Design of cost-effective wearable sensors with integrated health monitoring system

Nayyer Sultana[1], Dr. Shanila Mahreen[2]
[1]*Master of Engineering, Nawab Shah Alam Khan College of Engineering & Technology*
[2]*HoD, Associate professor, Nawab Shah Alam Khan College of Engineering & Technology*

***Abstract:** The growing need for continuous, real-time health data to improve medical diagnosis and personal well-being has led to a recent spike in demand for wearable health monitoring systems. This article outlines a wearable health monitoring device that uses an Arduino microcontroller board to continuously check a patient's temperature, oxygen saturation level, and heartbeat. These days, IoT is crucial to healthcare systems, and because wearable sensors and smart phones are being used more frequently, remote health care monitoring has developed so quickly. The design and development of an affordable wearable sensor system that is connected to an extensive health monitoring platform is presented in this study. The suggested system makes use of sophisticated yet reasonably priced sensor technologies to track vital indications like blood pressure, body temperature, heart rate, and blood oxygen levels.*

***Keywords:** Wearable Health Devices (WHDs), Cost-effective sensors, Health monitoring, Internet of Things (IoT) Real-time data transmission, Vital signs monitoring, Remote health monitoring.*

The Internet of Things (IoT), wearable technology, and cloud-based solutions are just a few of the technical innovations that are used in modern healthcare systems. Through the Internet of Things, the healthcare industry may remotely record medical data, monitor patient actions, and transfer this information. To keep this link, safe data transmission is essential. IoT technology needs to be built with many communication protocols and excellent performance in order to be used in healthcare. A resource-based approach to data retrieval has been developed for health applications that require a lot of information. This technology controls patient activities by integrating with a smart box, which serves as a medical system. Effective use of the Web Real-Time Communication procedure is made to improve the security of data transfer.

These days, the Internet of Things is crucial to medical systems, and the growing usage of sensor devices has accelerated the development of surveillance of health remotely. The rapid advancement of wearable technology has opened new horizons in the field of healthcare. Wearable sensors, when integrated with health monitoring systems, offer a promising solution to enhance patient care and disease management. These devices enable continuous monitoring of vital signs such as temperature, heart rate, oxygen levels, and more, providing real-time data that can be crucial for early detection and intervention of health issues.

Wearable Health Devices (WHDs) represent an innovative technology that allows continuous monitoring of vital signs during daily activities—whether at work, home, during sports, or in clinical settings. These devices offer the advantage of minimizing discomfort and interference with normal human activities. WHDs are a component of personal health systems, a concept introduced in the late 1990s to place the individual at the center of the healthcare delivery process, enabling them to manage their own health and interact with care providers—commonly referred to as “patient empowerment.” The aim was to increase public interest in personal health, enhance the quality of care, and leverage new technological capabilities.

These devices create a synergy between multiple scientific domains, including biomedical technologies, micro and nanotechnologies, materials engineering, electronic engineering, and information and communication technologies. The use of WHDs allows for the ambulatory acquisition of vital signs and health status monitoring over extended periods (days/weeks) and outside clinical environments. This feature ensures the collection of vital data during various daily activities, providing better support for medical diagnosis and aiding in faster recovery from medical interventions or injuries.

WHDs are also highly beneficial for sports and fitness activities to monitor athletic performance and are used by first responders and military personnel to evaluate and monitor their body responses in hazardous situations, managing their effort and occupational health. These devices serve both medical and fitness/wellness purposes, always focusing on human body monitoring. Given this focus, the term "health" best describes these devices, leading to the term WHDs. The denomination of WHDs can be more specific depending on their application areas. Regardless of their purpose, four main design requirements are paramount: low power consumption, reliability and security, comfort, and ergonomics.

In the wake of the COVID-19 pandemic, the need for efficient and cost-effective health monitoring solutions has become more apparent. Traditional healthcare systems often face challenges such as limited resources, high costs, and accessibility issues, especially in remote areas. Wearable sensors, combined with Smartphone technology, can bridge this gap by offering affordable and accessible health monitoring solutions.

