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Implementation of Non-Invasive Blood Glucose Monitoring System

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Abstract*— In the case of diabetes, measuring blood sugar levels is made challenging by the need to pick one's finger. Laboratory testing and one-touch glucometers are intrusive procedures that increase the risk of blood-related illnesses. In the current work, we propose a novel edge device with IoMT (Internet-of-Medical-Things) capabilities for precise, non-invasive blood glucose monitoring to solve this crucial issue. In this study, a NIR (Near-Infrared) spectroscopy method is used to identify the glucose molecule in human blood at two wavelengths (940 nm, and 1300 nm). The cutting-edge gadget known as iGLU is based on high-accuracy ML (Machine Learning) models and NIR spectroscopy. For accurate measurement, a DNN (Deep Neural Network) model and an ideal multiple polynomial regression model have been provided. An open IoT platform is used to evaluate the proposed gadget, and blood glucose levels are then saved there for endocrinologist remote monitoring. For device validation, the blood glucose measurements obtained from the invasive device and the projected blood glucose levels have been compared. The AvgE (Average Error) & MARD (Mean Absolute Relative Difference) of the predicted blood glucose concentration levels were determined to be 4.66 percent and 4.61 percent, respectively. There is a 0.81 regression coefficient. An accurate and economical solution for smart healthcare is offered by the suggested spectroscopic non-invasive gadget.

Keywords — IoMT, MARD, NIR, ML, DNN

I. INTRODUCTION

A simple sugar molecule is a glucose. Chemically, the sugar molecule is represented by the formula C6H12O6. This indicates that there are the glucose molecule has 12 Hydrogen (H) atoms, 6 Carbon (C) atoms, as well as 6 Oxygen (O) atoms. The sugar level molecule glucose circulates in human blood.

Our body normally breaks down dietary sugars after eating or drinking them and utilizes them to provide our cells with energy. To do this, our pancreas generates the hormone insulin. Sugar is taken out of the blood by insulin and placed in the cells for utilization. Our pancreas can't create enough insulin if we have diabetes.

As a consequence, the amount of blood glucose increases. Our cells experience a critical energy deficit as a consequence. This may result in several possible side effects, such as blood vessel damage, renal illness, nerve damage, amputation, blindness, and other conditions. Although there is no cure for diabetes, it is possible to avoid it or control it by maintaining blood glucose levels normal. Given this, it's critical to routinely monitor blood glucose levels with a glucometer.

The market is filled with several glucometer varieties. However, they are intrusive. These intrusive glucometers need a little quantity of blood via a fingerpick and the application of a test strip that measures the blood glucose level. People may be put off by finger puncturing since it is painful, infectious when a similar needle is employed on several patients, and more costly. As a result, a non-invasive technique that doesn't need finger pricking and is affordable for diabetes patients must be developed.

Invasive diagnostic techniques are often used for blood glucose systems. The easiest way to take a blood sample is probably to prick your finger. The medical professional taking the blood first sterilize the area with an antiseptic to get rid of any microorganisms. The patient's veins will bulge with blood when an elastic band is tied around the patient's upper arm. They locate a vein and push a clean needle into it. After taking blood from the patient into a tube linked to the needle, the healthcare professional will remove the needle and cover the puncture site with a bandage. To avoid bruising, pressure will be administered to the puncture site for a short period. The blood sample is subsequently sent to a lab for analysis. The blood sample will be put on the strip and inserted into the blood glucose meter at the pathology labs to test glucose. A sequence of chemical processes will occur within a glucometer, and as a result of these processes, the blood's level of glucose will be anticipated.

The intrusive technique of measuring blood sugar is uncomfortable; finger-pricking has several drawbacks. There is a danger of infection, many individuals loathe using sharp tools and witnessing blood, and over time, this habit may harm the tissue in the finger. To overcome the aforementioned issues, a non-invasive method for monitoring blood glucose employing a near-infrared LED is given in this work.

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II. LITERATURE REVIEW

The design element for non-invasive blood glucose monitoring is suggested in this research using the absorbance principle. According to the results of the spectrometer experiment, the glucose concentration may be detected more precisely at a 940 nm wavelength. The photo-plethysmograph signal is produced via near-infrared spectroscopy, which uses IR light to pass through a finger before being amplified and filtered. As a consequence, we looked at the link between voltage and glucose levels for several samples and found that there was a linear association. The glucose level is also shown on an LCD by a microcontroller (MSP 430), and this information may be supplied to the physicians through an Android app so that patients can start taking prescriptions right away [1].

