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Non-Invasive Blood Glucose Estimator using Arduino and NodeMCU

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Abstract

This paper is designed to revolutionize healthcare delivery by enabling real-time, remote monitoring of key health parameters. The system uses IoT-based sensors to continuously track vital signs like weight, body temperature, blood pressure, heart rate, and SpO₂. The data collected is transmitted wirelessly to healthcare providers via cloud technology, allowing doctors to monitor patients anywhere. This system is particularly beneficial for elderly, chronic, and rural patients who may face challenges in accessing healthcare services regularly. By providing continuous monitoring, the system aids in the early detection of health issues, potentially preventing serious medical emergencies. It also generates instant alerts for abnormal readings, ensuring timely medical intervention. The system reduces the need for frequent hospital visits, saving both time and healthcare costs. Additionally, all patient data is securely stored in the cloud, providing long-term tracking and analysis for better treatment planning. The IoT-Enabled Smart Healthcare System is cost-effective, scalable, and user-friendly, making it a practical solution for both personal and clinical use. Ultimately, this system enhances healthcare accessibility, efficiency, and quality, enabling smarter, faster, and more connected healthcare services.

Keywords:

Non-Invasive Glucose Monitoring, Near-Infrared (NIR) Sensor, Arduino, NodeMCU, IoT, Wireless Health Monitoring, Real-Time Data, Blynk Application, Smart Healthcare, Remote Patient Monitoring.

1. INTRODUCTION

Diabetes mellitus is a widespread chronic metabolic disorder that significantly impacts the quality of life of millions worldwide. It is characterized by elevated blood glucose levels, which, if left unmanaged, can lead to severe complications such as heart disease, kidney failure, and nerve damage. Therefore, Regular and accurate blood glucose monitoring is critical for effective diabetes management and prevention of associated health risks. Conventional glucose monitoring techniques typically involve invasive finger-prick tests. While clinically reliable, these methods are often painful and inconvenient for users. The repetitive nature of pricking discourages individuals from frequent monitoring, leading to inconsistent glucose tracking and poor disease control. There is an increasing demand for user-friendly alternatives that minimize discomfort while maintaining measurement accuracy.

The emergence of Internet of Things (IoT) technologies provides a promising avenue to address these challenges. By integrating microcontrollers, sensors, and wireless communication, IoT enables real-time health monitoring with improved accessibility and efficiency. In particular, non-invasive glucose sensing technologies are gaining momentum, offering continuous glucose tracking through bodily fluids like sweat or interstitial fluid, thus eliminating the need for blood sampling. This paper presents a prototype of a Handy Non-Invasive Blood Glucose Estimator developed using Arduino and NodeMCU. The system aims to deliver a portable, cost-effective, and pain-free solution for real-time glucose monitoring. It uses non-invasive sensors interfaced with Arduino for data acquisition and NodeMCU for wireless data transmission to cloud-based platforms, thereby enabling real-time access and analysis. This approach aims to improve user compliance and foster proactive diabetes management.

2. LITERATURE SURVEY

The integration of IoT in healthcare has revolutionized chronic disease management, particularly in continuous monitoring and smart diagnostics. A congestion-free routing mechanism was proposed to improve data delivery and network efficiency in Wireless Sensor Networks (WSNs) for healthcare applications, ensuring reliable transmission of patient data [1]. Bandodkar et al. developed epidermal tattoo sensors for non-invasive sweat-based glucose monitoring, enabling real-time, painless measurement of glucose levels [2]. Lee et al. introduced a graphene-based wearable patch capable of continuous glucose detection, demonstrating high sensitivity and flexibility suitable for long-term use [3].Patel and Doshi designed an IoT-enabled smart glucometer using NodeMCU for wireless glucose monitoring, emphasizing portability and ease of data transmission to mobile devices [4]. An integrated cloud-based health monitoring system was developed by Kumar et al., which utilized Arduino and NodeMCU to log and analyze glucose data remotely, supporting timely interventions [5]. Singh et al. created an Arduino-based biosensor platform to measure glucose concentration in artificial fluids, confirming Arduino's utility in biomedical prototyping [6].Ahuja et al. presented a wearable health monitoring system that captures real-time physiological data and uploads it to the cloud, enhancing remote diagnostics and physician accessibility [7]. Mishra and Rathi emphasized Arduino's role as a cost-effective and reliable microcontroller for biomedical device development, particularly for resource-limited settings [8]. Tripathy and Das reviewed the limitations of existing non-invasive glucose monitoring devices, pointing out usability, cost, and calibration challenges [9]. Chen et al. proposed a secure IoT model for health monitoring systems, addressing vulnerabilities in patient data privacy through a zero-trust framework [10].

