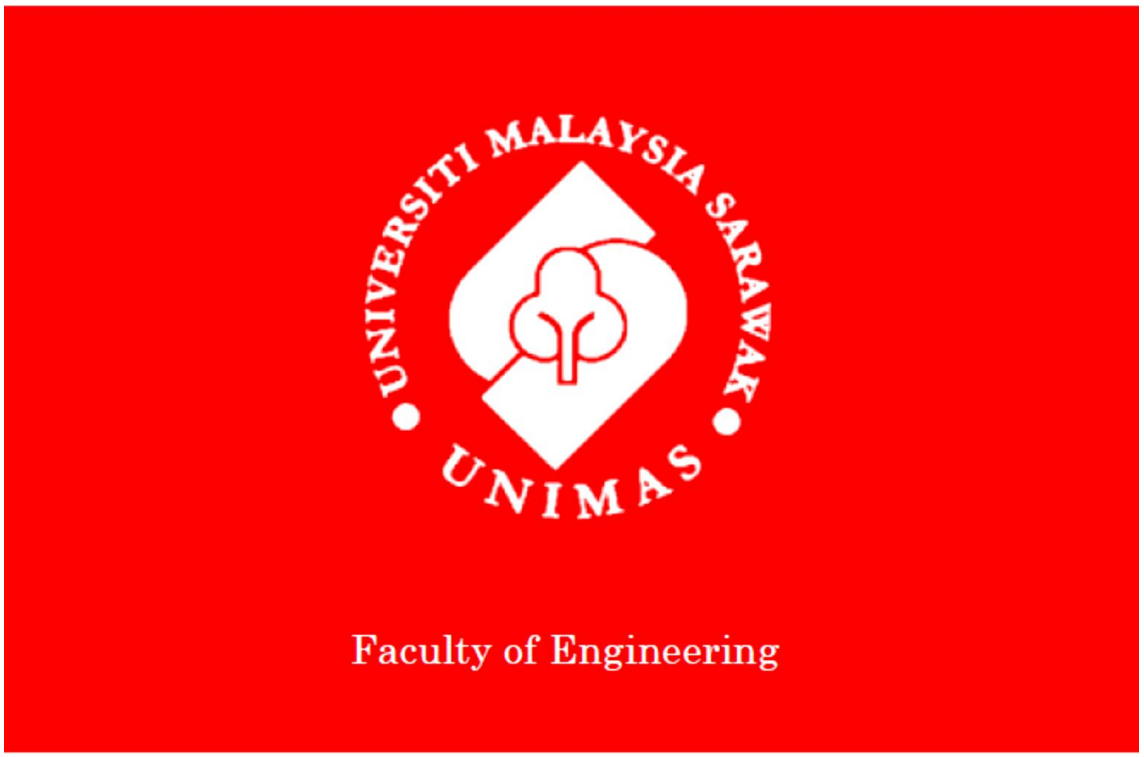

PORTABLE SMARTPHONE-BASED LASER GLUCOMETER FOR NON-INVASIVE MEASUREMENT OF GLUCOSE LEVEL OF DIABETIC PATIENTS

Nur Adilah Binti Ahmad

Bachelor of Engineering (Hons)

Mechanical and Manufacturing Engineering

2017

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

Please tick (√)

Final Year Project Report	/
Masters	
PhD	

DECLARATION OF ORIGINAL WORK

This declaration is made on the _____day of ____, 2017.

Student's Declaration:

I (NUR ADILAH BINTI AHMAD, 42968, Faculty of Engineering) hereby declare that the work entitled Portable Smartphone-Based Laser Glucometer for Non-Invasive Measurement of Glucose Level of Diabetic Patients is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

_____ _____

(Date of submission) (Nur Adilah Binti Ahmad, 42968)

Supervisor's Declaration:

I, Dr Khairul Fikri Bin Tamrin hereby certify that the work entitled Portable Smartphone-Based Laser Glucometer for Non-Invasive Measurement of Glucose Level of Diabetic Patients was prepared by the above named student, and was submitted to the "FACULTY" as a full fulfilment for the conferment of BEng (Hons) Mechanical & Manufacturing Engineering, and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: _____ Date: 25/7/2017

(Dr. Khairul Fikri Bin Tamrin)

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*

☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*

☒ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirm with free consent and willingly declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature: _____
(Nur Adilah Binti Ahmad)

