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NON-INVASIVE GLUCOMETER

Chethan G, Abhijeet Kulkarni, Hemanth V, Dr. D J Ravi, Varun H J
Department of Electronics and Communication Engineering
Vidyavardhaka College of Engineering, Mysuru, India

Abstract— **One of the most serious illnesses that affect people nowadays is diabetes. The individual's blood sugar level has to be monitored often to treat diabetes. The present methods for measuring blood sugar that is available on the market employ intrusive approaches; a finger prick is performed and a blood sample is obtained. This procedure is painful and not economical. In this study, we describe a NIR spectroscopy-based non-invasive technique for measuring blood glucose levels. We can classify the problem as normal, hypoglycemia, or hyperglycemia using the proposed approach.**

Keywords- **Non-Invasive, NIR Spectroscopy, Hyperglycemia, Hypoglycemia.**

I. INTRODUCTION

Diabetes is among the most common chronic illnesses that people deal with for the rest of their lives. It is mostly caused by immunological problems, genetics, and other characteristics of the human body, which among other things lead to decreased islet function and insulin resistance. Hyperglycemia and impaired glucose metabolism are the outcomes of the body's unstable glucose levels [1]. The two kinds of diabetes are type 1 and type 2. Insufficient pancreatic insulin synthesis results in diabetes type 1. Contrarily, individuals' declining insulin sensitivity and rising insulin resistance are the main causes of type 2 [2].

Diabetes is a widespread condition that has a wide range of complications and pathogenic factors, is difficult to treat, and has several underlying causes. The International Diabetes Federation predicts that the percentage of people worldwide affected by diabetes would climb substantially and that the count of diabetics will continue to rise, with type 2 diabetes accounting for more than 90% of cases [4].

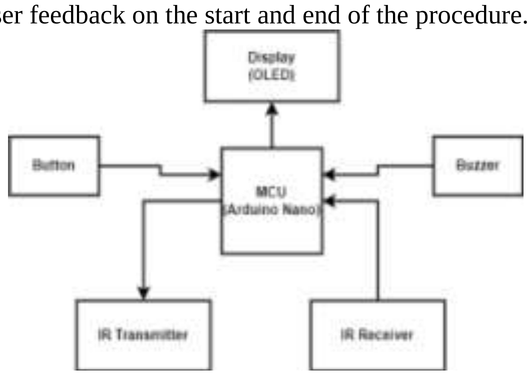
The World Health Organization (WHO) estimates that there are presently 450 million diabetes cases worldwide. Human cells in the body receive the energy they require to function from glucose. Many physiological fluids, such as intracellular fluids, interstitial fluids (ISF), tears, saliva, and urine, contain glucose [1]. Nowadays, the blood glucose level is the main indicator used to identify diabetes. The 2009 WHO recommendation states that typical individuals' fasting blood sugar must range between 3.9 to 6.1 mm, and their blood sugar should be 7.8 mM or less two hours after a meal.

Patients with polyuria, polydipsia, and unexplained weight loss who also have arbitrary blood sugar levels - 11.1 mM or higher, blood glucose levels (fasting) - 7.0 mM or more, or blood glucose levels of 2 hours after 11.1 mM eating, can be diagnosed with diabetes. In addition to hyperglycemia, hypoglycemia also harms the human body. The risk coefficient of hypoglycemia is significantly larger for senior people. Although hypoglycemia is more common at night, it is difficult to identify it quickly with regular blood glucose-determining methodologies. The risk of hypoglycemia is also anticipated to rise with strict blood glucose management [7]. Because of this, non-invasive glucose monitoring in diabetics may have a greater therapeutic use and be more in line with consumer preferences.

II. WORKING OF NON-INVASIVE GLUCOMETER

The Gluco Sensor model consists of an IR transmitter, an IR receiver, a push button, a buzzer, and a display interfaced with a microcontroller (MCU). When enabled by the microcontroller, the IR transmitter transmits Infrared of a specific wavelength. The IR receiver which is based on a photodiode placed in front of the transmitter receives this radiation, converts it into an electrical signal, and sends it to the microcontroller. The program on the microcontroller will be able to measure the strength of the received radiation. The button, buzzer, and display together form a user interface that will enable the user to control the device.

