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Non-invasive Blood Glucose Determination using Near Infrared LED

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Abstract

Diabetes Mellitus in human beings is an inability to produce adequate insulin or process them which will cause a rise in blood sugar level. To maintain the blood glucose level check-up at a regular interval is required. The conventional method available currently involves pricking which irritates skin when done repeatedly. The objective of this paper is to overcome the painful process and to be noninvasive. Our proposed system is based on the NIR (near-infrared) spectroscopy method of a selected wavelength which is more sensitive to blood glucose. This helps to reduce the error factor and the system is implemented with machine learning to improve the efficiency of the output.

Keywords: Diabetes, NIR, glucose, infrared, noninvasive

1. Introduction

Diabetes is a popular chronic disease that occurs in human beings. Although, it is incurable its effect can be minimized by proper monitoring and treatment. International diabetes federation survey stated that diabetes prevalence will rise to 10.2% by 2030 from the existing rate of 9.3% in 2019. It also mentioned that prevalence was superior in urban areas and high-income nations [1] The total number of diabetic cases in urban (10.8%) is higher than rural (7.2%) areas and in high income countries (10.4%) than low- income countries (4.0%). The survey says that 80 percentage of people who are affected by the diabetes are living in the under developed countries [4].

Type I diabetes- other wise called as juvenile diabetes this type disease occurs when the body fails to produce insulin. People with this type of disease are dependent on insulin, which means that they must take the insulin daily by any of the external methods to do their daily activites. There are two variants Hyperglycemia and Hypoglycemia. Hyperglycemia is the one that deals with a high glucose level in the blood (>150 mg/dl) which can lead to blindness, diabetic coma etc[5]. on the other hand, Hypoglycemia is the one where the blood glucose level falls below the mentioned/critical level (<60 mg/dl)[6] left alone hypoglycemia could cause coma, stroke, irreversible brain damage and confusion. To avoid such severe complications, blood glucose level needs to be tested regularly. Regular testing of blood glucose can reduce the problems caused due to diabetic complications.

Type II diabetes. It affects the body in the manner how the cells use insulin. While the body still makes insulin, unlike in type I, here the body produces insulin, but the body cells do not respond to it, as they did earlier. This is the most common type of diabetes, according to the National Institute of Diabetes and Digestive and Kidney Diseases, and it has strong links with obesity [3]. For this regular testing is required. Moreover, there are many invasive methods are available which are painful [9],[10].

To alleviate the discomfort caused by the pricking methods, to test the glucose level, non-invasive methods are being developed to determine the blood glucose level. There are many notable techniques of the non-invasive method which include- Breathalyzer, Bio-impedance spectroscopy method, Metabolic Heat Confirmation method, Near-Infrared spectroscopy method, mid-Infrared spectroscopy method, Optical Polarimetry System, ultrasound method, Earlobe, mid-infrared spectroscopy [11]-[15],[6], Ultrasound, Electromagnetic sensors, Thermal emission spectroscopy etc. But there is no standard method that is being used globally to measure the glucose level due to less percentage of accuracy [16].

2.Literature Survey

Nowadays, many projects are being undertaken to develop the non-invasive method to find out the blood glucose level by using a near-infrared spectroscopy method. The major advantages of this technique are- a wide range of availability of NIR photo-detectors, these have high sensitivities and available at low cost too. The results which are obtained in this type of method can get affected due to variation in atmospheric variables and physical changes [17]. In this type of NIR spectroscopy technique, [18] Mauro et al. did work on the NIR system based on optical fibre to establish a relation between NIR and blood glucose level where they mentioned the inherent of NIR spectroscopy as a technique to find out blood glucose level without pricking. [19] Robinson et al. determined the relationship between NIR spectra and blood glucose level, though the proposed system did not give any information about what wavelength should be used for the method to be successful. [20] Shyqyri et al. make use of Near-infrared spectroscopy of wavelength 940nm transferrence spectroscopy to find out the relationship between transmitted light and glucose level. [21] Heinemann et al. did a working model on a camera-based system and optical fibre where they tried to find out the scattering coefficient. the suggested system shows a worthy relationship between blood glucose level and near-infrared scattering volume. [22] Zhanxiao et al. suggested an idea of using a multi-sensor project, where they went with a humidity sensor and bio-impedance sensor to find out the blood glucose level by using the time series analysis. [23] Yadav et al. make use of Near-infrared spectroscopy of wavelength 940nm. They used the concept of diffused reflectance where they formed the relationship between diffused reflectance and blood glucose level. By reading all the above papers we noticed that there was of lack simplicity and built models cost high. In addition to that, the devices that are suggested above are not satisfactory for wearing. Our proposed system provided with NIR method where specific infrared waves have been used which are more sensitive to the glucose content in the blood. The system implemented with Machine learning to reduce the error occurs due to the external factor.

3.Theory

The Beer-Lambert law states that the absorbed intensity of light due to a substance that is dissolved in a fully transmitting solvent is directly proportional to the concentration and the path length of the light travelling in the solution.

