NIR BASED NON-INVASIVE GLUCOMETER

ICIR11 PROJECT REVIEW PAPER

Submitted by

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ACKNOWLEDGEMENT

We would like to express our special thanks of gratitude to the project guide professor Dr G UMA who gave us the golden opportunity to discover this wonderful project on the topic of NON-INVASIVE GLUCOMETER, which also helped each one of us in doing a lot of research and we came to know about so many new things which were solely due to the project given

Secondly, we would like to thank our parents and friends who helped us a lot in finalizing this project within the limited time frame

Date : 25.05.2022

CONTENTS :

ABSTRACT:

According to the International Diabetes Federation (IDF) in 2017, approximately 425 million adults (20-79years) were Living with diabetes and this number will rise to 629 million by 2045. It is a metabolic pathological condition of concern, which affects vital organs of the body if not diagnosed and treated on time. Regular monitoring of blood glucose is important to avoid any further complications. Commonly used glucose measurement methods are invasive and generally involve finger puncturing. This method causes pain and damage to tissues and often leads to irritation due to regularly repeated punching which may sometimes cause infection. Also, these methods generate a lot of medical waste which requires careful management otherwise there is a high risk of spreading infectious diseases if the needle is contaminated and used more than once. Therefore there is a need to develop a non-invasive glucose monitoring system which can measure glucose and is easy to use for diabetic populations.

Keywords: diabetes; glucose; non-invasive; optics; spectroscopy; infrared; Raman; terahertz; fluorescent; photoacoustic

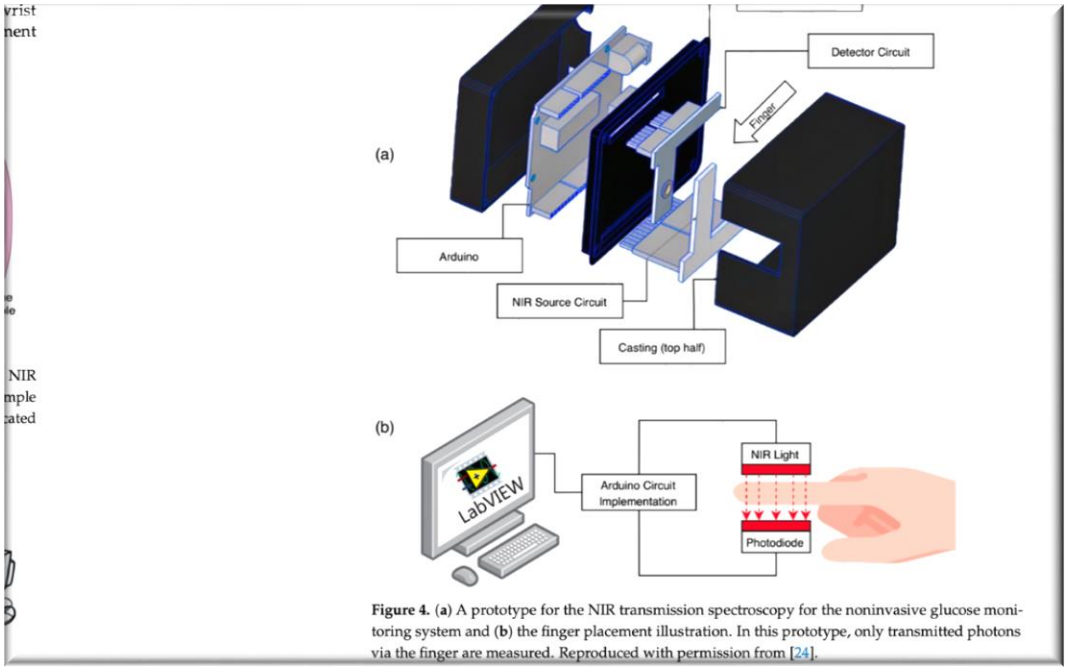


Figure 4. (**a**) A prototype for the NIR transmission spectroscopy for the noninvasive glucose monitoring system and (**b**) the finger placement illustration. In this prototype, only transmitted photons via the finger are measured. Reproduced with permission from [24].

