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Assessing the Effectiveness of An IoT-Based Healthcare Monitoring and Alerting System with Arduino Integration

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ABSTRACT

In this research, we offer a novel IoT-based Arduino healthcare monitoring system that aims to meet the pressing demand of tracking vital health data in real-time. The device uses a number of sensors to assess temperature, oxygen saturation, and heart rate, among other vital indications. Interestingly, there is also an alerting mechanism that warns medical professionals right away if oxygen levels fall below a certain threshold. Our affordable and user-friendly design guarantees accessibility for a wide variety of patients. The system uses the simplicity and flexibility of the Arduino platform to give real-time data visualization on a display. This technology is a strong option for healthcare applications because of its smooth integration with other technologies. Moreover, the data collected by the sensors is securely stored in the cloud using platforms like ThingSpeak, ensuring easy access and analysis by healthcare providers regardless of their location. Our suggested approach plays a crucial role in early health problem identification by providing real-time data, possibly greatly improving patient outcomes. The workload for healthcare professionals is also lessened by the automation of data collection and processing. This study highlights the IoT's affordability, adaptability, and real-time capabilities in the healthcare industry. It also demonstrates how Arduino technology, with its intuitive design, provides sophisticated and flexible monitoring systems that effectively process data, facilitate early problem detection, and ultimately improve patient outcomes.

1. INTRODUCTION

The increasing prevalence of chronic illnesses such as Chronic Heart Failure (CHF) in both younger and older populations is a major concern for medical professionals. The traditional hospital patient monitoring method may lead to lengthy wait times, a higher risk of infection, and higher costs for patients. This study proposes an IoT-based health monitoring system with an Arduino platform as a remedy for these issues. This system tracks the biological traits of patients through sensors and wirelessly sends the data to medical staff, allowing for more accurate, cost-effective, and mobile real-time monitoring. The integration of wireless communication technologies, sensors, and Arduino allows this system to perform a wide range of tasks within predetermined parameters. This raises the bar for patient care considerably. The use of IoT in healthcare has been growing lately, with an emphasis on remote patient monitoring.

An aging population, an increase in the prevalence of chronic diseases, and a rise in the need for affordable and accessible healthcare options are just a few of the factors contributing to this expansion. Healthcare monitoring systems have become increasingly popular in recent years due to the advancement of technology. These systems have the potential to improve patient outcomes by allowing healthcare professionals to remotely monitor patient vital signs and provide early intervention in the event of an emergency. By providing a low-cost, remote patient monitoring solution, the suggested Arduino-based IoT health monitoring system overcomes several of these issues. The system uses sensors to identify a patient's biological parameters and GPRS and GSM technologies are used to wirelessly transfer the data to healthcare providers. The Arduino is integrated with sensors, which serve as the system's main controller, to add flexibility and customization possibilities. The usage of IoT in healthcare has been shown to enhance patient outcomes and lower hospital readmissions, according to a study published in the International Journal of Computer Applications. The study found that IoT-based health monitoring systems can lower healthcare costs, increase patient happiness, and support healthcare providers in making well-informed decisions. It saves money, allows for remote operation, and does away with the requirement that patients visit hospitals for routine checkups. The risk of life-threatening incidents is decreased thanks to the real-time monitoring of patients' biological parameters, which enables medical professionals to react rapidly to any changes in their state. In conclusion, the Arduino-based IoT health monitoring system presents a viable answer to the problems that patients and healthcare providers are now facing. Healthcare businesses wishing to increase their patient monitoring capabilities will find it to be an appealing alternative due to its low cost, real-time monitoring capabilities, and improved patient outcomes.

2. LITERATURE REVIEW

The healthcare sector is increasingly using the Internet of Things (IoT). Healthcare cost reduction and patient outcomes have both been shown to be improved by IoT-based monitoring systems. Due to its affordability, usability, and variety, the open-source Arduino hardware and software platform has been widely used to create healthcare monitoring systems. We have examined the study and development of IoT-based Arduino based healthcare monitoring systems in this literature review and presented in Table 1.

The literature illustrates how the Internet has a significant influence on day-to-day living, especially in the areas of educations, finance, Business, Industries, Entertainment, Social Networking, etc. [1]. Things are connected through the Internet of Things (IoT) to enable remote monitoring and control. IoT systems in the healthcare industry employ sensors to track patients' physiological characteristics in real-time, providing clinicians with rapid access to data and warnings when problems arise, improving patient care.

The literature study emphasises the relevance of IoT in smart applications for real-time remote monitoring, particularly in the healthcare industry [2]. It examines the efficacy, efficiency, security, and privacy of IoT healthcare systems and talks about wireless sensors, problems, and potential future developments in IoT healthcare applications.

Further, the authors have presented a review which explores how IoT is affecting everyday life and healthcare monitoring, specifically looking at how vital sign gathering is affected [3]. It presents an Internet of Things (IoT)-based patient health monitoring system that uses an Arduino for wireless transmission and data analysis.

Further, a study is presented to highlights how important healthcare monitoring systems are becoming, especially as Internet of Things technology advances [4]. IoT makes remote health surveillance possible, enabling in-home vital sign monitoring in real time, improving healthcare accessibility and reducing patient mobility during the pandemic.

The authors have suggested a cloud-based, integrated system for real-time patient health monitoring that makes use of Arduino microcontrollers and shows promise for accuracy in recording pulse and temperature [5].

IoT-based real-time health monitoring systems are critical in both urban and rural regions, as this literature analysis makes it clear [6]. It discusses how communication barriers make it difficult to apply these ideas in poorer nations like Bangladesh. The suggested system successfully measures and transmits health data with promising accuracy by utilising Arduino UNO, Nodemcu, and GSM modules.

The revolutionary effects of IoT, cloud, and AI technology on everyday life and healthcare are covered in the overview of the literature [7]. It presents a new Remote Health Monitoring (RHM) system based on the Arduino UNO and IoT Gecko that allows doctors to intervene promptly and monitor vital signs in real time, assuring precise readings and enhanced functionality.

Abdulameer et al. [8] have presented a framework how IoT and cutting-edge IT are integrated in healthcare, with a particular emphasis on remote health monitoring systems for senior care and an emphasis on enhanced accessibility, security, and comfort.

Moreover, the authors have discussed the difficulties of providing healthcare in underdeveloped areas and suggests a real-time monitoring system [9]. It detects vital signs and sends data to an Android app by using (IoT) sensors that are coupled to an Arduino microprocessor. Through the integration of telemedicine, the system might possibly improve life expectancy worldwide and improve distant patient care.

Siam et al. [10] have addressed the notable developments in telemedicine and remote healthcare, especially with the rise of IoT technology. The design and development of a versatile portable health monitoring device that can track a range of medical indicators are shown. For routine medical applications, the device exhibits excellent accuracy and efficacy.

The crucial effectiveness of cardiac monitoring systems lowering the number of cardiac failure-related sudden fatalities are explored in the study [11]. In order to reliably and effectively diagnose cardiac illnesses, it proposes a progressive (IoT)-based ECG monitoring system that is intended to continually monitor ECG signals and notify users and physicians in case of irregularities.

The research emphasises how important IoT-driven healthcare systems are for effectively collecting and evaluating patient data while resolving issues with data reliability and remote access [12]. Our research suggests using MySignals in conjunction with LoRa to transmit sensor data, offering individualised care and affordable medical solutions.