This research aims to design a cost-effective wearable sensor system that integrates seamlessly with smart phones to provide real-time health monitoring. The proposed system will not only reduce the burden on healthcare infrastructure but also empower individuals to take charge of their health through self-testing and remote monitoring. By leveraging advancements in Internet of Things (IoT) and telemedicine, this system aims to create a smarter and healthier society.

1.1 Problem statement:

Public health is suffering the most from an increasingly stressed lifestyle. Doctor expenses have skyrocketed due to the growing number of people and hospital lines, which is particularly hurting people who are unable to pay the fees or who do not have serious illnesses but only learn of them after paying a large amount to the doctor.

Traditional healthcare practices often face challenges such as limited resources, high costs, and inadequate accessibility, particularly in remote and underserved areas. These issues are exacerbated by the increasing prevalence of chronic diseases and the aging population, which demand continuous and efficient health monitoring.

1.2 Aim and Objectives:

Aim: The project's aim is to create a comprehensive and reasonably priced health monitoring system that makes use of cutting-edge sensor technology and Internet of Things connectivity. The goal of this project is to develop wearable sensors that detect vital indications including body temperature, breathing, and heart rate continuously and in real time. These sensors will be safe for data transmission and comfortable for prolonged wear thanks to their ergonomic design, low power consumption, and strong security features.

Objectives:

- Our main goal is to create an automated solution that will assist with remote host monitoring.
- To design an intervention or alarm system that will activate in the event of a dangerous circumstance.
- To offer an Arduino microcontroller-based method of remotely controlling blood pressure, temperature, and pulse.
- To make a contribution to the Internet of Things in order to open the door for a future technological development project.
- Wearable technology will be used to monitor biological vitals.
- To improve continuous health monitoring and guarantee safe and dependable data transfer.

II. LITERATURE WORK

[1] In this study, a wearable Tele-ECG and heart rate (HR) monitoring device with an innovative ECG circuit architecture is presented. The system has also been expanded to include a server, a web page, a smartphone, and Bluetooth low energy (BLE) for remote monitoring. Velcro makes it easy for the user to attach and detach the TE from the singlet, allowing for easy dry cleaning for extended use. In order to assess the TE-based ECG system, a new ECG system was created, and the average correlation between the recorded ECG signals was found to be 99.23%. BLE is used to send a filtered digital signal with a high signal-to-noise ratio of 45.62 dB to the smartphone.

[2] IoT is quickly transforming the healthcare sector, as seen by the large number of new healthcare technology start-ups. In this project, we used ESP8266 and Arduino to design an Internet of

Things-based patient health monitoring system. Thing Speak is the IoT platform utilized in this project. Thing Speak is an open-source Internet of Things (IoT) application and API that uses the HTTP protocol to store and receive data from objects across a local area network or the Internet. This Internet of Things gadget could measure the ambient temperature and read the pulse rate. It updates an IoT platform with the pulse rate and ambient temperature, which are continuously monitored.

[3] This study describes an IoT-based system for continuously monitoring a patient's body. Researchers and patient guardians are increasingly using patient monitoring systems these days. Every 15 seconds, this device is able to track the patient's physiological parameters. This device is in charge of taking the patient's pulse, body temperature, and heart rate. It then uses a Wi-Fi module to send the data to an IoT cloud platform, where it is recorded together with the patient's health status. It makes it possible for the authorized person or medical specialist to keep an eye on the patient's health, as the patient's state can be continuously monitored on the cloud server.

[4] One of the most popular and cutting-edge applications in the medical industry is telemedicine, which developed to help patients and people receive better and quicker medical aid. Networked sensors, which can be embedded in our living spaces or in the form of wearables, enable the collection of rich data that is indicative of our mental and physical health in order to provide the best patient health monitoring. This study explains the approach used and identifies some design factors that should be taken into account to ensure the efficacy of the patient health monitoring system. Using this technique, the patient's vital signs—such as their heart rate and body temperature—are recorded and transmitted as an alarm to the preferred smartphone app.

[5] Health monitoring is an issue for healthcare professionals and patient safety. Bringing accessibility through technological advancement, we developed the IoT based patient monitoring system using Arduino. The sensor measures heart rate along with the SpO2 levels of blood. When monitoring, data is sent to the Arduino device and transmitted to a custom Android app via Bluetooth, syncing data with the IoT platform hosted on Google Firebase, an open-source application that stores and retrieves data over the internet. Information is displayed on an 0.96” OLED screen implemented by an Arduino Sketch which also allows transmission of data to the Bluetooth module.

