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Non-invasive glucose measurement based on NIR spectrum and regression method

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***Abstract*— Clearly glucose can be considered one of the most important molecules in metabolic processes or food systems. This paper deals with the design of a new solution to measure and quantify glucose and other carbohydrates. The designed device glucose meter is a reliable, simple, painless and portable for monitoring glucose level non invasively. Seven samples have been used during the experiment set. The glucose meter consists of an infrared emitter which placed over test tube for measurement all characteristics optically. The near-infrared light will be sensed by the photo diode which having a certain wavelength. By analyzing the variation in receiving signal intensity, glucose concentration can be predicted by using the regression analysis.**

***Keywords*—Glucose meter, Non-invasive, Near Infrared, regression analysis, optical measurement.**

I. INTRODUCTION

Among the many biological compounds found in nature, glucose is arguably one of the most critical for life. There are a myriad of analytical assays in which glucose can be determined in food products and food product precursors. The large number of assays presents a challenge: how might glucose be unambiguously identified and quantified.

Today, several methods for detecting and quantifying glucose and other carbohydrates have been developed. These methods may be broadly grouped into two main categories: enzymatic approaches encompassing both spectrophotometric assays and glucose meters and non-enzymatic instrumentation such as HPLC (hight performance liquid chromatography) systems and their associated detectors. We cote for example, various forms of fourier transform (FT) spectroscopy, (Barnaba, A., & Mencarelli, 2014) and FT-NIR (Chen, Danao, Singh, & Brown, 2014), as well as 1H NMR (Cao et al., 2014) have been applied with good success against a variety of food matrixes.

An overview of the history of glucose would not be complete without mention of its role in human diabetes. In 1965, the first blood glucose test strip – the Dextrostix – was developed at Miles-Ames; it too relied upon the activity of glucose oxidase, and was widely adopted by the medical community.The first glucose meters produced were cumbersome, but by 1974 technology had progressed sufficiently that Boehringer Mannheim was able to market a meter for home use.

Modern glucose meters, including the popular Accu-chek, precision, and optimum lines. The enzymes are directly impregnated onto the test strips, and a small (1-10 µL) drop of fluid is applied directly. The concentration determination is performed in less than a minute, and based on either reflectance photometry. Each detection system has strengths and weaknesses, in part dictated by the specificity and stability of the enzymes employed, and by the sensitivity and accuracy of the meter. Overall, most handheld meters tend to be acceptably accurate and precise, with intra-assay precision between 3-7% and a high correlation (r = 0.99) between a reference standard and meter output (Pfützner et al., 2012).

Self-monitoring of glucose concentrations has advanced over the past few years. Glucose values determined by home meters correlate well with laboratory results. Because of the importance of precision and accuracy of self-monitoring glucose devices, guidelines for the performance of these devices were recommended in 1987 by the American Diabetes Association [1].Noninvasive glucose measurement based techniques like IR spectroscopy have been used for years, but a reliable method has not been established yet. Many research problems in IR spectroscopy are yet to be solved. Non-invasive determination of the glucose also promotes regular testing, adequate control, complications reduction and consequently health care cost reduction.

The goal of this study is to suggest a reliable, simple, painless and portable device for glucose measurement. The method proposed here makes use of the variation in the intensity of the signal, received from the NIR sensor, to detect the glucose concentration. The remaining portion the paper is organized into different sections. In section II the basic methodology have been discussed,while section III discusses the proposed system architecture,in section IV discusses the measurement procedures and section V gives the experimental results.Conclusions and future developments have been illustrated in section VI.

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II. METHODOLOGIE

Until now many methods have been proposed for the non-invasive measurement of glucose. But the main concern in non-invasive techniques is achieving a high accuracy of results.

In this research, the technology chosen is based on the scattering property which has direct effect on glucose [2]. The methodology is based on passing NIR through the samples and the amount of light present on the other side of the tube is measured. The presence of glucose blocks the light from passing through the glucose solution. The samples glucose present can be measured by analyzing the variations present in the light intensity. The mismatch in refractive index between scatterers and their surrounding media is caused by decrease in glucose concentration. As a result, with the growing concentration of glucose, fewer photons are absorbed and the light intensity increases [3]. The proposed method is based on the principle of absorbance transmittance photometry.

