Original Article

Non-invasive Blood Glucose Level Monitoring System for Diabetic Patients using Near-Infrared Spectroscopy

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ABSTRACT

This paper describes a non-invasive method for monitoring blood glucose levels of diabetic and non-diabetic peoples. A non-invasive method for glucose monitoring provides adequate control and greatly reduces the complications in diabetic patients; and consequently reduces the health care costs. Non-invasive method is advantageous as the possibilities of infections get reduced and even there is no pain of pricking the blood. The proposed method uses near infrared sensor for determination of blood glucose. Near-Infrared light is sent through the fingertip before and after blocking the blood flow. By analyzing the voltage variation received after transmission through fingertip, approximate glucose level is predicted. The obtained glucose level is further transmitted to the smart android app for further analysis and storage of the data.

Keywords: Non-Invasive, Diabetes, NIR, Transmittance Spectroscopy, Glucose Level.

INTRODUCTION

Diabetes is major challenge of current century. It is non-communicable disease. Currently more than 150 million peoples are suffering from this disease and are expected to increase in future to 400 million by 2035. Diabetes people check blood glucose level more than two times per day. Hence they are inconvenienced every time. They are suffering the danger of infection by pricking the finger. Also expenses associated with strips and Lancets are more because each test requires a new test-strip.

The current method uses the self-monitoring glucose meter. These methods are invasive. The main disadvantage of such a method is that, it requires pricking the finger, extracting the blood from forearm and doing chemical analysis which uses test strips. Also it gives pain and discomfort due to frequent finger pricks. Non-invasive techniques are more useful and user

friendly. It reduces the healthcare cost and other difficulties involved in invasive method of glucose determination. Researchers are still cannot overcome many drawbacks of non-invasive glucose monitoring method. Some problems are scanning pressure that must be applied, physiological differences such as width of tissues, correlation error, hardware sensitivity and stability.

This paper describes the possible design and development for blood glucose monitoring system non-invasively. The proposed technique uses a near infrared sensor for transmission and reception of rays from forearm. By analysing intensity variation in received signal by using photo-detector at another side of forearm, level of glucose can be predicted. Then the data can be transmitted to remote android device for further analysis. Subsequent section describes basic principle for measurement of glucose level in blood.

BASIC PRINCIPLE

Beer-lamberts law states the relationship between absorbance and concentration of absorbance through which it is travelling. When IR light is incident on a material, part of it is absorbed by the molecules in the material. The absorption of IR light is different for different wavelength.

Absorbance is expressed by beer-lamberts law as given below,

$$A(\lambda) = \mathrm{Log}_{10}(I_i / I_t)$$

I_i = Intensity of incident light

I_t = Intensity of attenuated light

Absorbance is also expressed in terms of concentration as

$$A(\lambda) = ЄCD$$

D: optical path length

Є: molar absorption coefficient

C: concentration of material

A (λ): absorbance of material

From the law, the absorbance of light is proportional to the concentration of material. The light absorption depends on how many molecules it interacts with. As light passes through the material, the intensity of light exponentially decays because it is absorbed by molecules of material. Thus based on Beer-lamberts law, a single wavelength is selected for glucose concentration evaluation.

SYSTEM ARCHITECTURE

1. Algorithm flowchart of system

The algorithm flowchart for glucose level measurement is shown in fig.1.

2. Selection of wavelength

There are some peak points at which glucose absorption is very large. These are 935nm, 1150nm, 1450nm, and 1536nm. This band is transparent for water and hence very useful for analysis on glucose. Hence a wavelength of 940nm has been selected for analysis. Above 1550nm penetration depth of human tissue is very large but absorption of light by water in blood increases greatly.

3. Hardware Development

The main objective is to analyse infrared spectra through glucose human sample for blood glucose level measurement. The method used is by emitting IR light through the finger. The attenuated light is received by the photodiode positioned at opposite side of IR emitter. Component specification for development of system is given in Table1.

An NIR LED, also known as NIR transmitter, is a special purpose LED that transmits infrared rays. Such LEDs are usually made of gallium arsenide or aluminium gallium arsenide. They have the capabilities of 100mA current and 1.5v~2.5v voltage carrying capacities. To minimize the fluctuation in the current through the NIR, a constant current circuit is designed by using op-amp for emission of NIR light. The proposed system block diagram is shown in fig.2.

