Detection of Blood Glucose Level in Humans using Non-Invasive Method-RL BGM

M. Julie Therese, P. Dharanyadevi , A. Devi, C. Kalaiarasy

Abstract*: Blood sugar in the body is called glucose and it is important that the amount of sugar in the blood is fairly maintained. The body has sugar and blood that is used to store energy in the body. Low or high blood sugar is dangerous to life if it is not treated. The fasting blood glucose level in the morning ranges between 70 mg/dL to 110 mg/dL, after the meal the blood glucose should be less than 140 mg/dL. This paper proposes a method that is best suited to detect blood glucose in the human body and avoid serious health issues by sending a message instantly to the respective number of the patient. Currently, in market Blood Glucose Monitoring (BGM) techniques are vigorous and painful as the blood sample is pricked from the finger that leads to the risk of infection, the strips that were being used were also costly. The solution to this problem statement is a design of non-invasive smart equipment for observing the blood glucose level. One non-invasive method is Red Laser (RL) BGM technique, that is very superior to the other invasive method and non-invasive techniques. Here the refractive index of the laser light is analyzed to determine the blood glucose level. Several tests and experimental results are generated to prove the proposed method is highly accurate.

***Keywords*: BGM, Blood glucose, Invasive method, non-invasive method, RL-BGM**

I. INTRODUCTION

The human body has to maintain the blood glucose level to avoid drowsiness, nausea, vision complications, tiredness, increase in heart beat, etc. The abstraction of this paper is to detect the blood sugar level of a person using visible Red laser light and send a message to the persons mobile using GSM. There are several methods to find blood sugar level in a person. It can be detected using Invasive method, minimally invasive method and non-invasive method. In recent years the FDA and CDC are altering the healthcare specialists on the HBV outbursts that is linked with the monitoring of blood glucose in invasive method of detection. This danger occurs in any situation where blood glucose monitoring device's is shared or those executing the monitoring don't observe basic infection control practices.

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This places involves acute-care services, clinics, health fares, schools and several camps. It is suggested that the reusable finger-stick lancing equipment's should not be utilized for more than one person to prevent the risk of blood borne pathogens. This method seems to be costly and painful. To overcome this, came minimally invasive technique that makes use of electrodes that is being attached to the skin, this technique decreases the probability of infection and reduces discomfort[1]. Yet in this method the poor signal to noise ratio and hence low accuracy makes it a non-fulfilled model. A far more superior model is the non- invasive technique. In which to identify the concentration of secretions due to blood glucose, like sweat, saliva, urine, tears are used instead of blood[1]. Or laser light passes through the skin tissue to identify the concentration of glucose. The latter technique in the non-invasive method is discussed in this paper. Optical techniques for BGM are Raman spectroscopy, Thermal emission spectroscopy, Diffuse reflection spectroscopy, Photo acoustic spectroscopy, Absorption spectroscopy, Fluorescence spectroscopy etc. amongst this the widely used technique is absorption spectroscopy that clearly spot the absorption, scattering, reflection and refraction of light that is passed through biological tissue. This characteristic of light plays a vital role in the determination of blood glucose level in human beings. Here Red laser light is used as the light source that passes through the tissues without affecting the internal and external organs of the human being.

II. EXISTING MODEL

A. Breath Acetone sensor

The presence of acetone in human breath that is being exhaled plays a vital role in blood glucose level detection. The breath acetone detector [4] should be placed right in front of the mouth and the patient should be allowed to blow air very close to the device held in front. This then senses the amount of acetone present in the exhaled breath and indicates the result (HIGH/LOW/HEALTHY) on the display of the device.

B. NIR based BGM

The Near Infrared (NIR) based BGM technique [5] consists of infrared LED light source, a photodiode and data processing algorithms, an analog to digital converter a microcontroller unit and an LCD display[17]. The NIR LED is made with Gallium arsenide or even aluminum gallium arsenide.

C. Performance of NIR-BGM

Before transmitting the near infrared LED light[6] through the fingertip of a person the blood flow is blocked by pressing the finger. The light thus passed through the body tissues is received by a photodiode placed behind the finger. The signal processing unit performs support vector mechanics regression and partial least square regression for analysis as shown in equation 1.1. These techniques collectively combined along with the examination of change in the light intensity provides extraction of the chemical components inside the tissue that includes the glucose content and finally displays the value on the LCD. The existing system uses the below equation:

$$A = \varepsilon c L \qquad (1.1)$$

where, A is the absorbance, c is the concentration of blood in moles/liter, ε is absorption coefficient, L defines the path length.

