DEVELOPMENT OF A DIABETIC CARE SYSTEM BASED ON IOT AND ANDROID APPLICATION PACKAGE

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DEDICATION

To my beloved parents,

Nadzri bin Othman and Faeza binti Abdul Wahab who consistently provide me their moral, spiritual, emotional, and financial support, who have inspired me and given me courage when I felt like giving up.

ABSTRACT

Diabetes is a chronic illness that has grown to be a major global health concern, particularly in Malaysia. Over time, Malaysia's diabetes prevalence has been rising significantly, placing a heavy burden on both the afflicted individuals and the healthcare system. This report presents the development and implementation of a smart health monitoring system designed for diabetes management using non-invasive blood glucose monitoring techniques integrated with Internet of Things (IoT) technology. The system utilizes MAX30102 sensor, LCD display, and ESP32 module to provide real-time glucose level monitoring and data transmission to an Android application. The study includes a comprehensive literature review on recent advancements in non-invasive blood glucose monitoring devices, emphasizing their interoperability with IoT platforms. The methodology involves designing a user-friendly interface for continuous monitoring and educating patients through an Android app with modules on diagnosis, management, healthy lifestyle, physical activity, and complication prevention. The results show that the MAX30102 sensor and ESP32 module used in the designed system provide precise and dependable real-time glucose monitoring. Continuous monitoring and patient education are made possible by the system's successful transmission of glucose data to the Android application. According to performance reviews, the non-invasive monitoring approach ensures patient comfort and compliance while offering promising accuracy when compared to traditional approaches. To sum up, by improving patient outcomes and encouraging proactive disease management, the combination of IoT with non-invasive glucose monitoring offers a practical and creative approach to current diabetes care.

ABSTRAK

Diabetes adalah penyakit kronik yang telah berkembang menjadi kebimbangan kesihatan global utama, khususnya di Malaysia. Dari masa ke masa, kelaziman diabetes di Malaysia telah meningkat dengan ketara, meletakkan beban berat kepada kedua-dua individu yang menderita dan sistem penjagaan kesihatan. Laporan ini membentangkan pembangunan dan pelaksanaan sistem pemantauan kesihatan pintar yang direka untuk pengurusan diabetes menggunakan teknik pemantauan glukosa darah bukan invasif yang disepadukan dengan teknologi Internet of Things (IoT). Sistem ini menggunakan penderia MAX30102, paparan LCD dan modul ESP32 untuk menyediakan pemantauan tahap glukosa masa nyata dan penghantaran data kepada aplikasi Android. Kajian itu termasuk tinjauan literatur yang komprehensif tentang kemajuan terkini dalam peranti pemantauan glukosa darah bukan invasif, menekankan kesalingoperasian mereka dengan platform IoT. Metodologi ini melibatkan mereka bentuk antara muka mesra pengguna untuk pemantauan berterusan dan mendidik pesakit melalui apl Android dengan modul mengenai diagnosis, pengurusan, gaya hidup sihat, aktiviti fizikal dan pencegahan komplikasi. Keputusan menunjukkan bahawa sensor MAX30102 dan modul ESP32 yang digunakan dalam sistem yang direka bentuk menyediakan pemantauan glukosa masa nyata yang tepat dan boleh dipercayai. Pemantauan berterusan dan pendidikan pesakit dimungkinkan oleh kejayaan penghantaran data glukosa sistem kepada aplikasi Android. Menurut ulasan prestasi, pendekatan pemantauan bukan invasif memastikan keselesaan dan pematuhan pesakit sambil menawarkan ketepatan yang menjanjikan jika dibandingkan dengan pendekatan tradisional. Ringkasnya, dengan meningkatkan hasil pesakit dan menggalakkan pengurusan penyakit proaktif, gabungan IoT dengan pemantauan glukosa bukan invasif menawarkan pendekatan praktikal dan kreatif untuk penjagaan diabetes semasa.

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IoT	-	Internet of Things
NHMS	-	National Health and Morbidity Survey
NDR	-	National Diabetes Registry
T2DM	-	Type 2 Diabetes Mellitus
NIRS	-	Near-Infrared Reflectance Spectroscopy
ISF	-	Interstitial Fluid
PCP	-	Primary Care Provider
NIBGM	-	Non-Invasive Blood Glucose Monitoring
InGaAs	-	Indium Gallium Arsenide
NIR	-	Near-Infrared
VNA	-	Vector Network Analyzer
MCU	-	Microcontroller Unit
IDE	-	Integrated Development Environment
WHO	-	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Diabetes is a chronic metabolic disorder characterized by elevated levels of blood glucose. Diabetes can lead to long-term harm to vital organs such as the heart, blood vessels, eyes, kidneys, and nerves. Type 2 diabetes, the most common form of the disease, typically affects adults and is caused by inadequate or resistant insulin synthesis in the body. During the past three decades, the prevalence of type 2 diabetes has significantly increased in all countries, irrespective of their economic status. Diabetes type 1 is a persistent medical condition characterized by insufficient natural production of insulin by the pancreas. Previously, it was known as juvenile diabetes or insulin-dependent diabetes. Accessible and affordable therapy, such as insulin, is crucial for the survival of individuals with diabetes. By 2025, there is a global objective to halt the increase in diabetes and obesity[1].

The entire process of obtaining a blood sample from a finger is invasive, causing pain and carrying a risk of infection. Therefore, the need for non-invasive and continuous monitoring of blood sugar levels is of utmost importance. Our goal is to create an application that utilizes IoT devices to monitor blood glucose levels. Additionally, the application will offer an educational module for individuals living with diabetes. Users will be granted access to a module that contains comprehensive information about diabetes. Integrating IoT into this system enables real-time monitoring for users and healthcare providers, allowing continuous monitoring of blood glucose levels day and night. The application enables users to easily access the system.

This project addresses the educational needs of people with diabetes by developing an IoT-enabled diabetes care system. This will empower individuals to more effectively control their condition, enhance their well-being, and experience an elevated standard of living.

1.2 Societal Issue for Development of a Diabetic Care System Based on IoT and Android Application Package

The purpose of developing a diabetic care system and an Android application is to improve patient care and management by offering easily accessible diabetes education and expanding healthcare systems with features like remote monitoring and data-driven insights. By offering information on diabetes management, this system addresses the societal issue of access to healthcare. Healthcare services, particularly specialized treatments such as diabetes control, are not widely accessible in many regions of the world. In order to ensure that even people in remote places may obtain prompt support and guidance, an IoT-based system combined with an Android application can close this gap by offering remote monitoring and consultation capabilities.

Furthermore, this system contributes to achieving poverty-free goals. By integrating technology into healthcare systems, this project ensures that all individuals have access to basic healthcare services, including those who are in low-income areas. The affordability and scalability of mobile and IoT-based devices can provide those essential services to those who might not be able to afford them.

In addition, this project plays a significant role in achieving the quality education goal. This is because the project has developed an application that helps promote health education and awareness for diabetes patients. The application includes educational content about managing diabetes, eating habits, healthy lifestyle choices, and the importance of regular monitoring.

1.3 Problem Statement

The World Health Organization (WHO) reports that over 422 million individuals worldwide are suffering from a diagnosis of diabetes. Moreover, it is a prominent contributor to mortality worldwide, causing 1.6 million fatalities caused by this disease. Over the past few decades, the incidence of diabetes has increased. According to the International Diabetes Federation (IDF) Diabetes Atlas, it is projected that about 700 million individuals will be affected by diabetes by the year 2045. In 2019, the Ministry of Health (MOH) in Malaysia issued the National Health and Morbidity Survey (NHMS), which indicated that around 3.9 million individuals aged 18 and older were affected by diabetes. Based on the NHMS 2019 report, nearly half (49%) of individuals with diabetes had not attended any medical examination or acquired a formal diagnosis for this long-term health problem. The diagram below displays the statistical data regarding patients diagnosed with diabetes[2].

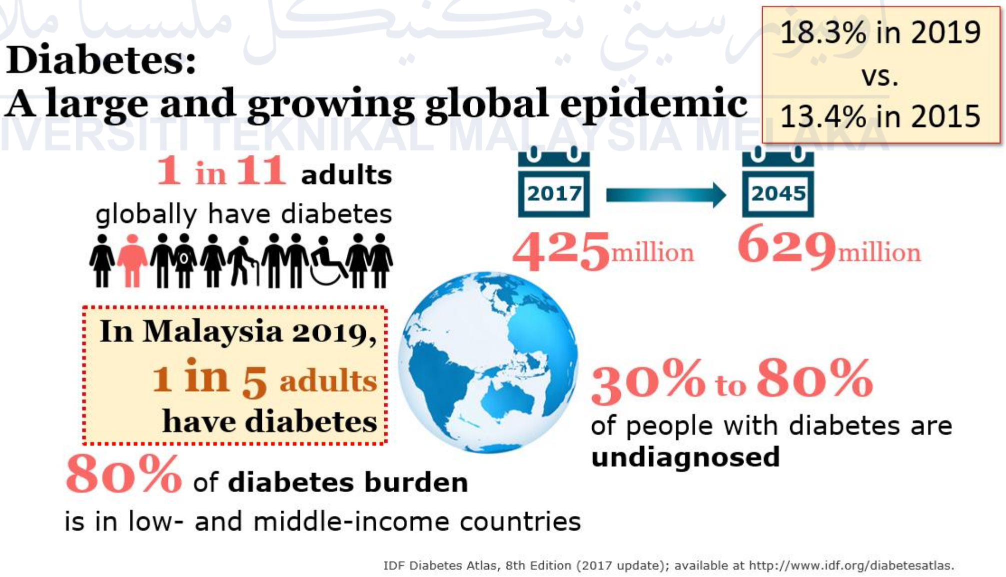

Figure 1.1: Statistics of diabetes.

