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Fixed Wavelength Light Sources Estimation of Glucose

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Abstract:

The author proposes a design a soft core FPGA based hardware to estimate the glucose level in human blood. The instrumentation uses fixed wavelength NIR light sources to probe glucose which has good spectral signatures in Near Infrared (NIR) region. The NIR radiation is directed on the human tissue and a NIR detector will collect the transmitted NIR radiation. The system will have a Partial Least square regression (PLSR) processing running on FPGA platform to estimate the concentration of glucose in blood tissue.

Keywords: *Biomedical instrumentation, non-invasive, soft-core, Glucose Analysis, PLSR, NIR.*

I. Introduction:

One of the main threats to the human well being in the 21st century is Diabetes mellitus (DM), commonly referred to as diabetes. Diabetes mellitus is a group of metabolic diseases in which there are high blood sugar levels over a prolonged period[1][2]. It is also referred as breakdown of ability to regulate the amount of glucose (sugar) in the blood stream. More prevalent in the developing, as estimated by the World Health Organization (WHO), around 70 million people suffering from diabetes mellitus [3].

High blood glucose produces the classical symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger) [4]. Long term effects of Diabetes include diabetic ketoacidosis and nonketotic hyperosmolar coma[6]. Serious long-term complications include cardiovascular disease, stroke, chronic kidney failure, foot ulcers, and damage to the eyes[5].

There are three main types of Diabetes mellitus:

Type 1 DM results from the pancreas' failure to produce enough insulin. This form was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or "juvenile diabetes". The cause is unknown [5].

Type 2 DM begins with insulin resistance, a condition in which cells fail to respond to insulin properly [5]. As the disease progresses a lack of insulin may also develop [7]. This form was previously referred to as "non-insulin-dependent diabetes mellitus" (NIDDM) or "adult-onset diabetes". The primary cause is excessive body weight and not enough exercise [5].

Gestational diabetes, is the third main form and occurs when pregnant women without a previous history of diabetes develop a high blood sugar level [5].

Glucose level in the blood changes and if this change is not monitored may cause health problems to the patient. The acceptable range of glucose concentration is from 70 mg/dL (milligram of glucose in 100 millilitres of blood) to 110 mg/dL or 3.9 to 6.0 mM/L[4]. After consuming food glucose concentration of a person may rise to a level up to 140 mg/dL. The methods technologies available to the layman requires him to take a blood sample and then measure using chemical reaction the glucose concentration, being painful and also costly the above method is a burden to the patient . So there is a need of blood glucose measuring device which may provide continues monitoring of blood glucose concentration non-invasively. This will allow for a more frequent and efficient monitoring of the blood glucose for a needy patient which is not possible in recent times owing to the high cost of the market solutions. This has prompted many companies and scientific groups to set up research and development for developing a biosensor for non invasive methods which are user friendly and cost effective. Different optical approaches are investigated to get desired goal namely polarimetry [8], Raman spectroscopy [9], near infrared (NIR) absorption and scattering [10], and photo acoustics [11].It is

well evident that there is a urgent need for a good instrument to monitor blood glucose non-invasively. Keeping this in mind the problem was formulated to develop the various skills, techniques and system to analyze the glucose using fixed wavelength NIR spectroscopic technique.

II. Fixed Wavelength Near Infrared Light Sources:

NIR Spectroscopy is a spectroscopic method which uses the near infrared region of the electromagnetic spectrum and then utilizes the information such as the transmittance or absorbance. NIR can penetrate relatively deep into biological soft tissues. The NIR absorption property of tissue varies with tissue constituents especially water, fat, collagen, and their combination ratio. Most biological soft tissues have a relatively low light absorption property in the visible and NIR spectral regions. This spectral region is known as a "tissue optical window" or "therapeutic window" [12].Outside this region, light is greatly absorbed by tissue pigments (such as haemoglobin and melanin).Our system proposes to use fixed wavelengths NIR sources

III. Behaviour of Water & Glucose in NIR

Water, being the major component of biological tissues, accounts for 60% to 80% of total body mass [13].The water content depends upon the tissue type and it is also age and gender-dependent. Water is considered to be one of the most important chromophores in tissue spectroscopic measurements because of its high concentration in most biological tissue. The absorption spectrum of water is shown in Figure 1 over the wavelength range 1000nm – 2500 nm[14].