Supervisor signature: _____
(Dr. Khairul Fikti Bin Tamrin)

Current Address:

_____

_____

_____

Notes: * If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.
[The instrument is duly prepared by The Centre for Academic Information Services]

APPROVAL SHEET

Final Year Project attached here:

Title	:	Portable Smartphone-Based Laser Glucometer for Non-Invasive Measurement of Glucose Level of Diabetic Patients
Name	:	Nur Adilah Binti Ahmad
Matric No	:	42968

Has been read and approved by:

_____ _____

Dr. Khairul Fikri Bin Tamrin
(Supervisor)

Date Approved

PORTABLE SMARTPHONE-BASED LASER GLUCOMETER FOR NON-INVASIVE MEASUREMENT OF GLUCOSE LEVEL OF DIABETIC PATIENTS

NUR ADILAH BINTI AHMAD

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Mechanical and Manufacturing Engineering)

Faculty of Engineering
Universiti Malaysia Sarawak

2017

To my beloved family and trusted friends

ACKNOWLEDGEMENTS

The author felt deeper gratefulness for the love and mercy shown by the Almighty Allah who gave strength, courage and patience to endure all the obstacle and stresses faced during the completion of this project. Without His support the author would not be able to complete it.

First and foremost, the author would like to express her gratitude towards her supervisor Dr. Khairul Fikri Bin Tamrin form Mechanical and Manufacturing Department who has given his unlimited guidance and support throughout the completion of this thesis. This thesis could not have been completed without his resources.

The author would also like to extend her thanks towards the great love and support shown by family members especially my beloved mother, Hamidah Binti Mamat. Thus, to be able to complete this task and graduate would be greatest moments the author could have.

Last but not least, to the classmates that have been with the author throughout the four years, all the best in your future endeavours and in life itself.

ABSTRACT

A glucose meter (or glucometer) is a medical device for determining the approximate concentration of glucose in the blood by pricking a finger to draw blood as the sample using a sharp needle. However, diabetic patient has quite slow level in wound healing process which causes their fingers constantly in a state of wounded and exposed to bacteria. More importantly, a two main factor for the weakness of invasive technique is a painful process and cost often because constant monitoring of glucose level is very expensive. The main objective of this project is to design and develop a non-invasive optical measuring technique to measure body glucose level automatically and painless by using laser source. The invention attempts to address the previously mentioned concerned using smartphone, laser pointer, and image processing method to automatically determine measurement of the sample under experiment. A laser pointer is used to illuminate a urine sample and the light scattered is recorded using a smartphone. The image is then analysed using a Matlab software to determine the refractive index of the urine sample. By mapping the refractive index, one is able to correlate it with the measurement taken using a glucometer. Hence, this allows continuous measurement of glucose level of diabetic patients. The cost of developed device was located in considerable price region. However, some features of the system are needed further improvement.

Keywords: Diabetic Patient, Glucose Monitoring, Non-invasive Measurement, Urine Test, Snell's Law

ABSTRAK

A meter glukosa (atau glukometer) merupakan perani alat perubatan untuk menentukan kepekatan anggaran glukosa dalam darah dengan menusuk jari untuk mengeluarkan setitis darah sebagai sampel dengan menggunakan jarum tajam. Walaubagaimanapun, pesakit diabetes mempunyai proses penyembuhan luka yang agak perlahan menyebabkan jari mereka sentiasa dalam keadaan cedera dan terdedah kepada bakteria. Lebih penting lagi, dua faktor utama untuk kelemahan teknik invasif adalah satu proses yang menyakitkan dan mengeluarkan kos yang tinggi kerana pemantauan berterusan tahap glukosa adalah sangat mahal. Objektif utama projek ini adalah untuk mereka bentuk dan membangunkan satu teknik pengukuran optik menggunakan teknik bukan invasif untuk mengukur tahap glukosa badan secara automatik dan tidak menyakitkan dengan menggunakan sumber laser. Percubaan inovasi untuk menangani masalah yang dinyatakan sebelum ini denngan menggunakan telefon pintar, penunjuk laser, dan kaedah pemprosesan imej untuk menentukan pengukuran sampel di bawah percubaan secara automatik. Penunjuk laser digunakan untuk menerangi sampel air kencing dan cahaya biasan dirakamkan menggunakan telefon pintar. Gambar tersebut akan dianalisis menggunakan perisian Matlab untuk menentukan indeks biasan bagi sampel air kencing. Dengan pemetaan indeks biasan, seseorang mampu untuk mengaitkan dengan ukuran yang diambil menggunakan glukometer. Oleh itu, ini membolehkan pengukuran berterusan tahap glukosa pesakit kencing manis. Kos peranti yang dibangunkan terletak di rantau harga yang agak besar. Walaubagaimanapun, beberapa ciri-ciri sistem ini yang perlu ditambahbaikan.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