3 METHODOLOGY

The methodology of the IoT-Enabled The proposed system is built around the ESP32 microcontroller, which plays a central role in managing sensor data acquisition, processing, display, and IoT-based communication. Various health-monitoring sensors are integrated into the setup, including a non-invasive glucose sensor, a pulse sensor for heart rate monitoring, and a DHT11 sensor to measure ambient temperature and humidity. These sensors are interfaced with the ESP32 through its analog and digital input pins. The ESP32 is programmed using Arduino IDE to handle data collection at regular intervals, ensuring real-time monitoring of vital parameters. A 16x2 LCD display is connected to the ESP32 using an I2C module to minimize wiring complexity and enhance readability. The display provides a user-friendly interface, presenting real-time values for glucose level, heart rate, temperature, and humidity. The layout is designed to be clear and simple, enabling even non-technical users to easily interpret the readings. For remote monitoring, the system incorporates cloud integration. The ESP32 uses built-in Wi-Fi capabilities to securely transmit data to cloud platforms such as ThingSpeak or Firebase using HTTP or MQTT protocols. Authentication and encryption techniques are used to protect patient data during transmission. Sensor readings are processed within the ESP32 using basic signal filtering algorithms to reduce noise and improve accuracy. This includes smoothing glucose readings, stabilizing heart rate signals, and calibrating environmental data from the DHT11 sensor. Alerts can be generated based on threshold values for critical parameters. Finally, all components—including the ESP32, sensors, and LCD—are assembled in a compact configuration with proper wiring, power regulation, and pin compatibility, ensuring the system is both efficient and portable for real-world application

4 EXISTING SYSTEM

Current glucose monitoring techniques primarily rely on invasive methods, particularly finger-prick tests using glucometers. These traditional systems require individuals to manually prick their fingers to extract a small blood sample, which is then analyzed by the device to determine the blood glucose level. While accurate and widely used, this method is painful, inconvenient, and not user-friendly for long-term and frequent monitoring, especially for patients with diabetes who require multiple readings daily. These devices only provide a snapshot of the glucose level at a specific time, resulting in gaps in the data. These data gaps make it difficult for both patients and healthcare providers to detect sudden spikes or drops in glucose levels, which can be critical for effective diabetes management. Moreover, users must manually record their glucose readings, which introduces the possibility of human error, misreporting, or even forgetting to log the data. This manual process not only adds to the user's burden but also compromises the reliability and accuracy of long-term glucose trend analysis. Furthermore, traditional systems do not support real-time data transmission or remote monitoring. As a result, physicians are unable to monitor a patient's glucose status remotely or intervene in time during emergencies. This lack of integration with modern communication technologies hinders proactive healthcare approaches. Consequently, there is a growing demand for a non-invasive, continuous, and connected solution that offers real-time glucose monitoring while minimizing user discomfort and improving clinical outcomes

4 PROPOSED METHOD

The Handy Non-Invasive Blood Glucose Estimator using Arduino and NodeMCU is a cutting-edge system designed to measure glucose levels without the need for skin pricking, leveraging Near-Infrared (NIR) technology. NIR spectroscopy works by using infrared light to penetrate the skin and analyze the reflection from glucose molecules, offering a non-invasive and continuous method of glucose monitoring. The system integrates various health sensors, including heart rate, body temperature, and humidity sensors, providing a comprehensive view of the user's health. Data is processed by an Arduino microcontroller, which collects readings from these sensors and sends them via NodeMCU, a Wi-Fi module, to a cloud-based platform for remote access. This cloud connectivity allows healthcare providers and users to monitor real-time health metrics and analyze trends over time. The system also features an LCD display for instant feedback, allowing users to view their glucose levels and other health parameters at a glance. Additionally, a mobile-friendly app syncs with the cloud platform, offering convenient access to historical data and alerts on abnormal readings. Continuous monitoring enables better decision-making and early detection of potential complications like hypoglycemia or hyperglycemia. By combining NIR technology, real-time data transmission, and a user-friendly interface, the system provides a reliable, non-invasive, and comprehensive approach to managing glucose levels and overall health. This device is particularly beneficial for individuals with diabetes or those who need constant health tracking, offering greater convenience and accuracy compared to traditional methods.

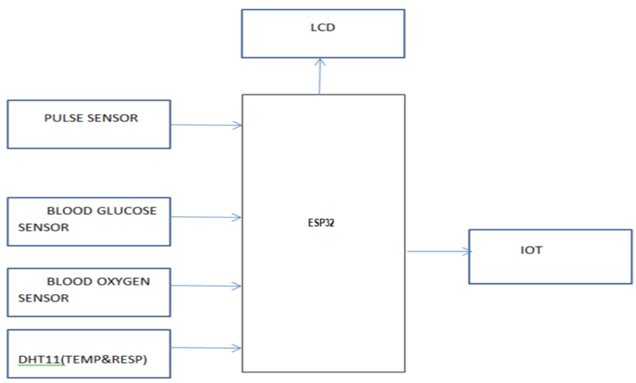

Figure 5.1 Block Diagram

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5 RESULTS AND DISCUSSIONS

This chapter presents the successful implementation and performance analysis of the Handy Non-Invasive Blood Glucose Estimator using Arduino and NodeMCU. The system effectively monitored and displayed real-time glucose levels without the need for skin pricking by utilizing Near-Infrared (NIR) technology. In addition to glucose monitoring, it accurately tracked heart rate, body temperature, and environmental humidity, offering a complete health overview.

