Non-Invasive Monitoring of Glucose Level in Blood 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

I. 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 and Lancets.

Diabetes is considered as one of the major death contributors in non-contagious diseases. 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 ear lobe, level of glucose can be predicted. Then the data can be transmitted to remote android device for further analysis.

II. RELATED WORK

Kiseok song, et. al. (2015) have developed a multi-modal spectroscopy IC which combines impedance spectroscopy and multi-wavelength near-infrared spectroscopy. It has high precision for non-invasive glucose level estimation. It compensates glucose estimation error. IMPS circuit
measure dielectric characteristics of tissues for estimation of glucose level. NIRS uses the three wavelengths, 850nm, 950nm, and 1300nm. These two results are combined for highly accurate estimation. [1]

Jyoti yadav, et. al. (2014) have introduced the glucose sensor. This sensor works based on the principle of NIR LED. They have used 940nm spectrum continues wave to analyse the glucose concentration. They have taken different concentration of glucose for experiment. The experiment is tested on human forearm and observed the reflectance spectra of blood and the result is good with greater accuracy. [2]

Nina Korlina Madzhi et. al. (2014) have done the comparative investigation using GaAs (950nm), GaAlAs (940nm) and InGaAsP (1450nm) sensors for glucose level measurement. Firstly they proceed by using test tube which contains various percentage of glucose concentration and then same method has been used for human blood samples. There is larger voltage range for 950nm as compared to 940nm wavelength and more consistency in pattern. [3]

K A Unnikrishna Menon, et. al. (2013) have introduced voltage intensity based Non-invasive blood glucose monitoring. The proposed method makes the use of near-infrared sensor. The NIR is sent through the fingertip, before and after blocking of blood flow. By analysing the variation in voltages received after reflection, the current diabetic condition as well as approximate glucose level of individual is predicted. The obtained result is then communicated with a smart phone through Bluetooth. [5]

Matthew sidley et. al. (2011) have introduced the feasibility of estimating blood glucose level using a micro strip antenna strapped on patients arm. They show that antenna resonant frequency can track the changes in glucose concentration. An equivalent circuit model has been developed to measure the input impedance with changing glucose level. [6]

Jens Kraital, et. al. (2010) have introduced the non-invasive measurement of blood component. They used principle of photoplethysmography and NIR spectroscopy. They have measured the different blood component including glucose non-invasively. The blood absorbs NIR light with different absorption coefficient. This characteristic is used for measurement of blood component. This technique is also used to measure the haemoglobin and oxygen saturation in blood. For measurement of different component a range of 600nm to 1400nm wavelength is used for system. [7]

III. METHODOLOGY AND SYSTEM ARCHITECTURE

3.1 Flowchart of System
The complete flowchart of system is shown in fig.1. Firstly system initializes NIR light. The attenuated light is received by the photodiode placed at other side of forearm. This received signal is amplified and filtered for noise by first and second order filtering. It is processed to determine the characteristics of signal. The determined characteristics or variable is given as input to linear regression equation obtained from data analysis in SPSS. Finally the glucose level is determined and it is displayed on LCD or other terminal.
3.2 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.

3.3 Hardware Development
The main objective is to analyze 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. The proposed block diagram is shown in fig.2.

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 2.5v voltage carrying capacities. To minimize the fluctuation in the current through the NIR, a constant current circuit is designed for emission of NIR light. A BC557 PNP epitaxial silicon transistor is used with LM358. The output of opamp is given to the base of transistor for controlling the average power transmitted by NIR LED. It is kept constant. The circuit diagram is shown in fig.3.

![IR Emitter Circuit Diagram](image)

*Figure 3: IR Emitter circuit*

At the output of photodiode, signal is corrupted due to power line interference, motion artifacts etc. Also to remove the DC noise and high frequency signals, the low pass filter and high pass filter are designed. Tranimpedance amplifier with high current gain of 1000 is connected at the output of photodiode. Two stage low pass filter is used to remove unwanted noise from signal. One passive low pass filter with cut-off approximately 160Hz and one active low pass filter with cut-off approximately 28Hz is used. Also one high pass filter with cut-off 0.86Hz is connected at initial stage of signal conditioning circuit. OPA 2340PA op-amps are used for above implementation. The signal conditioning circuit is shown in fig.4.

![Signal Conditioning Circuit Diagram](image)

*Figure 4: Signal Conditioning Circuit*

After receiving the signal from 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 analyzing 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 smart phone android application.

IV. TEST AND RESULT ANALYSIS
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 obtained. The output is PPG waveform which shows changes in light absorption as shown in fig.5. It is set as the input to the microcontroller.

![Output of signal conditioning circuit after inserting the finger](image)

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. 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. Total 48 Samples are collected from 34 persons. Out of 48 samples, 28 samples are collected from MD pathology Lab and remaining samples are taken with Accu-Check active Glucometer.

The age limit of individuals who came forward to volunteer the service was in the range from 20-80. Some Sample readings are not getting acquired properly. Hence this are discarded for analysis. The results obtained by comparing both the testing methods found to be in close correlation. Sample readings with device experimentation and actual Lab testing result are shown in Table 1.
Table 1: Human Sample Reading

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<tr>
<th>Sr. No.</th>
<th>Age</th>
<th>Glucose Concentration (mg/dL)</th>
<th>Output Voltage (mv)</th>
<th>Glucose Concentration (mg/dL)</th>
<th>Output Voltage (mv)</th>
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Linear Regression analysis is also performed on collected samples using SPSS software. The curve fitting plot for regression analysis is shown in fig.6. Based on database analysis and algorithm glucose level is determined and displayed on LCD. At the same time the glucose level is communicated to a smart phone via Bluetooth. The complete hardware setup of system is as shown in fig.7 and fig.8.

Figure 6: Curve fitting Plot for regression analysis in SPSS
V. 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.

REFERENCES

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