n	-	Index of Refractive
θ_1	-	Angle of Incidence
θ_2	-	Angle of Refraction
Θ_{md}	-	Angle of Deviation
θ_c	-	Critical Angle
Θ_p	-	Prism Apex Angle
c	-	Sugar Cncentration

ABREVIATIONS

DM	-	Diabetes Mellitus
WHO	-	World Health Organization
SMBG	-	Self-Monitoring of Blood Glucose
CGM	-	Continuous Glucose Monitoring
ISF	-	Interstitial Fluid
RBC	-	Red Blood Cells
MIR	-	Mid-Infrared
NIR	-	Near-Infrared
OCT	-	Optical Coherence Tomography
3D	-	3-Dimensional
2D	-	2-Dimensional
COM	-	Communication
USB	-	Universal Serial Bus

CHAPTER 1

INTRODUCTION

1.1 Background

Diabetes Mellitus (DM) is a gathering of metabolic illnesses in which there are high glucose levels over an extended time usually known as diabetes. Besides, DM is a serious ailment in which the body does not generate or appropriately utilize insulin, and is describe as one of the wellbeing significant issues in the society. In 2013, World Health Organization (WHO) stated that about 3.4 million people died from the effects of high blood glucose in 2004, and 347 million people worldwide have diabetes.

Throughout the time, high blood glucose can lead to a damage to nerves and veins, heart disease, blindness, limb amputations, kidney disease and cardiovascular disease. In addition, there are some other complications may include complications during pregnancy, rapid aging, and lack of weight gain. The main cause of DM is still remain

scientifically unclear but scientists consider body weight, diet, gender, genetic and environmental factors are among the causes in most cases (Williamson, 2009).

There are two principal types of diabetes which are Diabetes Type 1 and Type 2. Diabetes Type 1 frequently happens in children and young adults, in spite of the fact that it can happen at any age. Diabetes Type 1 accounts for 5-10% of the overall diabetes in the United States (Reading, 1986). This is caused due to an autoimmune insulin-producing β-cells in the pancreas have been destroyed by interstitial cells that lead to the real causes of the lack of insulin. Lack of insulin thwarting the normal regulation of blood glucose. In some cases, Type 1 often genetically inherited diabetes. Typically, bacteria, virus, and other harmful foreign materials are damaged by the immune system to protect the body. But, the immune system cracks down on body's own cells in autoimmune diseases (Khalil, 2004). In Type 1 Diabetes, decay of β-cell can take several years, but symptoms of this disease usually occur in a short period of time (Williamson, 2009).

In addition, Type 2 diabetes results from insulin resistance triggers the symptoms. Literally, people who have a healthy lifestyle such as physical activity are high, vibrant lifestyle, and do not have the habit of smoking is less prone to problems related to diabetes. Diabetes Type 2 is often faced by patients due to several factors, including insulin resistance that a state in which the body's muscles, fat, and liver cells cannot use insulin effectively (Srivastava, Chowdhury, Sharma, & Sharma, 2013). By the way, the ability of reduced visibility because the body can no longer produce enough insulin to compensate for vision capabilities. Symptoms of Type 2 Diabetes affect the body precisely and grow gradually and sometimes take the next several years to diagnose. The disease develops most often in the middle-aged and older people who are overweight or obese (Williamson, 2009). Type 2 Diabetes is rare among the youth, however, is common

in children who are overweight and obese children and adolescents with diabetes. Most people deal with Type 2 Diabetes represents 90-95% of all diabetes compared with Type 1 Diabetes (Reading, 1986).

In general, blood glucose can be measured using three techniques which are invasive, minimally invasive, and non-invasive. Technically, invasive techniques are mostly used for the measurement of glucose known as glucometer devices. A glucose meter (or glucometer) is a medical device for determining the approximate concentration of glucose in the blood by pricking a finger to draw blood as the sample using a sharp needle. Glucometer will use a strip of paper and dipped into blood samples to measure blood glucose levels and it is widely used because it has a relatively high accuracy (Shichiri et. al, 1982).