[6] Using a data fusion strategy based on many discrete data types—eye characteristics, bio-signal fluctuation, in-car temperature, and vehicle speed—this article suggests a way to monitor driver safety levels. The driver safety monitoring system was created in practice as an Android smartphone application, which eliminates the need for additional equipment or financial investment to measure safety-related data. Additionally, the technology offers versatility and great resolution. In the process of safety monitoring, information obtained from several sensors—such as video, electrocardiography, photoplethysmography, temperature, and a three-axis accelerometer—is combined and fed into an inference analytic framework. The driver's capability level is shown via a Fuzzy Bayesian framework that is updated continually in real-time.

[7] The state of the art in the literature on mobile health care is presented in this study. The study was carried out using a systematic review, which is a method of evaluating and analyzing all of the research that is currently accessible on a specific issue in a certain area using a trustworthy and rigorous approach. 40 (2.69%) of the 1,482 publications that initially met our selection criteria were fully read in order to extract and analyze the data. In addition to presenting current trends and technological challenges on the topic, our analysis since 2010 demonstrates current progress in ten application areas. Infrastructure, software architecture, modeling, framework, security, fixations’, multimedia, mobile cloud computing, patient monitoring, and literature reviews are some of the application fields.

III. EXISTING AND PROPOSED SYSTEM

3.1: Existing System

Doctor-assisted diagnosis, conventional equipment that can only gauge one parameter, and gadgets that require intrusive connections in order to obtain measurements are all part of the present wellness surveillance system. There isn't an automatic system; Smart watches are costly and not specifically designed for medical use.

Under the current system, a patient must be admitted to the hospital for ongoing care. After he or she is released from the hospital, it is impossible. You can't utilize this system at home. The current systems measure the patient's health characteristics and transmit the data via Bluetooth, zigbee and other protocols; these are only utilized for immediate data transmission. The doctor may not be able to retrieve this information always.

3.1.1: Disadvantages of existing system

- Expensive
- Restricted Accessibility
- Periodic Surveillance
- Intensive on Resources
- Inconvenience for Patients
- Challenges in Data Management
- Insufficient Patient Involvement
- Security Issues
- Problems with Scalability
- Limitations on Emergency Response

3.2 Proposed System

The suggested wellness tracking solution is intended to track people's wellness around-the-clock. The Arduino microcontroller is utilized in this framework to gather and analyze every piece of information. With their diverse variety of functions, wireless gadgets have infiltrated the medical field. Using current technologies to periodically monitor information about patients is overhead. New wireless technologies for sensing have been developed to get around this. Advanced detectors were added, such as a pulse oximeter to measure saturation level of oxygen. Various sensors are employed to measure various parameters. For remotely assessment, all of this data has been shared to Adafruit server.

The device that is being developed would have the dual purpose of keeping track of the patient's well-being both while the patient is bedridden and while he is outside. The system's main objective is to send data via a webpage to enable ongoing online evaluation of patients. A device like this would continuously measure vital body characteristics like temperature and heart rate, compare them to a preset range, and notify the doctor right away if the numbers exceeded the predefined limit. The information stored in this framework is transmitted via a microcontroller.

It is linked to the Internet of Things, which gives the caregiver or physician statistics. The online database stores the patient's medical records. The condition of the patient is readily accessible to a physician from any location at any moment.

IV.BLOCK DIAGRAM AND IMPLEMENTATION

By combining a microcontroller with various detectors and connectivity parts, this architecture offers a complete configuration for a system for health surveillance. An economical and practical option for ongoing wellness surveillance, it allows for secured wireless transfer, immediate data interpreting, and presentation.