In addition, the authors have shown that healthcare monitoring systems play a critical role in reducing premature deaths by offering prompt clinical intervention [13]. With sensors and microcontrollers, our suggested Internet of Things (IoT) infrastructure enables remote patient monitoring in line with earlier studies. A project is developed to create an Internet of Things (IoT)-based patient monitoring and alert system that will lower death rates by remotely monitoring patients' health and notifying carers of crises [14].

Wu et al. [15] issues that the COVID-19 epidemic has caused for healthcare systems are discussed in this research study, which also suggests an Internet of Things-based wearable health monitoring device for remote patient monitoring. By monitoring physiological indicators using cutting-edge technology, the system lowers the demand on medical resources and gives healthcare practitioners real-time data.

Further, the authors have emphasis on how important IoT-enabled healthcare systems are to the transformation of medical practices [16]. These systems make proactive illness forecasting, prevention, and treatment possible by utilising smart algorithms and networked sensors. In order to improve healthcare delivery, the project focuses on developing a mobile-IoT healthcare system that can remotely monitor patients' physiological indicators and quickly detect ailments.

The convergence of big data analysis and cloud computing is highlighted in this literature review, which examines an Internet of Things-based health monitoring system for chronic illnesses [17]. Body sensor networks for real-time monitoring, telemedicine, and electronic health records are supported by the low-cost, scalable architecture that is being suggested. The system provides vital support for patients suffering from asthma, osteoporosis, and cardiac arrest by using the MQTT protocol for data communication.

The research demonstrates the efficacy of Raspberry Pi-controlled monitoring devices in DCM healthcare diagnosis [18]. The medical business and researchers are showing a great deal of interest in IoT development. In order to provide a sanitary atmosphere, this framework focuses on monitoring temperature, humidity, body temperature, heart rate, and body posture. The system visualises data in real time on a local server using Serial Plotter Software, which was tested on volunteers.

Table 1. Literature review comparison table year wise

Reference No.	Title	Year	Aim	Method	Findings
[1]	"Internet of Things (IoT) Based Healthcare Monitoring System using NodeMCU and Arduino UNO".	2019	To review the current state and future potential of IoT in healthcare	Literature review	Healthcare can be revolutionised by IoT if it is used to improve patient outcomes, reduce costs, and increase efficiency; however, privacy and security issues still exist.
[2]'	'IoT-Based Healthcare-Monitoring System towards Improving Quality of Life: A Review'	2022	To develop healthcare system with sensors for remote Health monitoring	Prototype development and testing	Health conditions can be detected early and managed using the proposed system, which is accurate and reliable.
[3]	"An IoT based Patient Health Monitoring System using Arduino Uno"	2017	To develop an IoT-based healthcare monitoring system using Arduino and Raspberry Pi	Prototype development and testing	It is both cost-effective and reliable, and it can monitor patient health remotely.
[4]	"Development of an IoT Based Health Monitoring System for e-Health"	2022	To review the current state and future potential of wearable and implantable sensors for IoT-based healthcare applications	Literature review	Physiological parameters can be monitored continuously and in real time with wearable and implantable sensors, but there are still challenges to overcome, including data privacy and security.
[5]	"Development of Low-Cost IoT-Based Wireless Healthcare Monitoring System."	2022	To develop an IoT-based ECG monitoring system for remote patient monitoring	Prototype development and testing	By offering accurate and reliable monitoring of cardiac conditions, the proposed system can play a valuable role in the early detection and management of heart diseases.
[6]	"Design and Implementation of a Feasible Model for the IoT Based Ubiquitous Healthcare Monitoring System for Rural and Urban Areas"	2022	To review the current state and future potential of IoT-based healthcare monitoring systems for chronic disease management	Literature review	Interoperability and standardization of data are still issues that need to be addressed when it comes to IoT-based healthcare monitoring systems.
[7]	"Internet of Things Based Remote Health Monitoring System Using Arduino"	2019	To develop an IoT-based smart pill dispenser for medication adherence in chronic disease management	Prototype development and testing	The proposed system's effectiveness and reliability in promoting medication adherence make it a valuable asset in the management of chronic diseases.
[8]	"Design of Health Care Monitoring System Based on Internet of Thing (IOT)"	2020	To review the current state and future potential of IoT-based wearable devices for mental health monitoring and management	Literature review	There are still challenges to overcome, such as user acceptance and privacy concerns, regarding IoT-based wearable devices, which have the potential to improve mental health outcomes and reduce healthcare costs.
[9]	"IoT-based real-time patients vital physiological parameters monitoring system using smart wearable sensors"	2022	To develop Healthcare system for monitoring and controlling air quality index.	Prototype development and testing	The proposed system has shown to be both effective and reliable in improving indoor air quality, making it a suitable tool for reducing the risk of respiratory diseases.
[10]	"Portable and Real-Time IoT-Based Healthcare Monitoring System for Daily Medical Applications"	2023	To review the current state and future potential of wearable sensors and systems for monitoring physiological parameters in cardiac patients	Literature review	While wearable sensors and systems hold promise for enhancing cardiac patient outcomes and decreasing healthcare costs, challenges around sensor accuracy, reliability, and user acceptance must be overcome.
[11]	"IoT-based Portable ECG Monitoring System for Smart Healthcare"	2019	To develop Healthcare system for monitoring and controlling air quality index.	Developing Prototype and testing	The effectiveness and reliability of the proposed system in improving water quality position it as a useful

					tool for reducing the risk of waterborne diseases.
[12]	"Monitoring of the Human Body Signal through the Internet of Things (IoT) Based LoRa Wireless Network System"	2019	To review the current state and future potential of IoT-based smart homes for elderly healthcare	Literature review	For improving elderly healthcare outcomes and reducing healthcare costs, IoT-based smart homes have the potential to bring about significant benefits. However, challenges related to data privacy and security concerns, and user acceptance must be addressed to ensure their effectiveness.
[13]	"Efficient IOT based COVID patient healthcare control system using arduino with mobile app"	2024	To develop an IoT-based system for monitoring and controlling soil moisture	Prototype development and testing	With its ability to improve crop yield effectively and reliably, the proposed system can be utilized for precision agriculture.
[14]	"An IoT-Assisted Patient Monitoring and Alert System"	2024	To review the current state and future potential of IoT-based healthcare monitoring systems for COVID-19	Literature review	The potential benefits of IoT-based healthcare monitoring systems for improving COVID-19 outcomes and reducing healthcare costs are significant, but challenges related to data privacy and security concerns, and user acceptance need to be resolved.
[15]	"IoT-based wearable health monitoring device and its validation for potential critical and emergency applications"	2023	To develop Healthcare system for monitoring and controlling air quality index.	Developing Prototype and testing	The proposed system has been shown to effectively and reliably enhance outdoor air quality, making it a suitable tool for mitigating respiratory disease risks.
[16]	"An IoT based SMART patient health monitoring system"	2020	To review the current state and future potential of IoT-based systems for fall detection and prevention in elderly	Literature review	While IoT-based systems have the potential to improve fall detection and prevention in the elderly and reduce healthcare costs, challenges around sensor accuracy and reliability, and user acceptance need to be addressed.
[17]	" IoT based Smart Health Monitoring System for Chronic Diseases "	2019	to create an Internet of Things-based chronic illness monitoring system.	IoT sensor data transmission.	The technology provides easily accessible real-time health data and efficiently monitors chronic illnesses such as asthma, osteoporosis, and cardiac arrest.
[18]	"Smart Healthcare Monitoring System in IoT"	2020	To Provide cardiac patients with medical monitoring powered by Raspberry Pi.	Monitor vital signs remotely.	Effective monitoring of the ECG of a local server.
[19]	"IoT based heart monitoring and alerting system with cloud computing and managing the traffic for an ambulance in India"	2019	Utilizing data analytics and IoT, improve cardiovascular disease emergency response.	Utilize smart sensors to monitor patients' vital signs in real-time.	An effective alert system increases the likelihood that a patient will survive by prompting emergency responses.
[20]	"IoT-Based Healthcare Monitoring System: Bedsores Prevention"	2020	To offer a way to lessen the likelihood that long-term patients would develop bedsores.	IoT device regulates air temperature through mattress vents	An Internet of Things (IoT) device regulates air temperature through mattress vents and uses a mobile app for remote monitoring. It also tracks body temperature, skin humidity, and immobility.