1.2 Problem Statement

However, diabetes patient has quite slow level in wound healing process which causes their fingers constantly in a state of wounded and vulnerable to germs and bacteria. Even patients with diabetes Type 1 and Type 2, they need to constantly monitor their own blood glucose levels several times a day as to keep the blood glucose level at normal or near-normal range (Williamson, 2009). According to Reading (1986) if the level of blood glucose is low at less than 4 mmol/l it is known as hypoglycaemia . Diabetes patients will face a several number of symptoms such as shaking, sweating a lot, blurred vision, headache, too tired and lack concentration. While the hyperglycaemia also mean glucose is in the high level of which more than 7 mmol/l. Diabetes patients will often want to urine, too thirsty and headache when in a state of hyperglycaemia.

Despite that, this method is painful, expensive, cumbersome, aesthetically unpleasing and troublesome. More importantly, two main limitations of the invasive techniques are painful process and cost, because constant monitoring of glucose level is very expensive.

Therefore, these limitations gave a big boost to researchers for development of non-invasive method for the continuous monitoring of blood glucose because it presents major advantages over existing invasive methods. The proposal to use a laser pointer will be pointed to pass through the urine sample to get the glucose level. This method is supposed to be quick and easy. The cost of the proposed test equipment will be significantly lower than existing methods because it only uses a laser pointer and urine samples from subjects only. In addition, the number patient for this method is expected to be high because it painless, low cost, and rapid.

1.3 Research Objectives

To overcome the aforementioned problems, the following research objectives are proposed:

i. To develop a non-invasive optical measuring device to automatically measure body glucose level using a laser source
ii. To calibrate the developed device by investigating the relationship between concentration of sugar solution and its refractive index
iii. To correlate urine refractive index measured using the developed device with the actual reading of blood glucose level measured using a glucometer

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An increasing number of people with diabetes lead to increased demand for continuous non-invasive technique of glucose monitoring. This recognizes the fact that the long-term outcome of these patients can be increased dramatically by frequent careful and accurate glucose monitoring and control. In this chapter, some of the latest technology in invasive, minimal invasive and non-invasive of glucose monitoring will be reviewed under development or introduced to the current market. Figure 2.1 demonstrates the technology that has been used in blood glucose measurement (Ferrante do Amaral & Wolf, 2008).

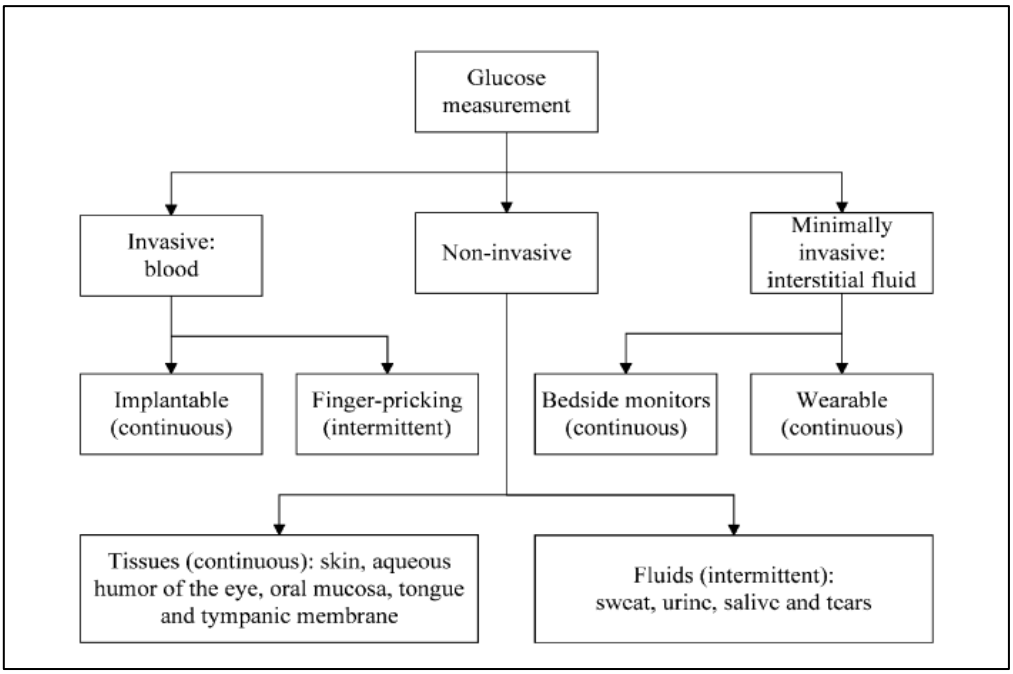

Figure 2.1: Overview of technologies for non-invasive blood glucose control (Ferrante do Amaral & Wolf, 2008)

