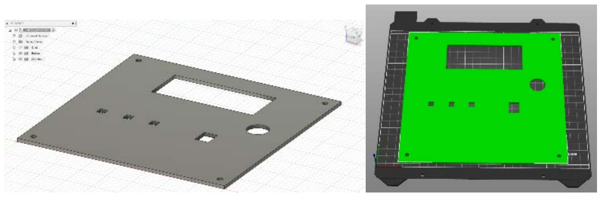

Fig. 16. The final 3D design of the sketch with Fusion 360 – (a) and The design imported by the 3D printer software – (b).

After compiling the data for a print with a layer thickness of 0.2mm, we get a print time of 6 hours and 41 minutes and a print material consumption of 132.58 grams.

V. The Experimental Setup and the Results Collected from the ThingSpeak IoT Platform

The system developed according to the Fritzing design was successfully implemented, and an overview of the laboratory prototype is depicted in Fig. 17.

The sensor readings were correct, so the next step was to build the health monitoring system from Fig. 17, as a compact solution that may be used under real world conditions.

The system was built by adding together the 3D printed mechanical components with the electric and electronic parts. In this manner, a robust and compact system was obtained, suitable for long-term use.

Data provided by the developed health monitoring system can be stored and displayed on a personal computer, using the Arduino IDE and an LCD, or remotely, via a ThingSpeak channel, provided by the MATLAB server.

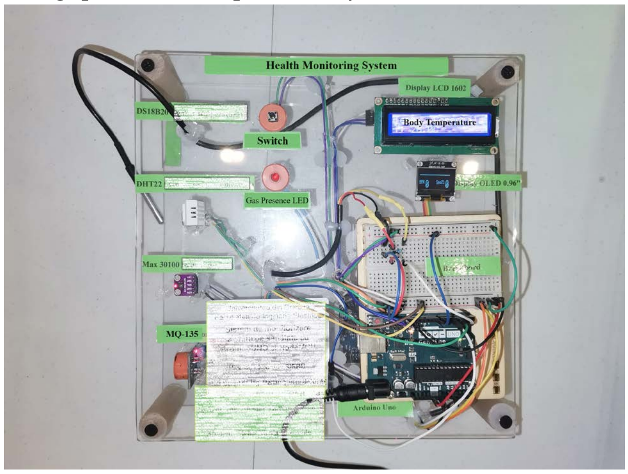

Fig. 17. Overview of the implemented health monitoring system.

In Fig. 18 may be noticed the variation of the room temperature over time, resulted from the data collected by a ThingSpeak channel.

Fig. 19 depicts the variation of the average body temperature, based on data collected from the three sensors.

One or more persons can permanently examine the data gathered from the three temperature sensors on the ThingSpeak channel to keep an eye on the patient's condition.

Fig. 18. The experimental IoT system built for health monitoring.

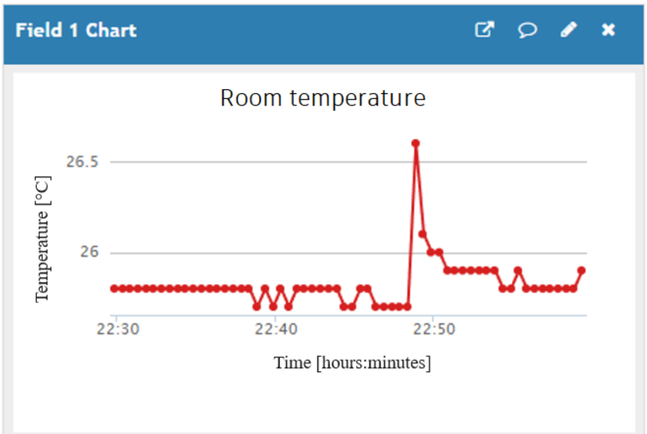

Fig. 19. Time variation of the room temperature [6].

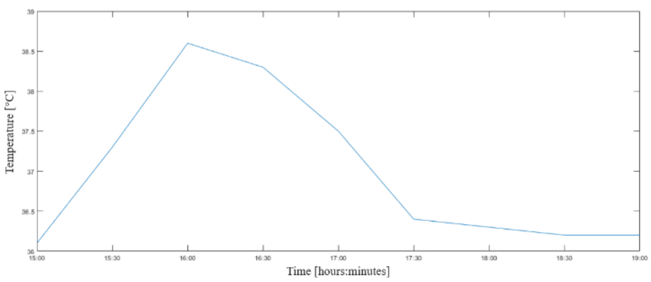

Fig. 20. The average human body temperature.

In case a threshold value imposed for one of the sensors is exceeded, an alarm may be triggered.

CONCLUSIONS

Such a system has several benefits. Real-time monitoring of the body temperature, pulse and oxygen level, on one hand, and room temperature, humidity and air quality, on the other hand, allows for the prompt identification of any changes or abnormalities that may indicate health issues requiring immediate attention.

By using the personalized notifications and advice provided by the system, users can take the necessary steps to maintain their health condition and prevent problems.

Room environment is also important, being monitored in order to ensure that it contains no smoke, while the temperature and humidity are ideal for a patient.

The suggested health monitoring solution is resilient and an effective way to remotely monitor certain vital signs that could point to a patient's health changing.

In addition to the obvious benefits for people, such a system can aid in the gathering of data for study and analysis. The monitored data can be utilized to spot patterns and trends in the development of health status and can offer important details to help with better condition diagnosis and care.

Based on the collected data, the system can provide a preliminary result, according to which the patient is infected or not.

The possibility of storing data collected from such a system for a longer period of time may lead to proving whether a treatment is effective or not.

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First author – 30%
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Fourth coauthor – 15%

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