The goal of creating a diabetic care system utilizing IoT technology and an Android application package is to overcome significant barriers in diabetes management. Individuals with diabetes still face significant challenges in accessing suitable and affordable treatment options, despite the progress made in medical technology. A primary issue arises from the challenge of obtaining diabetes education due to constraints on healthcare access, such as a lack of specialized medical facilities and financial limitations. This increases the likelihood of complications and leads to inadequate medical care[3].

Moreover, the problem of diabetes sufferers is that they lack of knowledge and instruction about blood sugar monitoring, taking prescribed medications, and also behavioral changes, which leads to poor self-care habits and detrimental health effects. Many people do not have a thorough understanding of how to successfully manage diabetes. The difficulties that patient with diabetes encounter are made worse by this lack of information and education, which raises the entire cost of the condition[4].

Lastly, effective connection and communication between diabetes patients and healthcare providers is also essential for successful education and self-management. Unfortunately, this relationship is restricted by the short consultation times in typical healthcare settings. Effective education and self-management initiatives are constrained by the inability to establish trustworthy patient-provider connections and the absence of continuing support. Improving support systems and communication are crucial for addressing these issues and improving the provision of diabetes care[5].

1.4 Project Objectives

To successfully finish this project, certain objectives must be accomplished. The objectives are:

a) To develop a system that can monitor blood glucose level using non-invasive method based on IoT.
b) To develop an application that can monitor blood glucose level as well as providing information such as education module for patient living with diabetes.
c) To evaluate the data performance of the blood glucose level.

1.5 Scope of Project

The project covers the following scope:

a) Development of a system that can monitor blood glucose level.
b) Development of an application that can monitor blood glucose level for patient living with diabetes.
c) Providing information about diabetes in the application so that users can gain more knowledge from the apps.
d) Integrating IoT to a system by using ESP32 for glucose monitoring.
e) The data will be transmitted to Blynk for the purpose of monitoring the blood glucose level and conducting additional analysis and graphical representation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This review of the literature delves into the initiatives, studies, and research that have already been done on Malaysians who are struggling with diabetes management. This review attempts to highlight the gaps in existing knowledge that need to be filled in order to shed light on the difficulties of diabetes self-regulation among Malaysians, by combining and evaluating findings from numerous scholarly publications.

2.2 Understanding Current Issue in the Literature

This section will examine the available literature to understand the present problems associated with diabetes care systems, with a specific focus on the integration of IoT and Android application packages. Managing diabetes is a substantial worldwide health obstacle, and the progress of technology presents encouraging alternatives to enhance patient outcomes and the efficiency of care.

Through an analysis of recent studies and publications, our objective is to determine the primary obstacles and constraints in existing diabetic care systems. These encompass concerns regarding the continuous monitoring of glucose levels, the precision of data, user involvement, the protection of data privacy, and the smooth incorporation of IoT devices into mobile applications. Gaining a comprehensive understanding of these difficulties is essential in order to create a strong and efficient system for caring for diabetics that takes advantage of the most recent technology breakthroughs.

The knowledge acquired from the literature will guide the creation and advancement of our proposed system, guaranteeing that it effectively tackles the essential requirements and worries of both patients and healthcare providers. This literature analysis will establish the groundwork for developing a complete, user-friendly, and secure diabetic care solution using IoT and Android technologies.

2.3 Introduction of Diabetes

Diabetes is a chronic condition characterized by elevated levels of blood glucose. Glucose serves as the primary fuel for our body. Glucose is naturally synthesized by our body, but we can also obtain it by consuming food. The pancreas produces insulin, a hormone that enables glucose to enter cells for energy consumption. Individuals with diabetes suffer from insufficient insulin synthesis or usage within their bodies. Glucose persists in the bloodstream and is unable to reach the cells. Diabetes increases the likelihood of experiencing harm to the eyes, kidneys, nerves, and heart. There is a correlation between diabetes and some types of cancer. Adopting steps to prevent or control diabetes can decrease the chances of experiencing complications associated with the disease[6].

By the end of the reporting year in 2020, the National Diabetes Registry (NDR) had a total of 1,698,683 registered patients, out of which 902,991 were actively diagnosed with diabetes. The NDR study mostly included patients diagnosed with type 2 diabetes mellitus (T2DM) (99.33%), whereas type 1 diabetes mellitus accounted for just 0.59% of cases. The remaining cases were classified as other kinds of diabetes (0.06%)[7]. Figure 2.1 displays the characteristics of the patients.

Age Group (at Enrollment, years)		
<18	5,271	0.31
18-19	2,657	0.16
20-24	11,003	0.65
25-29	28,649	1.69
30-34	59,853	3.52
35-39	104,734	6.17
40-44	170,300	10.03
45-49	237,865	14.00
50-54	291,474	17.16
55-59	281,759	16.59
60-64	216,957	12.77
65-69	144,782	8.52
70-74	84,326	4.96
75-79	40,351	2.38
>80	18,702	1.10
Total	1,698,683	100.00
Type of Diabetes		
Type 2	1,687,384	99.33
Type 1	10,184	0.59
Others/Unknown	1,115	0.06
Total	1,698,683	100.00

Figure 2.1: Characteristics of patients enrolled in NDR, 2020

17.16% of the total patients participating in NDR were diagnosed with diabetes between the ages of 50 to 54. The age categories that followed in frequency were 55–59 (16.59%) and 45–49 (14.00%). Figure 2.2 illustrates the distribution.

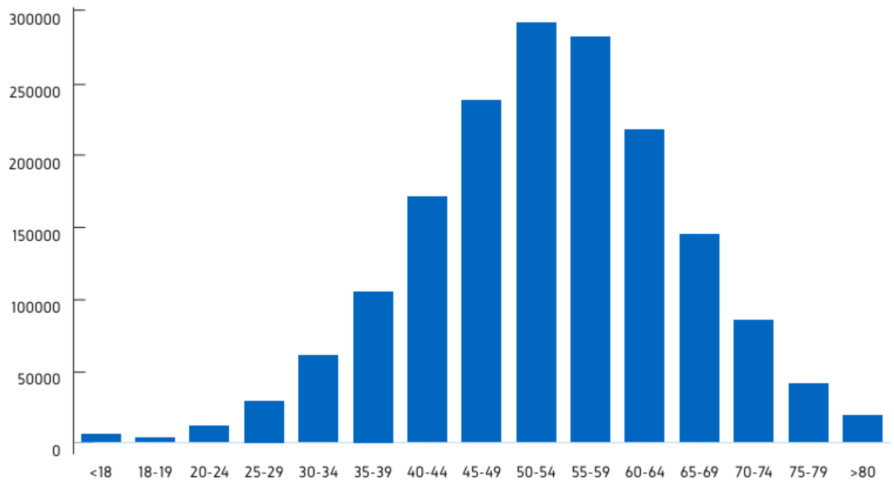

Figure 2.2: Distributions of T2DM patients according to age at diagnosis.

The acceptable blood glucose levels are determined by variables such as the time of day and the duration since the most recent meal. According to the guidelines provided by the National Institute of Diabetes, Digestive, and Kidney Diseases (NIDDK), it is critical to maintain ideal blood sugar levels to fulfil your organs' sugar requirements and avoid signs of hyperglycemia or diabetes complications. Blood glucose levels that deviate from this range are deemed detrimental[8]. Figure 2.3 displays the blood glucose levels for normal, prediabetes, and diabetes in individuals with T2DM[9].

Type 2 Diabetes Mellitus

Diagnosis

	Hemoglobin A1C (HbA1c)	Fasting Blood Sugar Test	Oral Glucose Tolerance Test	Random Blood Sugar Test
Normal	< 5.7%	< 100 mg/dL	< 140 mg/dL	N/A
Prediabetes	5.7 - 6.4%	100 - 125 mg/dL	140 - 199 mg/dL	N/A
Diabetes	≥ 6.5%	≥ 126 mg/dL	≥ 200 mg/dL	≥ 200 mg/dL

Figure 2.3: Blood glucose levels for individuals with normal, prediabetes, and diabetes in T2DM.

2.3.1 Type 1 Diabetes

Diabetes type 1 is a long-term medical illness. This is a situation where the pancreas produces less or no insulin. Insulin is a hormone that helps the body produce energy by facilitating the movement of glucose into cells. Type 1 diabetes can be caused by a variety of factors, including viruses and genetic factors. Type 1 diabetes usually appears during infancy or adolescence, but it can also emerge in adults. Despite extensive research, type 1 diabetes remains an incurable condition. In order to prevent complications, the treatment primarily aims to regulate blood glucose levels through the use of insulin, dietary management, and lifestyle modifications[10].