To start the glucose measurement procedure, the user needs to place a finger in between the IR transmitter and receiver and press the button. This will trigger the microcontroller to measure the strength of the received IR radiation from the receiver. After capturing the data for a few seconds and averaging it, the glucose value is calculated using the programmed calibration factors and constants. This value is finally displayed on the OLED. The buzzer is used to give the user feedback on the start and end of the procedure.



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III. LITERATURE REVIEW

To determine an individual's blood glucose level non-invasively, A. M. Joshi et al [1] advised a model. This study presented the "wearable consumer device iGLU 2.0 for continuous glucose tracking" in diabetics. It is founded on the idea of optical detection, and an efficient regression model is designed to accurately estimate blood glucose. The device is tested on pre-diabetic, diabetic, and healthy people ranging in age from 17 to 80 using real healthcare data. Avge and Mard offer improved calibration and authentication results for serum glucose when linked to capillary glucose. In zone A, the predicted serum glucose sample levels are seen at 100%. The suggested glucometer is an accurate and economical option for measuring blood glucose in the 80–420 mg/dl range. The potential aimed at the proposed iGLU 2.0 to offer a self-monitoring solution for smart healthcare is quite high.

J K. Bagais et al [2] have suggested a non-invasive way of detecting the concentration of the glucose level. They have specified various other non-invasive methods and the advantage of using nir spectroscopy method over other principles. LED1550E is used as a transmitter and FGA10 is used as a receiver. Amplifiers and noise filters are used to make the signal compatible with the Arduino, which is used to process the received signal. The results will be displayed on the LCD. Fresnel Equations are used to determine the transmitted light. The experiment is performed several times with the transmitter wavelength at 1550nm and it shows the linear association between the glucose concentration and the voltage level of the received signal.

A paper about the "Diabi Tech- Non-Invasive Blood Glucose Monitoring System" has been proposed by S. S. W. I. Udara et al [3]. The study's goal intend to create a non-invasive, affordable, transportable, and precise blood glucose monitoring system. Lack of accuracy is the key reason why the current solutions are unable to access or tap into the market. Furthermore, it might be difficult to get the necessary permissions from the health regulatory organizations regarding the accuracy, even if they complete the clinical trial phases. Nonetheless, numerous currently available blood glucose measurement systems are only about 80% of the time, which indicates that the outcome might vary by about 20%. However, because these data are kept secret in user manuals, customers feel that they are entirely true. In comparison to the current cost-effective solution, "Accu-Chek" was used as the standard reference in this study. Numerous user-specific calibration systems, the opposite sensor emitter, and sensors and emitters arrangement have produced results with roughly 90% accuracy. Comparing this number to the actual blood sugar levels obtained from a report from a lab, the DiabiTech device's accuracy level is about 90%. Optics can be viewed as the top choice for future non-invasive blood glucose monitoring because of proficiency, ease, and practicality. Due to their compact form factor, hardware components are more affordable and can even be included in smart watches such as the heart rate sensors that are now in use. In this study, it was determined that light of the 630 nm red and NIR wavelengths can easily pass through the skin at locations like the fingertips and earlobes and transfer to the skin's opposite side, allowing a refraction-based solution with sensors and emitters on the opposite side. Blue (460 nm) and green (530 nm) light may pass through the skin, but they don't have the same amount of wavelengths as red or near-infrared light to reach the other side of a fingertip or earlobe. However, all three hues and NIR may be employed if the side sensors and emitters are the same for a reflection-based approach., which can assist offer information about various skin properties (skin thickness, fat levels, etc.) contingent on the amount of infiltration and light reflection. The study team also discovered that noninvasive solutions are best used as self-monitoring tools than as diagnostic ones because diagnosis is a more delicate procedure and cannot provide false positives or false negatives. Furthermore, thanks to high-quality hardware components, non-invasive monitoring devices need not be pricey, unlike other competing alternatives. Multiple inexpensive components can be used to obtain a reasonable accuracy level, benefiting the user with a cost-effective solution.