INTRODUCTION :

1.1 BACKGROUND AND MOTIVATION

There are some methods which can be used for Non-invasive glucometer Blood Glucose Measurement like Near-infrared spectroscopy, photoacoustic spectroscopy, Raman spectroscopy, and Polarisation. Using these methods we can predict the concentration of glucose in a sample infrared spectroscopy is most common as its results are more accurate. It is relatively easy to implement in hardware so we will use this method in our project.

The major challenge to NIR detection of glucose levels is the multiple internal features (which cannot be measured non-invasively) like Haemoglobin, Water, tissues, Melanin and other components in blood. These components also absorb infrared lights so it would be difficult to distinguish between the effects caused by glucose and that caused by these factors. Fortunately, we have a solution to this problem. By using Monochromatic infrared light we can indeed take the effects caused by only glucose. There is the basic law of spectroscopy i.e. different materials or chemicals have their own spectrum. The same applies to glucose. It has its own absorption peak points which are unique to it. Forex. 950nm is a peak point for glucose which is relatively very less absorbed by other components listed above. By Transmitting only 950nm IR light inside the sample, we can easily detect the received intensity at the opposite end based on the amount by which intensity is reduced we can get a proportional voltage at the output.

1.2 PROJECT OBJECTIVES

- To Predict the level of glucose in blood non-invasively and displays it on LCD with maximum possible accuracy.
- Deliver an alternative low-cost solution to traditional invasive glucose testing methods for the control of glucose-related diseases.

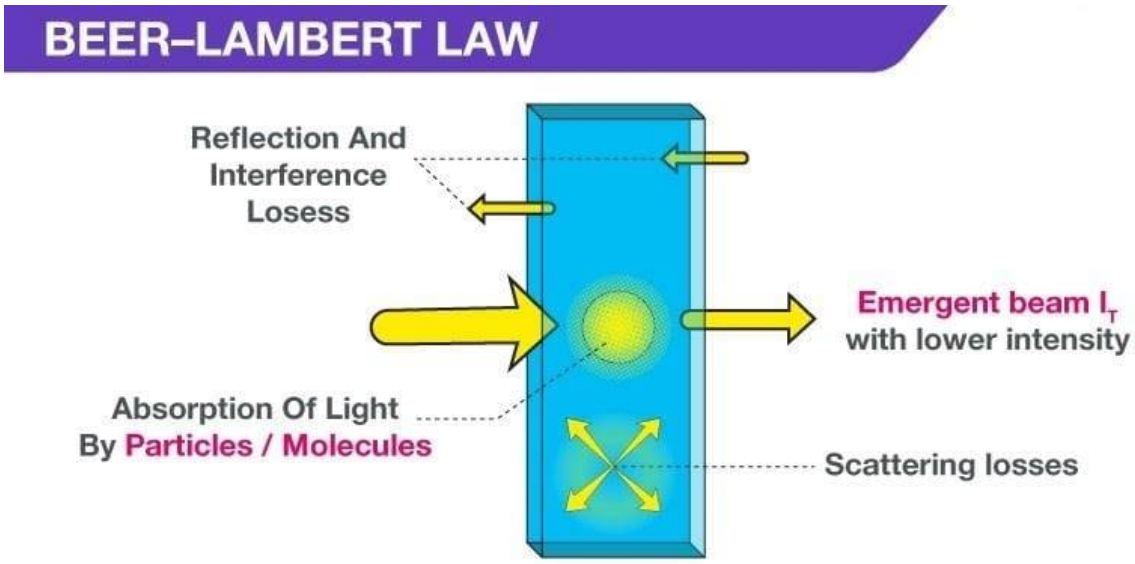
1.3 DELIVERABLES PLANNED TO ACHIEVE THROUGHOUT THE PROJECT

- Use of NIR Spectroscopy on a part of the ear lobe to predict the relative glucose level
- Design an analogue circuit model to get the amplified voltage level for the corresponding relative glucose level and to feed this voltage to the microcontroller
- Achieve a Multiple Linear Regression Model for predicting glucose levels from the voltage value received
- Showing the voltage value and the corresponding glucose level on the LCD screen