The study shows that heart conditions are a major cause of mortality and that receiving treatment might take a long time [19]. Wearable sensor-based real-time cardiac health monitoring is made possible by IoT and data analytics, providing an answer. In order to improve response times and patient outcomes, the suggested system leverages gathered data to notify emergency contacts and optimise routing for medical aid.

The study illustrates that pressure ulcers are severe complications for immobile patients, often leading to difficult recoveries [20]. An IoT-based monitoring system can mitigate this by continuously tracking body temperature, skin humidity, and immobility duration. This system can adjust patient conditions through the bed mattress and allows remote monitoring via a mobile application, thereby reducing bedsores, errors, and healthcare costs.

2.1 Arduino models

In this section, we have presented comparison of various available Arduino models as shown in Table 2 and explained as follows:

1) Arduino Uno: The Arduino Uno is a microcontroller board that is well-suited for uncomplicated electronics projects. Its features include an ATmega328P microcontroller, 14 digital input/output pins, 6 analogue inputs, a 16MHz quartz

crystal, USB connection, and a power jack, which enable it to support a wide range of sensors and modules (shown in Figure 1). Consequently, the board is a popular choice for hobbyists and electronics enthusiasts who want to explore and experiment with different electronic concepts.

2) Arduino Mega 2560: The Arduino Mega 2560 is a microcontroller board that is larger in size than the Uno, and it comes with an ATmega2560 microcontroller. With its 54 digital input/output pins, 16 analog inputs, 4 UARTs, 16MHz quartz crystal, USB connection, and power jack, this board is ideal for more intricate projects that require additional input/output pins and memory.

3) Arduino Nano: The Arduino Nano, powered by the ATmega328P microcontroller, is a small and space-efficient microcontroller board. It comprises 22 digital input/output pins, 8 analog inputs, a 16MHz quartz crystal, a USB connection, and a power jack. The Nano is particularly useful for projects that demand a compact size.

4) Arduino Due: The Arduino Due is a powerful microcontroller board that utilizes the Atmel SAM3X8E ARM CortexM3 CPU. It boasts 54 digital input/output pins, 12 analogue inputs, 2 DACs, an 84MHz clock, a USB connection, and a power jack, making it perfect for demanding projects that require high processing power and memory.

5) Arduino MKR1000: The Arduino MKR1000 is a microcontroller board designed for IoT projects. It features an Atmel SAMD21 Cortex-M0+ 32-bit low-power ARM microcontroller, a WiFi module, 8 digital input/output pins, 12 PWM pins, 1 analogue input, a 32.768kHz crystal oscillator, USB connection, and a power jack. The MKR1000 is great for projects that require wireless connectivity and low power consumption.

Table 2. Arduino comparison

Model Name	CPU	RAM	Connectivity	Release Date	Price (approx.)
Arduino Uno	ATmega328P	2KB	USB, Serial, SPI, I2C, Analog, Digital	2010	1500 INR
Arduino Mega 2560	ATmega2560	8KB	USB, Serial, SPI, I2C, Analog, Digital	2010	3750 INR
Arduino Nano	ATmega328P	2 KB	USB, Serial, SPI, I2C, Analog, Digital	2012	2250 INR
Arduino Due	Atmel SAM3X8E ARM Cortex-M3	96 KB	USB, Native USB, Ethernet, CAN, SPI, I2C	2012	3750 INR
Arduino Leonardo	ATmega32U4	2.5KB	USB, Serial, SPI, I2C, Analog, Digital	2012	1875 INR
Arduino Zero	Atmel SAMD21G18 ARM Cortex-M0+	32KB	USB, Native USB, SPI, I2C, Analog, Digital	2015	2625 INR
Arduino MKR1000	Atmel SAMD21 ARM Cortex-M0	32KB	WiFi, USB, SPI, I2C, Analog, Digital	2016	3000 INR
Arduino MKRZERO	Atmel SAMD21G18 ARM Cortex-M0+	32KB	USB, SPI, I2C, Analog, Digital	2016	1650 INR
Arduino Nano 33	nRF52840	256KB	BLE, USB, SPI, I2C, Analog, Digital	2019	1500 INR
Arduino Portenta	STM32H747XI ARM Cortex-M7	2MB	USB, Ethernet, WiFi, Bluetooth, CAN, SPI	2020	7500 INR