For a method of non-invasive blood glucose measuring, S. Raj et al [4] have developed a model for a new design of a "CSRR-loaded truncated patch antenna". The truncated microstrip patch antenna presented in this study is a unique design for a device monitoring blood glucose in a non-invasive manner. It is advised to utilize two 20 mm by 15 mm by 1.524 mm CSRR-loaded antennae as a biosensor. With a 10% increase in the blood's dielectric constant, the variation in the S21 value is visible. The suggested antenna's sensitivity is adequate to detect little variations in the dielectric characteristics of blood. For real-time access to blood glucose levels, the suggested biosensor may also be used in the 5G band between 27.6GHz and 29.6GHz.

Adnan Hossain Khan et al [5] have presented a non-invasive blood glucose measurement technique. This study uses the diffused reflectance technique to compute blood glucose levels. They have established a correlation between diffusion reflectance and glucose concentration, and their device, which is based on near-infrared LEDs, is intended to measure blood glucose levels. The suggested system makes use of an Arduino, a photo detector, and NIR LED. The light that was detected is processed using MATLAB. Error analysis is performed using the Clarke Error Grid Analysis. Test data exhibits an inaccuracy, despite being within the Clarke grid analysis's permitted range. The suggested technology may be made into a wearable device because of its low cost and simplicity.

Y.N.R. Reddy et al [6] have proposed a system that determines glucose levels in Non-invasive. Microwaves can be used for non-invasive blood glucose testing if they are operated in the linearity range (6-8GHz) and complicated permittivity values are calculated using transmission characteristics. A precise model to suit the dielectric values of human tissues is produced using the “third-order Cole-Cole equation”. The CST program feeds the data collected using the equations previously described into the model at various frequencies. The model is subjected to a broadband sweep to look for an area of linearity. Because the conductivity and dielectric constant drop as frequency rise, the discrepancies are more pronounced at higher frequency ranges. This can propose an exact amount of insulin to be consumed by the body and is utilized to warn patients during hyperglycemia circumstances.

S. Sunny et al [7] have proposed this paper whose objective is to monitor glucose level using non invasive technique by optical and IoT technology. The proposed sensor circuit consists of IR LED's of wavelength 650–2500nm for optical blood glucose measurement and NIR photodiodes (InGaAs) to receive the reflected light from body parts to determine the glucose level. The Beer-Lambert law is used for signal processing along with GSM based IoT real time information transmission. The project is implemented using Arduino IDE for finding the performance matrix of the system as well as various analytical studies.

Gayathri B et al [8] proposed a system for monitoring the glucose level in a non-invasive manner. An improved approach for estimating glucose concentration utilizing the scattering property of glucose molecules and the photo plethysmography principle is developed using both linear regression and polynomial regression analysis. The transmitter is an IR sensor. The glucose molecules found in the dermis layer of the fingertip absorb, scatter, and reflect an infrared light beam when it is focused on the tip of the finger. A diabetic patient's blood will have more glucose molecules, which will cause the molecules to scatter more light. In other words, the amount of glucose in your blood is inversely related to how much light is reflected. The optical capabilities of the PPG sensors allow them to detect changes in blood flow volume. It keeps track of variations in the brightness of light reflected from the skin's dermis layer. The MSP430 microcontroller processes the output signal according to the CCS-coded algorithm. As a future directive, the work should be extended by integrating the system with the display module and smartphones.

Wang Shulei et al [9] have proposed a Near-infrared spectroscopy-based non-invasive blood glucose measurement method. In this research, they developed a system based on a noninvasive approach for detecting human blood glucose. We employed the PLS approach to do cross-validation modeling using the association between pulse wave, blood pressure, heart rate, and blood glucose to further decrease individual differences. The experimental results show the system to have good detection accuracy, a 93.2% correlation coefficient, and a prediction error of only 0.23 mmol/L, demonstrating the system's feasibility. The system performance will be further optimized via later research efforts, which will also help the technology meet clinical standards.