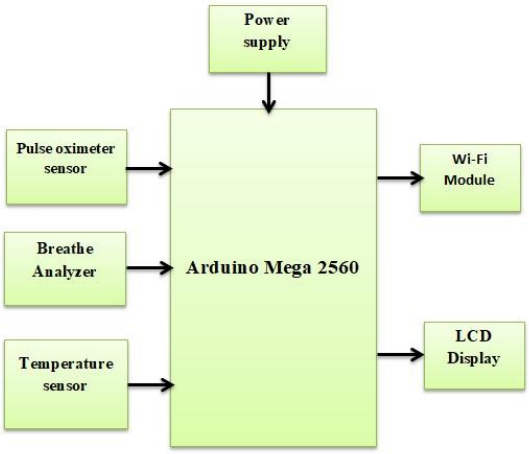

Figure 4.1: Block diagram of health monitoring system

The Arduino Mega 2560 receives unprocessed information from the various sensors (temperature sensor, breath analyzer, and pulse oximeter) that constantly records a person's health indicators. The detectors' data that arrives is processed by the Arduino Mega 2560. It guarantees that the information is correct and prepared for communication or presentation. The liquid crystal monitor (LCD) receives the data that has been processed and shows it to the user graphically. The user can now monitor their health parameters in real time thanks to this. The Arduino Mega 2560 may wirelessly transmit the information it processes to other equipment or medical professionals at the same time thanks to the Wi-Fi adapter. This guarantees that the health information can be kept in a safe database and watched over from a distance.

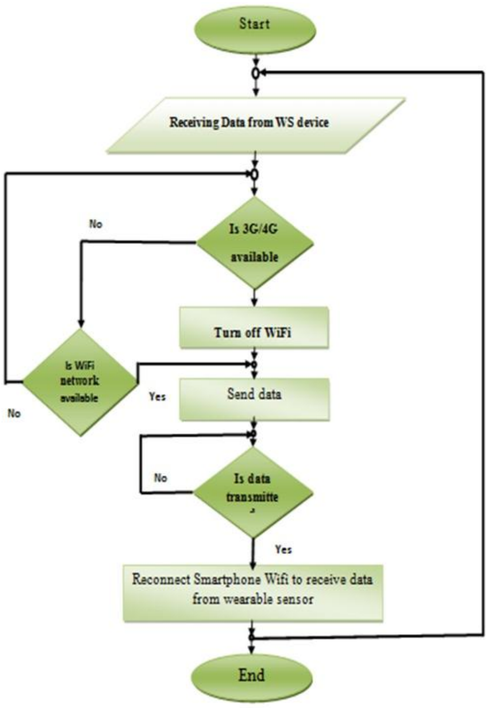

Figure 4.2: Flow diagram of the methodology

4.1 Hardware Components

4.1.1: Power Supply: gives all parts, such as the Arduino Mega 2560 controller and attached detectors, the required voltage as well as current they require.

4.1.2: Arduino Mega 2560: This is the main component of the architecture, handling end controlling devices as well as processing information collected by several sensors. It communicates with a number of important parts.

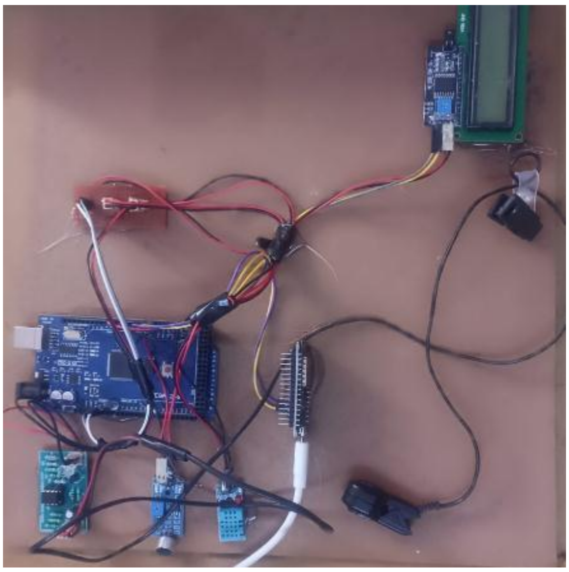

Figure 4.2: Arduino setup

4.1.3: Pulse Oximeter Sensor: Small and light, a pulse oximeter sensor usually attaches to the user's fingertip or earlobe. It features a digital display screen and a clip-like appearance. The Arduino Mega 2560 processes the data from this sensor, which determines the saturation level of oxygen in the blood.