To inject the necessary quantity of insulin into the body using this procedure, they must remove a drop of blood from the patient's body and measure the blood's level of glucose. In this prototype, we are adopting non-invasive methods to get around the issues brought on by the intrusive method. The major goal of this research is to develop a portable, "non-invasive blood glucose level monitoring" system that makes use of near-infrared sensors. The apparatus is equipped with an ATMEGA328 microcontroller, a photodiode, and an infrared LED [2]. The gadget not only can measure blood glucose levels but also shows the user the amount of insulin that is needed depending on the user's BMI and blood glucose levels.

Using a NIR LED (940 nm) and a photodetector to assess the blood glucose level, the authors of this research presented a non-invasive blood glucose testing technique. They measured the blood glucose level in our article using the diffused reflectance approach. Following the device's implementation, we compared the data from our devices and produced a commercially available intrusive blood glucometer. We tried to keep the prototype's construction as simple and inexpensive as feasible. Our prototype employs 940 nm NIR and also collects data from the finger, which minimizes any potential issues with temporal delays that might occur during data collecting. The gadget may be worn as a wearable for continuous blood glucose level testing [3] tenth "International Conference on Electrical and Computer Engineering 20-22 December 2018, Dhaka, Bangladesh". The investigation of the clinical and technological underpinnings that permit a non-invasive measurement of blood glucose is the focus of the study discussed in this article. We offer a feasibility analysis of a non-invasive sensor that integrates three distinct kinds of techniques: electromagnetic, acoustic speed, and near-infrared spectroscopy, in contrast to earlier work that concentrated on a single approach or technology. The cross-compensation of these three strategies may reduce the poor performance of single technique approaches, even though our prototype is susceptible to many causes of bias [4].

Here in this paper, the medium is Illuminated By laser light, which in turn causes the temperature to rise and results in stress that increases the volume of the medium and results in generates the thermoelastic acoustic wave. With the help of a Photoacoustic signal, Amplitude and Frequency of the Sound Spectrum can be Obtained Which is required to realize glucose measurement. They concluded that increase in the amplitude of the photoacoustic sound spectrum results in an increase in glucose concentration. Hardware implementation is difficult, processing of the signal entails a significant quantity of unique data that is challenging to acquire because of real-time processing [5].

In this research, they created a microwave NIBGM system that should run at 1.4 Giga Henry and enhance accuracy-related performance. By using the idea of subject-specific linear correlation, the data received from microwave sources are transformed to estimate the glucose content. The findings show that there is no temporal lag in the measurement of the data, and the results from the error grid and MARD [6] are satisfactory. The existing approach is neither user-friendly, portable, or wearable, the report says.

Here In this paper, the technique using diffused reflectance is utilized to evaluate the glucose level in the blood. The principle of Beer Lamberts Law is used where attenuation arises as a result of light scattering and absorption Decrease this results in diffusion reflectance also gets decreases. Blood glucose concentration is calculated using this diffusion reflectance relationship. Results are promising and measurements lie in the accepted region of Clark's error Grid Analysis. Infrared rays come from sunlight it also affects the readings and intensity of light reaching the photodetector changes by which error is present [7]. Regression analysis may help from the application of ML algorithms to improve accuracy.

Near-infrared sensors are utilized in the work to measure blood glucose levels, and the user's Body Mass Index (BMI) is used to determine the appropriate insulin dose in addition to the glucose level. the methodology for determining blood glucose levels using the principles of light scattering and absorption. Results include identifying the numerous relationships between voltage and glucose levels, and the system has an inaccuracy of roughly 20% [8].

III. PROBLEM FORMULATION

One of the illnesses that pose the greatest risk to life is diabetes. Because blood glucose levels are not being properly monitored, the number of individuals with diabetes is rising nowadays. The IDF ("International Federation of Diabetes") study report estimates that around 425 million persons worldwide had diabetes in 2017 and predicted that figure will increase to 6 million by 2045 [9]. According to the study, there would be 48percent more individuals with diabetes in the next 28 years. individuals with diabetes must use invasive techniques to measure the quantity of glucose in the body. In

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this invasive procedure, a little quantity of blood must be drawn from the patient to assess the necessity for insulin injection and evaluate the level of blood glucose. To eliminate the issues raised by the intrusive method, we must create a portable, "non-invasive blood glucose monitoring" system.