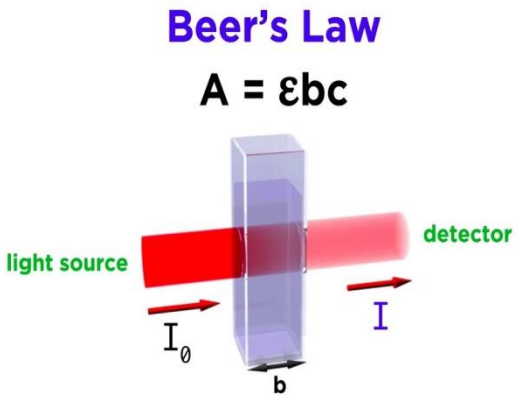

Fig. 1: Beer-Lambert law of light intensity Absorption and Scattering [25]

When the glucose level in the blood increases, the absorption of the light increases whereas the scattering of the light decreases. Due to this decrease in the scattering of the light, the diffuse reflectance also gets reduced [26]. The relationship between blood glucose level and diffusion reflectance, a NIR (1650 nm) based model can be developed to determine the blood glucose level by a non-invasive method.

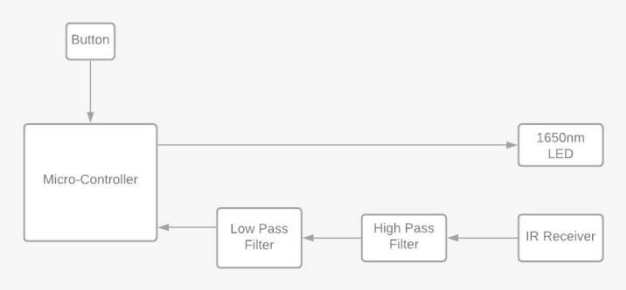

Fig. 2: Block diagram of the proposed system

4.Methodology

The proposed model will be initially in a sleep mode, When the user places the finger system will be getting turned on. In our proposed model, we are gonna take the input from the finger. The reason behind this is, the data collected from the finger has a lesser fat percentage present in the finger, which has a high density of the blood vessels. In addition to that, error due to time delay in measuring the blood glucose level gets reduced.

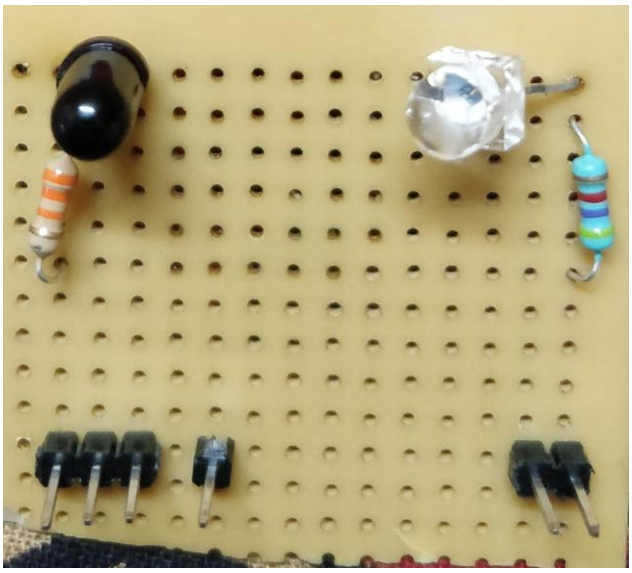

Fig. 3: Module of the system

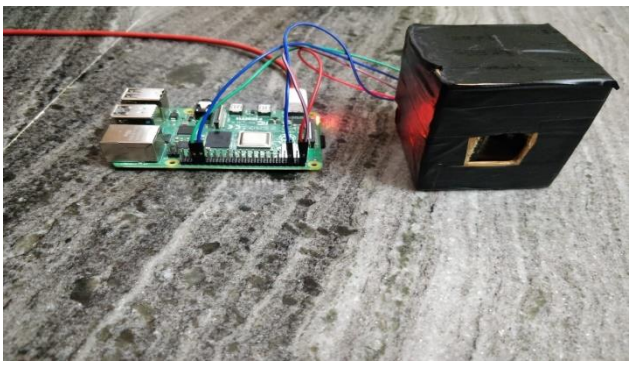

Fig. 4: setup of the system

The system is provided with NIR LED 1650nm, Infrared ray from the source will pass through the finger and get absorbed, IR receiver will be used to determine the absorption of the IR ray by the blood glucose level. To reduce the error finger will be surrounded by an IR receiver and the output of the receiver will be given to the raspberry pi. Raspberry Pi is powerful for Artificial Intelligence and Machine Learning. The processing capabilities with a low power requirement makes it a great choice for robotics and embedded projects. We planned to collect data by using both invasive methods as well as by our system.

Collected data helps us to find a suitable Regression Algorithm which provides a more precise output. We

need to test the system by using some of the collection which left out for training purpose.

