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GLUCOSE DETECTION IN BLOOD USING NEAR-INFRARED SPECTROSCOPY: SIGNIFICANT WAVELENGTH FOR GLUCOSE DETECTION

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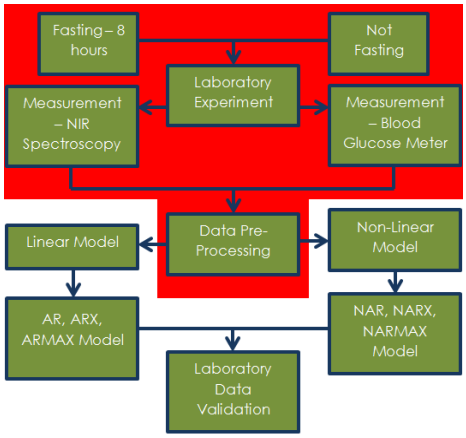
Graphical abstract



Abstract

World Health Organization (WHO) stated in 2004, about 347 million people suffered from diabetes and from this statistic, about 3.4 million died from the complication of kidney failure, heart attack, body part amputation and adequately reported suffered from blindness. There are several non-invasive techniques in measuring the blood glucose level developed nowadays and among the popular technique is the near-infrared (NIR) measurement, ultrasonic sensor implementation, multisensory systems, absorbance of transmittance, bio-impedance, voltage intensity, and thermography. Among these techniques, there are several approaches that displayed a lot of potential; nonetheless some of them have produced unsatisfying results. The NIR technique has been applied in some of previous research, however the wavelength used vary for different researcher. There are several points of views on the significant wavelength range that contains suitable information regarding the peaks of glucose in blood. This paper is focusing on the experimental data collection using the near-infrared spectroscopy technique. This paper furthermore discussing on determine the significant peaks of glucose that is suitable to be used as the indicator of the glucose in blood. The highest significant peaks of blood glucose detected from the range around 1450nm and 1930nm.

Keywords: Near-infrared (NIR), blood glucose, non-invasive, wavelength

1.0 INTRODUCTION

Glucose is an example of a carbohydrate which is commonly known as blood sugar or dextrose. Its chemical formula is $C_6H_{12}O_6$, and this empirical formula is shared by other structural sugars. In blood and cells of plants and animals, most of the glucose consists of molecules shaped into a ring. Maintaining the glucose level in blood is important to human body, as the sugar play an immense part in human daily lives. However, the excessive glucose in blood can contribute to diabetic. For diabetic patients, it is importatant to maintain their glucose level in the normal clinical range (3.5–6.1 mmol/L) [1].

The clinical range of the glucose level in blood stated as:

$$Diabetic = \begin{cases} 0, & 4\ mmol/L \leq BGL \leq 7\ mmol/L \\ 1, & BGL > 7\ mmol/L \end{cases} \quad (1)$$

where, 0 = person without diabetic
1 = person with possible diabetic

However, there are cases of late detection of diabetic merely because of the personal whose refuse to the blood examination, due to terrifying of needles and blood. Therefore, the non-invasive blood glucose measurement is one of the optional solutions to encourage the blood examination among the potential patients. The exceed of normal glucose level could contribute to kidney failure, heart disease and stroke may occurred in long term [2].

1.1 Previous Non-Invasive Research

The non-invasive methods in predicting the glucose level in human body has caught interest of many researchers. It is a must for a frequent monitoring of patient with severe condition as it is an incurable disease with a life-threatening metabolic disorder [3]. The experiment on the subject for the research in glucose level should be performed in accordance to the Good Clinical Practice and the Declaration of Helsinki [4,5].

There are several other non-invasive techniques that were implemented by researchers to overcome the shortcoming of the previous technique [6], such as ultrasonic sensor implementation, multisensory systems [5,8–10], absorbance of transmittance photometry [11,12], bio-impedance [13–15], voltage intensity [16] and thermography [3]. Some of the techniques show promise as non-invasive techniques in monitoring the glucose level in blood and work as an alternative way to the current invasive method.

