Non Invasive Blood Glucose Monitoring System Using IoT

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Abstract - In order to improve the management of diabetes, this research presents a novel Internet of Things (IoT) based glucose level monitoring system that offers automated notifications for the administration of insulin and medicine as well as real-time blood glucose data. A non-invasive glucose monitoring device is used in the proposed system to continually detect blood glucose levels and send the data to a centralized IoT platform. Through a specific mobile application, users can access this data, enabling remote monitoring and prompt interventions. The Internet of Things (IoT)-enabled glucose monitoring device ensures user comfort and compliance by correctly measuring glucose levels without intrusive procedures by utilizing advanced sensing technologies. The cloud-based IoT platform receives the collected data securely and processes, analyzes, and presents it to users via an intuitive interface. Users of the mobile application can customize blood glucose thresholds, and the system will send out automated messages to the user when these thresholds are surpassed. Furthermore, the program offers graphical depictions of glucose patterns in real time, which assist users and healthcare practitioners in making well-informed decisions regarding medication adjustments and lifestyle changes. The user receives an instant alarm from the system in the event of a low blood glucose level, directing them to take the appropriate action. The application helps users by guiding them through the procedure, offering detailed instructions and guaranteeing quick action in emergency scenarios. In addition to enabling people with diabetes to actively control their illness, the suggested Internet of Things-based glucose monitoring system makes it easier for medical practitioners to monitor patients remotely. The objectives of this approach are to lower the risk of problems related to inadequately managed blood glucose levels, improve patient outcomes, and raise the standard of diabetes care overall.

Keywords: IoT, Health Monitoring, Glucose Level Monitoring, MAX30100, Diabetes.

I.INTRODUCTION

One of the most prevalent diseases in the world is diabetes. Since blood sugar levels must be kept within a certain range, monitoring blood sugar levels is crucial for diabetic patients. Consequently, it's essential to routinely check the diabetes patients' blood glucose levels. It is currently necessary to pierce the finger to assess blood sugar, which is an uncomfortable procedure that can lead to infections. Since the finger is not pinched during the non-invasive operation, there is no discomfort or risk of infection. To monitor the glucose level in real time, we therefore suggest a non-invasive technique that uses an infrared sensor to transmit and receive light at the fingertip.

Most of the glucose sensors have been demonstrated to be dependable by the use of Clarke error grid analysis or comparable techniques; nonetheless, these glucose sensors were dependent upon a costly vector network analyzer (VNA), in addition to all other known issues like repeatability, specificity, and sensitivities. [1]. When a ferrite-made ring resonator is positioned next to a microstrip line (MTL), the traveling waves whispering gallery modes (WGM) are activated or launched. With the intended connection in the frequency range of 22–32 GHz, the sensor structure is suitably built to accommodate four different WGM modes. In order to produce the bias magnetic field required to produce a nonreciprocal effect in the resonator, a permanent magnet disk is integrated beneath the MTL substrate. [3].

The potential relationships between blood glucose levels, mm-wave, NIR, skin temperature, pressure data, and other variables and used an ML model for prediction. The random forest technique, which served as the basis for the model, was trained and evaluated using information gathered from a study in which five healthy individuals underwent an intravenous glucose tolerance test.[6]. A single-pole Debye model is used to statistically examine the sensitivity performance for glucose detection at various geometrical parameters in order to mimic the dispersing behavior of the fluctuating glucose on top of a skin layer [8]. The system is designed to measure the blood glucose level of the diabetic patient in a non-invasive way. The Infrared LED is used as the light source and the sensor is Max30100 which acts as both a transmitter and a receiver. The reflected light is used to measure the amount of light absorbed by the blood and the data can be sent to the microcontroller which acts as a microcontroller to process the signal to measure blood glucose level [2]. The proposed digital processor removes motion artifacts, and baseline drift from the PPG signal extracts six distinct characteristics, and finally predicts the blood glucose levels using Support vector regression with fine Gaussian kernel MLR[4].

The benefits of 530 nm PPG in blood flow monitoring and 1550 nm infrared light in blood glucose concentration detection led to the selection of the dual-channel PPG. Here a range of amplitude features in PPG is tested at different fiducial points.[13]. The Internet of Medical Things (IoMT) is integrated with it for smart healthcare, allowing users and caregivers to access and store healthcare data on the cloud. The optimized regression model is analyzed, and healthy, prediabetic, and diabetic individuals are used to calibrate and validate the system. [5]. Field programmable gate arrays (FPGAs) are used in the implementation of a portable embedded system that uses photoacoustic measurements on tissues to obtain glucose concentration estimates. The photoacoustic signal amplitude varies linearly with sample glucose concentration, corroborated both in vitro on glucose solutions and in vivo on tissues using the glucose assessment technique. [15]. Analysis has been done on insulin secretion, diabetes level, food plan, physiological factors, and frequent blood glucose readings. Every case is closely checked for glucose levels while adhering to the recommended diet plan for diabetes management [19].