BASIC PRINCIPLES USED

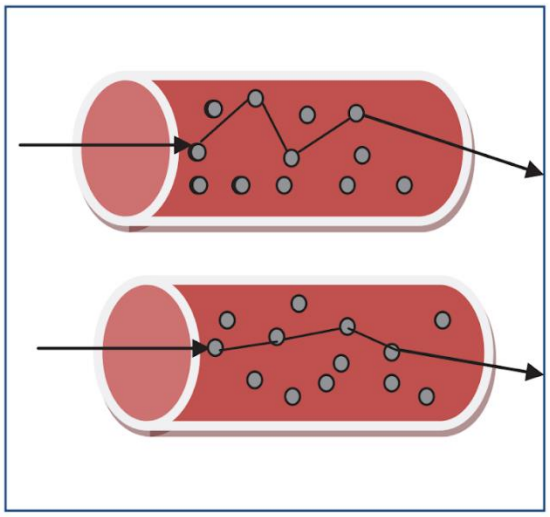
BEER-LAMBERT LAW:

As the model is based on the absorption of the infrared waves by glucose, it involves spectrometry. The spectrophotometer is based on the Beer-Lambert Law which states that the amount of light absorbed is directly proportional to the concentration of the solute in the solution and the thickness of the solution under analysis.



GLUCOSE MEASURING PRINCIPLE:

As the radiation interacts with biological tissue, it is attenuated by absorption as well as scattering. The attenuation of light can be described by light transport theory. Variation in glucose concentration affects the intensity of light scattered from tissue. When glucose level increases, the scattering property of tissues decreases. Therefore changing the optical paths.



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THE EFFECT OF GLUCOSE ON THE LIGHT PATH IS SHOWN HERE. MORE GLUCOSE RESULTS IN LESS SCATTERING CONSEQUENTLY LESS OPTICAL PATH AND LESS ABSORPTION.

EXISTING WORKS IN THIS FIELD

Conventional devices currently in use, such as the self-monitoring blood glucose (SMBG) devices, so-called glucometer, and the continuous-glucose-monitoring (CGM) devices, follow the invasive and minimally invasive methods, respectively. They are both based on electrochemical biosensors. The SMBG sensors require drawing a drop of blood to be tested through finger-pricking, while the CGM sensors are based on a needle implanted subcutaneously.

Among the non-invasive glucose monitoring techniques, the optical methods give the best measurements. Optical technologies such as near-infrared, mid-infrared, or Raman spectroscopy have great selectivity for glucose sensing given the complexity of the blood/tissue

MID-INFRARED (MIR) SPECTROSCOPY

MIR utilizes a wavelength of light in the region of 2500–10,000 nm that covers the fingerprint region of glucose. Consequently, less scattering and higher absorption occur in the tissue, resulting in distinct and sharp peaks in the absorption spectra of glucose and other chromophores, unlike the NIR band response that gives weak and broad peaks

RAMAN SPECTROSCOPY

Raman technique uses a monochromatic light source ranging from visible to MIR to detect the glucose concentration based on the Raman effect. When monochromatic light strikes the tissue sample, it produces scattered rays that travel in all directions. So the wavelength shift between rays of the incident and scattered wavelength provides information about the body fluids.