1.2 Near-infrared in Detecting Glucose Level in Blood

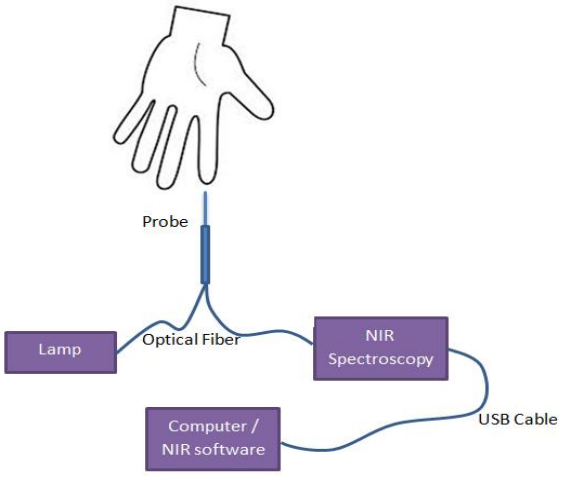
The near-infrared (NIR) has proven to be among the best technique in identifying certain amount of substances such as carbon, hydrogen and oxygen. The NIR also widely used in various field such as pharmaceutical [17], environmental, agrochemical and biomedical engineering [3,17–19] sectors. The NIR technique has been applied in some of previous research, however the wavelength used vary for different researcher. Among the other studies, the frequent used wavelength starts from as low as 650–800 nm [12,20,21], at the range of 1100–1900 nm [2,6,22–24] and there are some at the range of above 2000nm until 3000nm [19,25,26]. The range of the wavelength used must consider enough penetration into the skin. The adequate range of penetration would provide sufficient information on the substances in human skin [27]. There are several points of views on the significant wavelength range that contains suitable information regarding the peaks of glucose in blood. This paper is focusing on the experimental data collection using the near-infrared spectroscopy technique. This paper furthermore discussing on determine the significant peaks of glucose that is suitable to be used as the indicator of the glucose in blood.

The other parameter constantly used besides the wavelength is the wavenumber, also known as the number of waves per certain distances [28–31]. The most important factor to be considered when choosing the suitable NIR or FTIR spectroscopy in experiment is the wavelength range as the wavelength range will determine the optimum information collected to be analysed subsequently.

2.0 METHODOLOGY

Figure 1 shows the actual NIR spectroscopy setup and the illustration on in what way the measurement of the NIR was conducted on the fingertip of the subjects.

(a) The NIR spectroscopy setup



(b) The illustration of the NIR measurement setup

Figure 1 The measurement setup for collecting the NIR wavelength on the fingertip of the subject

Figure 2 shows the flow chart of the research methodology. The subjects in the research are divided into 3 groups which are the patients with diabetic, the non-diabetic personal and a control group without earlier diagnosis. The data of the diabetic patients were collected at Outpatient Department (OPD), Hospital Universiti Sains Malaysia (HUSM) Kubang Kerian, Kelantan, Malaysia.

The clinical conventional blood glucose meter was used as the measurement device for data reference. Besides the earlobe, human fingertips are the best position to be measured as the skin at fingertips is much thinner and more the blood vessel is more observable. NIR is capable of to measure multipart of body fluids and tissues.

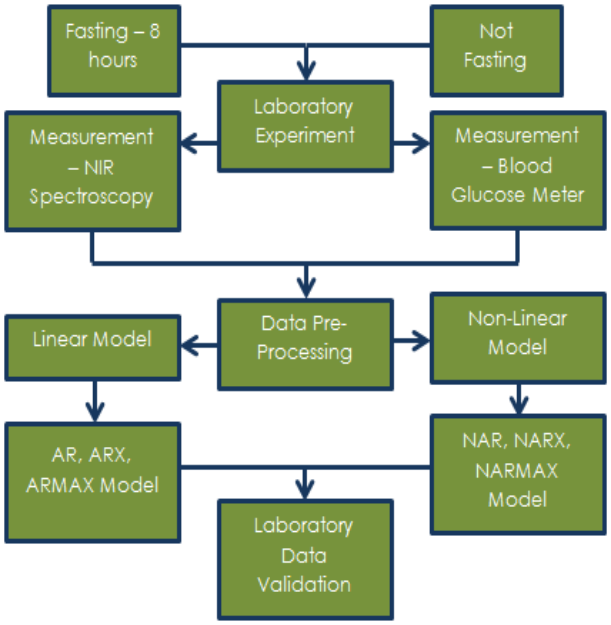


Figure 2 Methodology flow of the research for both diabetic and non-diabetic patients

The dataset contains 138 data from all 3 groups of subjects. The dataset used as the input data for the non-invasive prediction system subsequently. However, for this research paper, we will discuss until the data selection which is the selection of significant peaks from the NIR wavelength.