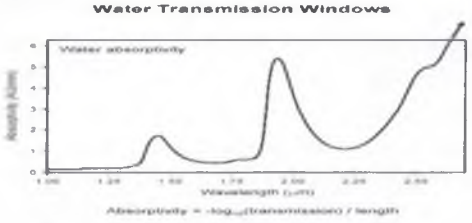


Figure 1: Water Absorbance spectra

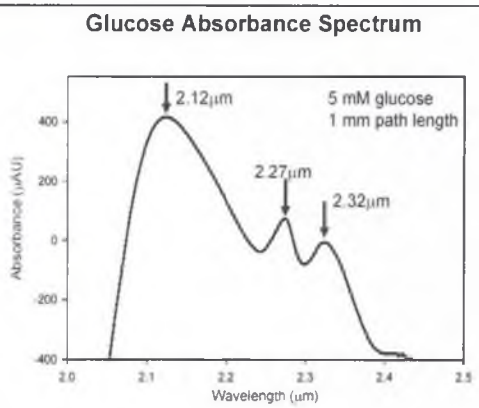


Figure 2: Absorption spectra of glucose

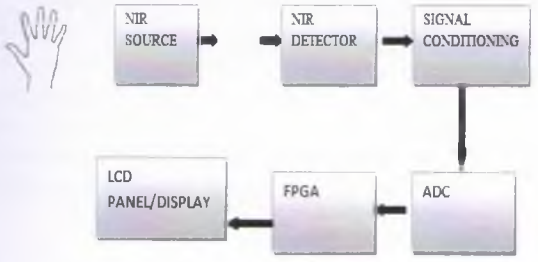
The NIR absorption spectra of glucose is shown in figure 2.The fundamental IR absorption bands of glucose have been reported in solid pellets and in solution [15]. The strongest bands that can generate intense combinations and overtones are the broad OH stretch at 2857 nm and the CH stretch vibrations at 3377 and 3393 nm[15]. Other bands at > 2000 nm are possibly combinations of a CH stretch and a CCH, OCH deformation at 2261 nm (νCH + vCCH, OCH) and 2326 nm (vCH + vCCH, OCH)[15]. The presence of the CCH, OCH ring deformation component confers some glucose specificity on these bands [16].

As seen above in the above figure2 the proposed technique will probe the human blood at the specific wavelengths which indicate a maxima and minima on the above figure, this data will be detected using a NIR detector will then be processed on the soft core FPGA system using PLS regression technique.

IV. Block Diagram

The proposed block diagram contains the following blocks namely

1) NIR SOURCE
2) NIR DETECTOR
3) SIGNAL CONDITIONING
4) ADC
5) FPGA/SOFT CORE SYSTEM
6) DISPLAY



The NIR light source may contain a NIR LASER/LEDs which will emit the fixed wavelengths as specified above. This radiation will pass through the human tissue and the remaining transmitted light will be collected by the NIR detector.

The detected signal has to be conditioned for further processing and various conditioning such as amplifying, filter will be applied to the detected signal before passing it to the Analog to Digital Converter.

Once the signal is digitised in the ADC block the data will be passed to the FPGA soft core for further processing and estimation of the glucose. The estimated glucose concentration will be displayed on the LCD panel so that the user can read the glucose level.

V. Partial Least Square Regression Technique for Processing

PLSR Model finds good use in the multivariate spectroscopic data. PLSR is an extension of the multiple linear regression models. Therefore PLSR is mostly used as an exploratory analysis tool to select suitable predictor variables and to identify outliers. The method is used to analyze glucose concentration in presence of large no of body parameters and its a extension of the multiple linear regression models. In its simplest form, a linear model specifies the relationship between a dependent (response) variable 'Y', and a set of predictor variables 'X's, so that

$Y = b_0 + b_1 X_1 + b_2 X_2 + ...+ b_p X_p$ Here b_0 the intercept and the b_i values are the regression coefficients computed form the data sets with the know constant concentrations.

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