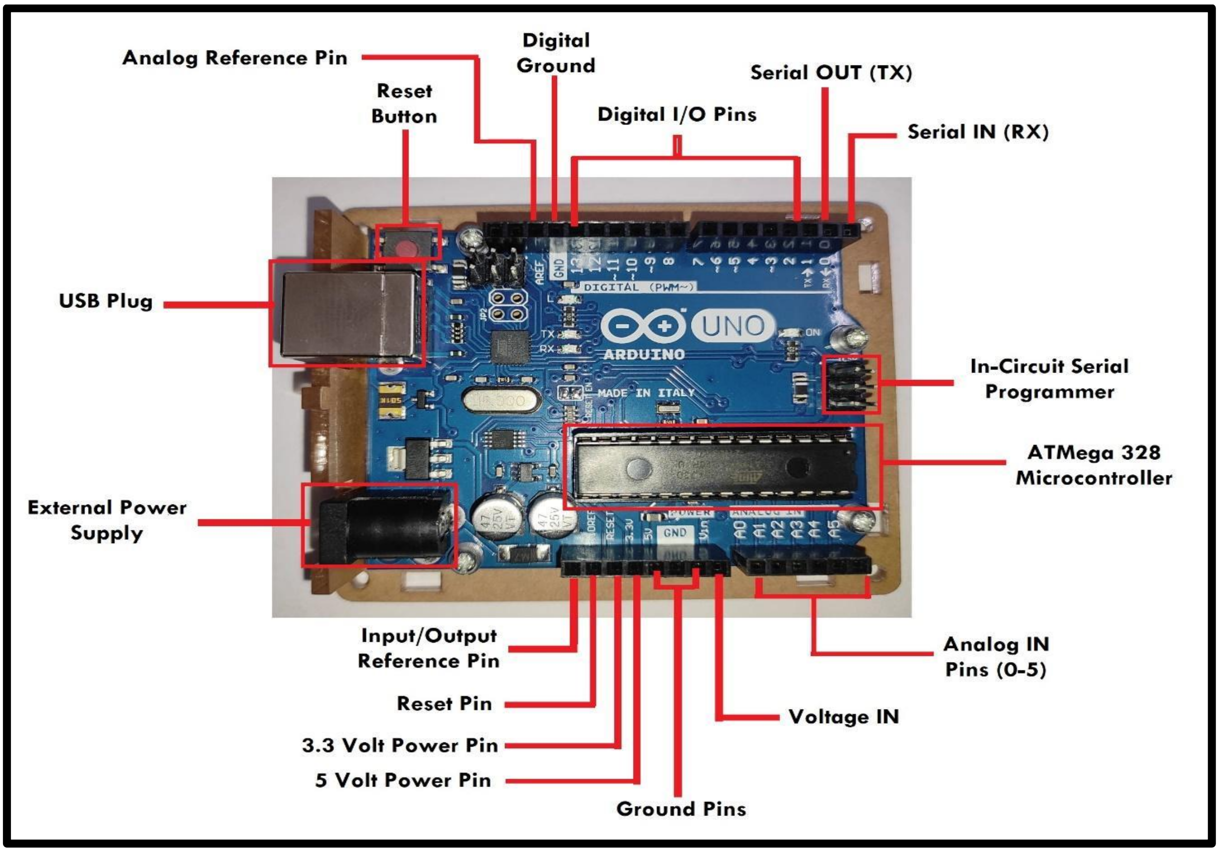

Figure 1. ARDUINO diagram

6) Arduino Nano Every: The Arduino Nano Every is an enhanced version of the Nano board, incorporating the ATmega4809 microcontroller. It comes equipped with 22 digital input/output pins, 6 analogue inputs, a 16 MHz quartz crystal, USB connection, and a power jack. Additionally, it is compatible with most Arduino shields and features improved power management and a broader range of supported voltages. Arduino Pro Mini: Launched in 2008, it is a smaller board than the Uno with fewer pins and is designed for use in embedded systems.

7) Arduino Esplora: Launched in 2012, it is a board with built-in sensors and buttons for gaming and other interactive applications.

8) Arduino Zero: Launched in 2014, it uses a 32-bit ARM microcontroller and has 14 digital input/output pins and 6 analogue input pins.

9) Arduino MKR: Launched in 2015, it is a series of boards designed for Internet of Things (IoT) applications with built-in Wi-Fi and/or cellular connectivity.

10) Arduino Nano 33: Launched in 2019, it is a newer version of the Nano with Bluetooth and/or Wi-Fi connectivity.

11) Arduino Portenta: Launched in 2020, it is a highend board with a dual-core Arm Cortex-M7 and a CortexM4 microcontroller and is designed for industrial and IoT applications.

12) Arduino Nano RP2040 Connect: Launched in 2021, it uses the Raspberry Pi RP2040 microcontroller and has Wi-Fi and Bluetooth connectivity.

13) Arduino Nano RP2040: Also launched in 2021, it is similar to the Nano RP2040 Connect but without the built-in connectivity features.

2.2 Sensors used

There are many healthcare sensors that are compatible with the Arduino are explained with their working principles are presented in Table 3:

Table 3. Sensors with working principle

Sensor	Working Principle
Heart rate sensor	Measures the heart rate by detecting changes in blood volume in the capillaries of a finger or earlobe using a light source and a photodetector. The light source shines through the skin and blood vessels, and the photodetector measures the amount of light that is reflected back. As the heart beats, blood is pumped through the capillaries, causing a small change in the amount of reflected light, which is used to calculate the heart rate.
SPO2 Saturation Sensor	Analyses a person's blood to determine its level of oxygen saturation. As the protein in charge of transporting oxygen through the bloodstream, oxygen saturation is the subject of particular attention. The sensor measures how much of the available haemoglobin is oxygenated (oxyhaemoglobin), as a percentage of the total amount. The oxygen-carrying capacity of the blood is expressed as a percentage in this measurement.
Temperature sensor	Measures the temperature of the body or the environment using a thermistor, a device that changes resistance in response to changes in temperature. The thermistor is connected to a circuit that converts the change in resistance into a temperature reading, which can be displayed on a digital screen or sent to a computer. Temperature sensors can be used to monitor body temperature for fever, or to measure the temperature of food, liquids, or the environment in various settings.

1) *Pulse Sensor*: A heart rate sensor is another name for a pulse sensor. LED and an ambient light sensor make up the pulse sensor. When the sensor is placed over a finger or a visible vein the LED starts glowing due to which the ambient light sensor will pick up the light reproduced by moving blood in the vein. This is then analysed, and a heart rate is calculated.

2) *Electrocardiogram (ECG):* An ECG works on the principle that contracting muscles generate a small electric current. This current is detected by strategically placed electrodes on the body. The electrodes pick up the current amplify them, and the wave produced is shown on display.

3) *SPO2 Saturation Sensor:* Also known as a pulse oximeter sensor determines the proportion of haemoglobin that is saturated with oxygen in the blood. The probes consist of 2 LEDs with different wavelengths and a photodetector. Oxygenated haemoglobin absorbs up to the infrared band (850-1100nm), whereas unoxygenated haemoglobin absorbs up to the red band spectrum (600-750nm). Thus, the light emitted is between 660nm to 940nm for optimal detection.

4) *Temperature Sensor*: This non-contact sensor is designed to measure the temperature of objects without physical contact. It operates on the principle that all objects, including living organisms, emit infrared energy that is inversely proportional to their temperature. The sensor detects and measures the amount of infrared energy emitted by the object to determine its temperature.

5) *GSR Sensor*: Adding a specialised sensor to our monitoring system that measures Galvanic Skin Response (GSR) is a great improvement. In reaction to emotional or psychological stress, skin conductance changes, a physiological phenomenon known as GSR. The integration of this sensor into our healthcare monitoring system allows us to monitor and evaluate an individual’s stress level. This creates doors for proactive intervention and individualised treatment in addition to offering insightful information about the monitored participants’ mental health. When paired with other vital sign readings, the Galvanic Skin Response data enhances the overall comprehension of an individual’s health condition, enabling a more complete and nuanced approach to healthcare monitoring and management.

3. METHODOLOGY

The steps for an IoT-based healthcare monitoring system’s methodology for the Arduino IoT include selecting the appropriate sensors and other components, integrating them with the Arduino, and developing the software to interpret the data obtained are shown in Figure 2. The sensors are attached to the patient’s body and take measurements of their oxygen levels, body temperature, and heart rate. This information is then sent wirelessly to the Arduino. Software is used by the Arduino to process the data before sending it to the monitoring system of the healthcare provider. This enables healthcare professionals to remotely monitor patient health and identify potential health issues before they become serious. In general, the system aids in delivering prompt and successful medical procedures.

3.1 System architecture

An Arduino-based IoT healthcare monitoring system comprises sensors, an Arduino board, a connectivity module, a user interface, and alerting/notification mechanisms. Health information from sensors, including blood pressure, temperature, and heart rate, is analysed by the Arduino board. Through a mobile application or dashboard on the web, users may access their health data and get both current readings and historical trends. In the event of aberrant readings, the system can also notify medical specialists or carers. Sensitive health information is safeguarded with data privacy and security procedures.