3.0 SELECTION OF THE NIR ABSORPTION WAVELENGTH

3.1 Data Sampling

For this research, the wavelength measured from 200nm until 3500nm as in Figure 3. Nevertheless, only the information from 1000nm until 2000nm is investigated. The purpose of the analysis is to discover the significant peaks that represent the glucose absorption points.

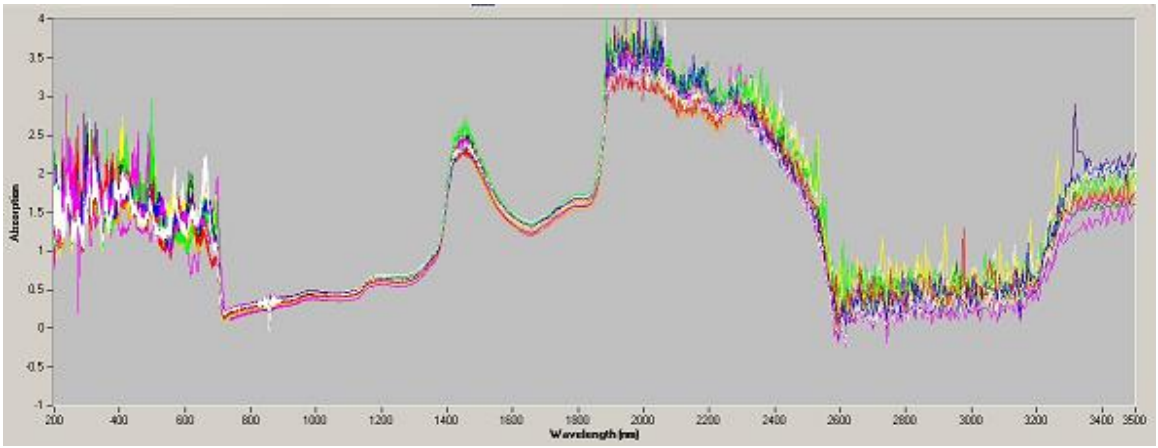


Figure 3 The example of the absorption NIR wavelength from 200nm until 3500nm

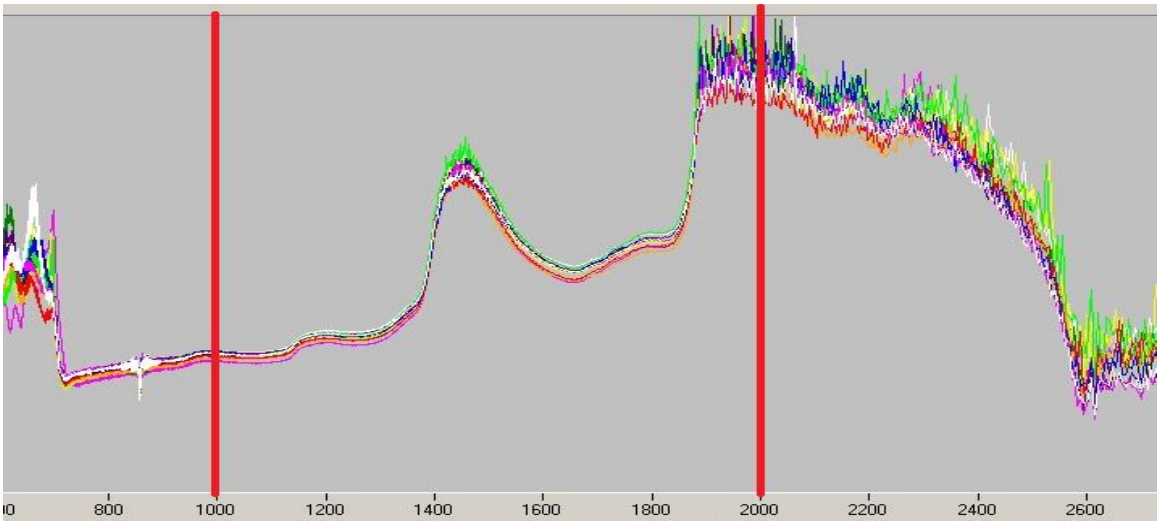


Figure 4 The absorption wavelength chose as the input source from 1000nm until 2000nm

From Figure 3, it shows that at 200nm until 700nm, it contains scores of noises, so as at around 2500nm and above. From Figure 4, it shows that the highest peaks obtained are from around 1450nm and 1930nm. However, these 2 peaks are not a sturdy evident to show the glucose level in human blood even though these points are the points with utmost concentration in carbon, hydrogen and oxygen. The wider the range, the information on the substances gets complicated, with the appearances of otherssuch as lactose and fatty acid. Thus, the selection from the wavelength range is desired. The range from 1000nm until 2000nm of the wavelength is chosen as the data input according to the reference of the spectral region of the near-infrared wavelength as in Figure 5.

