ISSN [Online]: 2583-2654

Implementation of Non-Invasive Blood Glucose Monitoring System

Prof. Deepa B M, MD Shoaib Shah
Department of ECE, Dr. T. Thimmaiah Institute of Technology, KGF, Karnataka, India

Abstract: The case of diabetes, fingertip pricking for a blood sample is inconvenient for glucose measurement. Invasive approaches like laboratory test and one-touch glucometer enhance the risk of blood-related infections. To mitigate this important issue, in the current paper, we propose a novel Internet-of-Medical-Things (IoMT) enabled edge-device for precise, non-invasive blood glucose measurement. In this work, a near-infrared (NIR) spectroscopic technique using two wavelengths (940 nm, 1300 nm) is taken to detect the glucose molecule from human blood. The novel device callediGLU is based on NIR spectroscopy and machine learning (ML) models of high accuracy. An optimal multiple polynomial regression model and deep neural network (DNN) model have been presented for precise measurement. The proposed device is validated and blood glucose values are stored on the cloud using open IoT platform for remote monitoring by an endocrinologist. For device validation, the estimated blood glucose values have been compared with bloodglucose values obtained from the invasive device. It has been observed that mean absolute relative difference (MARD) and average error (AvgE) are found 4.66% and4.61% respectively from predicted blood glucose concentration values. The regression coefficient is found 0.81. The proposed spectroscopic non-invasive device provides accurate and cost-effective solution for smart healthcare.

Keywords: Diabetes, Glucose measurement, Non-invasive, Internet-of- Medical-Things (IoMT), Edge-device, Near-infrared (NIR) spectroscopy, Machine learning (ML) models.

I. INTRODUCTION

Glucose is a simple sugar molecule. The sugar molecule is chemically symbolized as $C6H12O6$. This means that glucose molecule contains 6 Carbon (C) atoms, 12 Hydrogen (H) atoms, and 6 Oxygen (O) atoms. In human's blood, glucose molecule circulates as blood sugar.

Normally after eating food or drinking, our body breaks down sugars from food and uses them for energy in our cells. To perform this, our pancreas produces a hormone called insulin. Insulin pulls sugar from the blood and puts it in the cells for use [1]. If anyone has diabetes, our pancreas can't produce sufficient insulin.

For this, the blood glucose level increases. As a result, our cells fall into much-needed energy shortage. This can lead one to many potential complications including blindness, kidney disease, nerve damage, amputation, stroke, heart attack, and damage to blood vessels etc. [2]. Diabetes cannot be cured but it is possible to prevent or control it by keeping glucose level at normal range [3]. Considering this, it is important to regularly check blood glucose level by glucometer.

There are different types of glucometers available in the market. But these are invasive. These invasive glucometers need a small amount of blood by puncturing a finger using a needle and put on a test strip which shows the glucose level. Sometimes this method discourages patients because finger puncturing is painful [4][6], infectious when the same needle is used for multiple patients, and has a higher cost. Due to this, it is necessary to develop a non-invasive method which does not need finger puncturing and cost-effective for diabetic patients.

Motivations:

- The world is facing many major health problems anddiabetes or diabetes mellitus is one of them.

ISSN [Online]: 2583-2654

• The World Health Organization (WHO) estimated that thenumber of people with diabetes is more than 200 million.
• Diabetes can lead to major complications like heart failureand blindness in the human body.
• Generally, in the hospitals blood glucose level is measured by using invasive method. It involves requirement of sampleblood through finger pricks for measuring the amount of glucose in the blood, it is inconveniences are pain and infection.
• Many people dislike using sharp objects and seeing blood,there is a risk of infection, and, over the long term, this practice can result in damage to the finger tissue.
• There is always need to check the glucose level after certain time so it requires man power and test-strips are required every time to do the test.
• Non-invasive method provides better accuracy and precision. It reduces the manual operation and it gives continuous monitoring system. No more waste on test strips,lancets, and others.
• Reduced life cycle cost (less expensive than finger prick device in long term): Onetime expense with virtually unlimited measurements.

II. PROPOSED DESIGN

The proposed methodology for glucose level measurement in this system represents a pioneering approach that harnesses the inherent refractive properties of glucose molecules. As a fundamental constituent of the blood, glucose exhibits a unique capability to influence the refractive angle of light in a medium. This distinctive characteristic forms the cornerstone of a sophisticated refraction-based estimation technique grounded in Snell's law [5]. According to this principle, the refractive angle undergoes an inverse relationship with the concentration of glucose in an aqueous sample. Consequently, as the concentration of glucose increases, the refractive angle decreases, prompting a noticeable shift in the trajectory of light. This alteration is pivotal to the methodology, as it induces a proportional increase in the number of photons striking the photo-transistor.

