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SIMULATION OF PHOTOPLETHYSMOGRAPHIC GLUCOMETER

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ABSTRACT:

Diabetes mellitus is a chronic systemic metabolic problem and many people in this world are suffering from with this disease. Diabetes can lead to severe complications over time, including blindness, kidney failure, heart failure, and peripheral neuropathy associated with limb pain, poor circulation, gangrene and subsequent amputation. It is necessary to control this disease by regular monitoring of blood glucose and the appropriate adjustment in the dose of medicine. Regular monitoring can be done either with the help of Pathology laboratories or by the patient himself with the help of hand held instrument such as "Accu-Chek" or "Advance Micro-draw". Either of these methods necessitates a finger puncture, sometimes several times a day, to obtain a droplet of blood for chemical analysis. It is needless to say that this procedure, being invasive, is inconvenient and unpleasant for diabetic subject and often leads to poor patient compliance. A solution can be provided to this problem by developing a non-invasive method to assess the blood glucose using the principle of Photo Plethysmography. Then it was developed and interfaced with Lab VIEW using DAQ kit.

Keywords: Diabetes mellitus, Photoplethysmography, Noninvasive, Blood glucose.

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1. INTRODUCTION

Diabetes mellitus is a chronic systemic metabolic disease and its incidence rate is approximately 3% of the total world population [1]. It is necessary to control this disease by regular monitoring of blood glucose and appropriate adjustment in the dose of medicine. Regular monitoring can be done either with the help of pathology laboratories or by the patient himself with the help of hand held instruments like "Accu-Chek" and "Advanced Micro-draw". Either of these methods necessitates a finger puncture, sometimes several times a day, to obtain a droplet of blood for chemical analysis. It is needless to say that this procedure, being invasive, is inconvenient and unpleasant for diabetic subject and often leads to poor patient compliance. In the past three decades considerable amount of work has been done for the development of non- invasive technique for the assessment of blood glucose level. These efforts have been concentrated mainly in two different directions i.e. Electro-enzymatic approach and optical approach [1]. In electro enzymatic approach the oxidation of glucose with the help of glucose oxidase enzyme is measured to detect the concentration of glucose. The basic glucose enzyme electrode is comprised of glucose oxidase enzyme immobilized on a membrane or a gel matrix and an oxygen sensitive polarographic electrode. Changes in oxygen concentration at the electrode due to catalytic reaction of glucose and oxygen can be measured with electrical methods. In a commercial system two polarographic electrodes are used in place of one. One of the electrodes has active enzyme placed over it and senses glucose and oxygen whereas the other electrode senses only oxygen. The amount of glucose is determined from the difference between the readings of two electrodes. In recent systems hydrophobic membrane is placed over the glucose enzyme electrode, thus increasing the linear response of the sensor to glucose [2].

In the optical approach, unknown biological substances in aqueous solution are identified by absorption spectroscopy in the infrared (IR) region. In the ZR spectrum of anhydrous D-glucose in the wavelength region of 2500 to 13000 nm, strongest absorption peak has been observed around 9700 nm due to carbon-oxygen-carbon bond in the molecules pyran ring [3]. More recently Optical Coherence Tomography (OCT) in the near infrared region (1300 nm) has been employed for the non- invasive monitoring of the blood glucose. They have demonstrated the capability of the OCT technique to monitor blood glucose concentration in human subject and reported that further work is in progress [4]. Based on optical approach, another method called Metabolic Heat Conformation Method has been developed by Cho et al [5]. In this method metabolic heat generated and local oxygen supply are measured, which yield glucose concentration with the help of multi-variety statistical analysis with a correlation coefficient of 0.99. In this proposed method an infra-red light is made incident on the index finger of the subject and the transmitted light is received by a photo diode and detected by an electronic circuit. It has been observed that the output of the photo detector is related to the blood glucose content of the subject. With the above experience, the authors have studied the transmission of infrared light at different wavelengths through the index finger in a number of subjects and based on the observations have designed a hand-held instrument for monitoring the blood glucose level, which is described in this paper.

2. METHODOLOGY

A. Proposed method

In this proposed method an infra-red light is made incident on the index finger of the subject and the transmitted light is received by a photo diode and detected by an electronic circuit. It has been observed that the output of the photo detector is related to the blood glucose content of the subject. As we seen already increase in blood glucose value will decrease the output voltage.