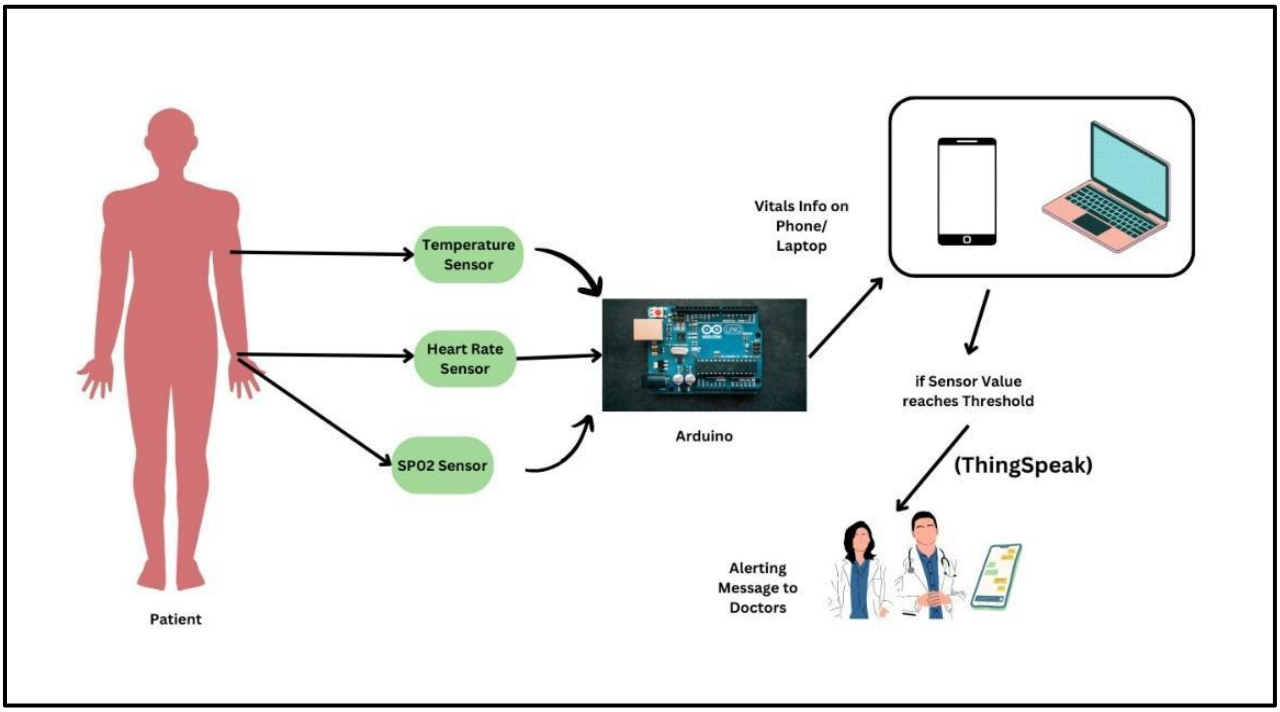

Figure 2. Block diagram of IoT based healthcare monitoring system

3.2 Data preprocessing

Data preprocessing is essential in an IoT-based healthcare monitoring system powered by Arduino to ensure accurate and trustworthy analysis. Preprocessing operations are performed on the gathered health data before sending it for additional processing and analysis. By eliminating any outliers or noise that may have been added during the sensing process, these procedures include cleaning the data. To standardise the data across many sensors and assure interoperability, data normalisation techniques can also be used. To find the most pertinent and useful qualities for analysis, feature selection or extraction may also be used in data preprocessing. The system can improve the quality and usability of the health data by carrying out these preprocessing procedures on the Arduino board itself, resulting in more efficient anomaly identification, trend analysis, and general monitoring.

3.3 Machine learning

Algorithms For efficient data analysis and decision-making, machine learning techniques are essential in an IoT-based healthcare monitoring system built on Arduino. These algorithms can be used to analyse the prepared health data and derive insightful conclusions and forecasts. To help identify anomalies or potential health problems early on, classification algorithms like logistic regression, decision trees, and support vector machines can be used to group health data into different classes or situations. Based on historical data, regression algorithms can be used to forecast future health patterns, such as linear regression or random forest. For individualised healthcare interventions, clustering algorithms like k-means or hierarchical clustering can also be used to find trends or group patients with similar profiles. The Arduino-based system can support timely interventions and improve the overall healthcare monitoring process by utilising these machine learning algorithms to provide useful information to users, medical professionals, or carers.

3.4 User interface design

The usability and user experience of an Arduino IoTbased healthcare monitoring system are directly impacted by the user interface design, making it a critical component. Users should be able to obtain and comprehend their health data with ease thanks to an intuitive, visually appealing, and simple-to-navigate user interface. It can be made up of a mobile app or a dashboard on the web that offers a thorough view of the monitored data, such as blood pressure, heart rate, and temperature. For improved data visualisation, the interface should provide real-time updates of the most recent readings, historical patterns, and graphical representations. To further assist customers in keeping track of their health, the user interface can include functions like personalised alerts, notifications, and reminders. Users can be helped in knowing how to interact with the system successfully by clear and concise instructions or tooltips. The design process should take a user-centric approach to guarantee that the interface suits the needs and preferences of the users, thereby increasing their engagement and happiness with the healthcare monitoring system.

3.5 User acceptance testing

A crucial stage in the creation of an IoT-based Arduino healthcare monitoring system is user acceptance testing. It entails involving end users to test the system's operation, usability, and usability, such as patients, medical professionals, or carers. Users get the chance to interact with the system during this phase, offer input, and assess how well it meets their needs and expectations. Before the system is implemented, user acceptability testing aids in locating any usability problems, technical flaws, or functional gaps that may need to be fixed. During this testing phase, user feedback is extremely helpful in honing the system's design, enhancing user experience, and ensuring that it satisfies the needs of the intended users. The Arduino IoT-based healthcare monitoring system can be improved by taking user feedback into account during acceptance testing, which will increase user happiness, usability, and overall efficacy in enhancing healthcare outcomes.

4. DISCUSSION

4.1 System feasibility

A key factor in the creation of an IoT-based Arduino healthcare monitoring system is the system's viability. It evaluates the system's viability and practicality from a number of angles. Technical viability assesses if the necessary connectivity, software, and hardware can be successfully integrated into the Arduino platform to produce the needed functions. Economic feasibility examines the costs involved, taking into account elements like development, upkeep, and scalability, and establishes whether the system is profitable. Operational viability investigates how well the technology can be integrated into current healthcare procedures and processes without causing any disruptions. The ability to implement the Arduino IoTbased healthcare monitoring system successfully and its capacity to deliver dependable, effective, and sustainable healthcare solutions are both made possible by feasibility analysis, which aids in the identification of potential risks and problems.

4.2 System limitations

Although an IoT-based healthcare monitoring system powered by Arduino has several advantages, it's vital to take into account its limits. One restriction is the Arduino boards' processing speed and memory capacity, which may limit the size and complexity of the algorithms and data that can be handled. Additionally, sending and receiving data may be difficult due to the restricted connectivity possibilities of Arduino boards, especially in remote or low-bandwidth locations. The monitoring process's overall dependability may be impacted by the system's reliance on sensors, which may lead to potential datagathering restrictions or mistakes. Further integration efforts might be necessary to ensure the system's compatibility with other healthcare systems or electronic health records. Finally, the Arduino boards' reliance on batteries may limit their ability to be monitored continuously and require periodic recharging or replacement. By being aware of these limits, it is possible to create an Arduino IoT-based healthcare monitoring system with the necessary considerations and trade-offs, ensuring that its capabilities match the demands and constraints of the intended healthcare environment.