D. Drawback of Breath acetone

The dis-benefit of the breath acetone sensor based BGM technique is that the large amount of moisture in the exhaled breath that does not give reliable response to ppb level of acetone, hence a ultrahigh acetone sensor with moisture resistivity should be used to detect blood glucose which is still under research.

E. Drawback of NIR-BGM

The drawback of the (NIR) based BGM technique[11] is that the human eye is sensitive to all types of radiation that includes infrared, prolonged IR exposure on the human body can lead to various side effects and since the blow flow is blocked before passing IR light that leads to various complications. Hence this method cannot be the safest and accurate method to determine and calculate the blood glucose level.

III. PROPOSED MODEL

This model uses RL laser based BGM [9][10]that is found to have 30 times greater transmittance in comparison to NIR based BGM. The transmittance for the absorbance values of RL laser is shown in Table I.

Table-I: Absorbance vs Transmittance of RL laser

Absorbance (optical density)	Light Transmittance %
0	100
1	10
2	1
3	0.1
4	0.01
5	0.001
6	0.0001

The transmittance of the finger is measured using an equation:

$$LT = 10^{-OD} \qquad (1.2)$$

where, OD is the optical density.

The absorbance (A) can be calculated using the equation:

$$A = 2 - \log(\%LT) \qquad (1.3)$$

As far as the laser is concerned its refractive index is highly responsive to the variations in the sugar level of the blood. This RL method provides high accuracy when compared with NIR.

The Fig.1 shows the RL based detection system has a 650 nm wavelength Laser module, a phototransistor that acts a sensor to estimate the amount of light intensity and is measured in (mV). The other devices of the RL-BGM are Arduino-UNO controller (ATMEGA 32A) and LM061 LCD (16x2) to show the output of ADC which shows the value of glucose. LM7805 IC along with the DC power jack inside the RL-BGM device is used to provide supply power to the entire device set up by ensuring it is connected to an adaptor whose voltage at the outset ranges from +5 V to +12 V. The analog to digital converter performs the role of a voltage regulator and uses LM7805 IC that assures a +5 V constant DC voltage to the microcontroller. The value of the ADC in the absence of finger will be at its highest bit and the “Finger removed” pop-up will be showed on the LCD display. When the finger is placed on the LDR it is repetitively scanned for 5 times and the laser light is allowed to pass via the finger to measure the glucose level.

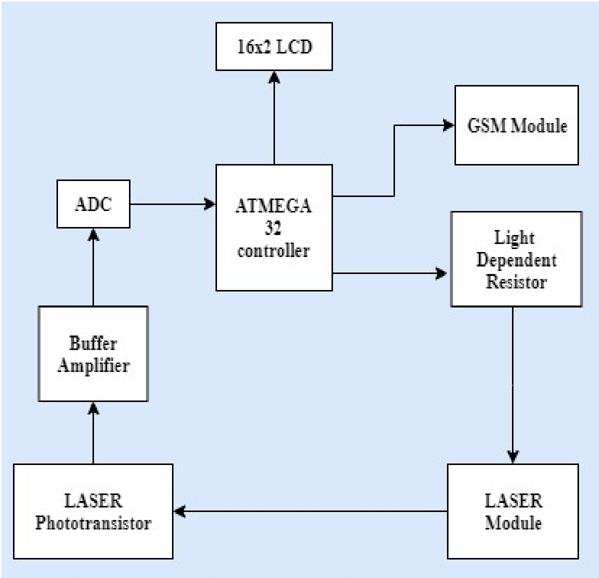


Fig.1 Block diagram of RL based BGM

The relation between ADC voltage and light intensity is:

$$V = \frac{mkT}{Q} \ln\left(\frac{LI}{I0}\right) \quad [21] \qquad (1.4)$$

where, mkT, is temperature constant, Q charge of an electron, L is the intensity of light, I is short circuit current and V is the ADC voltage.

$$V \propto \ln(L) \qquad (1.5)$$

$$E = \frac{h\,c}{\lambda} \qquad (1.6)$$

The equation 1.4 indicates that the energy of the photon depends on the wavelength of the laser light.

The LCD shows the value of the blood glucose in terms of mg/dL. SIM 900A / SIM 800C GSM module is used to send the Glucose level measurements to the mobile phones while the patient holds the record of his Glucose levels.

The training data that are being used to evaluate the system is shown in the Table II.