This paper proposed a new technological advancement that is non-invasive blood glucose monitoring system. Blood or other intrusive techniques are not needed for these devices to measure blood glucose. Their purpose is to provide patients with a reliable and secure means of tracking their blood sugar levels. A state-of-the-art non-invasive glucose sensor that was carefully chosen for its improved accuracy and user-friendly characteristics is used in the suggested system. Node MCU is a cloud-based IoT platform that offers comprehensive functionality for data storage, processing, and visualization. Its Wi-Fi capabilities enable smooth data exchange and real-time connectivity.

In Section II, the Related Work of the proposed system is scribbled. The methodology for implementing the IoT-based Smart Glucose-level Monitoring System involves a systematic approach, from understanding the healthcare facility's needs to system design, deployment, system architecture is presented in Section III, the proposed system is explained with block diagram in Section IV. In Section V, the proposed framework is assessed by implementing the prototypes and other relative experiments. Finally, in Section VI the conclusion is stated.

II.RELATED WORK

In 2017, Haider Ali et al. presented the implementation of a straightforward, small, and reasonably priced non-invasive device for BGM that uses visible red laser light with a wavelength of 650 nm (RL-BGM). There are three main technical advantages of the RL-BGM monitoring device over NIR. Red laser light has around a thirty-fold higher transmission through human tissue than NIR light. In 2020, María Celeste et al. presented a microwave sensor that measures blood glucose levels without intrusive procedures.In 2021, Yan Yu et al. presented a possible non invasive blood glucose monitoring device based on portable NIR technology. It presented the process and functions of a portable NIRS (900–1700 nm) system, together with its comprehensive hardware and software designs. In order to further minimize the differences between individuals, it used the PLS approach for cross-validation modeling after examining the ideal intervals or variables. At the same time, nonlinear regression models were simultaneously trained using the Extreme Learning Machine (ELM) algorithm.

In 2021, Priyansha Kaurav et al. presented a non-invasive sub-Terahertz device with a Processing Unit (PU) and Sensor Unit (SU) for measuring glucose levels. The SU measures the S parameters of glucose samples at various concentrations using waveguide probe sensors. To approximate the blood glucose levels found in healthy human bodies, which range from 70 to 140 mg/dl, the glucose sample concentration is employed in the range of 70–145 mg/dl.

In 2022, Ala Eldin Omer et al. introduced a low-cost, tiny, very sensitive microwave sensor for noninvasively measuring blood sugar levels. When a microstrip line (MTL) is in close proximity to a ferrite-made ring resonator, the traveling waves whispering gallery modes (WGM) are activated or launched. In the frequency range of 22–32 GHz, the sensor structure is suitably built to accommodate four different WGM modes with the requisite coupling. Under the MTL substrate, a permanent magnet disk is integrated to produce the bias magnetic field required to produce a nonreciprocal effect in the resonator. To approximate the internal biasing fields inside the FRR at many longitudinal layers, a magneto-static analysis is carried out. When practical observations of a magnetic FRR are compared with the EM models, the simulations are verified.

In 2022, Zengxiang Wang et al. presented a two ultrawideband (UWB) antennas, here the size of a finger are employed as blood glucose level (BGL) sensor system detectors. Based on the UWB microwave method, short-term memory (LSTM-R) is introduced to counteract the detrimental impacts of antenna shrinkage. It is possible to accomplish the high accuracy and robustness of BGL prediction using the suggested composite end-to-end architecture. In 2022, Zhenyi Ye et al. presented a novel technique for monitoring the biomarkers in breath using an electronic nose (E-Nose) device based on a metal oxide (MOX) gas sensor array in order to quantitatively identify and assess the blood glucose level.