4.3 Ethical considerations

The development of an IoT-based Arduino healthcare monitoring system must prioritise ethical issues. In order to preserve sensitive health information and guarantee that only authorised people have access to it, privacy and data security should be of the utmost significance. Users should be given the opportunity to give informed permission after being fully informed of the reason for data collection, how it will be used, and any associated dangers. Trust between users and the system is fostered via transparent data processing, storage, and sharing procedures. The system ought to place a high priority on user autonomy, giving people the freedom to manage their own health information and giving them the choice to delete or remove their information from the system. In order to prevent biases from being reinforced or uneven access to healthcare services being created by the system, fairness and non-discrimination must also be enforced. To guarantee the system adheres to ethical norms, regular ethical evaluations and compliance with pertinent laws like HIPAA or GDPR should be carried out. An Arduino IoT-based healthcare monitoring system can prioritise the rights and well-being of individuals while utilising technology to improve healthcare results by resolving these ethical issues.

4.4 Future directions

Healthcare monitoring solutions built on the Arduino IoT platform have a bright future in terms of improving patient outcomes. A wider range of health markers can be monitored with greater accuracy and precision thanks to enhanced sensor technology that may result from ongoing research and development. Integration with machine learning and artificial intelligence algorithms can improve the system's capacity to identify subtle irregularities, forecast health trends, and customise healthcare interventions. Data transmission can be improved and real-time monitoring made possible even in remote places thanks to advancements in connectivity choices like 5G or low-power wide area networks. A comprehensive picture of a person's health can be provided via the integration of wearable technology and smart home technologies, which can further increase the monitoring capabilities. Incorporating blockchain technology can also improve data security and privacy, ensuring transparent and incorruptible management of health data. Future directions for Arduino IoT-based healthcare monitoring systems include increasing accuracy, accessibility, personalisation, and integration with other healthcare systems. These advancements will ultimately improve patient outcomes.

4.5 Comparison with existing systems

Several advantages of Arduino IoT-based healthcare monitoring systems over current systems can be seen. First off, because Arduino boards and sensors are inexpensive, systems based on them provide cost-effective solutions. This makes them available to a wider range of consumers, including healthcare settings with limited resources. The open-source nature of Arduino also encourages innovation and customization, enabling developers to modify the system to meet particular healthcare needs. Additionally, Arduino's adaptability makes it simple to prototype and make iterative changes. Additionally, the incorporation of IoT capabilities offers real-time data transmission and monitoring, enabling rapid actions and lowering response times. On the other side, current systems might provide more sophisticated capabilities, more connectivity choices, and integration with current healthcare infrastructures. However, they frequently have higher prices, proprietary restrictions, and less flexibility. Compared to conventional systems, which might give more advanced capabilities at a higher price point, Arduino IoT-based healthcare monitoring systems offer a practical, adaptable, and affordable option. Specific needs, resources that are accessible, and the desired balance between cost, usefulness, and flexibility all play a role in which one should choose.

5. RESULTS

The incredible solution of monitoring vital health parameters such as Oxygen Level (SPO2) and Heart Rate through real-time tracking has been painstakingly designed using Arduino as shown in Figure 3 to create Health Care Monitoring System based on IoT. Our system is more than just a passive monitoring system as it incorporates special sensors that not only monitor the user's blood oxygen saturation and heart rate but also act on this information. The most noticeable addition is an improved alerting system. This alerting system works when the system detects oxygen levels below normal range. This diversified strategy ensures not only monitoring of vital signs but also a proactive response to potential health risks. To show how committed we are to the enhancement of user safety and well-being through state-of-the art information technology in health care, we incorporate a real time data driven alerting mechanism. As a result, our Health Care Monitoring System is an integrated solution not only providing information about health conditions but also acting where needed, enhancing the level of personalized and proactive care.

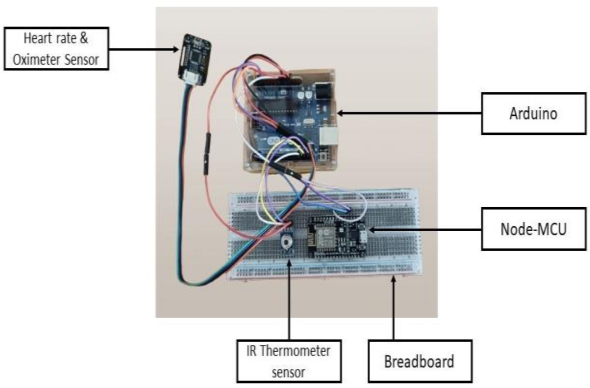

Figure 3. Structure of Arduino-based healthcare monitoring system

Key features of the project:

(1). Vital Parameter Monitoring: The system accurately measures the user's oxygen saturation (SPO2) and heart rate using dedicated sensors in real-time.

(2). Alerting System Integration: In addition to tracking heart rate and oxygen level (SPO2) in real time, the Arduino-built IoT-based health care monitoring system has an alerting mechanism. The system continually checks these vital indicators using specialized sensors, and when the oxygen level drops below the usual range. In reaction to possible health dangers, this creative warning function guarantees prompt intervention and improves user safety.

(3). Cloud-Powered Healthcare Monitoring: The healthcare monitoring system stores and manages real-time data gathered from several sensors using ThingSpeak, a secure cloud platform for IoT applications. ThingSpeak guarantees data accessibility and integrity, enabling medical practitioners to quickly and effectively monitor critical health metrics from a distance. ThingSpeak's robust data visualisation tools make it easier to analyse trends and patterns, which improves patient outcomes and treatment.

(4). Data Representation: The project enhances data visualization through three key outputs:

• SPO2 Level and Heart Rate Display (Figure 4): A dynamic display of the user's oxygen saturation and heart rate, ensuring immediate awareness of their health status.

• Heart Rate per Minute Graph (Figure 5) and (Figure 6): This graph offers a comprehensive view of heart rate variations, supporting trend analysis.

• Blood Oxygen Graph (Figure 7) and (Figure 8): The graph visualizes changes in oxygen saturation levels, providing insights into potential health issues.