FAR INFRARED (FIR) SPECTROSCOPY OR TERAHERTZ TIME-DOMAIN SPECTROSCOPY

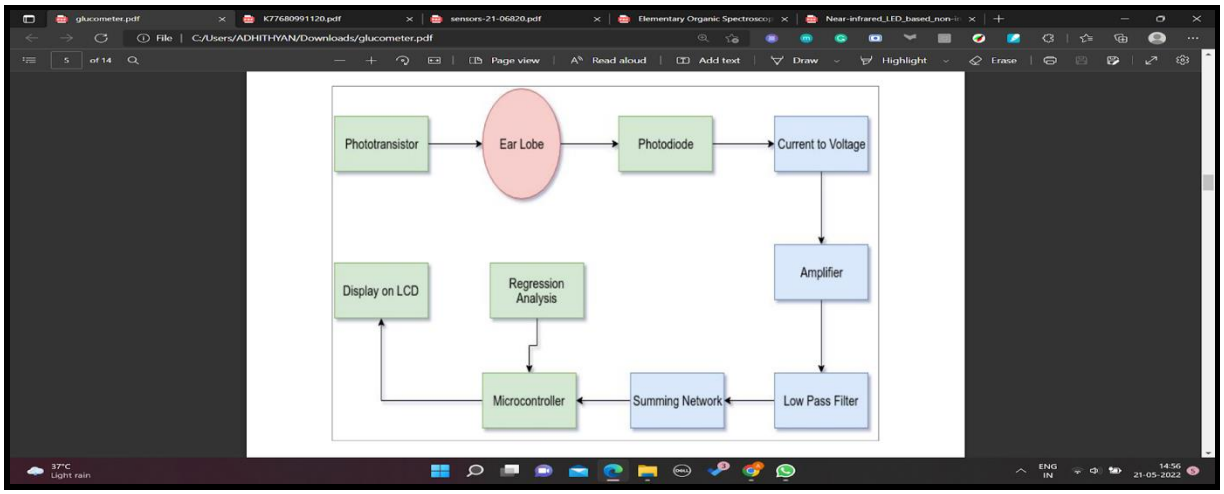
FIR spectroscopy, also known as terahertz spectroscopy, relies on the interaction between the electromagnetic field of light and the electric/magnetic dipoles of matter. These interactions produce vibrational and rotational transitions of weak bonds and bonds of large atoms with wavelengths ranging from 10 μm to 1000 μm. The glucose concentration and other optical properties can be extracted by evaluating the disruption of photons' time of flight, the shape of pulses, and the glucose absorption rates.

In this paper, we will discuss near-infrared spectroscopy more as we are using it in the project.

NEAR-INFRARED (NIR) SPECTROSCOPY

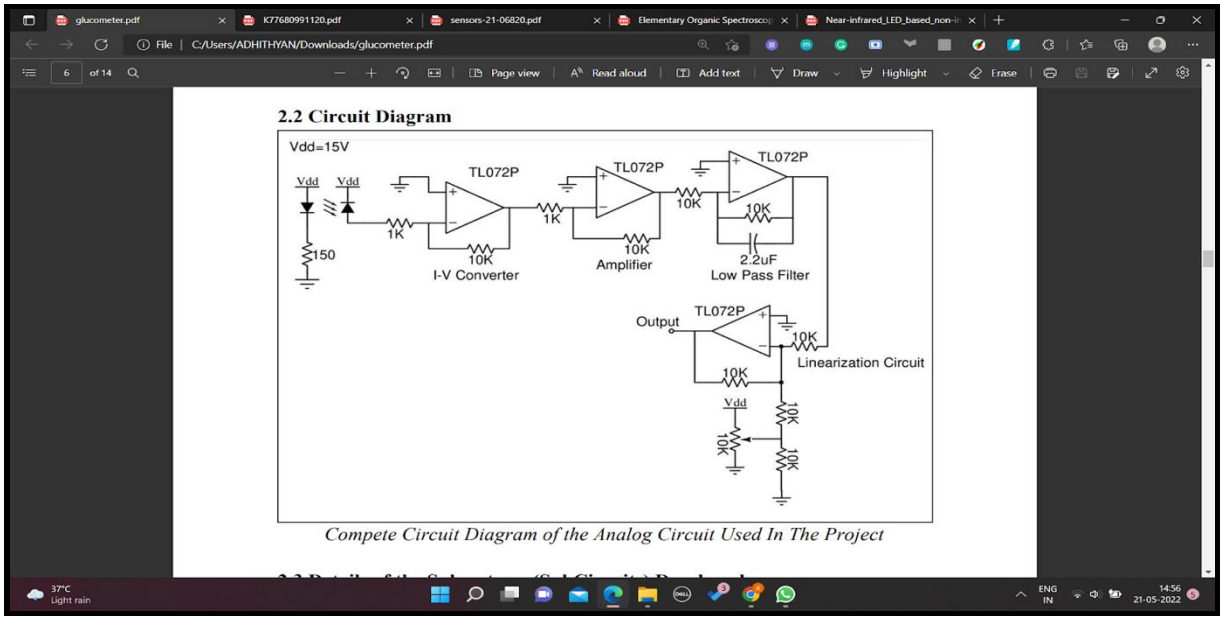
It employs light in the 750–2500 nm wavelength range of the electromagnetic spectrum in which the light can penetrate the skin beyond 0.5 mm with low-energy radiation. The existence of C-H, O-H, and C=O bonds in glucose molecules increases the NIR light absorption in the blood, which peaks at specific wavelengths. In contrast to other optical techniques, NIR spectroscopy has the advantage of measuring glucose without prior manipulation needed affordably and compactly.