Table-II: Selected training data

Patient	ADC value	Glucometer value
1	845	96
2	851	100
3	888	140
4	879	130
5	865	126
6	843	92
7	856	115
8	840	84
9	862	123
10	880	136

IV. IMPLEMENTATION

The components used in this model are shown and discussed below:

A. ATMEGA 32 A

It is a microcontroller shown in Fig. 2.1 that is used to provide display sensing, sensing the environment like temperature, senses the tilt from an accelerometer, senses light, angular velocity from gyros, sounds and controls LED's, displays. The microcontroller is programmed using any assembly level language. The program is fed into the programming space of the microcontroller from the personal computer using a development platform win AVR. ATMEGA 32 is a 40 pin IC that contains 4 ports. And is a 8 bit microcontroller which operates on 2.7 V to 5.5 V. The program memory type is 1 KB EEPROM, 2 KB SRAM and 32 KB flash. It is a high performance, lower power microcontroller that has advanced RISC architecture.

B. LCD

A 16 X 2 Liquid Crystal Display as shown in Fig. 2.2 is used to display the instructions and the output. It shows 16 characters across and two lines down, it uses a HD44780AOO controller. It has totally 16 pins in which pin 1 and 16 is ground and 2 is V_{cc}= 5 V, pin 3 is contrasted, 4^{th} pin is reset, 5^{th} pin is Read/Write mode, 6^{th} is enabled that triggers the LCD to execute the instructions, pin 15 is for LED backlight, the rest are data pins.

C. GSM Module

SIM800C shown in Fig. 2.3 is a GSM/GPRS module which supports 2G that allows in making or receiving voice calls, sending or receiving SMS. This module is compatible with Raspberry Pi, the module communicates to the Pi over serial port USART (8^{th} pin- TX, 10^{th} pin- RX) and it works on ATtention (AT) commands. The SIM800C supports Quad band, GSM850, EGSM900, DCS1800, PCS1900. It is designed to meet almost all the customer requirements such as mobile phones, Laptops, Personal Computers etc. Its size is 17.6 X 15.7 X 2.3 mm, the GSM module demands 3.4 to 4.4 V power to operate and transmits signals at 1 Watt to 2 Watt. When there is no hardware interrupt the module goes to sleep mode, but its OS remains active.

D. LDR

A Light dependent resistor is otherwise called as photo-resistor. It a resistor that is light dependent, it changes its resistance depending on the intensity of light. They are made of semiconductor material, when light hits on the material they be more conductive and has less resistance. It finds applications in street lights, light meters in cameras, light detectors for an alarm, etc. This work makes use of a 5mm LDR that has 2 pins and its resistance varied between 1-20 ohms. The maximum operating temperature is +800 C

E. LASER Phototransistor

The most common phototransistor is the NPN junction transistor as shown in Fig.2.5 where the base area is exposed to light. When light falls on the phototransistor, it produces a current. The current increases or decreases depending on the intensity of the light source. It is used in day, night switches, and alarm systems. The switching time of a phototransistor is in microseconds. It is more sensitive to light than photodiode. Its operating temperature ranges from $+40^{0}$ C to $+85^{0}$ C.

F. ADC

A bridge rectifier is employed to convert analog signal to digital signal. A W10 50 V 1.5 A Silicon Full wave rectifier is shown in the Fig.2.6. It is a single phase IC with 4 pins.

G. Amplifier

An LM 358 Op-amp is shown in Fig.2.7. It is a low power dual op-amp IC. This is particularly intended to operate using a single power supply over a wide-ranging supplies. It is an 8 pin DIP package, and produces a gain of 100 dB. It's bandwidth is 1 MHz. The output voltage swing is large.

H. Working Principle of the Proposed System

The Fig.2 depicts the working principle of proposed mechanism and the steps followed are:

The devices are initialized and the finger is placed across the light that is emitted by the Laser source. Scanning is done for continuous 5 times. If the ADC value is less than the threshold value it is assumed that finger is not placed. If the value at ADC is greater than the threshold, the value is read and the corresponding glucose level in the blood is indicated in the display and the same is sent as a message to the persons mobile through GSM module.

Step I: Initially the prototype takes 5 sec for the system initialization.

Step II: After completion of the system initialization, it displays the title of the project "LASER BASED NON INVASIVE GLOCOMETER".

Step III: Then the system displays the department, year and college of the project team.

Step IV: In step IV system starts the scanning process.