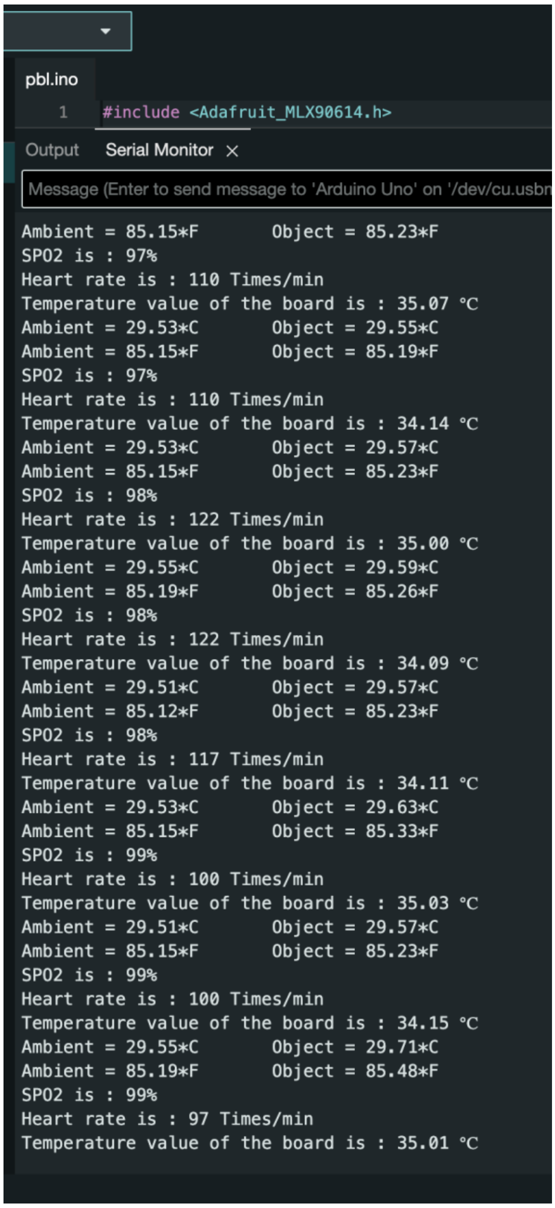

Figure 4. SPO2 level and heart rate of a sick person

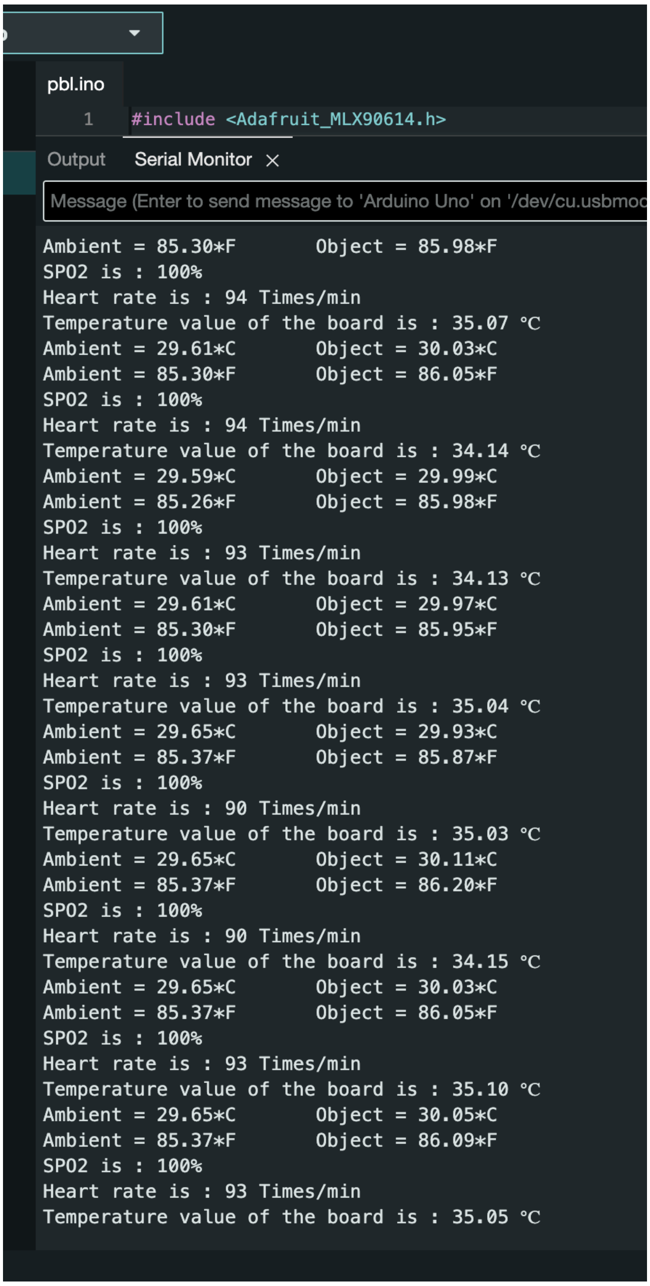

Figure 5. SPO2 level and heart rate of a normal person

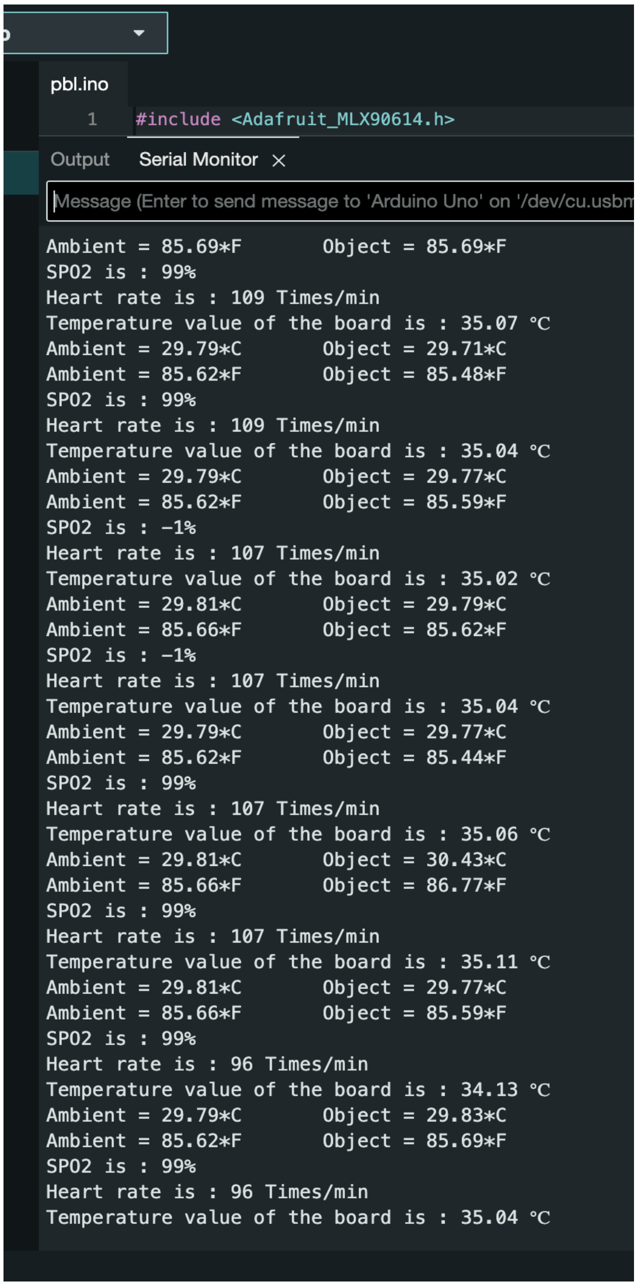

Figure 7. SPO2 level and heart rate of a person after exercise

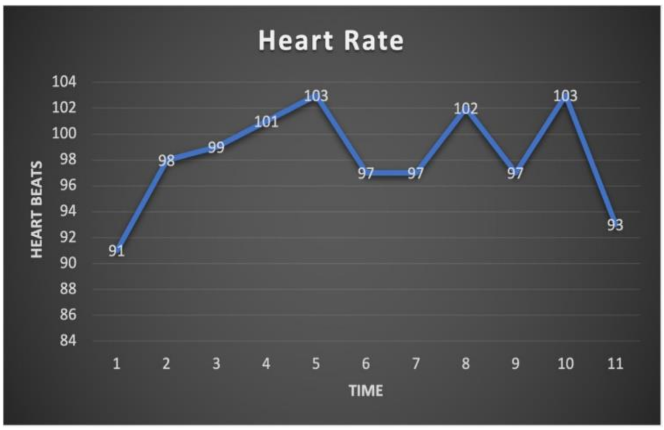

Figure 6. Heart rate per minute graph

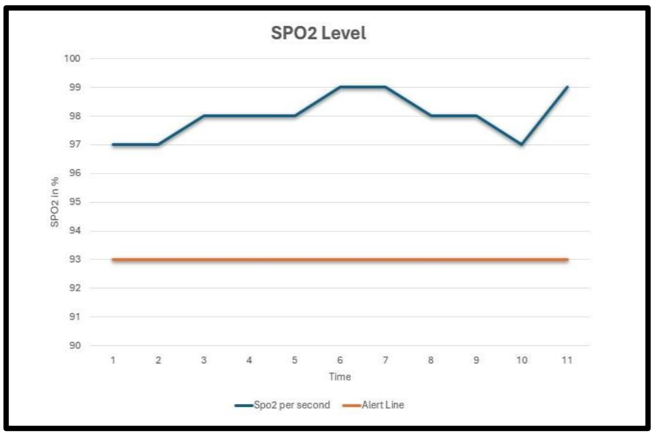

Figure 8. Blood oxygen graph

6. CONCLUSION

In this paper we have presented an IoT-based Arduino healthcare monitoring system for tracking the vital healthcare data in real-time and alerting system. The entire setup comprises a number of sensors to assess temperature, oxygen saturation, and heart rate, among other vital indications. Moreover, we have also added an alerting mechanism that warns medical professionals right away if oxygen levels fall below a certain threshold. From the presented results, it is perceived that our affordable and user-friendly design guarantees accessibility for a wide variety of patients. The system uses the simplicity and flexibility of the Arduino platform to give real-time data visualization on a display.

REFERENCES

[1] Aung, N.P., Htay, L.L., Wai, K.T. (2019). Internet of Things (IoT) based healthcare monitoring system using NodeMCU and Arduino UNO. https://www.ijtsrd.com/papers/ijtsrd26482.pdf.

[2] Abdulmalek, S., Nasir, A., Jabbar, W.A., Almuhaya, M.A.M., Bairagi, A.K., Khan, M.A.M., Kee, S.H. (2022). IoT-based healthcare-monitoring system towards improving quality of life: A review. Healthcare, 10(10): 1993. https://doi.org/10.3390/healthcare10101993

[3] Akhila, V., Vasavi, Y., Nissie, K., Rao, P. (2017). An IoT based patient health monitoring system using Arduino Uno. International Journal of Research in Information Technology, 1(1). https://www.academia.edu/35340974/An_IoT_based_Patient_Health_Monitoring_System_using_Arduino_Uno.

[4] Hossain, M.J., Bari, M.A., Khan, M.M. (2022). Development of an IoT based health monitoring system for e-Health. In 2022 IEEE 12th Annual Computing and Communication Workshop and Conference (CCWC), Las Vegas, NV, USA. https://doi.org/10.1109/ccwc54503.2022.9720825

[5] Zin, M., Mustafah, M.A.K., Arith, F., Isa, A.A.M., Barukang, L., Markarian, G. (2022). Development of low-cost IoT-based wireless healthcare monitoring system. Przegląd Elektrotechniczny, 1(1): 224-229. https://doi.org/10.15199/48.2022.01.48

[6] Bhuiyan, M.N., Billah, M.M., Bhuiyan, F., Bhuiyan, M.A.R., Hasan, N., Rahman, M.M., Miah, M.S., Alibakhshikenari, M., Arpanaei, F., Falcone, F., Niu, M. (2022). Design and implementation of a feasible model for the IoT based ubiquitous healthcare monitoring system for rural and urban areas. IEEE Access, 10: 91984-91997. https://doi.org/10.1109/access.2022.3202551

[7] Nduka, A., Samual, J., Elango, S., Divakaran, S., Umar, U., SenthilPrabha, R. (2019). Internet of Things based remote health monitoring system using Arduino. In 2019 Third International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, India. https://doi.org/10.1109/i-smac47947.2019.9032438