2.3.2 Type 2 Diabetes

Type 2 diabetes is primarily caused by the body's inability to control and use sugar as an energy source. The blood becomes too sugary as a result of this long-term sickness. Elevated blood sugar levels can eventually lead to problems with the brain system, immune system, and cardiovascular system. Although both types 1 and 2 diabetes can occur in infancy or adulthood, type 2 diabetes was once thought to only affect adults. Type 2 diabetes is more common in older people. However, the prevalence of type 2 diabetes in young people has increased, as has the number of obese youngsters[11].

2.3.3 Gestational Diabetes

Gestational diabetes is defined as the onset of diabetes during pregnancy. Gestational diabetes affects the way in which your cells metabolize glucose. Gestational diabetes results in elevated blood glucose levels, posing risks to both the pregnancy and the well-being of the infant. Throughout pregnancy, patients can manage gestational diabetes by adhering to a healthy diet, engaging in physical activity, and, if necessary, taking medication. Maintaining optimal blood sugar levels is crucial for ensuring the well-being of both the patient and the baby, as well as minimizing the risk of a difficult childbirth[12].

2.4 Methods for Diagnosing Blood Glucose Concentration

Blood glucose concentration measurement is an important assessment for managing metabolic disorders and diabetes. These methodologies can be broadly classified into two categories: invasive and non-invasive.

2.4.1 Invasive Blood Glucose Monitoring

Both hospitals and household glucometers currently utilize the widely used, convenient, and user-friendly invasive blood glucose measurement approach. The process includes initially extracting blood samples, which are subsequently examined to measure blood glucose levels. Hospitals use an automated biochemical analyzer to accurately assess people's fasting blood glucose levels by collecting blood samples in the morning. This method is not appropriate for continuous monitoring of individuals with diabetes because of its labour-intensive procedure, lengthy detection time, and significant requirement for extracting venous blood. However, the data obtained from this method is accurate and can provide a valuable basis for diagnosing diabetes. However, the majority of home blood glucose monitors utilize glucose oxidase biosensors. These monitors extract blood from the fingertip using a disposable paper strip, and then use the strip's chemical reaction current to determine the amount of glucose in the blood. Deep skin punctures will occur as each test necessitates the extraction of a precise blood volume from the fingertips. The higher frequency of blood collection has impacted the rapid healing of patients' fingertip wounds. Prior to the daily blood collection, the patient would experience intense discomfort, significant levels of tension, and an increased susceptibility to getting infections from the environment[13].

2.4.2 Non-Invasive Blood Glucose Monitoring

Non-invasive blood glucose monitoring refers to measuring glucose levels in the circulatory system without causing any damage to human cells. Non-invasive blood glucose measurement includes several techniques that can be categorized into optical, microwave, and electrochemical technologies. Optical techniques encompass near-infrared reflectance spectroscopy (NIRS), polarized optical rotation, Raman spectroscopy, fluorescence, optical coherence tomography (OCT), and other associated technologies. In addition to being present in human blood, substantial amounts of glucose can also be detected in many other biofluids, such as saliva, tears, perspiration, and interstitial fluid (ISF). The electrochemical method typically tracks glucose levels in bodily fluids and indirectly calculates the blood glucose value by calibrating the algorithm or data model. This is possible due to the reliable association between biofluids and blood glucose levels. The glucose levels in ISF closely correspond to the levels of glucose in the blood, both in healthy individuals and those with diabetes. This similarity provides a foundation for the analytical development of an ISF glucose sensor. Multiple research studies have shown a delay in the correlation between ISF glucose and blood glucose levels. Changes in blood glucose levels are manifested in ISF with a delay of around 4–10 minutes. Transdermal biofluid extraction commonly employs reverse iontophoresis (RI) technology to effectively and rapidly extract ISF[13].

2.5 Recent Applications of Diabetic Management

Various sectors have implemented the expanding field of mobile health (mHealth), covering health education, support for changes in behavior, and self-management of chronic diseases. mHealth, as defined by the US Food and Drug Administration (FDA), encompasses the delivery of healthcare services and the improvement of health outcomes using mobile and wireless technologies. Short message service text messaging, smartphone applications, and wearable technology are common methods used in mHealth interventions. MHealth is a constituent of digital health, often known as electronic health (eHealth), which includes health information technology, telemedicine, and personalized medicine[14].

Primary care providers (PCPs) who take care of diabetes patients may benefit from and face challenges from the rapid development of digital health apps. PCPs must know about these apps in order to properly educate their patients. But it's hard for them to get the right training and deal with problems that include app accuracy, clinical validity, and information quality. Some technological problems include the fact that iOS and Android cannot operate together, there are not enough common data sources, and sharing data is not always possible. But even with these problems, health apps can help a lot with managing diabetes. Table 1 shows a number of important aspects and traits of commonly used diabetes apps[15].

App	Platform*	Type	Cost	Patient Benefits	HCP Benefits
ADA SOC	Apple/Android	Medical care recommendations	Free	–	• Full access to ADA Standards of Care • Online Web app available • Interactive tools for evidence-based decisions • Quick access to the summary of new revisions to the Standards of Care • Classifications for diabetes type and special populations
OneTouch Reveal	Apple/Android	Glucose tracking	Free	• Wireless data pairing • Glucose alerts • Food, medication, and activity tracking	• Data sharing • HCP reports
My Sugr	Apple/Android	Glucose tracking	Basic: free; premium: My Sugr PRO $27.99/year subscription; coaching plans: $19.99-$399.99	• Wireless data pairing • Medication and carbohydrate tracking	• HCP reports • A1C prediction
iHealth Gluco-Smart	Apple/Android	Glucose tracking	Free; requires iHealth Gluco-Monitoring System	• Wireless data pairing • Diet and activity tracking	• Data sharing • Secure Cloud data storage

Figure 2.4: An overview of the key features and characteristics of frequently used diabetes application[15].

2.6 Literature Review Based on Several Research Paper

This review of the literature looks at new developments in non-invasive blood glucose monitoring (NIBGM) technology, with an emphasis on how these devices integrate with the IoT. It investigates the advantages and difficulties of integrating these devices into IoT systems and assesses the efficacy and accuracy of various NIBGM technologies and approaches. Through an examination of ongoing research and development, the aim is to provide thorough knowledge of the advancements and future potential of NIBGM in the context of the IoT.

The study by [16] examines non-invasive near-infrared spectroscopy as a more pleasant option for finger pricks in blood glucose monitoring. It measures glucose levels via light absorption in the finger using a portable device with a 1023 nm LED transmitter and an Indium Gallium Arsenide (InGaAs) photodiode. The results indicate a strong linear relationship between voltage and glucose content, with environmental factors and skin thickness influencing the inaccuracy by up to 25% when compared to invasive approaches. By using WiFi to connect to a smartphone app, the device reduces the chance of discomfort and infection. Although additional research is required for practical validation, future advancements aim to increase accuracy and penetrate deeper into the system.

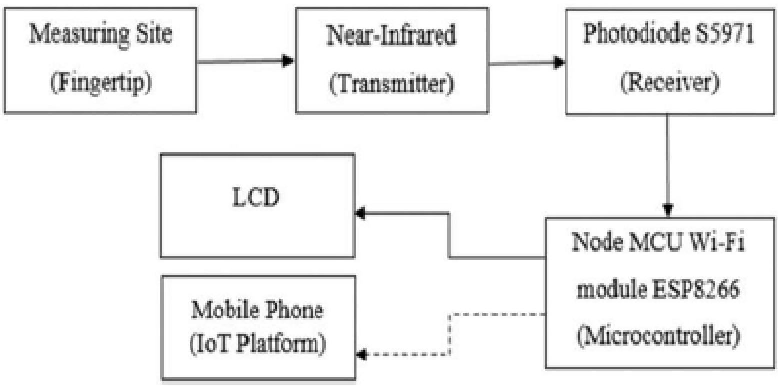

Figure 2.5 Block diagram for the proposed system[16].

In a study published in [17] , non-invasive blood glucose monitoring approaches such as breath acetone sensors and near-infrared (NIR) methods are examined. It shows a better, non-invasive way to measure transmittance through the finger using a 650 nm red laser (RL-BGM), which it says has 30 times more transmittance than NIR methods. The RL-BGM measures laser intensity using a phototransistor, then processes the data to estimate glucose levels using a microprocessor. The system, which uses five finger scans, outperforms NIR and breath acetone approaches with an accuracy of 90–92%.