Step V: As soon as the finger is placed on LDR the system starts sensing, the finger is sensed for five times.

Step VI: If the finger is removed while sensing process the system will display finger removed.

Step VII: After the finger gets sensed for five times it displays finger sensed.

Step VIII: A red light of wavelength 650 nm is made to pass through the finger, the light intensity coming out from the other side of the finger is received by the photo transistor. With the help of light intensity received by the photo transistor it displays the glucose content of the human being. It displays the glucose value as 72 mg which indicates it is detected before fasting [2].

Step IX: The detected BGL is sent as SMS for tracking their glucose levels. This glucose value of 84 mg indicates it is detected after fasting. The normal glucose content of the human being lies between 80-120 mg. If the value exceeds above 120 mg then the person is said to have diabetes.

Fig.2 Steps involved in the proposed system

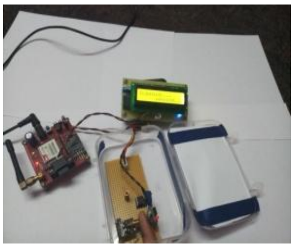
G. Experimental Results

STEP 1: System Initialization

STEP 2: Displaying Title of the project

STEP 3: Displaying Department

STEP 4: Scanning

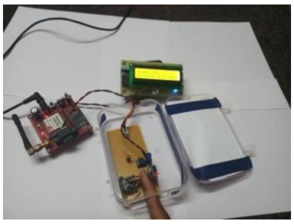


STEP 5: Sensing the finger

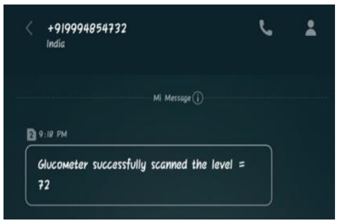
STEP 6: Finger removed

STEP 7: Finger sensed

STEP 8: Detection of BGL during fasting



STEP 9: Detection of post prandial BGL



STEP 10: SMS sent to the person

V. RESULTS AND DISCUSSIONS

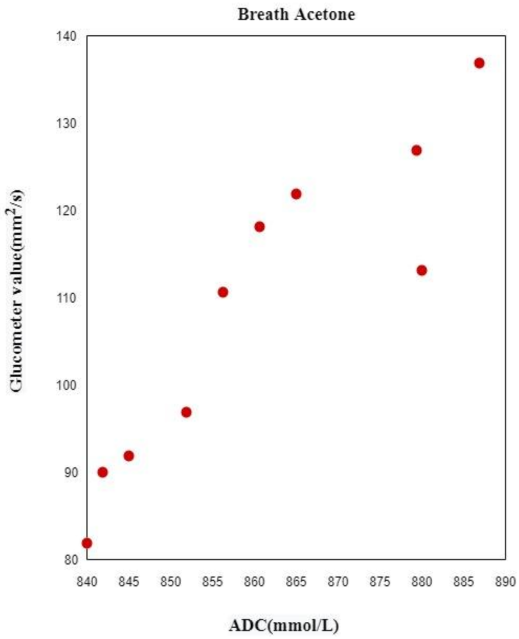


Fig. 3.1 Breath Acetone scatterplot

Figure 4.1 to Figure 4.4 shows the experiment results of the existing work (Breath Acetone, MID-NIR) and proposed work (RL-BGM). According to the scatterplots obtained, it is very clear that the proposed RL-BGM technique, produces the nearest accurate value of glucometer value.

