IMPLEMENTATION OF CONTINUOUS WEARABLE LOW POWER BLOOD GLUCOSE LEVEL DETECTION USING GALVANIC SKIN RESPONSE GSR SENSOR

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Date : 1st June 2017

Special dedication to my beloved parents,

James Tan Han Sing And Lim Lee Lee

To my supervisor

Dr Wira Hidayat Bin Mohd Saad

My friends and my fellow lecturers

Thank you for all your care, support and believe in me

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ABSTRACT

Diabetes Mellitus is one of the most common life threatening diseases in the world. Malaysia is ranked 10th in the world with the highest number of population with diabetes. The aim of this project is to implement a low power wearable system for continuously monitoring the glucose level in human blood by using GSR sensor. The development of non-invasive blood glucose level detector is desired to replace the invasive method which is inconvenient and expensive. This project is successfully detected the GSR value and establishing a correlation between GSR and the blood glucose level. This project was divided into two parts, which are the hardware implementation and software implementation. The GSR conditional circuit is being optimized into a compact and convenient for the end user by fabricated in SMT. For the software implementation, the Bluno Beetle microprocessor is developed to collect and save the user data and an Android Application is created to link together with the hardware prototype by using BLE. It is also a IoT devices where the end user can review their data in an online database. It is clearly demonstrated that GSR can be useful in assisting to determine the blood glucose level as an alternative method for non-invasive approach. A correlation of 65.73% was found from the result and a threshold of (+-2V) for GSR data is identified for the end user to alert on their BGL. However, there are some factor such as dynamic movement, temperature and calories burnt might affect the accuracy and precision of the prototype.

ABSTRAK

Penyakit kencing manis merupakan salah satu penyakit merbahaya kerana ianya akan mengancam kesihatan seseorang individu. Malaysia kimi berada dikedudukan Ke-10 di dunia dengan mempunyai bilangan tertinggi penduduk yang menghidapi penyakit kencing manis. Tujuan projek ini adalah untuk menghasikan satu prototaip yang dapat menjimatkan tenaga serta boleh memantau kandungan gula dalam darah dengan menggunakan GSR. Penciptaan projek pengesan tahap gula darah secara tidak invasif dapat menggantikan kaedah invasif yang agak sukar dipakai dan mempunyai kos yang tinggi. Projek ini telah berjaya mengesan nilai GSR dan mewujudkan hubungan antara GSR dan tahap glukosa dalam darah. Selain itu, projek ini telah dibahagikan kepada dua bahagian, iaitu dari segi perkakasan dan segi perisian. Litar GSR telah diperbaikikan supaya dapat memudahkan pengguna dengan dibina dalam bentuk SMT. Untuk pelaksanaan perisian, mikropemproses Bluno Beetle telah direka untuk mengumpul dan menyimpan data pengguna dan Aplikasi Android telah dicipta untuk menghubungkan bersama prototaip perkakasan dengan menggunakan BLE. Ia juga merupakan peranti IOT di mana pengguna boleh menyemak data mereka dalam pangkalan data talian . Projek ini jelas menunjukkan bahawa GSR boleh digunakan untuk membantu mengenal pasti kandungan gula dalam darah sebagai kaedah alternatif untuk pendekatan bukan invasif. Satu korelasi yang bernilai 65,73% didapati dari hasil dan ambang (+-2V) untuk data GSR dikenal pasti untuk pengguna mengambil berat terhadap kandungan gula dalam darah mereka. Walau bagaimanapun, terdapat beberapa faktor seperti pergerakan dinamik, suhu dan kalori dibakar berkemungkinan bakal menjejaskan ketepatan dan ketepatan prototaip.

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GSR	-	Galvanic Skin Response
BGL	-	Blood Glucose Level
PCB	-	Printed Circuit Board
SMT	-	Surface Mount Technology
BLE	-	Bluetooth Low Energy
NIR	-	Near Infrared
SC	-	Stratum Corneum
RC	-	Resistor and Capacitor

CHAPTER 1

INTRODUCTION

The development of non-invasive blood glucose level detector is desired to replace the invasive method which is inconvenient and expensive. This project is target to detect the blood glucose by using the GSR sensor and to establish a correlation between GSR and the blood glucose level. This project was divided into two parts, which are the hardware implementation and software implementation. For the hardware implementation, it is a conditional circuit between the GSR sensor and human skin conductance to detect the glucose level which contains in sweats. While for software implementation, the Bluno Beetle microprocessor is developed to collect and save the user data. The data collected is then transmitted to Android application via Bluetooth 4.0. There is a relationship between blood glucose and GSR where it is possible to find the inverse function and from it can calculate blood glucose level from the GSR voltage value.