Glucose known to have more than one absorption point in NIR wavelength regions and these peaks can help to overcome the difficulty in determine the glucose reading. The suitable range of the spectral region needed as to indicate the presence of the glucose in human blood.

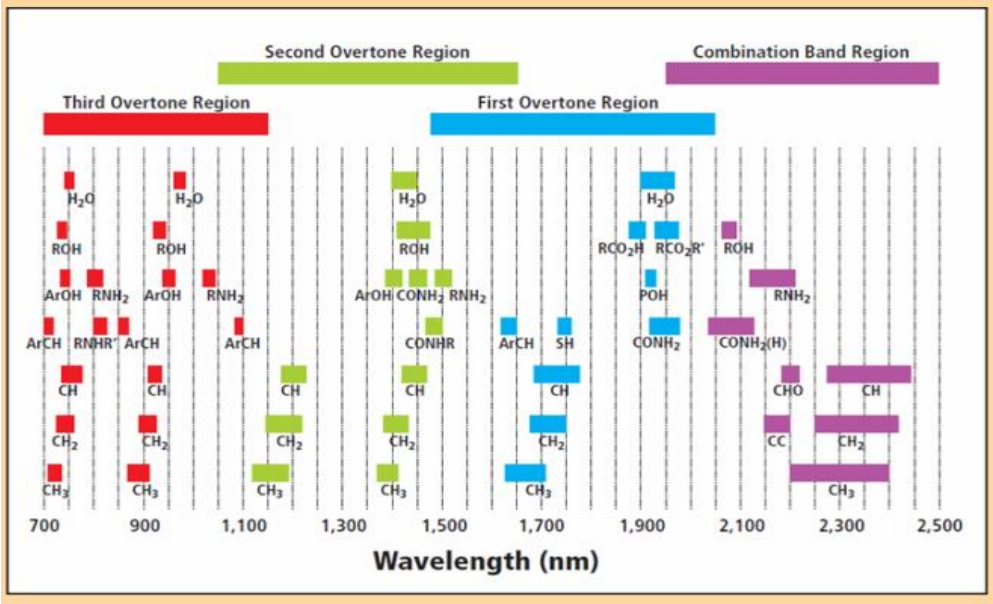


Figure 5 The spectral region of the near-infrared wavelengths

3.2 Noise Reduction

The NIR spectra measured from the experiment encloses with massive amount of noises. There are various reasons that contribute to noises in spectra reading. To overcome the noises disruption, noise filtering is applied on the spectra to yield an enhanced NIR wavelength.

The Zero Derivative First Polynomial Savitzky-Golay Filter used to enhance the quality of the acquired data by eliminating or minimizing the effect of unwanted signal. Figure 6 shows the raw data from the NIR spectra and Figure 7 shows the filtered data after the Savitzky-Golay is applied.

