Smartphone Based Non-Invasive Glucose Monitoring

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Abstract

Diabetes is a standout amongst the most extending disease around the world. It is a non-treatable sickness, yet sugar levels can be kept in charge by keeping up appropriate eating regimens and ordinary checking of the glucose esteem. The regular strategies performed in medical clinics are obtrusive technique, which are difficult and can make infections patients. In this manner, to defeat such issues, the non-obtrusive technique is proposed. In this paper, we have proposed a model which can be cost effective and non-obtrusive prototype utilizing NIR spectroscopy methodology. Also, Mobile application is utilized to show the Glucose esteem and to store the estimated data for future records. Through which the client can distinguish the glucose level to keep up the regiment regimen at opportune time.

Keywords - *Diabetes, Arduino Nano, Bluetooth module, Blood Glucose, Non-invasive, Mobile App, NIR spectroscopy, Machine learning*

I.INTRODUCTION

Diabetes is a non- communicable disease which has affected millions of people health worldwide. According to the prediction by the International Diabetes Federation (IDF), the rate of diabetes affected people will increase intensely and by 2035, 592 million people may have diabetes. Diabetes or Diabetic Mellitus is a metabolic imbalance disease which occurs when blood sugar level fluctuates from the normal range (90-150mg/dL). Diabetes are divided as Type1, Type2, and gestational diabetes. In type1 diabetes, the pancreas is unable to produce much insulin and commonly known as the insulin-dependent diabetes or the Juvenile diabetes. In type2, the body is not able to use the secreted insulin and commonly termed as the non-insulin dependent or the adult-onset diabetes. The gestational diabetes appears during the middle of pregnancy time and changes to type2 diabetes after delivery.

Diabetes causes various complications and risk to human life. It is accountable for the cause of renal failures, ulcer formation, kidney failure blindness, heart disease, and stroke. Proper diet care and monitoring are necessary to maintain the blood glucose level control and to avoid complications & risk of people's health.

There are two strategies accessible to screen the glucose level which is Invasive and Non-obtrusive strategy. The Invasive technique is done in the accompanying ways to be specific, pricking of fingertip and blood tests utilizing the syringe. These techniques are agonizing, which makes distress to patients and may cause disease in the pricked locale. To conquer the troubles of obtrusive techniques the non-intrusive strategies are considered.

In the non-obtrusive strategy blood isn't taken for glucose level checking, so they are without torment and exceptionally advantageous. A portion of the non-intrusive strategies utilized to recognize the glucose levels are Polarization change, Raman Spectroscopy, Fluorescent spectroscopy, Near-infrared spectroscopy, Mid-infrared spectroscopy, Bio-impedance spectroscopy, spit as analytic liquid and warm discharge spectroscopy. In which, the objective destinations considered for examination are eye, skin, intravascular, spit, sweat, numerous districts or volumes of the body, lower arm, fingertip, and ear cartilage. In any case, there is a slack between the glucose levels in blood and different liquids, for example, spit and tears, which can decrease the exactness of discovery.

Optical methods are considered to be one of the pain-free and the promising methods which can be used for non-invasive blood glucose measuring. In which the Near-infrared (NIR) is considered to be the most widely used optical techniques because of its high penetration in the skin. These techniques are applied in various regions of the body such as earlobe, finger, forearm, and palm. In which, at the earlobe the sensitivity and accuracy in detection are high because it is boneless. On comparing with other methods, the NIR method finds a good advantage in sensitivity, complexity, power consumption, cost, and accuracy.

In this paper, the NIR LED system is considered for the detection of glucose level. And an easily accessible system is necessary for the user to monitor and store their data for future reference, which can help the user and doctor to examine better.

II. OVERVIEW OF NIR SPECTROSCOPY (NIR)

The Infrared wave is classified as Near-infrared, Mid-infrared, and Far-infrared. Fig.1 shows the infrared classification in the Electro-magnetic spectrum.