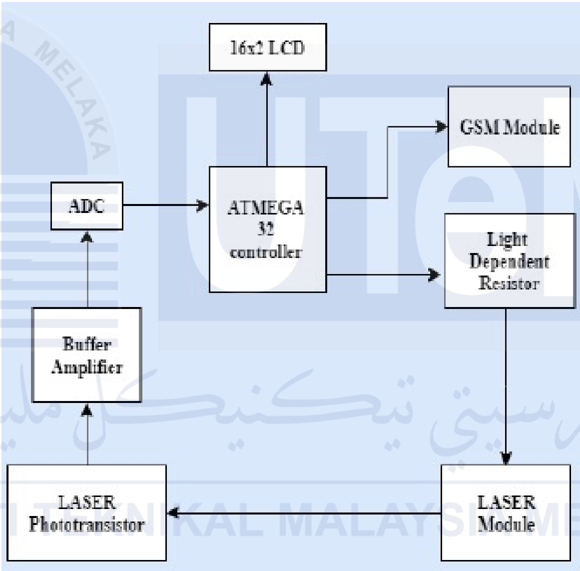

Figure 2.6 Block diagram of RL based BGM[17]

The study in [18] emphasizes the importance of diabetes mellitus as a serious illness that necessitates continuous blood glucose monitoring. Traditional procedures utilizing invasive finger pricks have resulted in a desire for noninvasive monitoring devices. This paper describes a unique prototype that uses Raspberry Pi, a portable camera, and a visible light laser to assess glucose content using an artificial neural network model. The pilot test findings reveal significant accuracy rates of 79% from finger pictures and 62% from ear images, indicating that the prototype has the potential for noninvasive monitoring applications. While considering constraints such as dataset size and other variables, the study underlines the need for more research to improve the prototype's dependability and usability, resulting in a more convenient and effective diabetes management solution.

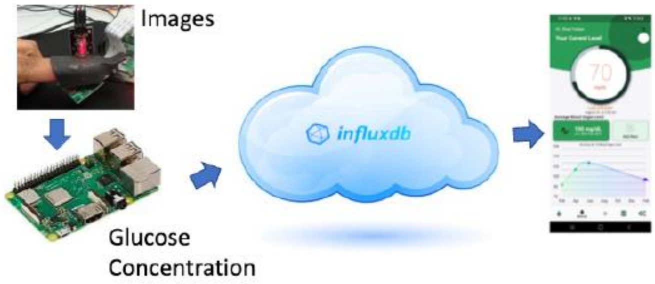

Figure 2.7 Overview of the proposed non-invasive blood glucose monitoring system[18].

Another study by [19] describes a new IoT-based system for non-invasive blood glucose monitoring using the Raspberry Pi Zero, which includes a visible laser beam and a Raspberry Pi Camera incorporated into a glove for data collection. The system consists of four stages: data acquisition, image processing, data analysis using an artificial neural network, and glucose level estimation. It has shown promising accuracy when validated against laboratory blood tests, with a mean absolute error of 10.37% and 90.32% accuracy in zone A of the Clarke grid. The combination of IoT technology, artificial neural networks, and non-invasive optical analysis demonstrates high scalability and potential for improving healthcare management by providing a convenient and efficient solution for continuous blood glucose monitoring, with implications for personalized healthcare and remote health monitoring.

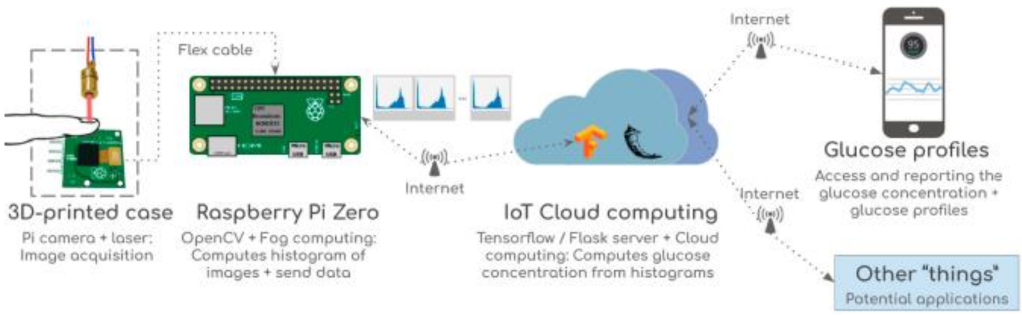

Figure 2.8 Diagram of the proposed IoT system[19].

The work by [20] uses infrared spectroscopy and a finger plethysmograph. An Arduino microcontroller determines the glucose levels, while a MAX30100 sensor detects reflected light from an infrared LED pointed at the fingertip. The results are transmitted wirelessly over Bluetooth and shown on an LCD. The approach closely matched invasive finger prick tests, with percentage differences ranging from 1.09% to 11.22%, according to testing on five subjects. They suggest that this infrared sensor technology could be a good, low-cost alternative to regular glucometers. However, more research is needed to confirm its effectiveness when compared to other non-invasive methods and with larger sample sizes.

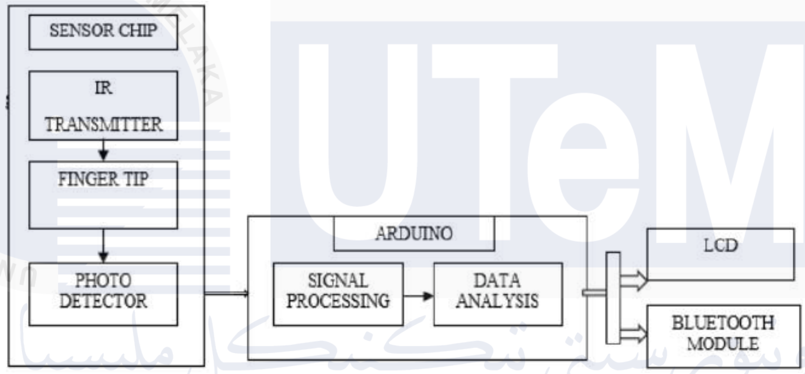

Figure 2.9 Block diagram of the proposed system[20].

Another study by [21] describes an intelligent IoT system built for remote monitoring of diabetic patients, with a focus on reliable data processing and diagnostics. The process involves developing a system that integrates sensors for monitoring glucose levels and body temperature. Data is classified using machine learning algorithms such as naïve Bayes, J48, ZeroR, random tree, sequence minimal optimization (SMO), and OneR. The system provides advanced features such as interoperability, local storage, and data processing to help predict and identify abnormal conditions. The system's performance is tested, and the J48 algorithm shows the highest accuracy, sensitivity, and precision in identifying glucose level data. The study demonstrates the system's ability to provide real-time monitoring, predictive analysis of glucose levels, and notifications for abnormal circumstances, emphasizing its potential to improve diabetes treatment and diabetic patients' quality of life.

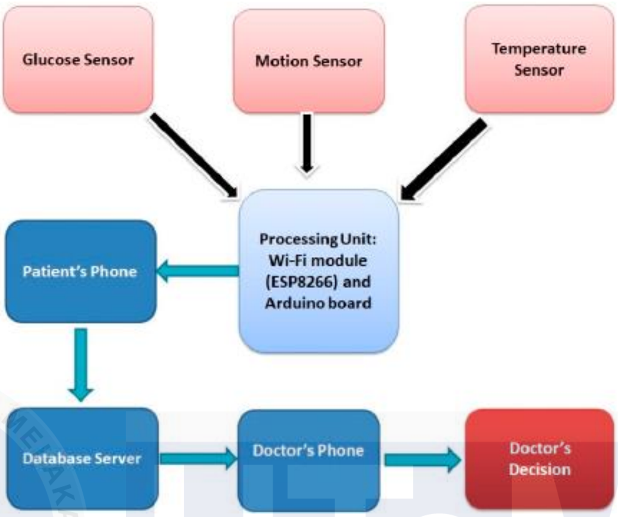

Figure 2.10 Hardware block diagram of the proposed system[21].

A study by [22] utilized near-infrared (NIR) optical technology with a light source with a wavelength of 940 nm. By detecting changes in light absorption brought on by glucose molecules, the device, which consists of an NIR emitter and receiver on either side of a fingertip, measures blood glucose levels. The results indicate that, when compared to invasive techniques, the method achieves above-85% accuracy. This NIR technique has the potential to be an acceptable alternative to conventional finger-prick procedures by providing diabetes patients with a convenient, affordable, and infection-free option.

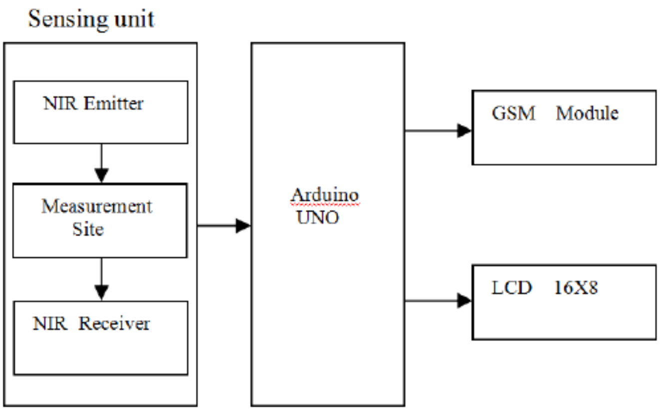

Figure 2.11 Block diagram of proposed methodology[22].

The study in [23] describes an IoT-based glucose monitoring system designed to protect senior individuals with diabetes from implications. The components of the system include a router, a Raspberry Pi-based server, a web server for data display, a NodeMCU Internet of Things device, and a wireless sensor worn by the patient. In order to assess previous readings and determine probable critical conditions, the system use a double moving average technique. To identify critical conditions and alert caretakers beforehand, the system computes averages and trends based on historical readings. By alerting family members and healthcare professionals before blood glucose levels higher than specified levels, the system seeks to deliver timely notifications and avoid unneeded alarms. Excellent results in terms of error rates and predictive powers were observed when the suggested architecture and algorithm were assessed for accuracy and compared with the exponential smoothing technique. The study underlines the value of early diagnosis and intervention in the successful management of diabetes and the potential of IoT technology to enhance glucose monitoring for senior patients.