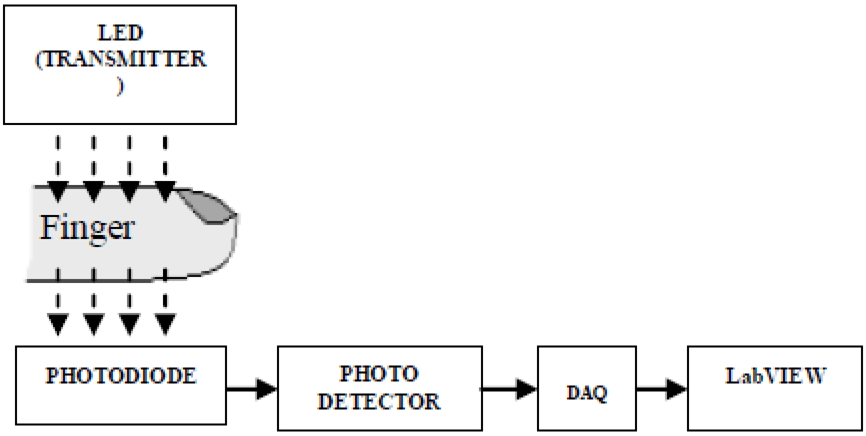

Figure 1 The basic block diagram of the project

This Photo Plethysmographic instrument comprises of Infrared light emitting diode transmitter. The transmitted light after passes through the finger falls on photo diode. The photo detector converts the photo current into voltage signal. Here the converted voltage signal is given as the input to Lab VIEW through DAQ. The detector output is given to the analog input of DAQ. Then depending upon the output voltage, corresponding blood glucose value will be displayed in the computer. The invasive and non-invasive measurements were repeated after 30 minutes, 90 minutes and 120 minutes of the intake of dextrose. Thus there were 4 sets of observations in every subject.

B. Plethysmography

The measurement of changes in the volume of organs or other body parts, particularly changes in blood flow. Some Plethysmographic devices are attached to arms, legs or other extremities and used to determine circulatory capacity. In water Plethysmography an extremity, e.g. an arm is enclosed in a water-filled chamber where volume changes can be detected. Plethysmography is a test used to measure changes in blood flow or air volume in different parts of the body. It may be done to check for blood clots in the arms and legs, or to measure how much air you can hold in your lungs.

C. Scatter changes

Light scattering occurs in tissues because of the mismatch of index of refraction between the extracellular fluid (ECF) and the membranes of the cells composing the tissue. In the near infrared region (NIR), the index of refraction of the ECF is ηECF ≈ 1.348–1.352, while the index of refraction of the cellular membranes and protein aggregates is in the range ηcell ≈ 1.350–1.460. It is well known that adding sugar to water increases the index of refraction of the solution. Similarly, adding glucose to blood in turn raises the refractive index of the ECF, which will cause a change in the scattering characteristics of the tissue as a whole. Hence, tissue glucose levels are correlated with scattering coefficients based on changes in the refractive index of the ECF. Of late, measurements on light scattering by blood show promising correlation between blood glucose and reduced scattering coefficient [1]. On the other hand, light scattering is not influenced by the red blood cells and other chemical composition of blood.

3. RESULTS

The sensor signal is acquired through the DAQ which is more convenient when compared to other acquisition process. The entire processing schemes were done through the Lab VIEW 9 software using specially designed signal processing toolbox and arithmetic functions. The block diagram shown above shows the input signal and its corresponding value. It also displays the resultant blood glucose value. The front panel is shown as follows.

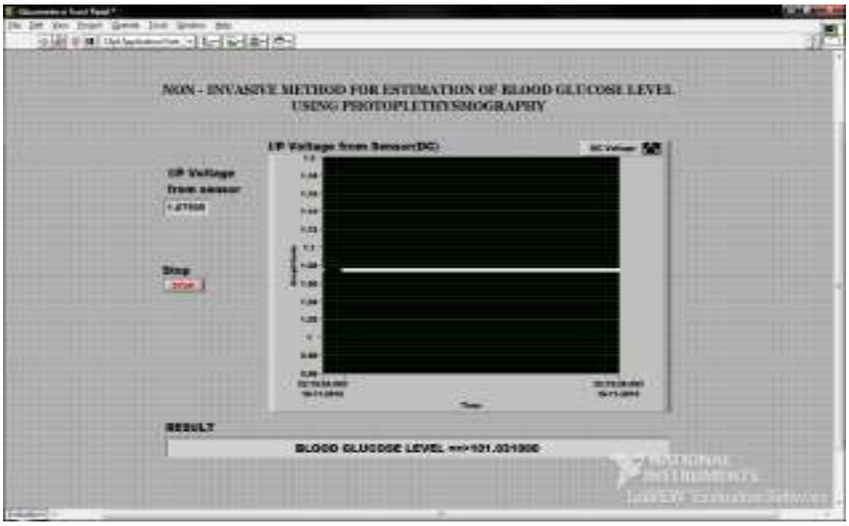

Figure 2 The front panel of the Lab VIEW simulation

Table 1 shows the invasive blood glucose level and photo-detector output for 650 nm at (a) fasting; (b) 30 minutes after the intake of dextrose; (c) 90 minutes after the inject of Photo Sensitive Diode dextrose and (d) 120 minutes after the intake of dextrose respectively in all the 5 subjects. Table II shows the invasive blood glucose level and photo-detector output for 940 nm at (a) fasting; (b) 30 minutes after the intake of dextrose; (c) 90 minutes after the inject of Photo Sensitive Diode dextrose and (d) 120 minutes after the intake of dextrose respectively in all the 5 subjects. Table III shows the invasive blood glucose level and photo-detector output for 1310 nm at (a) fasting; (b) 30 minutes after the intake of dextrose; (c) 90 minutes after the inject of Photo Sensitive Diode dextrose and (d) 120 minutes after the intake of dextrose respectively in all the 5 subjects.