A. Spectroscopic techniques

Spectroscopic technique is an optical method used to quantified glucose concentration by determining the quantity of light which is absorbed, transmitted or emitted as a function of glucose concentration [4, 5]. A small variation of the light after the light is passing through the target tube will be detected by the sensor [6]. The optical range of (700-1400) nanometer is the most suitable for detecting glucose signal [7]. NIR is based on the collection of tissue absorption or emission spectrum by diffused reflectance or transmission with a spectrometer. This method utilizes light absorption or emission data with a wavelength between 700-2500 nm to quantify the glucose.

B. Beer lambert law

In optics, the measurement of the number of photons delivered at a point in a given unit of time is called the Intensity I. If we measure the intensity of the beam of light entering our sample (Io) and compare it with the intensity of the beam of light exiting our sample (I) we can take the ratio I/Io to get an indication of what fraction of the light entering the sample was found exiting the sample. This ratio is called the Transmittance:

$$T = I/I0 \qquad (1)$$

The transmittance of the sample is directly measured by taking the strength of the wavelength measured and dividing it by the initial strength. The absorbance is computed as absorbance

$$A = -\log 10(I/Io) \qquad (2)$$

Consider a solution of a chemical species that absorbs light of a particular wavelength. We could imagine two interesting situations. First, if we pass a beam of light of the appropriate wavelength through a fairly dilute solution, we could imagine that the photons will encounter a small number of the absorbing chemical species, so we might expect a high % transmittance and a low absorbance. Alternatively, if we pass the same beam of light through a highly concentrated solution, we could imagine that the photons will encounter a large number of the absorbing chemical species, and we might expect a low % transmittance and a high absorbance. Thus absorbance is proportional to the concentration of the sample. Secondly, we could imagine that if we allow the beam of light to encounter the solution for a long period of time we might expect to see a low % transmittance and a high absorbance.Whereas, if the beam were allowed to encounter the solution for a short period of time we might expect to see a high % transmittance and a low absorbance. Since light travels at a constant speed, c = 3.0 x 108 m/s, this implies that the absorbance should also be proportional to the path length of the beam through the sample. These two considerations allow us to establish the following proportionality:

$$A = k * l * c \qquad (3)$$

Where k = proportionality constant, l = path length, and c = concentration of the absorbing chemical species

When the path length is measured in centimeters, and the concentration of the absorbing species is measured in Molarity, the proportionality constant is called the Molar Absorptivity, Our proportionality reduces to the Beer Lambert Law :

$$A = \varepsilon * l * c \qquad (4)$$

C. Regression analysis

In data mining, regression is a type of analysis that predicts continuous output/response variables from several independent input variables. Given a number of samples, each one of which is characterised by certain input and output variables, regression analysis aims to approximate their functional relationship. The estimated functional relationship can then be used to predict the level of output variable for new enquiry samples.

Generally, regression analysis can be useful under two circumstances:

1) When the process of interest is a black-box. In this case, regression analysis can accurately predict the output variables from the relevant input variables without requiring details of the however complicated inner mechanism (Bai et al., 2014; Venkatesh et al., 2014; Cortez et al.,2009; Davis & Ierapetritou, 2008).

2) When the detailed simulation model relating input variables to output variables, usually via some other intermediate variables, is known, yet is too complex and expensive to be evaluated comprehensively in feasible computational time. In this case, regression analysis is capable of approximating the overall system behaviour with much simpler functions while preserving a desired level of accuracy and can then be more cheaply evaluated (Caballero & Grossmann, 2008; Henao & Maravelias, 2011, 2010; Viana et al., 2014; Beck et al., 2012).

A large number of regression analysis methodologies exist in the literature, including: linear regression, support vector regression (SVR), kriging, radial35 basis function (RBF)

(Sarimveis et al., 2004), multivariate adaptive regression splines (MARS), multilayer perceptron (MLP), random forest, K-nearest neigh bour (KNN) and piecewise regressions.

III. ELECTRONIC CIRCUIT

Basically, the non-invasive technique designed is based on the principle of the absorbance transmittance photometry. The absorption value of light energy is dependent on the number of molecules present in absorbing material. Hence, the intensity of the light energy when leaved the absorbing material is consumed as an indication of concentration of that particular material. In quantitative, the absorbance is expressed by the Beer Lambert Law.

The proposed system setup consists of a reflective optical sensor, for transmission and reception of NIR rays with the test tube. The optical sensor used is TCR5000 operating at a wavelength of 950nm. The TCRT5000 is a reflective sensors which include an infrared emitter and phototransistor in a leaded package which blocks visible light. The measuring distance range from 1mm to 8mm, and the central point is about 2.5mm. There is also an on-board potentiometer to adjust the sensitivity.