Due to the considerably high penetration level, NIR measurements can be accomplished using the transmission and reflection modes. Blood glucose levels are estimated by detecting the variations in the light intensity caused by the absorption or scattering of glucose molecules to NIR light, which depends on the concentration of the glucose in the tissue.



THIS REPRESENTS THE SCHEMATIC BLOCK DIAGRAM OF THE MODEL PREPARED

Circuit diagram



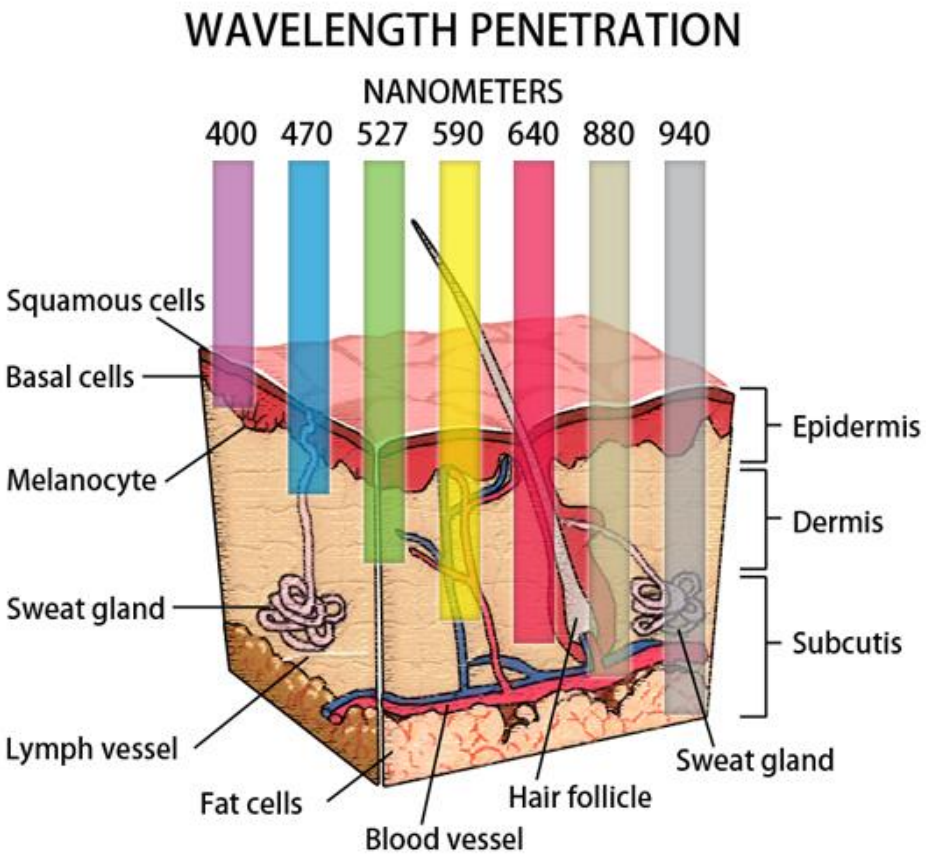
HARDWARE COMPONENTS USED AND THEIR FUNCTIONALITIES

Arduino Board (UNO)	1
LCD (RG1602 A)	1
Op-amp TL072	4
Photodiode	1
Phototransistor	1

Photodiode & Photo Transistor

The method employed is that we are emitting an infrared wavelength to pass through the finger using a Phototransistor. Then, the wavelength that passes through it is being received by a photodiode which acts as a photosensor. The value of the voltage increases as the glucose concentration value increases.