1.1 Problem Statement

Diabetes Mellitus is a continuous condition that impact the human body by reduce the insulin which conveys glucose into the platelets. According to World Health Organization, over the year 2016, the number of diabetes patient increase by doubled since 1980 to approximately 422 million worldwide [1]. While there are estimated 3 million diabetes patient in Malaysia and recorded 17.5% of the Malaysian Citizen ages 18 years old and above had the diabetes diseases [1]. Thus, it is very important for these patients to determine their blood glucose level so that they can maintain the insulin level or control their daily glucose intake.

Table 1.1: Statistic of Malaysian Diabetes 2006-2016

Years	Percentages of Diabetes Patients
2006	11.60%
2011	15.20%
2016	17.50%

The glucose monitoring technology have been used by the diabetes patients to monitor their blood glucose level for the past three decades. It becomes a very crucial technology that is useful for managing diet among the diabetes patients. The most common technology widely used now is the glucometer. In order to do the glucometer test, it requires user to draw their blood and apply it to the test-strip. Then, the test-strip needs to be inserted into the glucometer to obtain the reading. However, a lot of patient refused to undergo this kind of invasive method because it creates discomfort and pains to the patient. Basically, the diabetes patient is advised to take the blood glucose reading at approximately seven times a day to monitoring the regime of the blood glucose level so that the physician can recommend the right dosage of the insulin intake [2]. The test strip used in these glucometer is non-reusable and produces a lot of waste that will affect to the sustainability of environmental and economy.

Figure 1.1: Glucometer (Invasive Method) [2]

Generally, the method of measuring the blood glucose concentration can be divided into three major approaches which are invasive, non-invasive and minimally-invasive or known as interstitial.

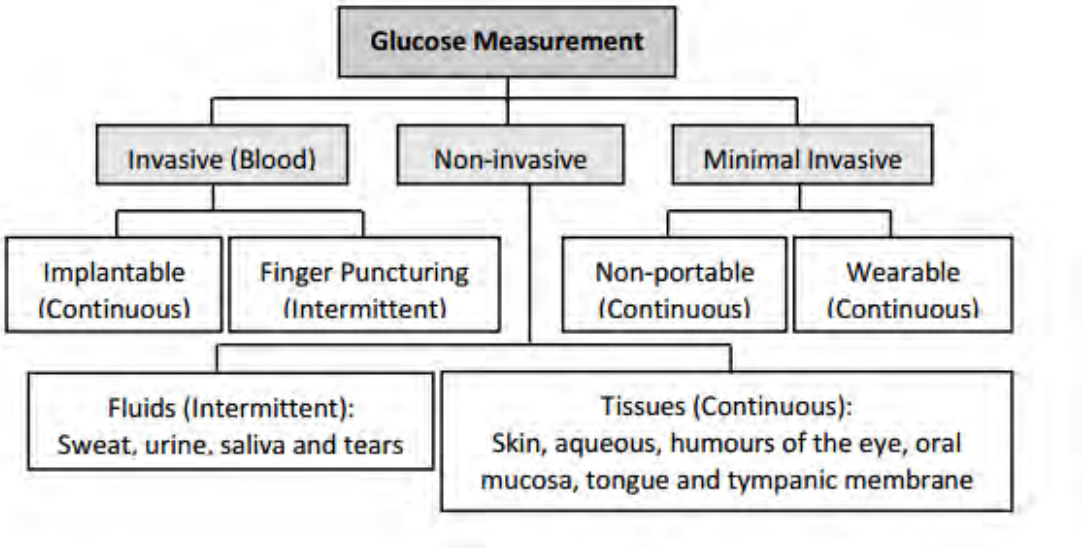

Figure 1.2: Categories of Blood Glucose Measurement [2]

The galvanic skin response (GSR) is under the non-invasive theorem. Based on the Figure 1.2, shown that under the non-invasive categories, it separates into two major part which is fluid for intermittent result and tissues for the continuous monitoring result. This project aims to creates a continuous monitoring non-invasive method for

blood glucose level detection. Thus, the tissues studies are more relevant for the result. These tissue signal can also recognize as physiological signal.