In 2023, Yaqub Mahnashi et al. proposed an end-to-end noninvasive microwave-based method for measuring the concentration of glucose in aqueous solutions. The substance under examination, a solution of glucose and water, produces and sends out a microwave signal. The received signal is then conditional using an RF detector, a band pass filter (BPF), and a low-noise amplifier . In 2023, Ryo Natsuaki et al. presented the equivalent quarter-wavelength interface and equivalent Brewster's-angle interface refer to two high skin-penetration interfaces. It examined their scattering properties between 60 and 90 GHz in frequency. The analysis's findings indicate that both interfaces reduce body-surface scattering, which makes it possible for MMWs to enter tissues and retrieve data on blood glucose concentration more sensitively. For example, by enhancing phase changes by 147 times. The realization of non-invasive blood glucose concentration determination may be aided by these interfaces.

III.SYSTEM ARCHITECTURE

The technique used in this system is based on the scattering property, which directly affects glucose. This entails shining a red laser light through the finger to measure the amount of light that emerges on the other side. The light cannot travel through the finger due to the glucose's presence. So it can able to determine the amount of blood glucose by examining the differences in light intensity. The system architecture diagram is given below Fig (1).

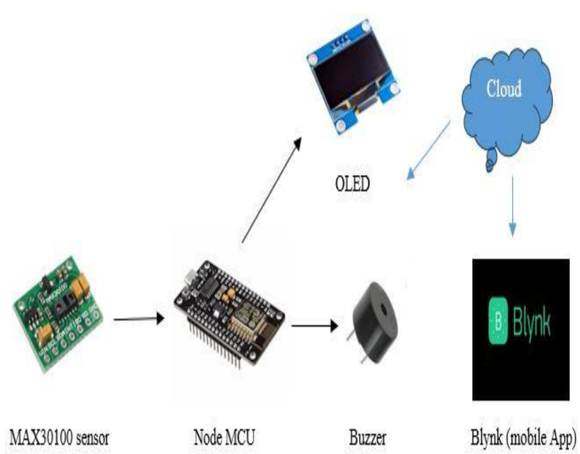


Fig.1 Architecture

MAX30100 sensor

For non-invasive blood glucose monitoring, there is an optical sensor with high integration called the MAX30100. It can be used to assess glucose levels by measuring the amount of light absorbed by the user's skin using a combination of photodiodes and LEDs. A Node MCU (microcontroller), would be attached to the MAX30100 sensor in the system architecture. The microcontroller would manage signal processing as needed and handle communication with the sensor. After that, the measured data from the MAX30100 sensor would be sent to a data gathering tool, like a smartphone or an IoT device.

Node MCU

The ESP8266 Wi-Fi module serves as the foundation for the open-source development board known as Node MCU. It offers a simple and affordable method for developing Internet of Things apps and connecting the creations to the internet. Programming and uploading code is made simple by the Arduino IDE's compatibility with the Node MCU hardware. It does not require an external programmer because it includes an integrated USB-to-serial converter. The inbuilt Wi-Fi functionality of the Node MCU is one of its primary features. By doing this, it is easily link the projects to the internet or local network and facilitate data transmission and communication between the devices and other online services. A variety of sensors, actuators, and other parts can be connected to the Node MCU's many GPIO pins.

OLED display

An organic light-emitting display (OLED) is a kind of display technology that emits light when an electric current is applied. OLED screens are more flexible and small since they don't need a backlight like conventional LCD displays. OLED screens provide a number of benefits. First off, because each pixel can generate light independently of the others, they offer superb contrast and brilliant colors. Deep blacks and brilliant whites are the outcome, which improves the visual experience. OLED screens also feature a broad viewing angle, which means that even when viewed from various perspectives, the image quality stays constant. OLED displays also have the benefit of having a quick response time, which is advantageous for applications like gaming and video playback that call for fluid motion.

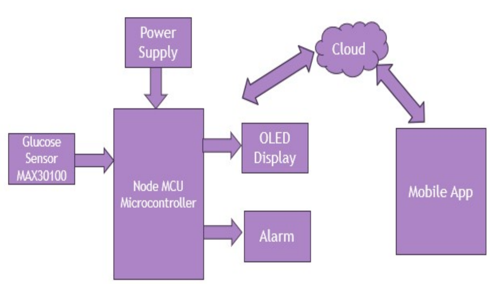
Blynk App

The well-known and user-friendly platform Blynk makes it simple to develop mobile apps for managing and tracking Internet of Things (IoT) projects. Unique mobile applications can be created with Blynk to communicate with hardware components like sensors and microcontrollers.

IV.PROPOSED SYSTEM

The suggested approach eliminates the need for the nurses to continuously monitor the patient visually from different angles. The foundation of the entire effort is Beer-Lambert's Law. The MAX30100 sensor and the Internet of Things (IoT) measurement device are both connected to the Internet of Things and run on Node MCU microcontrollers.