Marti Widya Sari and Muhtar Luthfi [10] proposed a paper on a Non-Invasive blood glucose level monitoring device. The test findings demonstrated that the method for measuring blood glucose levels was operational. After using testing devices intended to assess variations it can be inferred that the photodiode sensor can measure blood glucose levels operate just as well as sensors used to monitor instruments of noninvasive blood glucose levels. This is because the photodiode sensor's ability to detect light intensity, which is represented based on the output voltage value, will transform in line with changes in the level of blood glucose levels. By calculating the percentage inaccuracy of the measurement findings, data analysis was performed. Utilizing both equipment’s that are already in use in the hospital and newly developed tools, blood glucose levels were measured. 1.03% is the lowest and 9.40% is the greatest percentage error measurement, according to the outcome.

R. J. Buford et al [11] have proposed a microwave sensor having features useful for the noninvasive determination of blood glucose levels is described. The sensor output is an amplitude-only measurement of the standing wave versus frequency sampled at a fixed point on an open terminated spiral-shaped microstrip line. Test subjects press their thumb against the line and apply contact pressure sufficient to fall within a narrow pressure range. Data are reported for test subjects whose blood glucose is independently measured using a commercial glucometer.

D. W. Kim et al [12] have proposed a system based on the Skin Resistance Is Important in the Non-Invasive Glucose Monitoring System Based on Reverse Iontophoresis. In this experiment, it was suggested that skin resistance might be utilized as a metric for skin state, such as extreme sweating or a stabilization phase, in addition to serving as a compensation component. A few in vitro tests supported this theory by showing that adjusted total charge values and the supplied glucose concentration correlate more favorably than in the uncompensated condition. Skin porosity, in particular, is one of the numerous phenomena that the change in skin resistance during reverse iontophoresis entails. So, it makes sense to employ skin resistance as an additional characteristic for estimating blood glucose levels as well as a reliable indicator of the level of skin stabilization in the glucose monitoring system based on reverse iontophoresis. Also, it needs to be closely related to the volume of extracted glucose. In addition, the reverse iontophoresis procedure makes it simple to test the skin resistance with little additional circuitry. More exact data will be collected in the future, and applications in man will be made in vivo. The outcome might significantly help to increase the reverse iontophoretic glucose monitoring system's accuracy. The current methods for gathering this data are intrusive, uncomfortable, and only offer occasional readings. The creation of a painless, automated method would significantly enhance the quality of life for those who have diabetes. According to findings the UK Prospective Diabetes Project, the Diabetes Control and Complication Trial Research Group, and Kumamoto trials, a strict Regular glucose readings are used in a diabetes management plan to direct the delivery of insulin or oral hypoglycaemic agents, result in a significant reduction in the long-standing problems of diabetes, but there was a 3-fold increase in hypoglycaemic events. Additionally, even 7 BG checks a day were insufficient to catch certain severe hypoglycemia and hyperglycemic episodes. 4 A method for obtaining painless, automated, and noninvasive glucose readings are offered by the "GlucoWatch automatic glucose biographer" from Cygnus Inc. in Redwood City, California. After a first BG test for calibration, the gadget offers up to 3 readings every hour for as long as 12 hours.

IV. CONCLUSION

In this paper, a gadget for non-invasively measuring blood sugar that uses near-infrared spectroscopy (NIR Spectroscopy) has been discussed. As discussed in this paper it indicates that this method is feasible to measure blood glucose levels non-invasively, though it still needs improvement to achieve better results. One of the improvements that could be done is to get more sample data and a larger variety of data. It's widely known that Machine Learning (ML) model is prone to over fitting when it has a small and narrow training data set. The other improvement comes from the analog device itself, the optimization of an analog signal can be increased by reducing the percentage of components tolerance like changing the resistor and capacitors to surface mount device (SMD) type of components. In addition, optimization of filters in the analog device can be done, such as reduction of power-line noise in analog, so that the ADC and digital filters of converted analog signals are better than before thus getting a better output signal. From the signal acquisition perspective, additional LED with various wavelength can improve the main PPG signal reading by segmenting other components such as fat, water, and protein so that the main LED (940nm) only focus on getting PPG (Photoplethysmogram) signal which contains blood glucose.

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