From the study conducted by Zhao and Fairchild on the transmission of laser light through tissues over a range of skin types, the laser wavelengths in the range 532–1064 nm, had 1064-nm light penetrating deepest into tissues. For wavelengths greater than 1000 nm, there is not a great amount of information regarding the penetration depth, and there is also little information regarding the photobiological effects at wavelengths greater than 1000 nm. Therefore we have decided to use IR light (940nm
wavelength)



I-V CONVERTER

As we have to analyse the voltage, to amplify and convert the output current of the photodiode to voltage we used Op-amp TL072 in the circuit to achieve the required Voltage output. Furthermore, keeping in mind output impedance the opamp has to be chosen as otherwise, it will lead to incorrect output voltage results

AMPLIFIER CIRCUIT

Used to amplify the output voltage of the I-V Converter to a considerable value. The input of this stage is from the previous stage which is the I-V converter stage where the voltage that has been given from the photodiode is very small and needs to be amplified with a gain of 10. For the amplification part, we simply approached this standard circuit. The impedance must be taken care of and the resistors are decided during the experiments

LINEARIZATION CIRCUIT

As the Arduino operates between the desired voltage range of 0-5V, we use this linearization circuit to convert the output voltage of the amplifier circuit to the desired range, and the summing network is the standard circuit approach for this.

MICROCONTROLLER (ARDUINO UNO BOARD) CIRCUIT

Final voltage from the analog circuit is now provided as input to Arduino and this will give us the estimated blood glucose concentration and display it on LCD. The need for a microcontroller was obvious in this part as we had to move from analog to digital arena and Arduino Mega has DAC in it. Furthermore, we had to supply the input voltage and our linear regression model could be applied to this voltage through Arduino. We could feed in the regression model that is to be obtained by us with the help of the data collected from the microcontroller and we could convert the voltage reading to the glucose concentration that we are required to show on the LCD as desired. Thus we chose Arduino Mega as it satisfied all the requirements desired for this step

SIGNIFICANCE

- It is much easier and harmless for the elders and children, to use unlike the previous invasive methods which used pricking
- It is easier to perform continuous monitoring which decreases a lot of restrictions that used to exist in the traditional glucose monitoring system
- The availability of data can make sure to alert the responsible if there are any sudden changes in glucose levels, and also makes it easier for doctors to track their medical condition
- It is much cheaper as we don't have any additional requirements like the strips used in the conventional method
- Apart from the economic benefits, it's environment friendly too

COMMERCIAL DEVICES

Hitherto, many non-invasive glucose monitors have been developed. Some of these devices have shown promising outcomes and have been successfully introduced to the market. However, due to some issues, including accuracy errors, they were dropped. Nevertheless, manufacturing companies are working on improving their devices. Table 5 lists commercial non-invasive blood glucose monitoring devices that use the optical techniques addressed in this paper. The choice to evaluate the accuracy of the device depends on the manufacturer. Some use Clarke error grid analysis (EGA) while others use consensus error grid (CEG) analysis or the mean absolute relative difference (MARD).

CONCLUSION

Over the past decades, there has been great interest in developing innovative methods of measuring blood glucose levels without the necessity for blood samples. Several non-invasive optical glucose measurement techniques have been introduced. These technologies still need improvement in order to meet the regulations to be released in the market. This paper provided a technical view of some of the prevalent non-invasive optical approaches in glucose sensing currently under study. It also discussed the system configuration of each technique. A summarized comparison was made on the advantages, disadvantages, and other specifications of the non-invasive optical methods discussed. Although these methods show great potential, some challenges are facing them including sensitivity, stability, specificity, biological factors, and calibration issues. Therefore, an enhancement of these non-invasive optical methods is required to surmount their limitations and hopefully replace the conventional methods currently in use.

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