Building upon this foundational principle, the proposed methodology introduces a non-invasive technique that relies on the transmittance and absorbance of red laser light to ascertain blood glucose levels. By directing red laser light onto the fingertip and capturing the reflected light wave with a photo-transistor, the system generates a voltage output directly linked to the intensity of the blood. This non-invasive approach not only ensures accurate blood glucose measurements but also prioritizes user comfort by eliminating the need for invasive procedures.

The system incorporates a feature for emergency scenarios, exemplified by a Request Button. This button initiates a search for blood groups in nearby blood banks through the innovative integration of Internet of Things (IoT)technology. Acting as a Wi-Fi module, the Node MCU establishes bidirectional communication with a server,transmitting the request to a dedicated mobile application. Potential donors can then respond to the request, and the acceptance message is promptly displayed on the LCD screen [8]. This not only showcases the system's versatility but also positions it as a potential life-saving tool by efficiently addressing urgent blood group needs.

The Temperature Sensor is a fundamental component within the Non-Invasive Blood Glucose Monitoring System, playing a pivotal role in capturing environmental or object temperatures. Operating seamlessly, it transforms temperature data into a discernible electrical signal compatible with the Arduino Uno microcontroller [7]. This signal, rich in thermal information, becomes integral for the system's ability to calculate and interpret the temperature— crucial for a holistic health monitoring experience. By harnessing the Temperature Sensor's capabilities, the system gains an additional layer of sophistication in evaluating the user's physiological state.

The Pulse Sensor, a key contributor to the system's functionality, focuses on the dynamic aspect of cardiovascular health—the pulse rate. Conveniently clipped onto a finger, this sensor gauges variations in light passing through the fingertip with each

ISSN [Online]: 2583-2654

heartbeat. These light- induced changes are converted into an electrical signal by the Pulse Sensor, seamlessly integrated into the Arduino Uno's data stream. The resulting information enables the system to compute and present the user's pulse rate, offering valuable insights into their cardiovascular well-being. The Pulse Sensor's role in the system not only enhances its diagnostic capabilities but also reinforces its commitment to providing a comprehensive health profile.

The Max-30100 Pulse Oximeter extends the monitoring system's reach into the realm of oxygen saturation levels, adding a critical dimension to health assessment. Employing two wavelengths of light—red and infrared—the sensor penetrates the fingertip, measuring light absorption by the blood. The Max-30100 translates these absorption patterns into an electrical signal, fostering seamless integration with the Arduino Uno [3]. This introduces a vital parameter into the health monitoring framework, allowing the system to determine and relay information regarding the user's oxygen saturation levels.

At the heart of the Non-Invasive Blood Glucose Monitoring System lies the Arduino Uno—a versatile microcontroller board adept at processing the electrical signals generated by the Temperature Sensor, Pulse Sensor, and Max-30100 Pulse Oximeter. Beyond signal processing, the Arduino Uno takes on the crucial role of calculating and interpreting health parameters, including temperature, pulse rate, andoxygen saturation levels. This central processing unit acts as the brain of the system, orchestrating the seamless integration of diverse sensor inputs to provide a holistic overview of the user's health status.

The NodeMCU, a Wi-Fi-enabled microcontroller board, propels the system into the realm of connectivity, enabling the transmission of health data to external devices over the internet. This wireless capability enhances the system's versatility, allowing users to remotely monitor their health parameters through computers or smartphones. The NodeMCU

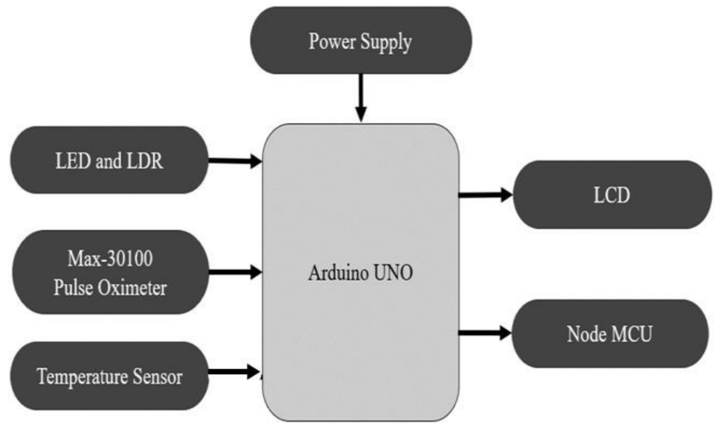

Fig 1: Block diagram

serves as the gateway between the monitoring system and the wider digital ecosystem, opening avenues for real-time health data access and facilitating seamless integration into modern telehealth frameworks.