Table 1 Photo detector Output Vs Blood Glucose Level for 650nm

S.No	Observation	Blood Glucose (mg/dl)	Detector Output (Volts)
1	a	84	0.50
	b	121	0.50
	c	126	0.50
	d	95	0.50
2	a	100	0.40
	b	160	0.40
	c	117	0.40
	d	89	0.40
3	a	104	0.70
	b	128	1.10
	c	91	0.70
	d	107	0.70

4	a	84	1.90
	b	123	1.90
	c	99	2.00
	d	71	1.80
5	a	89	0.80
	b	91	1.00
	c	98	0.50
	d	75	1.00

Table 2 Photo detector Output Vs Blood Glucose Level for 940 Nm

S.No	Observation	Blood Glucose (mg/dl)	Detector Output (Volts)
1	a	84	2.00
	b	121	1.80
	c	126	1.90
	d	95	1.90
2	a	100	1.10
	b	160	1.10
	c	117	1.20
	d	89	1.10
3	a	104	2.00
	b	128	2.50
	c	91	2.00
	d	107	2.00
4	a	84	5.00
	b	123	4.90
	c	99	5.60
	d	71	5.00
5	a	89	2.00
	b	91	2.50
	c	98	1.60
	d	75	2.50

Table 3 Photo detector Output Vs Blood Glucose Level for 1310nm

S.No	Observation	Blood Glucose (mg/dl)	Detector Output (Volts)
1	a	84	1.10
	b	121	0.65
	c	126	0.60
	d	95	1.00
2	a	100	0.70
	b	160	0.60
	c	117	0.70
	d	89	0.80
3	a	104	0.80
	b	128	0.60
	c	91	0.90

	d	107	0.80
4	a	84	2.00
	b	123	1.60
	c	99	2.20
	d	71	2.30
5	a	89	0.70
	b	91	0.80
	c	98	0.55
	d	75	0.70

4. DISCUSSION

From Table I, the detector output for 650 nm light does not appear to change appreciably from (a) to (d) in all subject and indicates poor absorption of 650 nm light by the glucose in blood. From table II, the 940 nm infrared light, some appreciable change has taken placed from (a) to (d) in some of the subjects. However, the same is not consistent from subject to subject. For instance, there is increase in the detector output from (a) to (b) in 2 subjects (S. Nos. 3 and 5); there is decrease in detector output from (a) to (b) in other 3 subjects (Sr. Nos. 1 and 4) and there is no appreciable change in one subject (Sr. No. 2). In all the subjects (b) to (c) and (c) to (d) trend is unpredictable; detector output increases in some cases and decreases in other cases for increase in blood glucose values. From table III, the detector output for 1310 nm infrared light has shown consistency with the rise or fall in blood glucose level in all the subjects The above results indicate that further processing of 1310 nm detector output can yield relative change in the blood glucose level in an individual. The limitation of this method is that it cannot determine the absolute value of blood glucose. This is because, for the same value of blood glucose (84 mg/ dl) in subjects 1 and 4, the detector output is 1 .10 and 2.00 V respectively. However, with the use of a suitable reference wavelength in the far IR region (typically between 4700 nm to 5000 nm), the detector output can be normalized to yield the absolute blood glucose measurement.

5. CONCLUSION

Considerable amount of efforts have been put in the last three decades for the development of non- invasive blood glucose meters/monitors. Based on electro enzymatic approach, some glucose meters have become available for personal use, in the size of a wristwatch. However, some adverse skin effects may be encountered in few cases. Furthermore these units need three hours warm up period and mandatory calibration with invasive method in the subject. The system based on optical approach namely optical coherence tomography has shown good correlation with the invasive methods. This system can find tremendous application in the hospitals; however the size and cost forbid its use in self-monitoring. Non-invasive measurement by metabolic heat conformation method shows good promise in self-monitoring, however the cost factor will be known only after the instrument is commercially available. In view of above the Photo Plethysmography based Blood Glucose Monitor described above offers a simple and inexpensive modality for self- Monitoring of blood glucose. Thus this project estimates the blood glucose value successfully with the IR signals from finger. It can be seen that Lab VIEW played a major part in total automation of the system. Therefore this project would serve as a platform for building a real time embedded system.

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