Figure 4.3: Pulse oximeter

4.1.4: Breathe Analyzer: The Arduino Mega 2560 receives the data from this sensor, which examines the user's breath and may measure things like respiration rate or alcohol concentration.

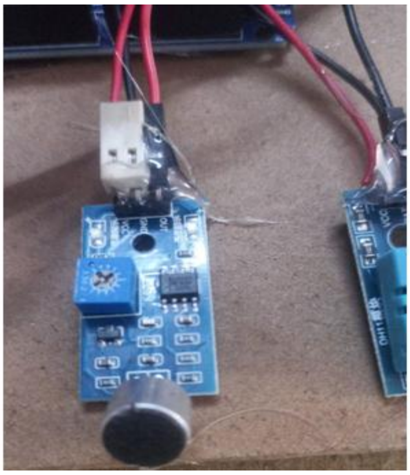

Figure 4.4: Breathe analyzer

4.1.4: DHT temperature sensor: This sensor measures the user's body temperature and sends this data to the Arduino Mega 2560.

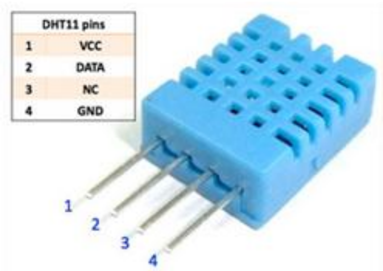

Figure 4.5: DHT sensor

4.1.5: Wi-Fi Module: This component enables wireless connection and data transfer to external hardware or websites by connecting the Arduino Mega 2560 to a network that uses Wi-Fi.

Figure 4.6: Wi-fi Module

4.1.6: LCD Display: This display provides a visual representation for individuals to track their health indicators in real-time by displaying the processed information from the detectors.

V. RESULTS AND ANALYSIS

This configuration serves as a working model for a portable wellness tracking device that combines a microcontroller and several sensors. It is advantageous for both medical applications and personal health management since it offers a workable option for ongoing, real-time health monitoring.

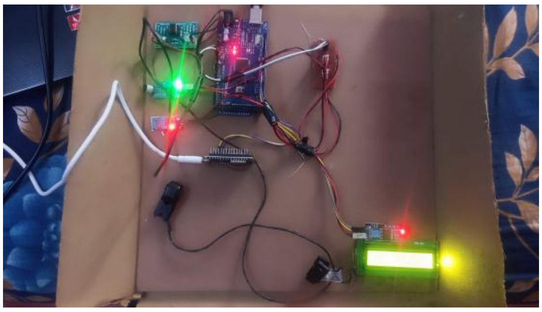

Figure 5.1: Experimental Setup

LCD display gives the user visual feedback by displaying a variety of outputs, including sensor data and system status. The Arduino Mega 2560 is the central component of the system. With numerous wires attached, this microcontroller board serves as the setup's brain, processing inputs from different sensors and managing devices that provide output such the LCD display. A pulse oximeter which measures the saturation of oxygen , is one of the sensors that is linked to the Arduino. The Arduino receives data from this sensor and processes it. In a similar manner, the thermal sensor constantly measures the individual's internal temperature and transmits this information to the Arduino, while the breathing analyser device tracks the the client's breathing, analyzing characteristics like respiration rate as well as particular signs.

A Wi-Fi module is incorporated into the configuration to facilitate wireless communication, enabling the Arduino to establish a connection with a Wi-Fi network. This module makes it easier to connect to other equipment or services in the cloud and transmit data remotely. A white USB cable that is attached to the Arduino's circuit board powers the entire system by giving all of the parts the voltage and current they require.

The Adafruit panel is a useful tool for healthcare applications and personal wellness tracking since it shows important health parameters in actual time and with clarity. It demonstrates how wearable smart detectors can be utilized to constantly monitor vital health information, which is essential for both regular wellness supervision and the initial medical problem diagnosis.