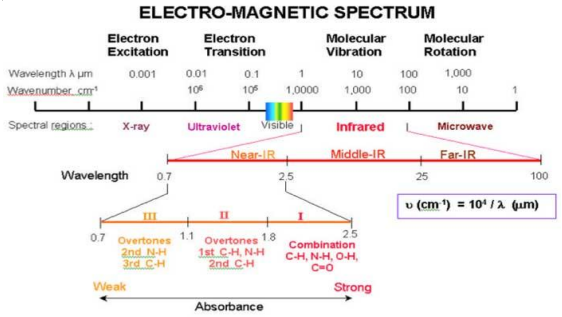


Fig.1. Electro-magnetic spectrum

NIR spectroscopy method is one of the optical methods used in non-invasive Glucose level detection. NIR has been used in the medical field for the detection of glucose level. The NIR light lies in the wavelength range of 750nm – 2500nm. The infrared (NIR) rays can penetrate through the skin at the wavelength range of 650-1350nm. The LED sensor (Both NIR transmitter and receiver) is used instead of a laser, to overcome the limitations of laser.

NIR based glucose monitoring systems are used in various regions of the body for examination of glucose non-invasively. Some of the regions considered for examination are Earlobe, Forearm, Fingertip, and Palm. On comparing the considered regions, the accuracy of glucose detection is better at the earlobe, due to its boneless tissue and small thickness. Near-infrared was passed on one side of the earlobe while the opposite end is the receiver side which receives the attenuated light. Normally, photodiodes are used for light detection at the receiver side. The variations of glucose concentration in the blood attenuate the light transmitted, which results in variation of photodiode voltage.

III. METHODOLOGY

Our design uses the NIR spectroscopy techniques to detect the concentration of glucose level in blood through non-invasive. A sensor clip giving near-infrared radiation of 950nm wavelength is used as the transmitter, which penetrates through tissue and attenuates the light signal. And the attenuated signal is perceived by the photodiode, of wavelength 900nm placed in the opposite side of the sensing clip. The sensor part is placed at earlobe for blood glucose level detection. The attenuated rays are converted to respective voltages by the photodiode. In which, the analog signal received from the photodiode is converted into digital signal by the Arduino Nano (Microcontroller) using the analog port. The Bluetooth module is used to transfer the processed data or resultant data (Glucose level) to the Mobile App. Through the Mobile App, the patients can view the glucose level & save it as excel format for future reference.

Fig.2 shows the Over view of our project to determine the glucose value with Arduino Nano and the mobile app. The sensor clip constructed will provide dark isolation under examination, for better accuracy in detection.

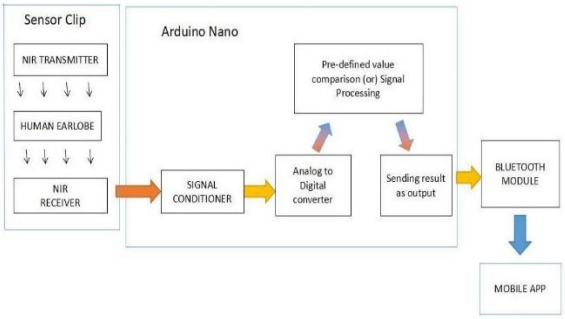


Fig.2. Over view of the Project

Arduino Nano can be operated at 5V as the input voltage. So, a 5V battery is used for power supply to the device. A switch is used to power ON the device and power cord or Barrel Connector is used for recharging the battery.

IV. HARDWARE DESCRIPTION

A. Sensor Clip

The sensor used here is the NIR sensor. NIR sensor is chosen amongst others is that it does not harm the human skin.

To measure the blood glucose non-invasively the NIR LED and the photodiode is used. One side of the sensor clip is attached with the NIR LED (TSAL5300) as Transmitter and the opposite side we have photodiode (BPW34) to measure the attenuated light received after the penetration of NIR waves through our earlobe.

NIR can penetrate through our skin at the range of 650-1350nm. In comparing many conditions 940nm range is used for better performance and accuracy in detection for glucose detection. Fig.3 shows how the sensor clip is constructed with the transmitter and receiver.