IV. MEASUREMENT PROCEDURE AND DATA ANALYSIS

The experimental procedure established is to have an accurate and valid data among the samples. There is need for a simple test tube assay that can be used to contain samples. NIR signal are passed through the test tube with and without change the sample components.A continuous spectrophotometric essay to measure the glucose concentration by measuring the amount of light transmitted is realised.The received transmitted signal is mesured and concluded in the table I.

Data obtain will be analyzed using simple polynomial regression. Regression analysis is the statistical technique for the purpose to identify the relationship between two or more quantitative variables. The relationship is focusing at a dependent variable whose value is to be predicted with the independent variable. This analysis is used to determine and predict the relations between an independent variable X (Voltage measured, (V)) and a dependent variable Y (glucose concentration, (mol/L)).

TABLE I
VOLTAGE MEASURED FOR SAMPLES GLUCOSE

SOL°	1	2	3	4	5	6	7
C(g/10ml)	0	3	2.5	2	1.5	1	0.5
V(mV)	-468	-548	-527	-510	-502	-500	-490

V. BASIC RESULT

The purpose of this design system is to determine a method for the prediction of glucose concentration for any samples. This invented system would enable the monitoring glucose level continuously and noninvasively. When the use of the noninvasively technique coupled with the several advantages such as the absence of pain, it will offer securely a technique to the user.

It was proved that the relationship between glucose concentration and Transmitted light voltage is inversely proportional; as shown in Figure.1.

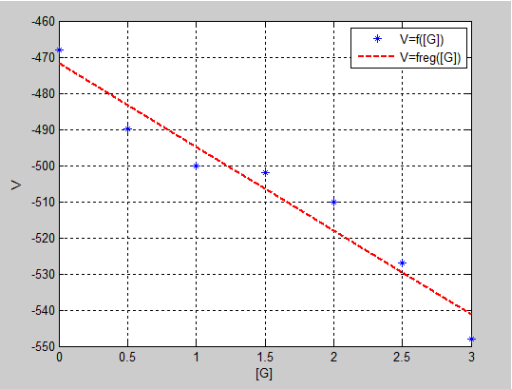

Fig. 1 Data obtain from the design device

Next, the prediction of the glucose is determined. By using the 1st order of the polynomial regression, the prediction is accomplished by using the equation generated :

$$mol/L = -23.14 * X - 471.71 \qquad (5)$$

The graph plottes proves that the designed device capable of give a reading for glucose concentration (fig.1).

VI. CONCLUSION

A lot of research work has been performed over the years to develop noninvasive measurements of glucose. Our research work provides an innovative idea to solve the existing problems, which patients are facing with the current glucose meter technique. Here an analog front end for noninvasive glucose meter is designed and simulated. On the other hand, many parameters for improvement could be made to increase accuracy and precision of measurement using the device.

REFERENCES

[1] Colwell JA, Dudley JD, McDonald JM, Metz R, Raskin P, Rizza RA, et al. Consensus statement on self-monitoring of blood glucose. Diabetes Care 1987;10:95–9.

[2] Scattering Property [Online]. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2769638/

[3] V.Ashok, A.Nirmalkumar, and N.Jeyashanthi:" A Novel Method for Blood Glucose Measurement by Noninvasive Technique Using Laser", World Academy of Science, Engineering and Technology, 2011

[4] O. Krushinitskaya, “Osmotic sensor for blood glucose monitoring applications,” Phd Thesis Vestfold Univ. Coll., no. 1, pp. 1–24, 2012.

[5] N. S. Oliver, C. Toumazou, a E. G. Cass, and D. G. Johnston, “Glucose sensors: a review of current and emerging technology.,” Diabet. Med., vol. 26, no. 3, pp. 197–210, Mar. 2009.

[6] J. T. Andrews, J. Solanki, O. P. Choudhary, S. Chouksey, N. Malvia, P. Chaturvedi, and P. Sen, “Towards a Wearable Non-invasive Blood Glucose Monitoring Device,” J. Phys. Conf. Ser., vol. 365, p. 012004, May 2012.

[7] J.L. Smith ,The pursuit of noninvasive glucose: Hunting the deceitful turkey, Second Edition, John L. Smith, 2011.