2.2 Invasive Technique

2.2.1 Glucometer

Glucose meters can now be connected in different fields of medicine for diagnostic purposes in distinguishing hypoglycaemia and hyperglycaemia in outpatient clinics, emergency rooms, ambulatory medical care (ambulance, helicopter, boat cruises), and self-monitoring of blood glucose (SMBG) at home. Glucose meter gives an analysis of blood glucose levels rapidly and permitting the management of both hypoglycaemia and hyperglycaemia disease with the objective of conforming the glucose to near-normal range, depending the patient group (Tonyushkina & Nichols, 2009).

According to Chee and Fernando (2007), the most common invasive techniques and cheaper is to require the production of blood from the finger by pricking a finger using a lancet (small, sharp needle). Glucometer use a strips of paper and dipped into blood samples until the test strip is protected adequately with blood, and then put the coated strip into a glucose monitor to measure blood glucose levels. Blood extraction can also be obtained from these parts of the body such as the upper arm, forearm, base of the thumb and thigh.

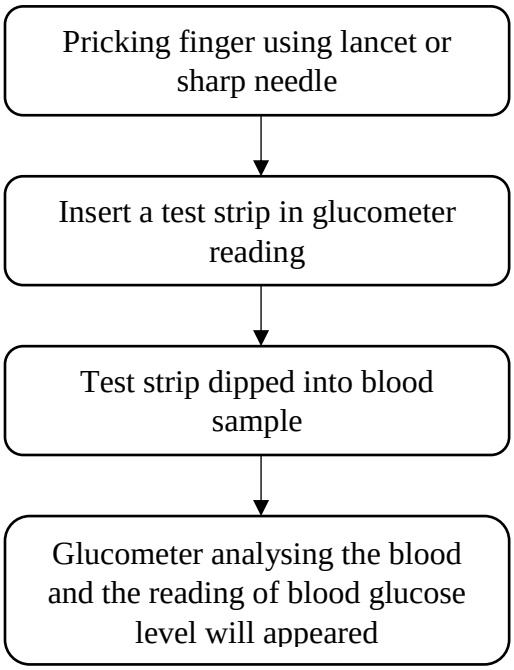

Figure 2.2: Flowchart System Operation of Glucometer

This method is very encouraging patient compliance and have a serious drawback. For most people, the prospect of implementing a 5 or 6 daily lancet is frightening and painful. In addition, it presents a great risk for infection because of diabetes patients suffer from very slow healing process compared to healthy people. There is a very small error to error in the test, and thus many people do not get the right decision because of poor testing practices. Furthermore, although

the current marketing strategy used by most manufacturers is to sell relatively inexpensive monitors, test strips remain expensive, regularly priced at about $0.80 each. Regularly, 5 or 6 test strip are required for daily blood glucose test. Therefore, patients cost roughly more than $1,000/year which is approximately RM 4,000/year (Jang et. al, n.d.). The reliability of the results can be influenced by environmental effects. In addition, the quality of the results is also influenced by the patient's condition, medicines, and other metabolic factors. Pre-analytical of these variables should be considered when interpreting the results of blood glucose. Pre-analytical variable is any factor that may affect the reliability of test results that occur before the sample is analysed (Tuchin, 2008).

2.3 Minimally Invasive Monitoring

2.3.1 Microneedle

Shichiri et. al (1982) were the first to present the advancement of minimally invasive technique by needle type electrode embedded subcutaneously. Issues, for example, septicaemia contaminations, fouling with blood thickening and embolism can be stayed away from by utilizing subcutaneous implantation. They have composed a glucose sensor with a fine needle or adaptable wire and dynamic detecting component is done toward the end and installed in the subcutaneous tissue (Shichiri et. al, 1982).

According to Wang & Mintchev (2013), development of microneedle as minimally invasive technique is to help diabetes patients by decreasing torment and bother experienced and expanding the quantity of blood glucose tests every