The silicon pin BPW34 of wavelength 900nm as peak voltage is used as a photodiode. When the attenuated light wave reaches the photodiode, depending on the amount of light intensity the voltage is received. To avoid the external factors the sensor clip is constructed in such a way to provide dark isolation when placed on the earlobe.

B. Arduino nano

Arduino Nano contains 8 analog pins and 13 digital ports which act as general input and output ports**.** Fig.4 shows the Arduino Nano picture used in our project. The output voltage from the sensor clip is analog and taken as input to the Arduino Nano (Micro-controller) through the analog port. The received signal from the sensor clip is converted to digital and analyzed.

Fig.4.Arduino Nano

The Arduino Nano is used to find the relationship between the different glucose concentrations and received attenuated voltages from the photodiode. The relational expression is processed through signal processing for glucose level prediction based on the above relation prediction. The processed data or resultant value is transferred as output to the Bluetooth module.

C. Bluetooth Module

The output from the Arduino Nano is transferred to the Bluetooth module (HC-05) for wireless data communication. **Fig**.5 shows the Bluetooth module used for data transfer.

Fig.5.HC-05 Bluetooth Module

This Bluetooth module helps to transfer the glucose result to the developed Mobile App through Bluetooth connectivity.

V. SOFTWARE DESCRIPTION

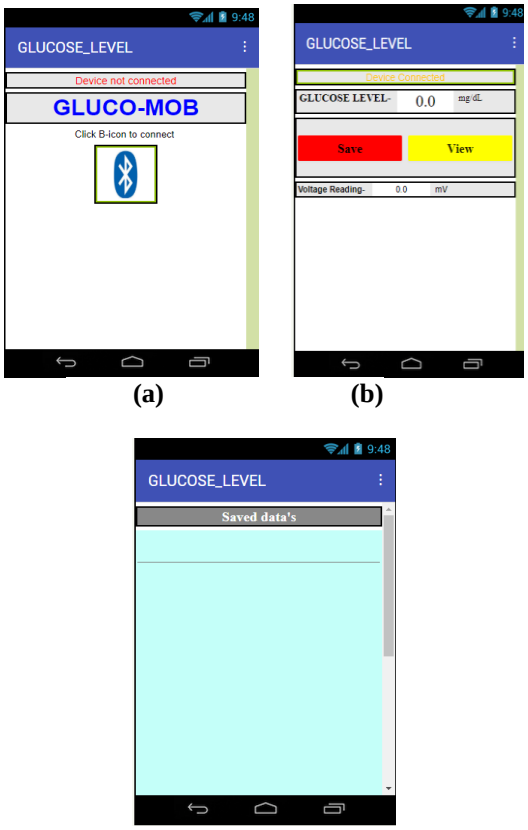
A. Functions Of Mobile App

The user needs to install the Mobile App developed, from the link. And after successful pairing with Bluetooth device (HC-05) by selecting the Bluetooth icon displayed. Through the Mobile App, the resultant glucose data can be viewed near to the glucose level label, in the screen. The user can also save and view their previous data by selecting the save and view button on the screen.

B. Development Of Mobile App

The mobile app is developed using the online MIT App Inventor. The MIT app inventor is a visual programming environment, where instead of normal coding, the blocks-based tool can make the creation of complex, high-impact apps in significantly less time than traditional programming environments.

The Second screen is used for (a)-Bluetooth device pairing, (b)- Glucose value display and (c)-viewing the saved data of previous recordings. Fig.7 shows the stages of the second screen of the app when selecting the required button.



(a) **(b)**

(c)

Fig.7. Stages of Second Screen, a- Bluetooth device paring, b- Glucose value display, c- Saved data display.

VI. IMPLEMENTATION AND RESULT

In this project, we have done two testing methods to detect the relationship between the glucose value and voltage value, they are the invasive and non-invasive method.