5. Evaluating & Exploration

our project was started with testing on 25 persons which includes all non-diabetic and diabetic people. We then gathered blood glucose level input by NIR detector and by some available pricking method of glucose testing (ACCU-CHEK Active) together. As the data which was collected by us was linear, so we went on to collect more 200 data samples from infected persons during the model building stage. The unicity of the data set which we have collected is, we have conducted the testing at different time intervals of the day instead of the standard data collection technique by conducting before and after intake of food. The person may need to check his blood glucose concentration at any time interval, so an equation has been found by the data which was collected considering all the factors instead of the standard technique to increase the exactness of the input. Some of the sample input is represented below.

Table 1 Selected Sample Input

S. NO	RECEIVER DATA	GLUCOMETER READING
1	338	71
2	384	93
3	397	103
4	428	117
5	475	145
6	486	163
7	497	175
8	509	185
9	513	189
10	528	205

After completetion of data collection, plothas been plotted by us between the receiver data and glucose level found by the invasive method of glucose testing. For doing machine learning part, first we have chosen 80% of data in random manner to train the model for better accuracy and the reamining 20% of the data is used fot testing the trained model.

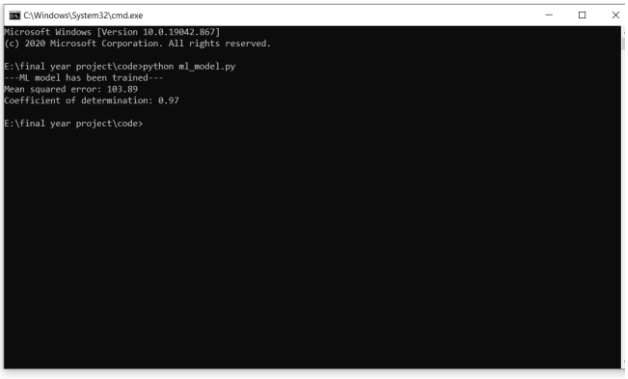

Fig. 5: ML model Accuracy

After the ml model has been trained then we have tested the reamining data. The graph plotted between the collected data and the predicted data is shown below.

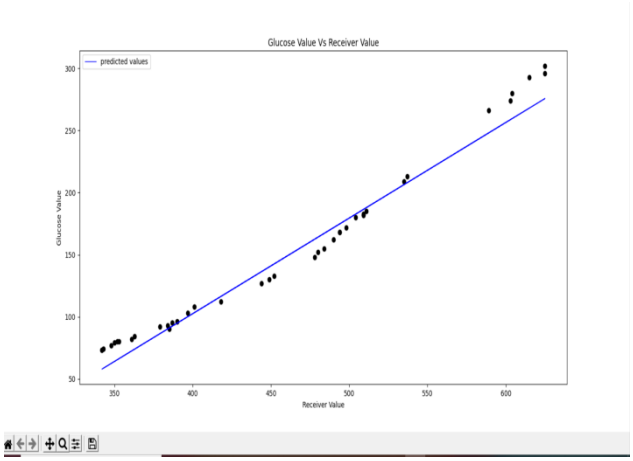

Fig. 6: Testing Results

we have formed an equation which we will be used to predict the glucose level by using the system.

The Equation developed by collected sample data is,

Y=0.7733*X-206.374

Where, Y= glucose concentration X= receiver data.

Graph plotted between the receiver value and the predicted blood glucose level by our instrument is shown above in fig.6. The sample outscreen is shared below.

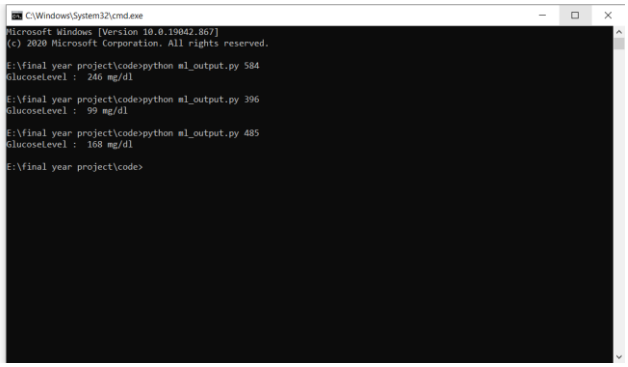

Fig.7 : Output for data sample

6 Conclusion

The demand for non-invasive glucometer is huge because diabetes is popular all over the globe. This product based on near-infrared spectroscopy, the choice of the 1650nm wavelength has a good accuracy rate as at this wavelength the glucose part will absorb the most part of the light. As we got the data in a linear, so we choose the linear regression model as our regression. So that our machine learning based has obtained high accuracy. The minute errors which are present in our project can be decreased by taking the more features in to the account while doing machine learning like temperature, gender, age and time of checking. Similarly, in the hardware side the accuracy could be increased by viewing the effect of sunlight. It will be a perfect replacement for the current invasive method as it eliminates the process of pricking into skin tissues. Moreover, it paves a convenient way for continuous monitoring of blood glucose level especially in the case of type-2 diabetes..

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