[8] Abdulameer, T.H., Ibrahim, A.A., Mohammed, A.H. (2020). Design of health care monitoring system based on Internet of Thing (IoT). In 2020 4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Istanbul, Turkey. https://doi.org/10.1109/ismsit50672.2020.9254291

[9] Ahmed, A., Khan, M.M., Singh, P., Batth, R.S., Masud, M. (2022). IoT-based real-time patients vital physiological parameters monitoring system using smart wearable sensors. Neural Computing & Applications, 35(7): 5595. https://doi.org/10.1007/s00521-022-07090-y

[10] Siam, A.I., El-Affendi, M.A., Elazm, A.A., El-Banby, G.M., El-Bahnasawy, N.A., El-Samie, F.E.A., El-Latif, A.A.A. (2023). Portable and real-time IoT-based healthcare monitoring system for daily medical applications. IEEE Transactions on Computational Social Systems, 10(4): 1629-1641. https://doi.org/10.1109/tcss.2022.3207562

[11] Shaown, T., Hasan, I., Mim, M.R., Hossain, M.S. (2019). IoT-based portable ECG monitoring system for smart healthcare. In 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), Dhaka, Bangladesh, pp. 1-5. https://doi.org/10.1109/icasert.2019.8934622

[12] Islam, M.S., Islam, M.T., Almutairi, A.F., Beng, G.K., Misran, N., Amin, N. (2019). Monitoring of the human body signal through the Internet of Things (IoT) based LoRa wireless network system. Applied Sciences, 9(9): 1884. https://doi.org/10.3390/app9091884

[13] Sudha, K., Theresa, M.M., Vinayagam, P., Suganthi, R., Sripriya, T., Uthayakumar, G.S. (2024). Efficient IoT based COVID patient healthcare control system using Arduino with mobile app. Measurement: Sensors, 33: 101161. https://doi.org/10.1016/j.measen.2024.101161

[14] Afreen, H., Amir, A., Farooq, U. (2024). An IoT-assisted patient monitoring and alert system. https://www.jcbi.org/index.php/Main/article/view/360.

[15] Wu, J.Y., Wang, Y., Ching, C.T.S., Wang, H.M.D., Liao, L.D. (2023). IoT-based wearable health monitoring device and its validation for potential critical and emergency applications. Frontiers in Public Health, 11. https://doi.org/10.3389/fpubh.2023.1188304

[16] Srinivasan, C.R., Charan, G., Babu, P.C.S. (2020). An IoT based SMART patient health monitoring system. Indonesian Journal of Electrical Engineering and Computer Science, 18(3): 1657. https://doi.org/10.11591/ijeecs.v18.i3.pp1657-1664

[17] Mahajan, S., Birajdar, A. (2019). IoT based smart health monitoring system for chronic diseases. In 2019 IEEE Pune Section International Conference (PuneCon), Pune, India, pp. 1-5. https://doi.org/10.1109/punecon46936.2019.9105717

[18] Begum, R., Dharmarajan, D. (2020). Smart healthcare monitoring system in IoT. European Journal of Molecular & Clinical Medicine, 7(4): 2647-2661. https://www.researchgate.net/publication/346605988_SMART_HEALTHCARE_MONITORING_SYSTEM_IN_IoT.

[19] Bhagchandani, K., Augustine, D.P. (2019). IoT based heart monitoring and alerting system with cloud computing and managing the traffic for an ambulance in India. International Journal of Electrical and Computer Engineering, 9(6): 5068. https://doi.org/10.11591/ijece.v9i6.pp5068-5074

[20] Abdelmoghith, A., Shaaban, R., Alsheghri, Z., Ismail, L. (2020). IoT-based healthcare monitoring system: Bedsores prevention. In 2020 Fourth World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), London, UK. https://doi.org/10.1109/worlds450073.2020.9210