The signal conditioning stage consists of four stages. Current flowing through the photodiode is proportional to the amount of light incident on photodiode. First stage consists of trans-impedance amplifier which converts small changes in current to voltage. At the output of photodiode, signal is corrupted due to power line interference, motion artefacts etc. Also to remove the DC noise and high frequency signals, the low pass filter and high pass filter are designed with cut off 0.7Hz and 10Hz respectively. The third stage is gain of amplifier circuit kept in between 0 to 100. At the output stage a buffer amplifier is connected to transfer the impedance level of circuit for interfacing to ADC.

After receiving the signal form signal conditioning circuit, analog to digital conversion is performed and stored in buffer. ARM Cortex-M0 based PSoC pioneer kit is used for programming as well as for analysis. When ADC buffer gets filled, intensity variation analysis is performed. A linear regression model is used for analysis which is performed by making the use of dataset. The dataset has been acquired by analysing individual patients using the accu-check gluco-meter as well as developed hardware setup. The result is displayed on LCD as well as can be sent to a developed gluco-smart android application.

RESULTS AND DISCUSSIONS

The output of the designed analog front end circuit is tested and results were acquired. Voltage output obtained as a result of variation in signal intensity from NIR sensor is set as the input to the microcontroller. The complete hardware setup is shown in fig.3. Here the analysis was performed under two phases; fasting and non-fasting. First the finger tip is placed over the NIR sensor. The attenuated signal is send to microcontroller where the average and RMS is calculated. Based on database analysis and algorithm glucose level is determined.

Data analysis is performed using the readings obtained from 15 individuals as the case study. Blood samples are collected and analyzed for glucose level along with developed device experimentation. The age limit of individuals who came forward to volunteer the service was in the range from 20-50. The results obtained by comparing both the testing methods found to be in close correlation. After successful analysis the developed device is tested with some

diabetic patients. The results are good and show reliability and consistency with measurement.

Whenever the full process is get completed, approximate glucose level along with the current diabetic condition is displayed on LCD display as shown in fig.4. At the same time the glucose level is communicated to the Gluco-Smart application via Bluetooth.

The Gluco-Smart app receives the data transmitted by microcontroller after successful analysis. The Gluco-Smart app stores the received data along with fasting or non-fasting state for further analysis to doctor. Also app consists of graph which shows how a person's blood glucose level may change over the course of a day and how eating of meal with lots of sugar can affect the glucose level.

CONCLUSIONS

The world health organization indicates that more than 400 million people have diabetes. Early detection and control of disease is necessary. Our approach for monitoring glucose level is healthier than invasive approach. An analog front end for non-invasive glucose measurement is designed and tested successfully. The obtained result shows that there exists a correlation between intensity level after transmission and glucose level in blood. Glucose level in both diabetic and non-diabetic persons is analysed using variation in intensity and results were obtained successfully. Also this information can be sent to doctor for further analysis.

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Table1. Component Specifications

COMPONENT	SPECIFICATIONS
NIR LED	VSML3710
NIR photodiode	BPW34S
Microcontroller	32 bit ARM Cortex-M0
Bluetooth module	PSoC BLE Module