Thirdly, the detection of blood glucose level using GSR is still in its very fundamental stages and the previous studies for the blood glucose level detection is limited. It is very crucial for us to find the correlation between the blood glucose level and the galvanic skin response. Previously, we had successfully created a device for blood glucose detection by using GSR [3]. However, the limitation of the prototype created is relatively bigger in scale and non-mobility and thus limit the usage of the devices. This study is attempted to overcome the limitation.

1.2 Aim and Objectives

The aim of this project is to implement a low power wearable system for continuously monitoring the glucose level in human blood by using GSR sensor. In order to accomplish the aim, there are three objectives that have been specified for this project. The objectives are as below:

- To analyze the relationship of dielectric properties of the skin and other parameter toward the blood glucose level.
- To optimize the conditional circuit of GSR conductor for blood glucose detection.
- To construct a BLE embedded system for blood glucose monitoring on Android application with IoT.

1.3 Scope of the Project

In generally, the scope of this project to design and develop a low power Bluetooth device that is portable for the detection of blood glucose level by using the GSR sensor. Then, the system is developed by using the Bluno Beetle and an Android application(.apk) for overall optimize system. The GSR data will be compared with the normal glucometer to obtain the correlation between the GSR data and the actual blood glucose level.

1.4 Chapter Review

Chapter 1 describe the general overview of this project. This chapter consists of brief introduction to the project, a problem statement, the aim and objectives, the scope of project and the chapter review.

While in Chapter 2, the review on the previous study or work which related to the project had been described. The Galvanic Skin Response (GSR) sensor technology has been discussed in this chapter.

Then, the methodology to achieve the project objectives have been stated in Chapter 3. In this part, it explains about the method used to develop a system. The software will help to trigger the circuit and display the data of the project. The software and hardware are combined to develop a GSR sensor device which can detect the blood glucose level.

Next, in Chapter 4, the result obtained is shown and a basic demonstration of how to use the blood glucose detection using GSR sensor is described. The analysis will be discussed in this part. The comparison between the GSR and Glucometer measurement had been taken by conducting the experiment.

Finally, in Chapter 5, it presents the conclusion of this project. The advantages and disadvantages of the project are then discussed. The recommendation for the improvement of this project also made.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it will interpret and illuminate the finding of a literature review of the project. In general, it covers up the related studies for continuously wearable devices for non-invasive blood glucose level detection method using GSR sensor. Initially, the basic concept of the skin conductance and blood glucose level in sweat condition is discussed. Then, the characteristic and fact of blood glucose level is being discussed. Later, the Bluno Beetle and Arduino Studio Platform is discussed. Finally, there are some previous work that relevant to this project is studied.

2.1 Characteristic of Human Skin

Firstly, human skin is the most outer layer of our organ and acts as a protective layer for us, with a total surface area of $1.8m^2$ and making up approximate 16% of the body weight, skin is identified as the largest organ of the body. Skin are distinguishing into three structural layers which are epidermis, dermis, and hypodermis [4]. Then, the others like hair, sebaceous, nails, sweat and apocrine glands act as derivatives of the skin. Thus, the epidermis is also known as the most front layer where served as the physical and chemical barricade between the internal organ and the external environment. Next is the dermis layer, it is the deeper layer which provides the anatomical support of the skin. Then, the third layer is the hypodermis which is also known as the subcutis layer that function to depot of fat and acts a connective of the tissue layers. The cross section of skin layer is on Figure 2.1.