For an invasive method of detecting the Glucose value, we have used the Accu-Chek (Glucometer) and sensing clip developed is placed on the person's earlobe for a non-invasive way of detection. Both invasive and non-invasive method was performed for around 50 peoples.

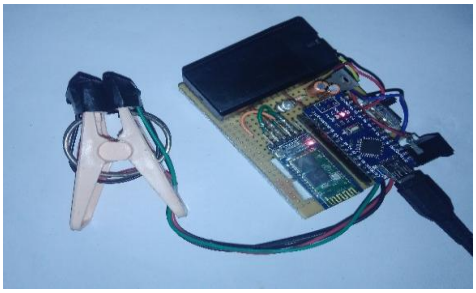


Fig.9. Developed module

The Fig.9. shows the developed non-invasive sensing module picture used for testing. The obtained values from the device are plotted in the scattered chart. From the scattered chart, the polynomial expression and regression are identified. The obtained expression is fetched into Arduino Nano for calibration of the result.

Regression analysis is an important tool for modelling and analysing data. Here, we fit a curve or line to the data points, in such a manner that the differences between the distances of data points from the curve or line is minimized. Using this tool, we were able to formulate the efficiency between the invasive and non-invasive method

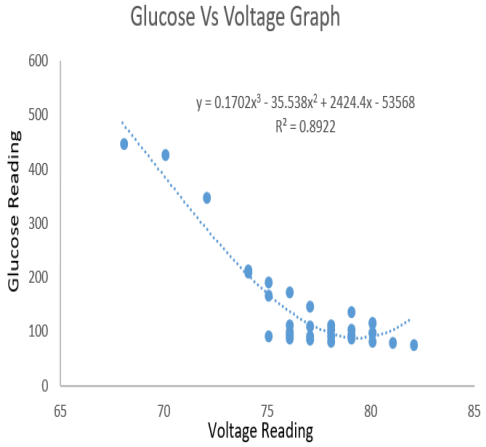
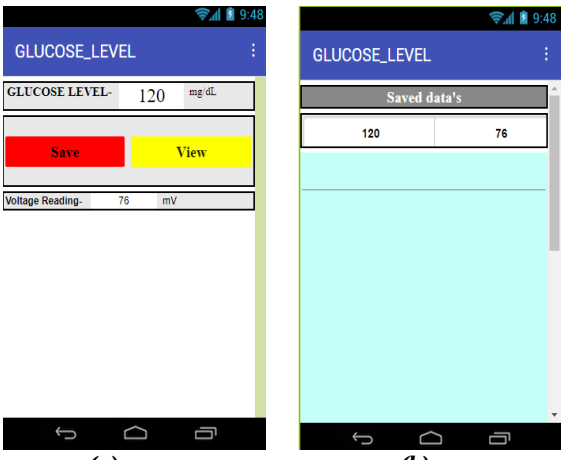


Fig.10. Scatter Chart output

The Fig.10. shows the scatter chart, performed to identify the polynomial expression and regression. We attained the regression value as 0.8922 in the third order of polynomial trendline.

This polynomial regression method of prediction is used in machine learning algorithms to calibrate the expected result in Arduino Nano. The calibrated value is transferred to Smartphone App through the Bluetooth module.



(a) *(b)*

Fig.11. (a)Glucose value and (b) saved value in App

The Fig.11(a &b) shows how the Glucose value is displayed and stored in the app. The Mobile App was used to display and store the obtained glucose value for future reference to the user.

VII. CONCLUSION

This research investigates a novel approach for smartphone App based Non-invasive Glucose monitoring device using the sensing Clip developed. The glucose level determination is done using NIR Spectroscopy method. Through Invasive and Non-invasive method, multiple values are taken to determine the relation between the glucose and the attenuated voltage. The obtained datasets are correlated through machine learning algorithms, by utilizing the polynomial regression method. From the polynomial regression chart the expression and regression value of 0.8922 are attained. The smartphone App based system was developed to provide user-friendly App to the user.

In the future, this system can be improved by adding an artificial intelligence-based system for better performance and message alerting facilities.

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