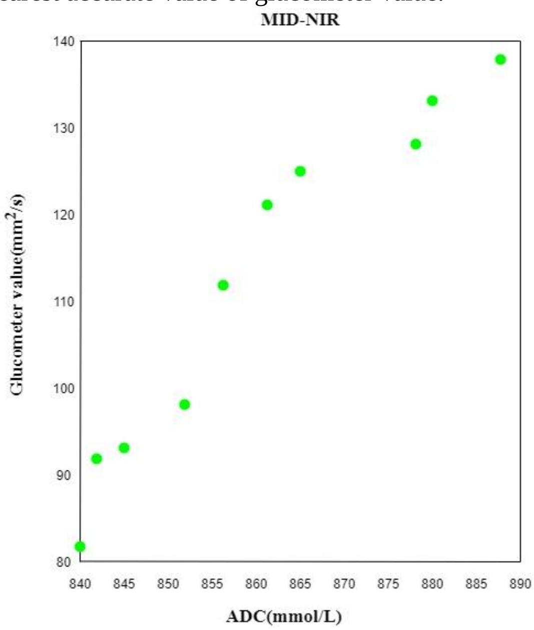


Fig. 3.2 MID-NIR scatterplot

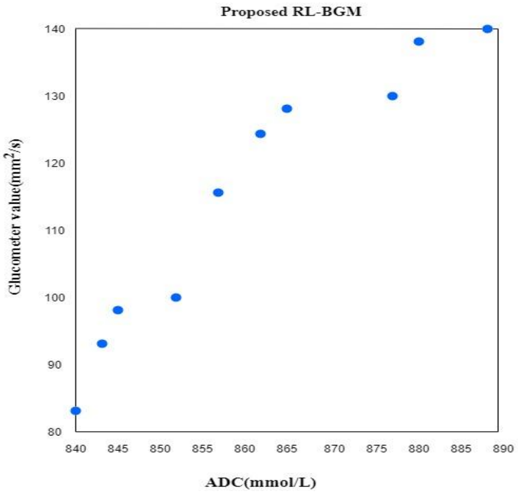


Fig. 3.3 RL-BGM scatterplot

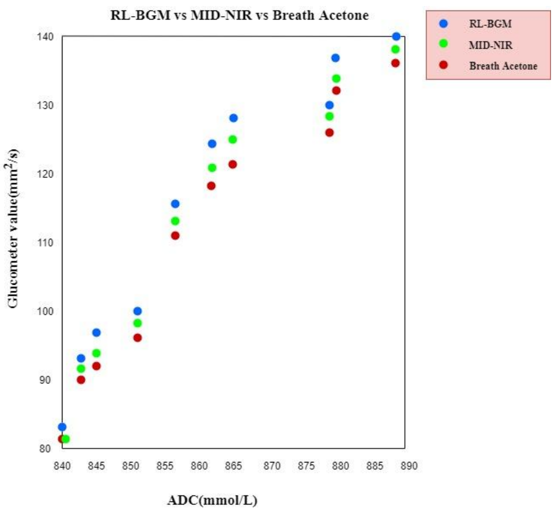


Fig. 4.1 Comparison of existing and proposed scatterplot

The breath-acetone method though non-invasive and rapid produces an error in the measured value due to mixed concentration of chemical substances with the environment. The MID-NIR technique though superior to the breath acetone, provides insufficient accuracy when used for actual medical applications. The best method that provides stable values irrespective of the environment is RL-BGM, this method proves to good accuracy for various ADC values. The exactness of the proposed model can still be increased by integrating machine learning algorithm.

VI. CONCLUSION

Anand Thati, Arunangshu Biswas, Shubhajit Roy Chowdhury and Tapan Kumar Sau (2015)[15] in their paper "Breath Acetone-Based Non-Invasive Detection of Blood Glucose Levels" proposed a technique wherein a sensor TGS822 tin oxide is being employed to estimate the concentration of acetone in the air that is being exhaled with which the blood glucose level of a patient has been calculated. The pros of the system are High sensitivity and selectivity. Wearable and Portable. The cons are Modification in the oxygen tension can cause error from the expected value, the exhaled breath may consist of water vapor and CO_2 that limits the performance.

Ryosuke Kasahara, Saiko Kino, Shunsuke Soyama and Yuji Matsuura (2018) in their paper "Non-invasive glucose monitoring using mid-infrared absorption spectroscopy based on few wavenumbers" proposed a technique, Here the blood glucose value is estimated using a NIR based BGM technique along with a photo-detector. The pros of the system are low cost, can be used widely and highly sensitive. The cons are it is prone to errors due to physical parameter and environmental parameters.

This paper presents a far more superior way of using RL-BGM device for detecting the blood glucose level. The handheld RL-BGM device when tested for precision with the Clarke Error Grid analysis produced an accuracy about 90 % to 92 %. And when compared to acetone and NIR based BGM it produces good accuracy.

VII. FUTURE ENHNACEMENT

Using GSM module kit the unread messages can be delivered as voice call to the respective person after a particular time interval. The voice call helps the visually impaired. Further as per trend this BGM method can be developed as a mobile application which contains the list of diabetes doctors. The patients who are suffering from diabetes can register in this application with their respective doctors. Using this app both doctor and patient can communicate with each other at any emergency conditions form anywhere. Any changes in the level of blood glucose in the patient is then sent as notification to the doctor through the mobile application. The records of the patients remain confidential between the doctors and the patients. This also maintains a clear database of all the registered patients.

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