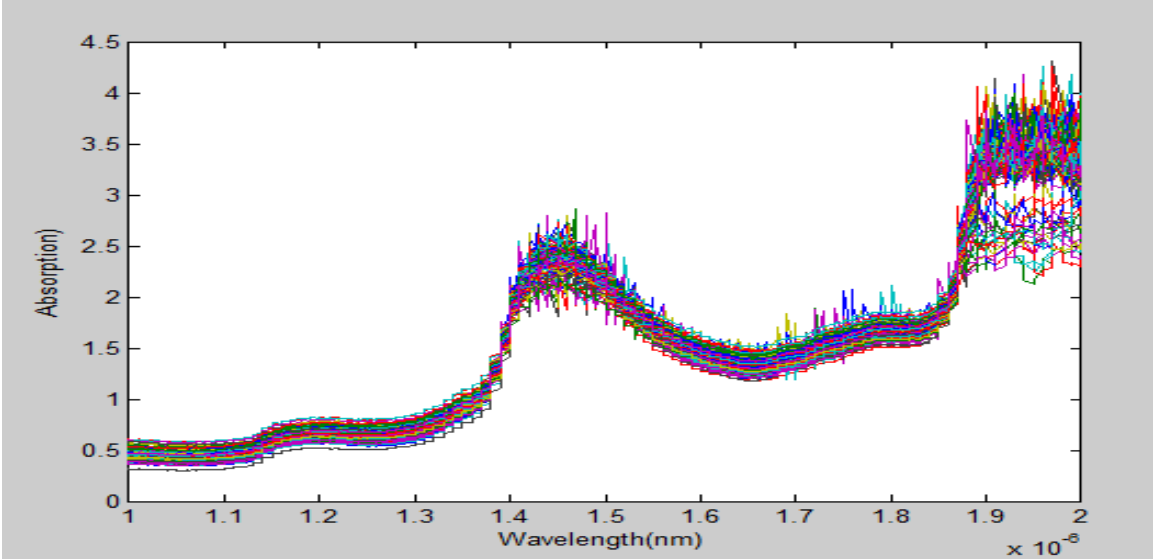


Figure 6 Raw Signal data at subject's fingertip

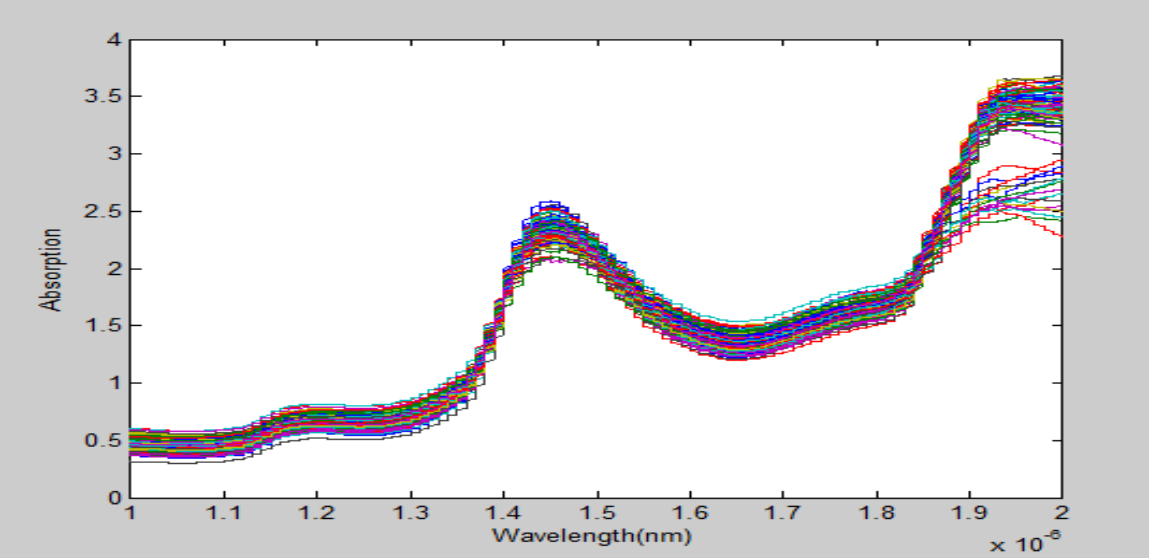


Figure 7 The processed signal data at fingertip using the Savitzky-Golay Filter

4.0 CONCLUSION

The NIR technique in measuring the glucose level in blood is receiving more attention as NIR is proven to be among the effective method in detecting substances such as carbon, hydrogen and oxygen.

In clinical practice, the new method that would be implemented required the accuracy rate of prediction higher than 90% compared to the reference method. In order to achieve the stipulated rate, the data measured using the NIR essential to contain sufficient information on the substances that represent the glucose empirical formula. In this research, thru the wavelength of 1000nm until 2000nm, highest peaks found were at 1450nm and 1930nm as the peaks represent the highest concentration of carbon, hydrogen and oxygen while comparing to the spectral region of the near-infrared wavelength. However, final verdict for these 2 peaks to be the exact indicator for the glucose level in blood could not be concluded.

The information from the wavelength will be used as the input data for the non-invasive prediction system subsequently. Therefore, the particular range from the whole wavelength chose as the input data for the glucose level in blood prediction system in future studies.

Acknowledgement

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