A. Research Objectives

The objective of the research are listed below:

- To conduct a thorough literature review on the subject of "Implementation of Non-Invasive Blood Glucose Level Monitoring System" and to develop a special, cutting-edge concept for a non-invasive system.
- Construct a platform to show the blood glucose concentration level and get familiar with the various hardware and software components used in creating a non-invasive blood sugar monitoring system.
- To allow data communication with the cloud and to make the gadget portable.
- To create a portable, non-invasive blood glucose level monitoring system.
- To design an inexpensive, continuous self-monitoring device for Diabetic Patients.
- To enable the doctor to remotely monitor the glucose concentration using a web application.

B. Research Motivations

- One of the many serious health issues the world is now dealing with is diabetes or diabetes mellitus.
- As per WHO ("World Health Organization"), more than 200 million individuals worldwide are believed to have diabetes.
- In the human body, diabetes may cause serious problems including heart failure and blindness.
- Typically, invasive techniques are used in hospitals to detect blood glucose levels. It requires the need to collect blood samples with finger pricks to measure the blood's glucose level; its drawbacks are discomfort and infection.
- There is a danger of infection, many individuals loathe using sharp tools and witnessing blood, and over time, this habit may harm the tissue in the finger.
- There is always needed to check the glucose level after a certain time, so it requires manpower, and test strips are required every time to do the test.
- The non-invasive method provides better accuracy and precision. It reduces the manual operation, and it gives a continuous monitoring system. Test strips, lancets, and other items are no longer a waste.
- Reduced life cycle costs (less costly over time than a finger prick device): One-time cost with almost infinite dimensions.

IV. DESIGN METHODOLOGY OF MONITORING YOUR GLUCOSE NON-INVASIVELY SYSTEM

The building levels of the suggested model approach have been addressed in this section. Along with their working principle

Fig 1 1 displays a block schematic for a designed model where the max30100 sensor that measures both blood glucose levels, as well as the SPO2 levels along with the heartbeat sensor and temperature sensor, is attached to the raspberry pi pico microcontroller. The node MCU is used to transmit the data from the microcontroller to the cloud. The LCD is used to display the values of the sensors. The buzzer is played in case of emergencies to alert the doctor and the hospital staff.

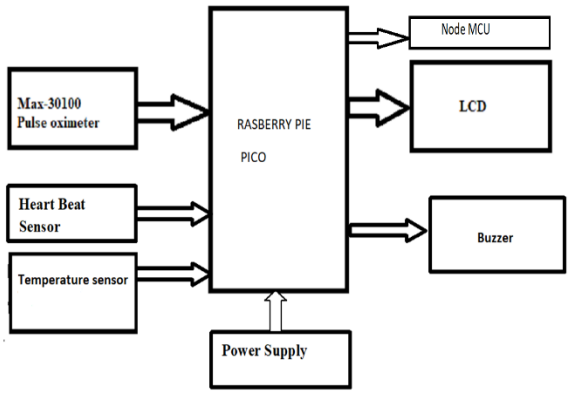

Fig. 1. Block Diagram of the Methodology

In this project, the A blood glucose meter may offer glucose values quickly and painlessly without requiring a blood sample or finger prick. The gadget checks the heartbeat, and it is displayed on the LCD.

The primary task is to identify the hardware components which are suitable for this project. Block diagrams consist of hardware components that are interconnected with each other to perform a specific task.

V. IMPLEMENTATION AND DESIGN METHODOLOGY OF PROPOSED SYSTEM

The implementation and design methodology of non-invasive glucose monitoring is explained in this section.

Table 1: Details of the hardware and software components

Hardware Requirements	Software Requirements
Raspberry Pi Pico	Raspberry Pi Pico IDE
Max 30100	Embedded C
LCD	
Temperature Sensor	
Nodemcu	

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A. Data Flow Diagram (DFD)

Alternatively called a "bubble chart". It is a fundamental graphical representation that may be utilized to represent a system in the form of data it receives as input, the processing it does on this data, and the data it produces as output.

- Among the most important modeling methods is DFD. The system's components are modeled using it. These components include the system's internal workings, the data necessary for those workings, a third party interacting with the system, and information flow inside the system.
- DFD is an example of how information moves through a system and a series of modifications. It uses a graphical method to demonstrate the information flow and changes that take place when data moves from I/P to O/P.
- The DFD is also referred to as a bubble chart. Any level of system abstraction may be represented by a DFD. It may be broken down into layers that show increasing functional granularity and information flow.