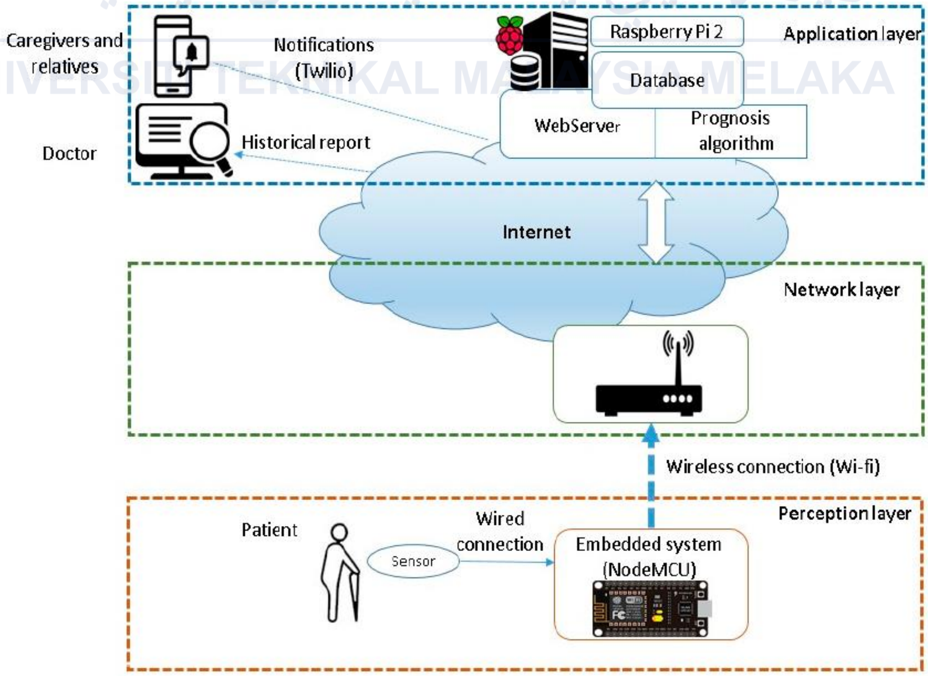

Figure 2.12 System architecture of the proposed system[23].

The work by [24] introduces a non-invasive sensor that is very sensitive and capable of detecting glucose levels in interstitial fluid in real-time. The system consists of a chip less tag sensor that may be attached to the patient's skin, as well as a reader that is inserted into a smartwatch. The tag sensor is energized through electromagnetic induction from the reader, and its frequency characteristics are manifested in the reader's spectrum. The tag sensor is free of any operational reading or communication circuits, resulting in a complete absence of power consumption. The sensor demonstrated a high level of precision in measuring glucose concentrations within the physiological range, with an accuracy of approximately 1 mM/l. Additionally, it exhibited a resonance frequency shift of 38 kHz. High sensitivity can be achieved by implementing the proposed novel design and increasing field concentration on the tag.

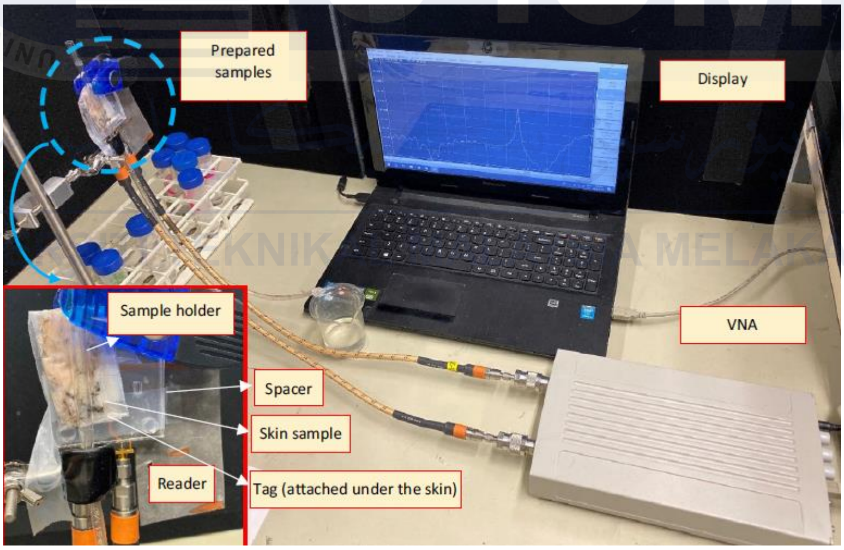

Figure 2.13 The experimental setup consists of a sensor structure, a skin sample, a holder and fixture, a VNA (Vector Network Analyzer), and its interface, the S2 VNA Windows Software[24].

The study by [25] presents a new method for monitoring diabetic patients by utilizing IoT technology and machine learning techniques. The system incorporates sensors for quantifying glucose levels, heart rate, and body temperature, with the collected data transferred to a central unit by Node MCU. Machine learning techniques like Naive Bayes, Support Vector

Machine, Random Forest, and Simple CART are used to analyze data and predict the diabetic condition of patients. The study assesses the effectiveness of the system in predicting diabetic conditions by analyzing parameters such as accuracy and sensitivity. The results demonstrate the system's capacity to enhance patient care by identifying health issues at an early stage and tailoring treatment approaches to individual needs.

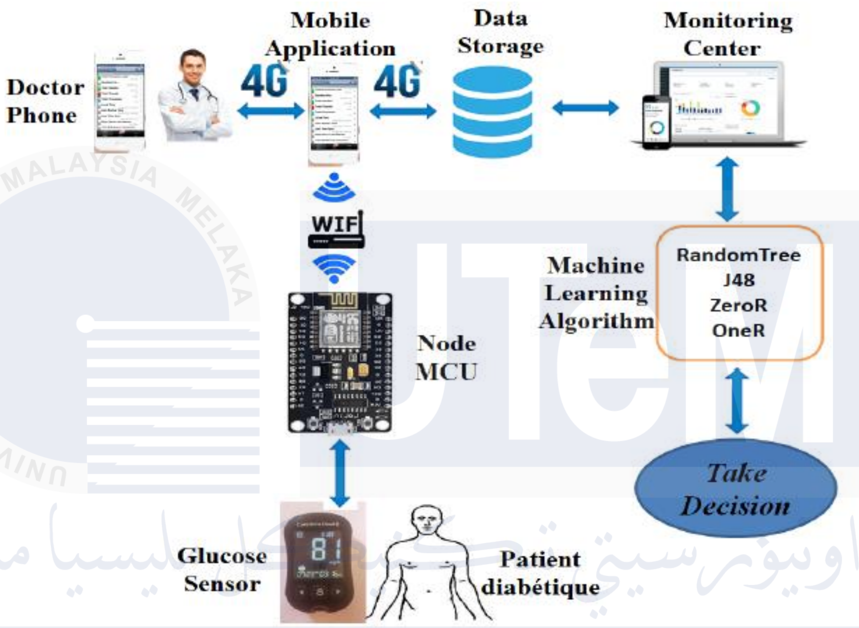

Figure 2.14 System overview of the proposed system[25].

Another study by [13] offers a thorough analysis of developments in non-invasive glucose monitoring. This study emphasizes the need for better monitoring techniques by highlighting the discomfort and shortcomings of the present Self-Monitoring Blood Glucose (SMBG) methods. Optical, microwave, and electrochemical techniques for non-invasive glucose detection are evaluated as part of the methodology, with wearable biosensors and microfluidic devices receiving particular attention for continuous monitoring. The results demonstrate a remarkable advancement in the development of real-time monitoring systems that provide improved glucose detection accuracy and dependability. Regarding obstacles such as individual variability and algorithmic errors, the review highlights the revolutionary potential of non-invasive monitoring technology in the management of diabetes, urging interdisciplinary cooperation that will drive additional progress in the area.

Then, another study by [26] describes a wearable-band type visible-near infrared optical biosensor developed for non-invasive blood glucose monitoring, which addresses the global challenge of diabetes management. To avoid complications, diabetes patients must monitor their blood glucose levels on a regular basis, and the biosensor intends to provide a cost-effective and highly wearable option for continuous monitoring. The biosensor uses visible-near infrared spectroscopy to analyze arterial blood volume pulsation in wrist tissue, providing a new approach for determining blood glucose concentration. In-vivo trials on 12 volunteers during carbohydrate-rich meals produced good results, with an average correlation value of 0.86 and a standard prediction error of 6.16 mg/dl. A full-day testing confirmed the biosensor's dependability, demonstrating its potential for long-term blood glucose monitoring. Overall, the biosensor is an important tool for diabetes care since it provides accurate and continuous blood glucose monitoring in a portable and wearable configuration.