The MAX30100 sensor is used to measure the patient's finger blood sugar level. The patient's blood sugar measurement data is displayed on both the Android smartphone and the OLED display. Also web server for cloud-based IoT connectivity makes recording the measurement data. A non-invasive blood sugar measuring gadget is constructed with an Internet of Things integration and a Max30100 basis. The goal of testing non-invasive blood sugar level monitoring equipment is to ensure that the sensors are producing high levels of accuracy and are functioning correctly.



The Blynk app uses a mobile device to send and receive data. At the 100milliliter threshold, the alarm on the smartphone is triggered by the shift in threshold level. But a message will be delivered to the smartphone at the 50 ml point. The smartphone's display shows the measuring results' value. The ability of Android cell phones to read the blood sugar level testing device was also tested. Android apps are tested on several smartphones to guarantee their dependability. Here is a summary of the main elements and attributes of the suggested system:

IoT Sensors: Carefully positioned IoT sensors inside glucose storage units make up the system's key component. These sensors have the ability to measure glucose levels accurately. They send this information wirelessly to a cloud platform or centralized server.

Centralized Server or Cloud Platform: A centralized server or cloud platform receives all of the data that the Internet of Things sensors have collected. All monitoring data is stored in this central hub, which is accessible from any location with an internet connection.

Alert System: When blood glucose levels drop below a set threshold, the system's advanced alert system sends out notifications. To guarantee a prompt reaction, these alerts can be issued by push notifications, SMS, or email.

To summarize, the suggested Internet of Things (IoT)-based Smart Glucose-level Monitoring System is a complete solution that maximizes the management of glucose solutions in healthcare facilities. This system attempts to save time and money, streamline healthcare operations, and improve patient care by automating monitoring procedures, improving data accessibility, and encouraging data-driven decision-making. It demonstrates the revolutionary potential of IoT technology in the healthcare industry and marks a substantial progress in healthcare infrastructure.

V. IMPLEMENTATION AND TESTING

We are using a red light sensor (max30100). So this red high brightness sensor will transmit the rays to the finger and the reflected rays will be captured by the photodiode and the photodiode output will be given to the analog pin of the Node MCU board and then the intensity is calculated. Intensity of the light is more than assuming as less glucose level, here as the glucose levels are increasing in the blade. Receiving light will be decreases as the thickness of the light will be increases. The thickness of the blade will be increases then the receiving light is going to be decreases. So it is the improper like inversely proportional to the receiving light and thickness.

The power flow is provided with 230 volts input and the transformer will step down to the volts AC 2-12 volts and after this regulator power supply board got 5 volts constant regulator power supply. So there will be 4 diodes, which are indicated used as a bridge rectifier. After this executive will get the pulsating DC capacitor will remove the pulses so we will get pure DC and after this similar zero regulator we will get the sufficient voltage. This is easy to run the input and output modules along with Node MCU and OLED display. When the user places the finger inside the max30100, the photo diode will receive the light which is emitted from the red blood cells. Based upon the receiving value the approximate glucose levels are calculated and that can be monitored Blynk.

Once the user place the finger, so its start calculating the data, and it will take maximum of 10-15 seconds so then it was calculated the approximate glucose levels and it will start displaying the same values in the mobile phone as well on the OLED display, At the same time if the glucose level is less than 70 then the buzzer is started alert the person through beep sound. Also the needed insulin level is display on the OLED.

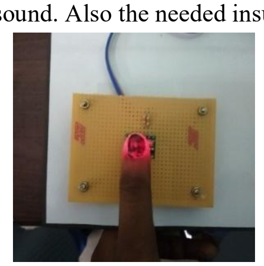


Fig. 3 Testing Input

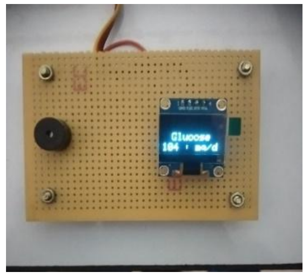


Fig.4 Output

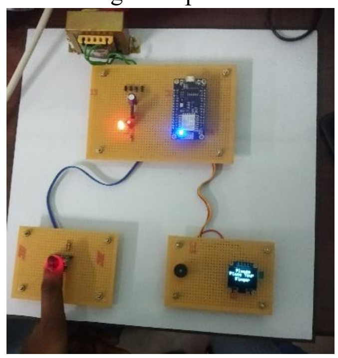


Fig.5 Non-invasive measurement

Testing

The goal of testing non-invasive blood sugar level monitoring equipment is to ensure that the sensors are producing high levels of accuracy and are functioning correctly. As many as 14 patients were tested throughout the testing phase, and the tests were conducted five times on the index finger sensors. The Android device and smartphone display the value of the measuring findings. The ability of Android cell phones to read the blood sugar level testing device was also tested. Android apps are tested on several smartphones to guarantee their dependability.