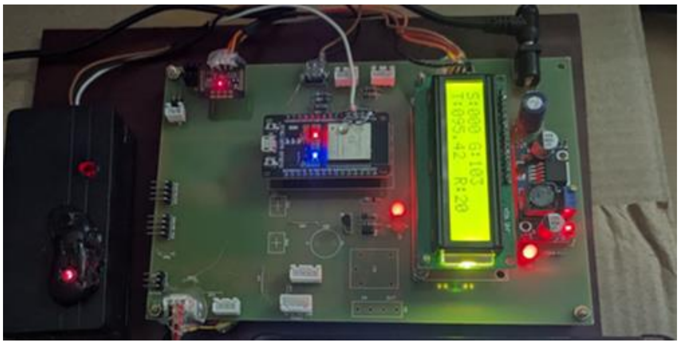

Figure 6.1 Healthcare System

shows the overall prototype of the device. The NIR sensor captured glucose readings through the skin, and values were processed using the Arduino microcontroller. The Node MCU module transmitted this data wirelessly to a cloud platform, enabling real-time remote access and monitoring.

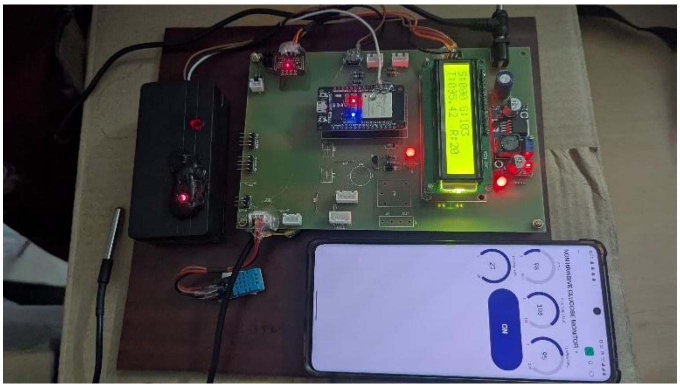

Figure 6.2 Gathering patients' information

displays the sensor integration setup. The system guided users through each step using a simple interface, and sensor readings were taken automatically when the user placed their hand or finger in the correct position. Readings were immediately shown on the **LCD display**, ensuring clarity and user-friendly feedback.

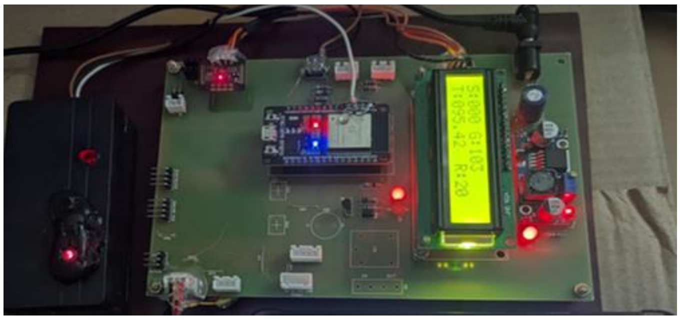

Figure 6.3 Displaying patients' information

highlights the display of health parameters. Upon successful data collection, values such as glucose level, heart rate, and temperature were shown, and simultaneously sent to the Blynk IoT application for remote viewing. The mobile interface offered users access to both current and historical data.

In cases where abnormal glucose levels or vital signs were detected, the system successfully generated alerts via the cloud interface, supporting early response and timely medical attention. The results confirm that the device is non-invasive, accurate, responsive, and suitable for regular glucose monitoring. The combination of Arduino, NodeMCU, and IoT integration makes the system a promising solution for affordable and user-friendly health tracking.

Token No.	Patient Name	Glucose Level (mg/dL)	Heart Rate (BPM)	Body Temperature (°C)	Humidity (%)	Status
T001	Ravi Kumar	105	78	36.5	45	Normal
T002	Asha Rani	190	95	37.8	50	High Glucose Alert
T003	Meena Sharma	85	72	36.2	42	Normal
T004	Rajesh Verma	250	110	38.4	60	Emergency Alert
T005	Sneha Patel	130	80	36.7	47	Normal

Table 6.4 Patient information

6 CONCLUSION

The Handy Non-Invasive Blood Glucose Estimator using Arduino and Node MCU successfully demonstrates a low-cost, user-friendly solution for continuous glucose monitoring without the need for invasive methods. By leveraging Near-Infrared (NIR) technology, the system effectively measured glucose levels through the skin, ensuring a painless and hygienic approach for users. Additional health parameters such as heart rate, body temperature, and humidity were accurately monitored, providing a holistic view of the user's health status. The integration of Node MCU enabled real-time data transmission to a cloud-based platform, with values accessible via the Blynk IoT mobile application. This feature supports remote monitoring, making it highly suitable for both personal health management and telehealth applications. The inclusion of an LCD further enhanced usability by providing instant feedback. The system's ability to detect abnormal readings and gene rate alerts adds significant value for early diagnosis and timely medical intervention. Overall, the device proves to be an efficient, responsive, and scalable model for non-invasive health monitoring, with great potential for further development and real-world healthcare applications.

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