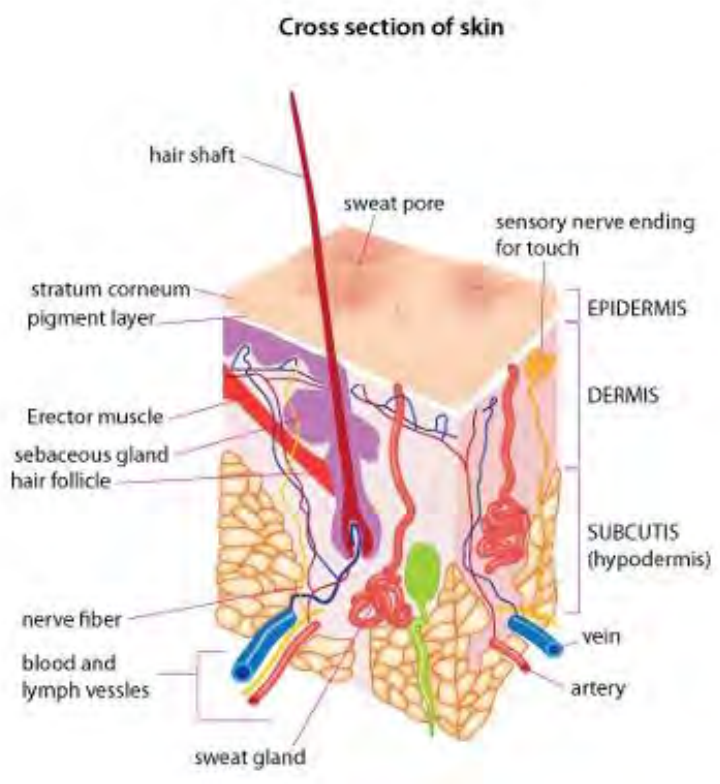

Figure 2.1: Cross Sectional of Human Skin [5]

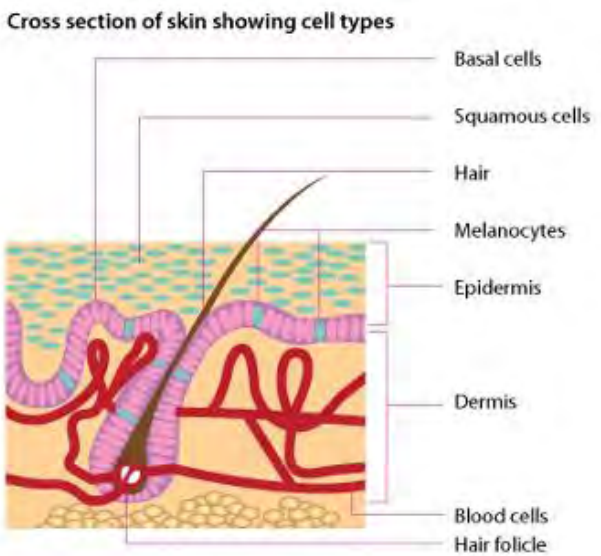

Figure 2.2: Cross Sectional of Human Skin Zoom View [5]

2.1.1 Characteristic of Sweat Glands

According to McClendon and Hemingway in 1930 stated that the sweat glands were recognized as the seat of the "Psychogalvanic Phenomena" [6]. There are over 2.5 million of sweat glands distributed equally along the skin surface. Thus, it can be said that the sweat is the easiest way to get access since it can freely accessible in a human being. The sweat glands are located within the dermis and composed of the coiled tubes which stow the water substances. The sweat gland can be categories into two main types, which are the eccrine gland and apocrine gland. So, the eccrine gland can be identified all over the skin particularly on the palms. This gland will stimulate by cholinergic nerve fibers and excrete sweat which contains lactic acid, fatty acids, chloride, urea, glycoprotein, and mucopolysaccharides. Then, the second types of sweat glands are the apocrine gland which is the duct that desolate out into the hair follicle. During the puberty, they will become active and secreting an odorless protein-rich secretion. Both of these glands, the eccrine gland and apocrine gland are under the control of the adrenergic nerves fiber [4].

Then, Grimnes in 1982 stated that the sweat is an electrolyte solution and stuffing of the sweat ducts gives a major conductive contribution to the electrical admittance. While in year 2001, Martisen and Grimnes again declared that the capacitive part represents the stratum corneum (SC) moisture content. Since the measurement is dominated by the impedance contribution from SC, in order to define the correlation between signal to noise ratio and system linearity, the low frequency and extremely low voltage is being used [6].

2.1.2 Skin Dielectric Properties

Since the galvanic skin sensor (GSR) is required to capture and measure the skin conductance, thus the skin dielectric properties are needed to be studied. Essentially, from the previous studies, the human skin is differing into three specific layers which are epidermis, dermis, and hypodermis tissue. However, different part of the outer layer of human skin(epidermis) has a different thickness. The thinnest layer recorded is on the eyelids approximately at 0.05mm and the thickest is on the palm and soles recorded approximately at 1.5mm [7]. There are also different layers of the epidermis, however, for the outermost layer, the stratum corneum(SC) contributes an enormous amount of dielectric properties for the skin. It is crucial to obtain the measurement of the dielectric of the skin in order to implement a stable and reliable interface between the sensor and the skin. The dielectric response of the skin had been attributed to the changes in dielectric polarization. This will lead to a variation in blood glucose concentration [7].