The Liquid Crystal Display (LCD) stands as the user-friendly interface of the monitoring system, translating complex health data into easily understandable visual information. This display unit presents real-time updates on temperature, pulse rate, and oxygen saturation levels, providing users with immediate insights into their physiological well-being. By offering a visual representation of health parameters, the LCD enhances user engagement and understanding, making the monitoring system more accessible and user-friendly.

The Power Supply block assumes a pivotal role in the health monitoring system, serving as the backbone that guarantees uninterrupted functionality. Its primary function lies in providing a stable and continuous power source to all system components, thereby mitigating the risks associated with power shortages or fluctuations. By ensuring a reliable power supply,The methodology employed for glucose level measurement in this system revolves around the refractive properties of glucose molecules. Glucose, being a molecular entity, possesses the ability to alter the refractive angle of light in proportion to its concentration in a given medium. This phenomenon is harnessed through a refraction-based estimation technique grounded in Snell's law. According to Snell's law, the refractive angle is

ISSN [Online]: 2583-2654

inversely proportional to the concentration of glucose in an aqueous sample. As the glucose concentration increases, the light ray tends to incline towards the normal, resulting in a decrease in the refractive angle ($\theta 2$). This change prompts more photons to strike the photo-transistor. Therefore, by observing the alteration in the refractive angle, the system can deduce the concentration of glucose in the aqueous solution. This principle forms the foundation of the system's non-invasive approach to measuring blood glucose levels. The proposed methodology for blood glucose level measurement in this system employs a non-invasive technique based on the transmittance and absorbance of red laser light. The process involves directing the red laser light onto the fingertip, where it gets reflected.

The second stage introduces a significant enhancement with the integration of Resonant Cavities into the Vivaldi Antenna. Resonant cavities are strategically placed structures designed to fine-tune the antenna's performance by further optimizing its resonance characteristics, as depicted in Fig. This addition enhances the antenna's efficiency in responding to specific frequencies, resulting in increased sensitivity, selectivity, and improved overall signal reception.

A. Formulas:

When a light ray passes through biological tissues, it is both absorbed and scattered by the tissues. Light scattering occurs in biological tissues due to the mismatch between the refraction index of extracellular fluid and the membranes of the cells. Variation in glucose level in blood affects the intensity of light scattered from the tissue. Beer-Lambert Law plays a major role in absorbance measurement which states that absorbance of light through any solution is in proportion with the concentration of the solution and the length path travelled by the light ray. Light transport theory describes light attenuation as

$$I = Ioe\ -\mu eff\ L \qquad (1)$$

where, I is the reflected light intensity, I0 is the incident light intensity and L is the optical path length insidethe tissue. Attenuation of light inside the tissue depends on the coefficient known as effective attenuation coefficient (μeff), which is given by

$$\mu eff = [3\mu s\ (\mu s + \mu s\ ')]\ ½ \qquad (2)$$

The absorption coefficient (μa) is defined as the probability of absorption of photons inside the tissue per unit path length, which is given by

$$\mu a = 2.303\ \in C \qquad (3)$$

∈ is the molar extinction coefficient, C is the tissue chromophore concentration and the reduced scattering coefficient (μs') is given by equation 4.

$$\mu s\ ' = \mu s\ (1-g) \qquad (4)$$

Where g is anisotropy and μs is scattering coefficient. Hence from the equations (1) to (4) it can be concluded that μa depends on the glucose concentration in blood. Thus, with the increase in blood glucose concentration, the scattering property of blood decreases.

III. DISCUSSION OF RESULT

A non-invasive blood glucose meter capable of delivering painless glucose measurements swiftly, without the need for blood samples or finger pricks, in mere seconds. This device seamlessly transitions to offering continuous blood glucose monitoring and tracking blood oxygen levels while retaining a comprehensive measurement history. Furthermore, its adaptable algorithm facilitates the incorporation of additional functionalities such as heart rate monitoring, utilizing the existing devices and sensors for enhanced versatility.

NodeMCU serves as the transmitter to relay the results to a Telegram Bot. Utilizing BotFather, users can seamlessly create their bot. After completing the creation steps and acquiring the unique authorization token, individuals can consult the Bot API manual.