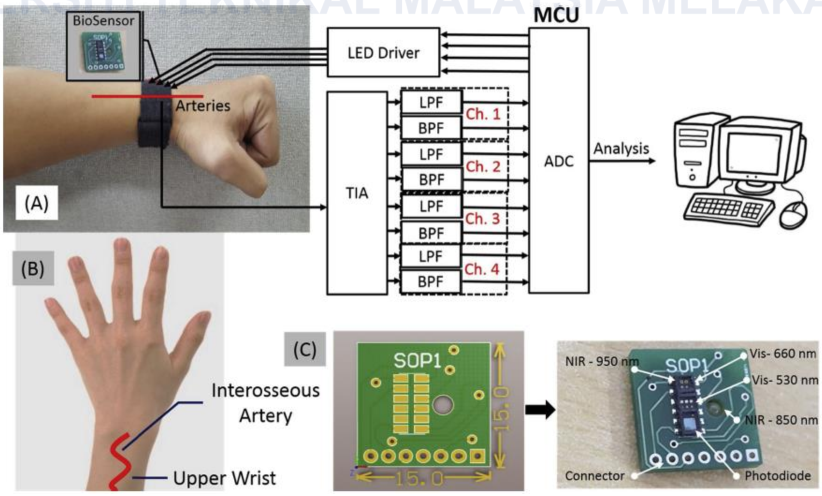

Figure 2.15 (a) An analog signal processing block diagram; (b) the location of the sensor on the subject's wrist; and (c) the PCB's overall sensor design[26].

The work by [27] explored the field of optical techniques, specifically focusing on Near-infrared Spectroscopy (NIRS), Mid-infrared Spectroscopy (MIRS), and Raman Spectroscopy. It offered a thorough evaluation of each technique's benefits and drawbacks when it comes to glucose monitoring. Because NIRS is a reasonably inexpensive and water-transparent technology, it has been shown in the study to have potential as a blood glucose measurement tool. The study also included a unique non-invasive blood glucose monitoring device that used infrared light to exhibit continuous monitoring capabilities. This device has advantages including low cost, painless operation, and a lower risk of infection issues. The results highlighted the significance of continuous improvements in non-invasive glucose monitoring technology to tackle important issues including increasing accuracy, reducing interference, guaranteeing patient safety, and boosting general comfort and economy.

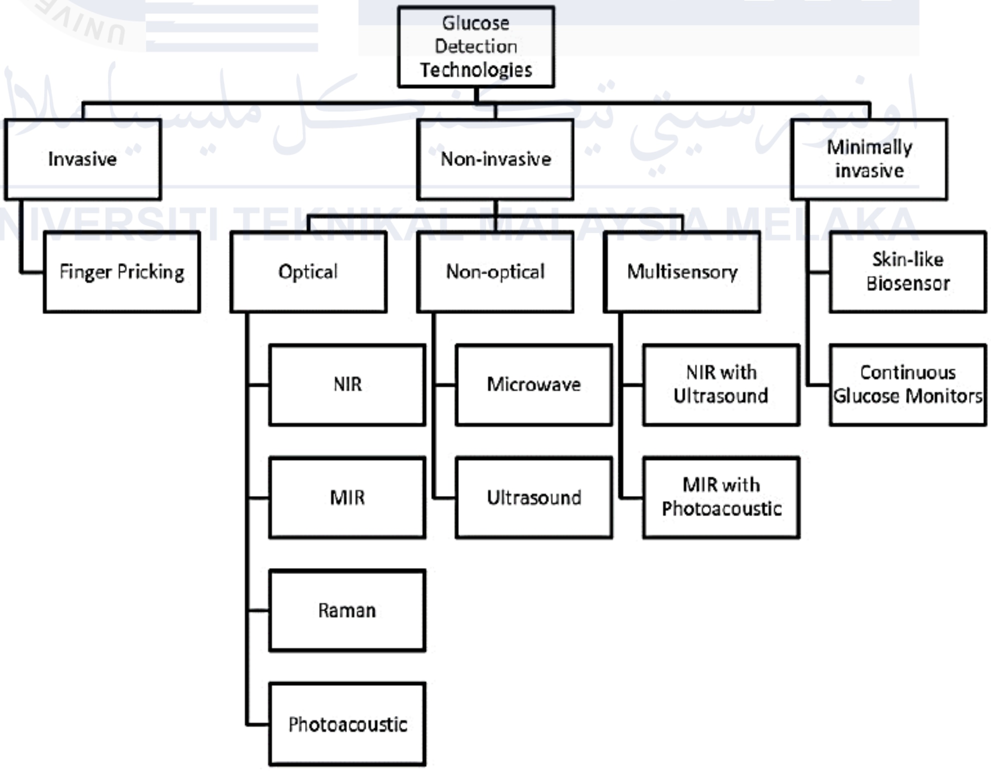

Figure 2.16 Summary of glucose detection technologies[27]

The research by [28] presents a novel approach to continuous sweat analysis using a flow-through glucose biosensor for noninvasive diabetes monitoring. The goal of the study is to find a relationship between blood glucose levels and sweating so that diabetes can be monitored in real time without the need for conventional blood draws. Prussian Blue and glucose oxidase immobilised in alkoxysilane gel or perfluorosulfonated ionomer were used in the development of the flow-through glucose biosensor. The biosensor proved to have a broad calibration range and good sensitivity, making it appropriate for ongoing sweat analysis. The noninvasive monitor was calibrated by directly applying standard glucose solutions to the skin's surface. Using a flow-through cell that mimicked the monitor, the operational stability of the biosensor was evaluated, and it demonstrated a constant response during a 25-hour operating period. The biosensor captured the dynamics of sweat glucose concentration in excellent agreement with blood glucose content without any time lag, indicating the viability of sweat analysis for noninvasive diabetes monitoring. The accuracy of the noninvasive monitoring strategy was supported by a strong correlation ($r > 0.99$) between the analytical results and monitor readings obtained from the monitor's validation utilizing a flow-injection analyzer.

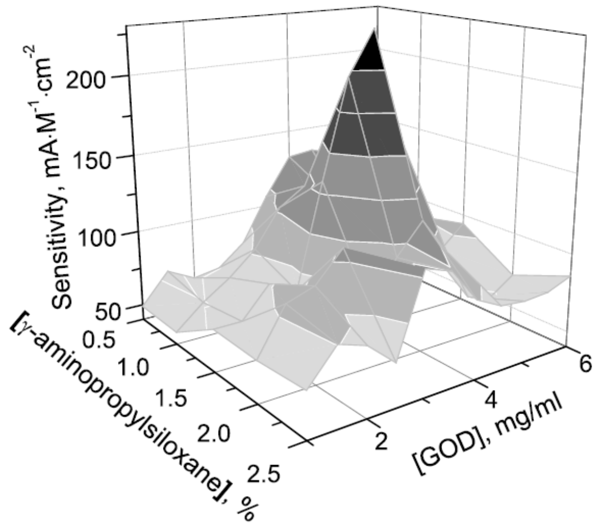

Figure 2.17 The relationship between the sensitivity of the glucose biosensor and the quantities of siloxane and glucose oxidase in the liquid used to produce the membrane[28].

Finally, another study by [29] describes a new non-invasive blood glucose monitoring gadget that uses smartphone PPG signal processing and machine learning to transform standard glucose testing methods. The system's basic methodology is to record PPG signals from smartphone camera films of the left index finger, which are then processed using a unique fitting-based sliding window algorithm that efficiently eliminates variable degrees of baseline drift and separates the signals into single periods. The system achieves an accuracy rate of 81.49% by utilizing a sophisticated machine learning classifier to categorize blood glucose levels into normal, borderline, and warning classifications. This is accomplished by extracting characteristic features from Gaussian functions and conducting a comparative analysis of PPG signals across different blood glucose levels. The results suggest that the device can precisely and immediately track blood glucose levels in a manner that is non-invasive and user-friendly. This presents opportunities for future advancements, such as investigating supplementary functionalities and incorporating deep learning methods to improve precision and efficiency in the domain of non-invasive blood glucose monitoring.

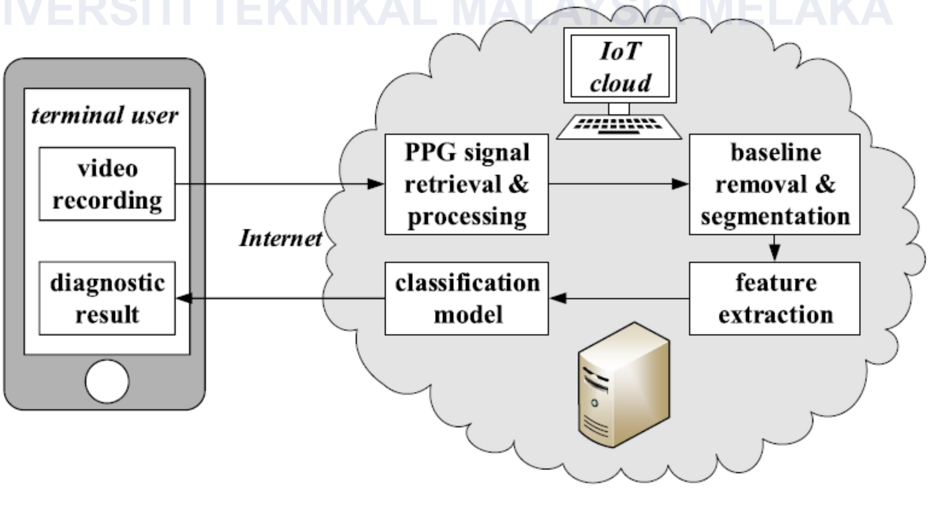

Figure 2.18 Noninvasive blood glucose monitoring system that utilizes Smartphone PPG technology[29].