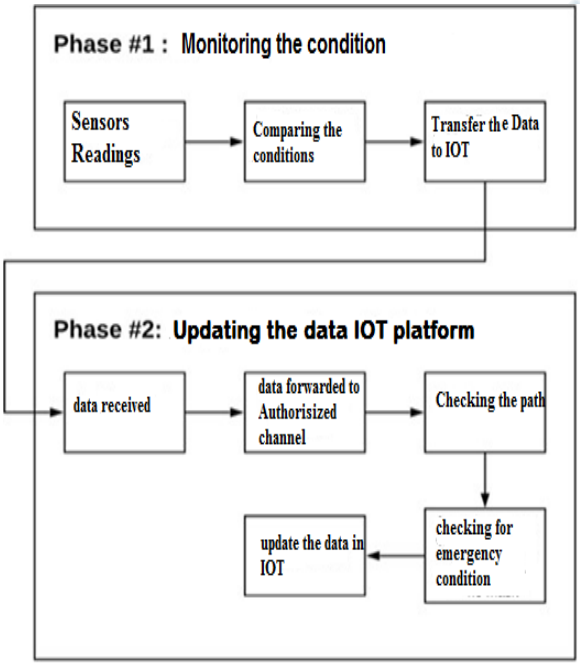

Fig. 2. Shows the phases of the working model

B. Use Case Diagrams

It is a kind of behavioral illustration that is defined by and produced from a use-case analysis in the UML ("Unified Modeling Language").

In terms of actors, their targets (characterized as use cases), and any connections among use cases, it seeks to provide a graphical representation of how the system is operating.

A use case diagram's main objective is to show which actors perform which system functions. The system's actors' roles may be shown.

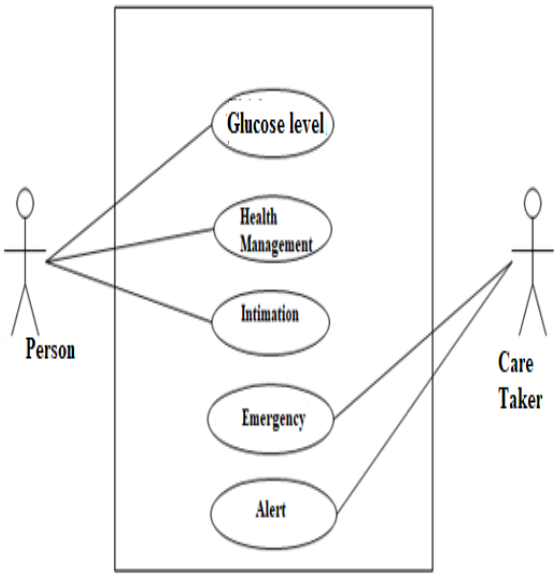

Fig. 3. Represents the process of intimidating the patient and the caretaker

C. Class Diagram

In order to demonstrate the structure of a system, a class diagram in the UML shows the classes, their characteristics, actions (or methods), and links between classes. It specifies the class of data.

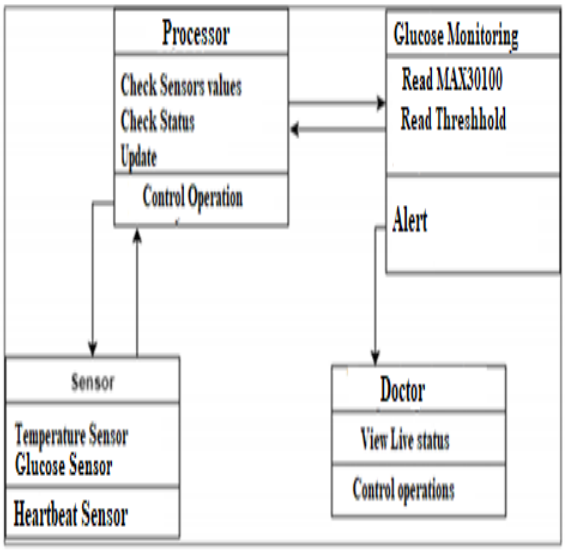

Fig. 4. Outline of the passing of the information from the processor to the doctor

D. Activity Diagram

Activity diagrams are visual depictions of sequential activities and actions in processes that aid in choice, iteration, and concurrent execution. The business and operational processes of system components may be represented using activity diagrams in the UML. The whole control flow is shown in an activity diagram.