Fig 2: Hardware Output

ISSN [Online]: 2583-2654

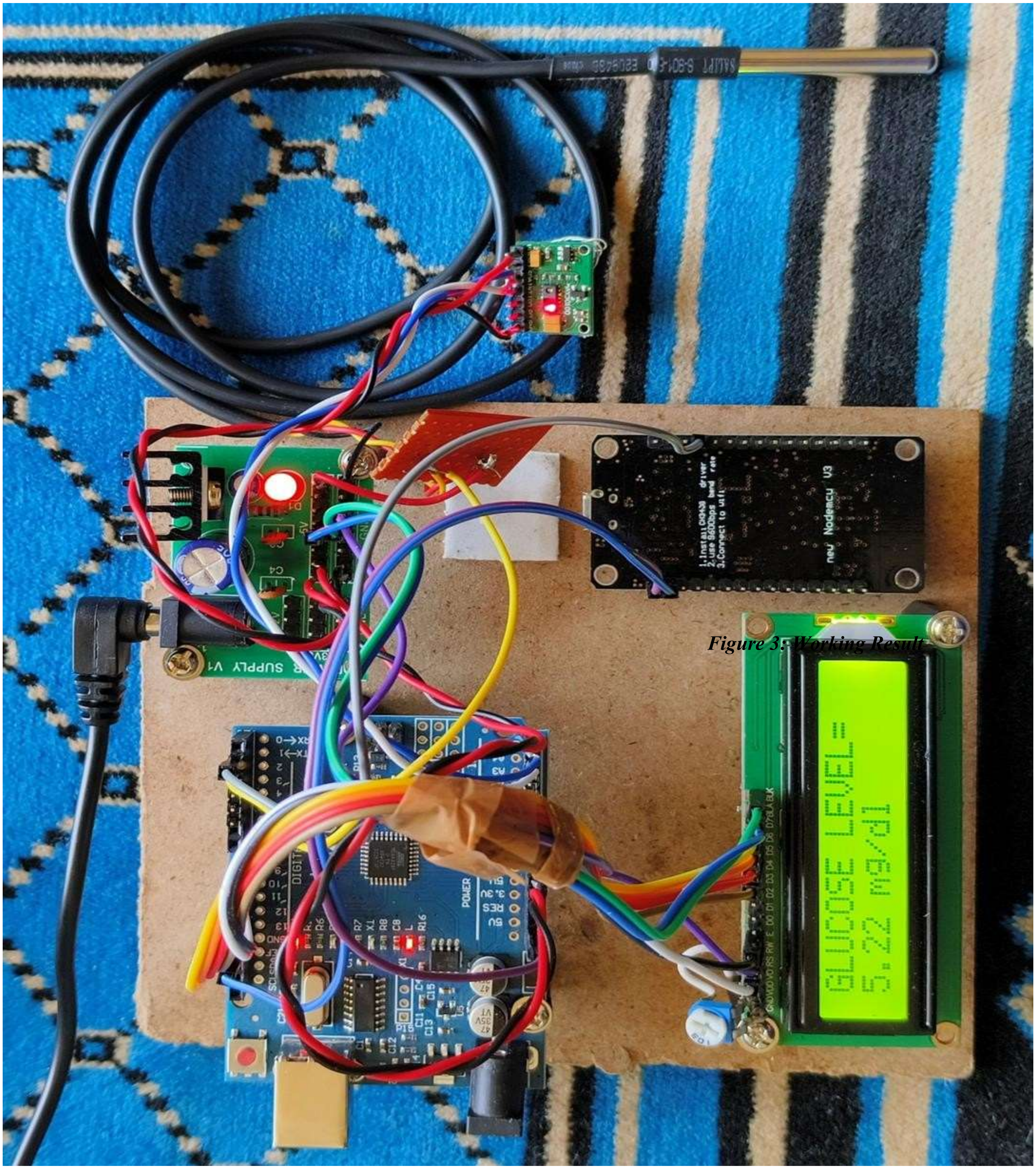

Fig 3: Working Result

ISSN [Online]: 2583-2654

By leveraging NodeMCU and the Telegram Bot platform, users can establish a dynamic communication channel, facilitating efficient data transmission and interaction. Through this integrated approach, individuals can harness the capabilities of both NodeMCU and TelegramBot to create tailored solutions for various applications, from IoT projects to communication systems.