2.7 Comparison of Selected Literature Review

When reviewing current literature, it is important to make some comparisons of the perspectives and findings given by different researchers. This section aims to assess the works of every different sources. By comparing all these literatures, we can acquire a better grasp of the similarities, and potential gaps in current knowledge about diabetic care system.

No.	Author	Year	Title	Components	Advantages	Summary
1.	Nur, Siti Binti Anis, Shahidah Bin Alias, Rozlan	2021	A Portable Non-Invasive Blood Glucose Monitoring Device with IoT	• IR light emitter • Photodiode S5971 • NodeMCU ESP8266 • LCD	• Used non-invasive method, reducing discomfort. • Enable real-time monitoring with healthcare providers or family members.	Researchers created a non-invasive laser sensor to test blood sugar. Diabetes patients can monitor their health with this inexpensive, reliable, and easy-to-use equipment. Improve its functionality under diverse lighting conditions. This approach may improve blood sugar management.
2.	M. Therese*, P. Dharanyadevi, Devi et al.	2020	Detection of Blood Glucose Level in Humans using Non-Invasive Method – RL BGM	• ATMEGA 32 A • LCD	• High sensitivity and selectivity. • Wearable and portable.	A finger-prick-free blood sugar measurement method is proposed in the study. Precision, portability, and practicality have been highlighted for its red laser

				• GSM MODULE • Light Dependent Resistor (LDR) • Laser Phototransistor	• Good accuracy, with precision tested using Clarke Error Grid analysis showing about 90% to 92% accuracy.	finger scan. However, it has limitations and may not benefit everyone. This technology could be used to create a diabetes management smartphone app.
3.	M. Valero et al.	2022	Development of a Non-Invasive Blood Glucose Monitoring System Prototype: Pilot Study	• Raspberry Pi camera • Laser light	• Eliminates the need for painful finger pricks. • Provides continuous monitoring of blood glucose level. • Portable	In the study, a camera and laser picture the skin and calculate blood sugar levels for non-invasive blood sugar testing. It was 79% accurate with finger photos and 62% with ear photos in eight tests. Improvements and data are needed to increase accuracy. Diabetes patients may find this method more comfortable and cost-effective.
4.	Alarcón-Paredes et al.	2019	An IoT-Based Non-Invasive Glucose	• Raspberry Pi Zero (RPi)	• Non-invasive • High scalability	A new needle-free blood sugar monitoring method has been

			Level Monitoring System using Raspberry Pi	• Visible laser beams • Raspberry Pi Camera		developed using a glove equipped with a laser and camera. The collected data is analyzed by software to determine blood sugar levels. Research suggests this method is more reliable than the conventional finger prick test, potentially making diabetes care easier and more effective.
5.	K. V Devi et al.	2021	Non-Invasive Glucose Estimation Based on Infrared using Finger Plethysmograph	• Infrared LED • Max30100 sensor • Arduino UNO • HC-05 Bluetooth Module	• Non-invasive • Continuous monitoring of blood glucose levels • Wireless data transfer	The paper describes a new finger-prick-free blood glucose monitor for diabetics. An infrared light source illuminates the fingertip; a sensor measures the reflected light; and an Arduino minicomputer estimates blood sugar levels. Experimental results strongly correlate with traditional tests, suggesting this technology

						could be a low-risk continuous glucose monitoring option.
6.	Amine Rghioui et al.	2020	A Smart Glucose Monitoring System for Diabetic Patient	• ESP8266 • Glucose sensor • Motion sensor • Arduino Nano	• Remote Monitoring • Early Detection • Secure Wireless Connection	This article highlights an innovative of blood sugar monitoring device for diabetic patients that makes use of cutting-edge technology. The system offers real-time data and remote doctor access by integrating sensors, artificial intelligence, and communication tools. It has the ability to identify abnormal glucose levels and activate preventive treatments, which may enhance the quality of life and lower medical expenses for diabetes patients.
7.	M. ud din Q	2020	GSM Based Needleless Blood	• NIR emitter	• Non-invasive	The GSM-Based Needleless Blood Glucose Monitoring

			Glucose Monitoring System	• NIR receiver • Arduino UNO • GSM Module	• Accuracy	System uses infrared light to provide a precise and non-invasive method for measuring blood glucose levels. This eliminates the necessity for unpleasant finger pricks, minimizes the risk of infections, and enables seamless data sharing with healthcare providers. This cost-effective system provides a dependable and convenient solution for measuring blood glucose levels in diabetic patients.
8.	F. Valenzuela et al.	2020	An IoT-Based Glucose Monitoring Algorithm to Prevent Diabetes Complications	• NodeMCU • Glucose sensor • Server based on Raspberry Pi	• Continuous monitoring • Remote accessibility • Accuracy and reliability	The articles cover about enhancing glucose monitoring for older diabetics with algorithms and IoT systems. These algorithms notify doctors and families of critical conditions using historical glucose data.

					• Notification system • Integration with IoT Technology	Exploring invasive and non-invasive glucose monitoring technologies shows the benefits of real-time data management and IoT monitoring. A predictive algorithm in the proposed IoT architecture intends to improve quality of life and enable remote monitoring for older patients and caretakers.
9.	M. Baghelani et.al	2020	Non-Invasive Continuous-Time Glucose Monitoring System using a Chipless Printable Sensor Based on Split Ring Microwave Resonators	• Chip less printable sensor	• High sensitivity • Wearable integration • Real-time monitoring • Cost-effective	The work introduces a non-invasive glucose monitoring device employing split-ring microwave resonators and a chipless printed sensor. The 4 GHz skin-attachable sensor accurately detects glucose levels from 0 to 200 mM/l in real time without electricity. It is appropriate for continuous glucose monitoring in wearable

						devices due to its low cost and easy replacement.
10.	A. Rghioui et al.	2021	An IoT Based Diabetic Patient Monitoring System Using Machine Learning and Node MCU	• NodeMCU • Glucose sensor • Cloud storage	• Early prediction of diabetes • Remote monitoring • Data analysis • Real-time interaction	A diabetic monitoring system using IoT, machine learning, and Node MCU is presented in the study. Real-time data from CGM sensors is monitored remotely using a smartphone app. Advanced, medically-approved algorithms capture, transmit, and analyze glucose readings in the cloud. This approach allows proactive healthcare, early diabetes detection, and individualized therapies, increasing therapy decisions and patient outcomes.
11.	L. Tang et al.	2020	Non-Invasive Blood Glucose Monitoring Technology: A Review	• Enzymes • Materials • Electrodes	• Continuous monitoring • Convenience	The article discusses optical, microwave, and electrochemical non-invasive blood glucose monitoring methods.

				• Microfluid/electronic system	• Improved sensor performance	Electrochemical technologies have potential despite sensitivity and cost, while optical and microwave systems require modifications and provide continuous monitoring. The major goals are to improve enzyme immobilization, sensor sensitivity and stability, and accuracy using physical parameters and biomarkers. Interdisciplinary collaboration to develop high-quality, portable devices is encouraged, as non-invasive monitoring can improve diabetes care.
12.	V. P. Rachim and W. Y. Chung	2019	Wearable-Band Type Visible-Near Infrared Optical Biosensor for Non-Invasive Blood Glucose Monitoring	• Trans-impedance amplifier	• Cost efficient • Highly wearable biosensor design • Non-invasive	Wearable visible near infrared optical biosensors for non-invasive blood glucose monitoring are described in the paper. It monitors PPG signals

				• Low power bipolar NPN transistors • Arduino Due		with several wavelengths and estimates glucose well. Integration into a smartwatch for continuous monitoring with a small data collecting window is the goal. Results show potential long-term monitoring and clinical use accuracy.
13.	J. Al-Nabulsi et al.	2022	Non-Invasive Sensing Techniques for Glucose Detection: A Review	• Microstrip bandpass filter • Split ring resonator and complementary structure • Ultra-wide band microwave • Ultrasonic techniques	• Cost-effective • Compact size • Linearity • Improved accuracy of the sensor • Continuous monitoring of glucose levels for diabetes patients	Non-invasive diabetic treatments using optical, microwave, and ultrasonic methods are examined. Microwave methods study tissue properties, ultrasonic methods improve measurements, and optical methods use light interactions. Non-invasive monitoring is cost-effective, compact, continuous, and accurate. Non-invasive technologies, especially ultrasonic, are more precise,

						reliable, and user-friendly, according to the assessment.
14.	E. V. Karpova et al.	2019	Non-invasive Diabetes Monitoring Through Continuous Analysis of Sweat using Flow-Through Glucose Biosensor	• Chemical components	• Continuous examination of undiluted sweat for immediate tracking of glucose levels • Enhanced sensitivity and expanded calibration range in comparison to conventional biosensors.	The research proposes a non-invasive diabetes monitoring approach. Using a flow-through glucose biosensor, this approach detects sweating continuously. This method shows that blood glucose levels are directly related to sweating, making it a reliable alternative to blood testing. The integrated device reliably and continuously monitors glucose levels, highlighting sweat as a non-invasive diabetes treatment.
15.	G. Zhang et al.	2020	A Noninvasive Blood Glucose Monitoring System Based on Smartphone PPG	• Machine learning algorithm • LED	• Portable • Real-time monitoring • Non-invasive	Smartphone PPG signals and machine learning are used to create a non-invasive blood glucose monitor. It properly

			Signal Processing and Machine Learning	• Photodiode	• Achieve high accuracy rate in predicting blood glucose levels	classifies glucose levels for health monitoring and is portable and real-time. Future research seeks precision and immediate response. This strategy is good for quick and accurate home monitoring.