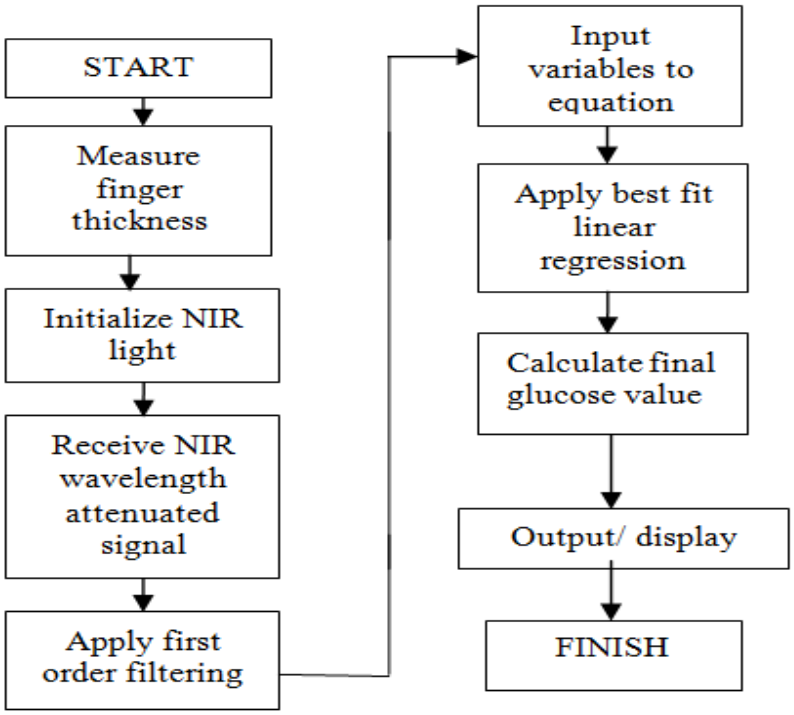

Fig.1 Algorithm Flowchart

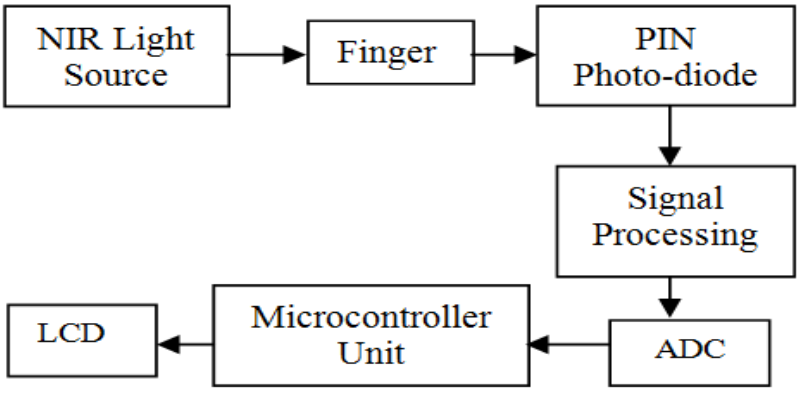

Fig.2 Proposed Block Diagram of System

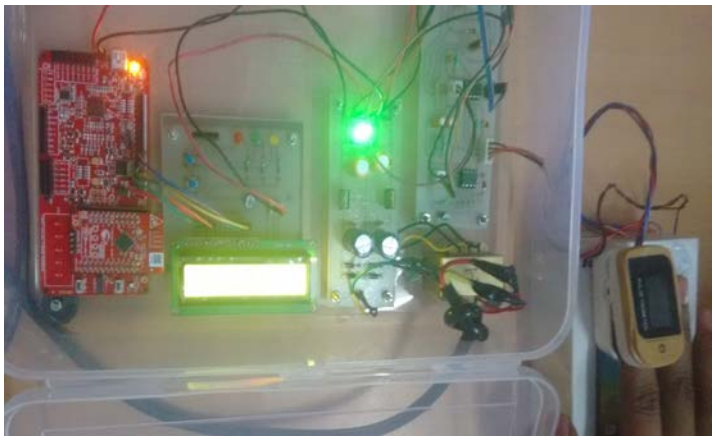

Fig.3 Complete Setup

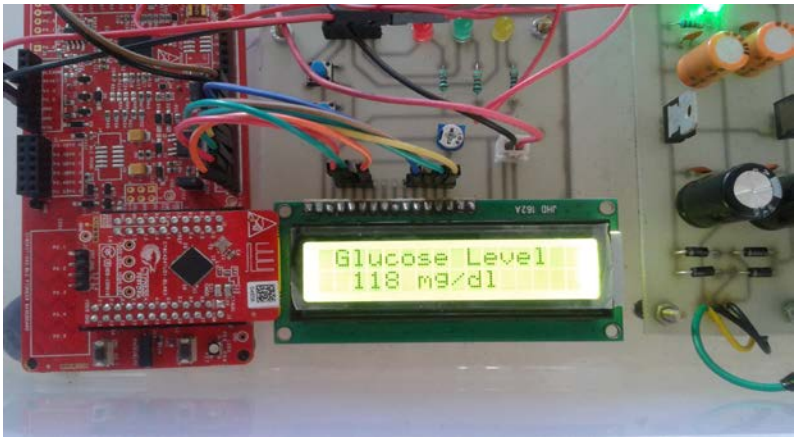

Fig.4 Glucose Level displayed on LCD