VI.CONCLUSION

In this proposed system, the Internet of Things-based glucose monitoring system is described, which marks a major advancement in the treatment of diabetes. This technology provides a thorough and easy-to-use method of blood glucose control by utilizing the Internet of Things. This system's non-invasive glucose monitoring gadget takes care of a vital component of patient comfort and compliance. Because it does not require invasive treatments, it encourages consistent and routine monitoring, which helps a more realistic portrayal of the person's glucose profile. The incorporation of cutting-edge sensor technology guarantees dependable and instantaneous data gathering, empowering users to make knowledgeable decisions regarding the treatment of their diabetes. As the user interface, the smartphone application enables people with diabetes to take an active role in their healthcare journey. Users are provided with the necessary tools to make timely and successful actions through personalized threshold settings, real-time graphical representations, and automatic notifications. One important part of managing diabetes is preventing complications and emergencies by having the system give out instant alarms in the event of low blood glucose levels. Users may inject insulin or other prescribed prescriptions with confidence with respect to the mobile application's step-by-step instructions, which also help them manage other medical conditions. This system's collaborative character, which involves both users and healthcare providers, has the potential to change the dynamics of managing diabetes and enhance people's general health. The system has the potential to improve the lives of millions of people managing diabetes globally as it goes through additional testing, improvement, and incorporation into clinical practice.

REFERENCES

[1] Mohammed Y Aalsalem, Wazir Zada Khan, Wajeb Gharibi, Nasrullah Armi “An intelligent oil and gas well monitoring system based on Internet of Things” International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET),2017.

[2] Sayeda Islam Nahid, Mohammad Monirujjaman Khan “ Toxic Gas Sensor and Temperature Monitoring in Industries using Internet of Things (IoT)” International Conference on Computer and Information Technology (ICCIT)2021

[3] S.Vivekanandan , Abhinav Koleti, M Devanand Autonomous industrial hazard monitoring robot with GSM integration International Conference on Engineering (NUiCONE)2013

[4] Meer Shadman Saeed, Nusrat Alim Design and Implementation of a Dual Mode Autonomous Gas Leakage Detecting Robot International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST)2019

[5] A.Sandeep Prabhakaran Mathan N Safety Robot for Flammable Gas and Fire Detection using Multisensor Technology International Conference on Smart Electronics and Communication (ICOSEC)2021.

[6] Ashutosh Mishra; Shiho Kim; N S Rajput" An Efficient Sensory System for Intelligent Gas Monitoring Accurate classification and precise quantification of gases/odors" International SoC Design Conference (ISOCC) 2020.

[7] Qiang Luo; Xiaoran Guo; Yahui Wang; Xufeng Wei "Design of wireless monitoring system for gas emergency repairing" Chinese Control and Decision Conference (CCDC) 2016.

[8] Mohammed Y Aalsalem; Wazir Zada Khan; Wajeb Gharibi; Nasrullah Armi "An intelligent oil and gas well monitoring system based on Internet of Things" International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET) 2017.

[9] C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.

[10] C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[11] C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor &; Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[12] C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[13] Nagarajan C., Neelakrishnan G., Akila P., Fathima U., Sneha S. "Performance Analysis and Implementation of 89C51 Controller Based Solar Tracking System with Boost Converter" Journal of VLSI Design Tools & Technology. 2022; 12(2): 34–41p.

[14] C. Nagarajan, G.Neelakrishnan, R. Janani, S.Maithili, G. Ramya "Investigation on Fault Analysis for Power Transformers Using Adaptive Differential Relay" Asian Journal of Electrical Science, Vol.11 No.1, pp: 1-8, 2022.

[15] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash "Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM" Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756

[16] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, "Perfromance Investigation of T-Source Inverter fed with Solar Cell" Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749

[17] C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007

[18] M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022

[19] M Suganthi, N Ramesh, CT Sivakumar, K Vidhya, "Physiochemical Analysis of Ground Water used for Domestic needs in the Area of Perundurai in Erode District", International Research Journal of Multidisciplinary Technovation, pp: 630-635, 2019