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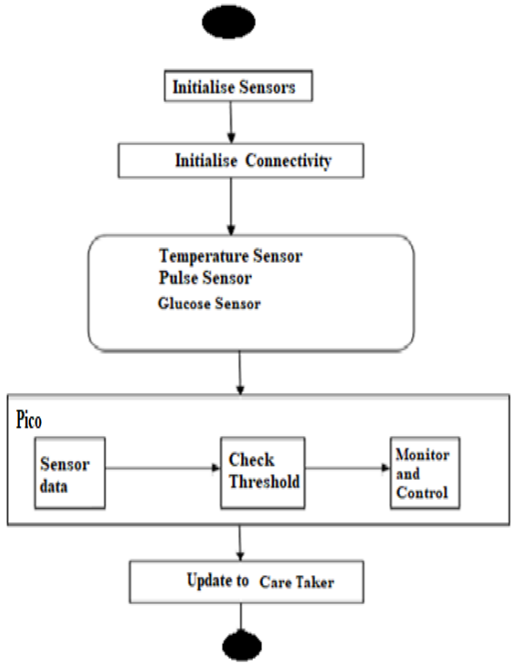

Fig. 5. Sequence diagram

E. Interaction Diagram/Sequence Diagram

It is a kind of interaction illustration used in the UML that demonstrates how and in what order processes interact. It is a construct of a message sequence chart. Event situations, event diagrams, and timing diagrams are further names for sequence diagrams.

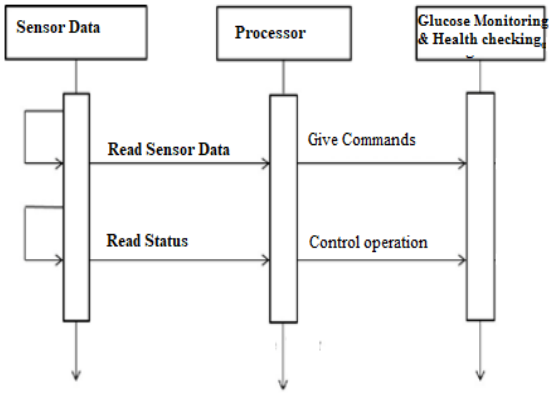

Fig. 6. Interaction Diagram /Sequence Diagram

VI. RESULTS AND DISCUSSION

This section has a noninvasive blood glucose meter that can offer glucose levels in a few seconds without requiring a blood sample or finger pricks. The relevant findings are listed in the section that follows.

The gadget is simply adaptable to enable continuous monitoring of blood oxygen levels and blood glucose levels and to record these readings. Using the same tools and sensors, the device algorithm may be updated to give other capabilities, such as heart rate, among others.

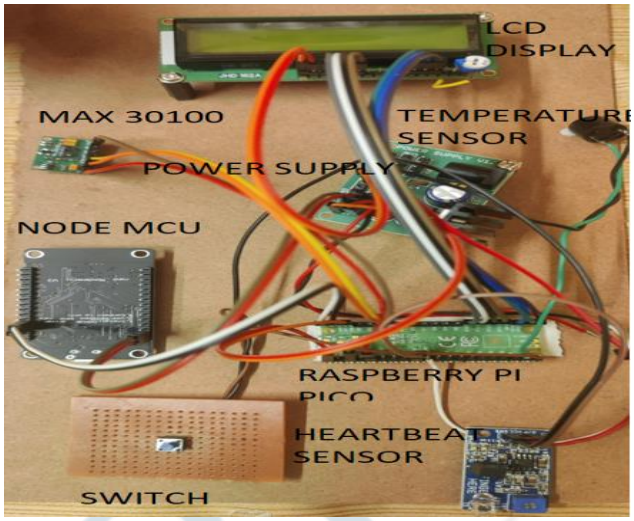

Fig. 7. The figure shows the hardware components

Fig. 8. The above image displays the patient placing their finger on the heartbeat sensor to take the readings of the heartbeat.

Fig. 9. The above image shows the readings of SPO_2 as well as the glucose level

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Fig. 10. The above image shows the display of the temperature of the patient.

Fig. 11. The above image displaying the values of the heartbeat sensor

VII. CONCLUSION

This research provides a non-invasive blood test that glucose meter that may deliver glucose levels in a few seconds without requiring finger pricks or blood samples. The gadget is simply adaptable to enable continuous monitoring of blood oxygen and glucose levels, as well as to record these results. Utilizing the same devices and sensors, the device algorithm may be updated to give other capabilities, such as heart rate, among others.

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