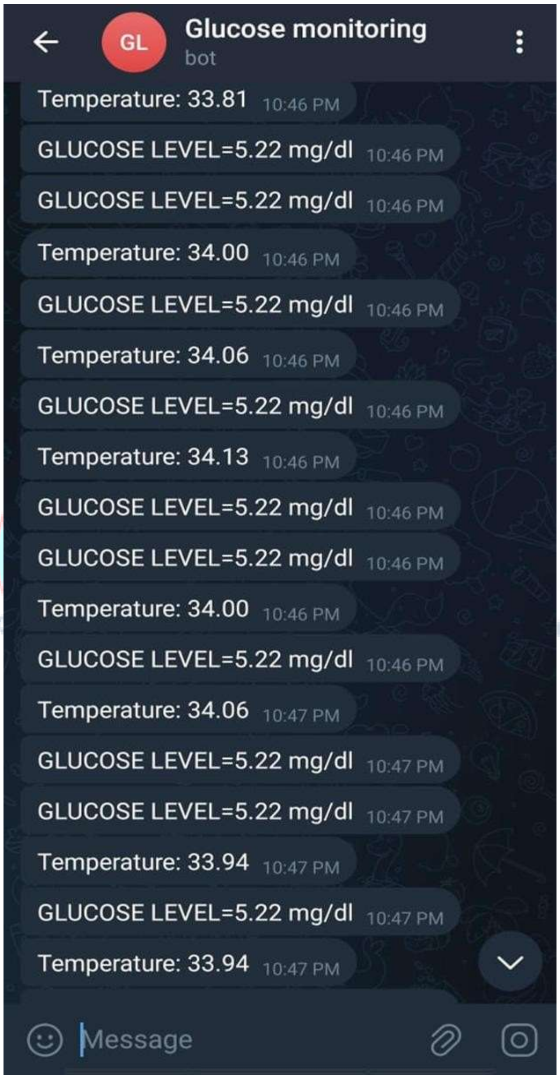

Fig 4: Telegram Chat

IV. CONCLUSION

The incorporation of near-infrared sensors and the utilization of Body Mass Index (BMI) to determine insulin dosages signify significant progress towards non-invasive and personalized blood glucose monitoring. The study's utilization of light scattering and absorption principles to detect glucose levels reflects a sophisticated methodology. The findings, which establish correlations between voltage readings and glucose concentration, present valuable insights into the potential effectiveness of the proposed smart insulin device. However, the recognition of an inherent 20 percent margin of error within the system underscores the existing challenges that need to be addressed for the technology to realize its full capabilities.

Moreover, the research introduces a non-invasive blood glucose meter capable of painlessly providing glucose measurements within seconds, without the need for blood samples or finger pricks. The device's adaptability for continuous blood glucose monitoring, as well as its ability to track blood oxygen levels and maintain a measurement history, underscores its versatility. Additionally, the device algorithm's potential for modification to incorporate additional functionalities, such as heart rate monitoring, using existing sensors, presents further avenues for exploration and development..

REFERENCES

[1] Haider Ali, Faycal Bensaali and Fadi Jaber "Novel Approach to Non- Invasive Blood Glucose Monitoring Based on Transmittance and Refraction of Visible Laser Light" IEEE-2017.

[2] SiWei Zhao, Wei Tao, Qiao Zhi He, Hui Zhao "A New Approach to Non-invasive Blood Glucose Measurement Based on 2-dimension Photoacoustic Spectrum".

[3] Mohammed Shahriar Arefin "Non-invasive Blood Glucose Determination Using Near Infrared LED in Diffused Reflectance Method", 10th International Conference on Electrical and Computer Engineering, 20-22 December .

[4] P Sampath Reddy "Development of smart insulin device for Non- invasive Blood Glucose Level Monitoring", 2017 IEEE 7th International Advance Computing Conference.

[5] Heungjae Choi, Steve Luzio, Jan Beutler, and Adrian Porch "Microwave Non-invasive Blood Glucose Monitoring Sensor Human Clinical Trial Results" 978-1-5090-6360-4/17 IEEE-2017.

[6] Vishnu Dantu, Jagannadh Vempati, and Srinivasan Srivilliputhur "Non-Invasive Blood Glucose Monitor Based on Spectroscopy Using a Smartphone", 978-1-4244-7929-0/14 IEEE-2014.

[7] Jyoti Yadav, Asha Rani, Vijander Singh and Bhaskar Mohan Murari "Near-infrared LED based Non-invasive Blood Glucose Sensor", International conference on Signal processing and Integrated Networks-2014.

[8] Shubhajit Roy Chowdhuri "A Non-Invasive Blood Insulin and Glucose Monitoring System based on Near-Infrared Spectroscopy with Remote Data Logging", 31st International Symposium on Computer-Based Medical Systems - 2018.