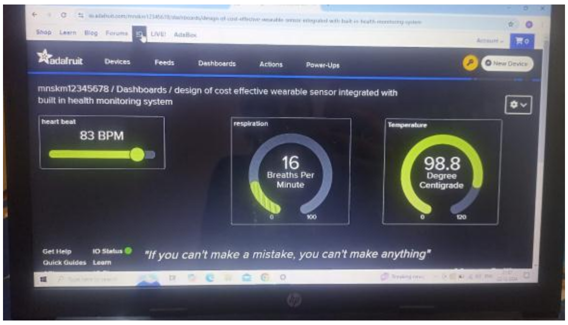

Figure 5.2: Adafruit panel for result analysis.

The Adafruit IO platform uses a sensor attached to a clothing to track health parameters. Three important health metrics are shown particularly on the dashboard, each with an easy-to-understand visual representation.

The Adafruit IO platform's interface is made to organize and display information collected by Network (IoT) components. In particular, the dashboard displays the user's health measurements gathered from wearable sensors by listing several data sources under the "Default" group. The feeds are updated in real-time and include "Temperature" with a value of 98.80 degrees Fahrenheit, "Respiration" having a frequency of sixteen breathes per minutely, and "Pulse" having the most recent logged rate of 83 rhythms per minute. Vital signs are continuously monitored by these streams, allowing for prompt health evaluations.

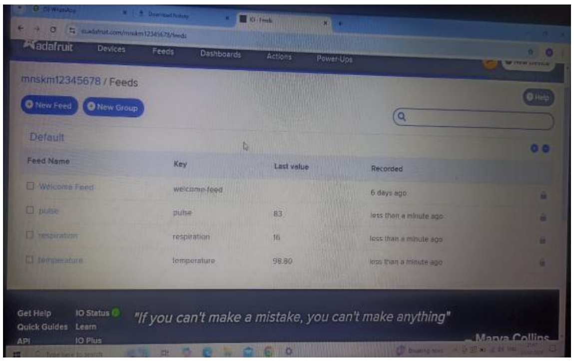

Figure 5.3: Adafruit dashboard

Health Indicators

- Heart rate: The present heart rate is displayed as a horizontal bar with a green part. The current value is 83 beats per minute, or BPM.
- Breathing: A circular gauge with the current respiration rate highlighted in a green part. 16 breaths per minute is the current value.
- Temperature: 98.8 degree Fahrenheit is recorded.

VI. ADVANTAGES OF PROPOSED SYSTEM

The suggested design has a number of benefits.

- Cost-effectiveness: These wearable sensors are accessible for a larger population, particularly those who live in underprivileged and isolated regions, thanks to the utilization of inexpensive supplies and manufacturing procedures.
- Ongoing Health Monitoring: Continuous and real-time vital sign monitoring is made possible by the sensors, which can greatly enhance patient outcomes by enabling early health issue discovery and prompt action.
- Self-Management and Empowerment: The system enables users to take control of their health by giving them the resources to keep an eye on their own health.
- Remote Observation: Remote health data monitoring is made possible by the integration of the Internet of Things and wireless communication methods, which enables medical Professionals to monitor patients' states from a distance.
- Ergonomics and Comfort: The wearable sensors' ergonomic design makes it possible to wear them for extended periods of time without experiencing discomfort or interfering with regular tasks.
- Scalability: More sophisticated features and capabilities, including integrating AI for statistical evaluation and tailored health advice, can be accommodated by scaling up the architecture.

VII. CONCLUSION AND FUTURE WORK

An important breakthrough in the healthcare industry is the creation of affordable wearable sensors that are connected with health monitoring systems. These gadgets offer constant, real-time vital sign monitoring, which makes it possible to identify and treat a number of illnesses early. This study effectively illustrates how accessible and reasonably priced health monitoring solutions may be created by utilizing the most recent advancements in IoT, materials science, and electronic engineering technologies. In addition to lessening the strain on the healthcare system, the suggested solution gives people the ability to properly control their own health. These wearable sensors are a feasible choice for extensive use in both clinical and private settings since the incorporation of secure data transfer guarantees the dependability and privacy of patient data.

FUTURE WORK

The development of sophisticated sensors with improved sensitivity, specificity, and accuracy for a range of health measures should be the main goal of future research. Data analysis can be improved by integrating artificial intelligence and machine learning computations, which can yield tailored medical recommendations and forecasting data. The battery life of wearable sensors can be increased by research into alternate electricity sources and energy-harvesting technological advances, making them more viable for long-term use.

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