Table 1.1 Comparison of selected literature review.

2.8 Summary

Finally, this project will benefit from a few papers comprises a literature review that explores existing research and studies related to the topic. It provides an overview of different kind of methods, technologies and approaches used in prior studies. The review discusses the techniques, explores various sensors, and technologies utilized, and highlights advancements in monitoring blood glucose levels. The review comprised overall progress and knowledge in the development of this project.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, this chapter will introduce the research methodology and explores different scientific frameworks, techniques, instruments and methods. The methodology focuses on using Arduino software and integrated pulse oximetry and heart-rate monitor module to create a user-friendly system for diabetic patient. It follows a step-by-step process which are choosing project title, conducting research, planning project design, integrating software and hardware, analysing the project and write a complete report. A flowchart is prepared to make it easier to visualize the steps. It is crucial to understand the software and hardware integration before starting the project. This chapter emphasizes both of the technique in designing the system and research process flow.

3.2 Selecting and Evaluating Tools for a Sustainable Development

It is crucial to carefully choose and assess tools for creating a diabetic care system that utilises IoT and an Android application package. This is necessary to guarantee long-term viability, compatibility, and optimal performance. The procedure initiates by selecting technologies that can seamlessly interface with the current healthcare infrastructure and diverse IoT devices, such as glucose monitors and wearable health trackers. It is crucial to ensure that these components function in a harmonious manner in order to create a unified and efficient system.

Performance and dependability are of greatest significance, particularly when it comes to continuous monitoring and real-time data analysis. The tools must have the ability to deliver consistent and precise measurements over prolonged durations. Furthermore, the importance of energy efficiency cannot be overstated when it comes to extending battery life and reducing environmental effect. Therefore, it is crucial to choose low-power IoT sensors and optimize the Android application to consume minimal energy.

Our objective is to create a diabetic care system that is both sustainable and efficient by prioritizing these essential factors. This strategy guarantees that our solution not only tackles existing healthcare concerns but also anticipates future expansion and technological progress.

3.3 Methodology

The aim of the project methodology, "Development of a Diabetic Care System Based on IoT and Android Application Package," is to develop a system that integrates ESP32 and IoT technology with a sensor to detect and measure blood glucose levels and improve the knowledge of individuals living with diabetes with an android application that provides education modules. The goal of incorporating these technologies is to provide diabetic patients with innovative tools for continuously self-monitoring their blood glucose level. The primary objective is to improve diabetes self-management and overall health for patients living with diabetes.

3.4 System Block Diagram

This system block diagram shows the relationships between its components. It becomes a guide, outlining the flow and features that are critical when developing an overall design concept.

The system architecture for this non-invasive glucose monitoring system for diabetic patients, which is shown in Figure 3.1, consists of some components. The MAX30102 glucose sensing module, one of the main components, makes the system non-invasive by measuring glucose levels without drawing blood. The module interfaces with a microcontroller unit

(MCU), which is an ESP32, acting as the main control centre. The MCU acquired the data from the sensing module, processed it and managed the overall system operation. Wireless connectivity, which is facilitated by Wi-Fi, Bluetooth or cellular networks, enables the MCU to connect to the internet. The system uses cloud-based data storage and analysis, in which the glucose data collected by the MCU is securely transmitted and stored. This cloud architecture offers extensible computational power for data analysis, visualization, and long-term storage. Diabetic patients and healthcare providers can utilize a simple mobile or online application to view real-time glucose readings, receive alarms, and track historical trends.

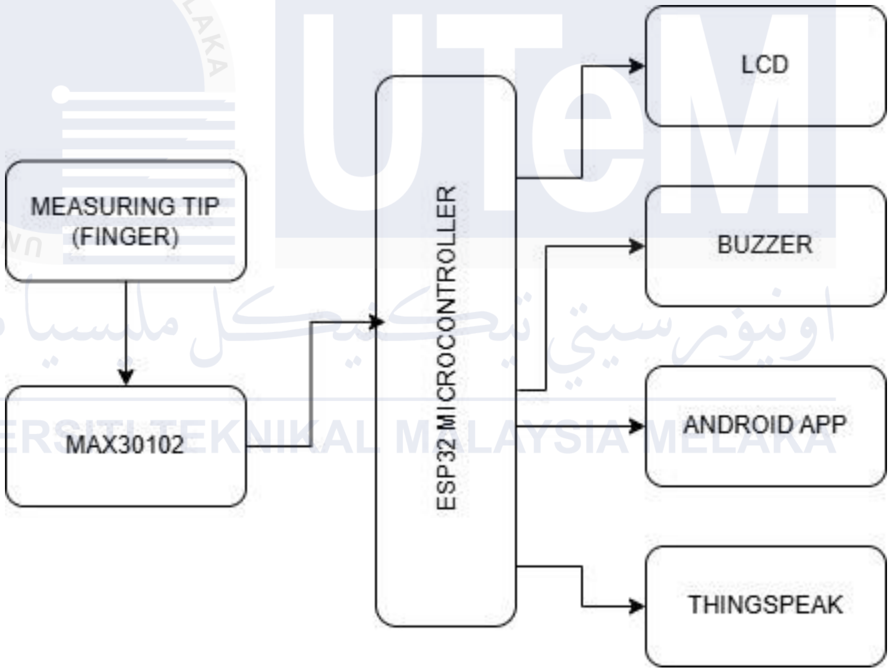

Figure 3.1: Block diagram of non-invasive glucose measurement system.

3.5 Flowchart

The flowchart becomes an important component in the development process by offering a thorough overview of the system's workflow.

3.5.1 Flowchart of the Project's Process

The provided flowchart in Figure 3.2 provides an illustrated overview of the project's entire process, illustrating each important phase from start to finish.

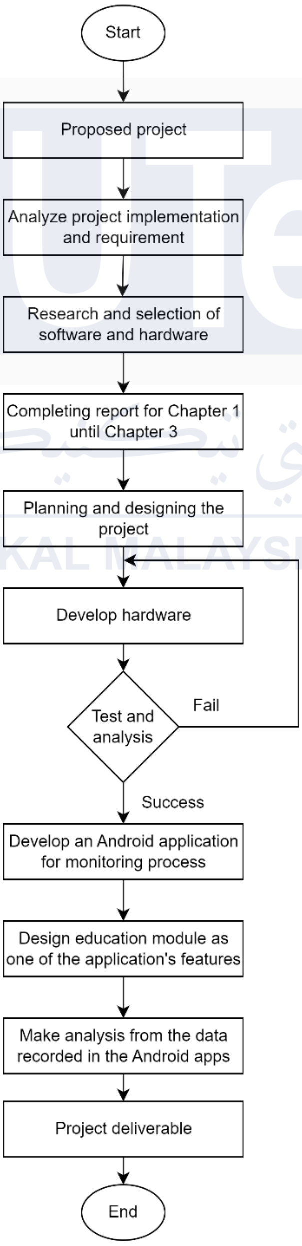

Figure 3.2 Flowchart of the project's process

This flowchart was specifically designed to provide a straightforward and thorough understanding of the project's process, ensuring that everyone involved can easily comprehend and contribute to each stage. The project process flowchart starts with the development of a glucose measuring system, which is then followed by an analysis of project implementation and requirements. The process involves conducting research and selecting appropriate software and hardware, as well as planning and designing the project. Subsequently, the hardware is developed and then subjected to thorough testing and analysis. Simultaneously, an Android application is being developed to track and analyse glucose levels, as well as an instructional component for people with diabetes. The application incorporates a self-login function that enables patients to securely check their own glucose levels. The project concludes with an examination of the data collected in the Android application, resulting in the ultimate project deliverable.

3.5.2 Flowchart of Developing the Android Application

The process of developing an Android application for glucose monitoring and diabetes education requires following a well-organized sequence of phases to guarantee a user-friendly and dependable tool for patients. The app is designed to assist patients in monitoring their glucose levels, accessing educational resources, and properly managing their diabetes.

In order to guarantee a user-friendly and effective solution, the development of an Android application for glucose monitoring and diabetes education is conducted in an organized way. It begins with the development of a user-friendly interface, which is followed by the implementation of a secure data storage system and a precise glucose measurement system. The extensive glucose monitoring system offers visual data displays, while a secure patient authentication system guarantees restricted access. Educational modules provide essential information regarding diabetes management. The application is guaranteed to comply with app store regulations and user requirements through comprehensive testing and refinements that resolve any issues. This approach ensures that the application is compliant and robust.

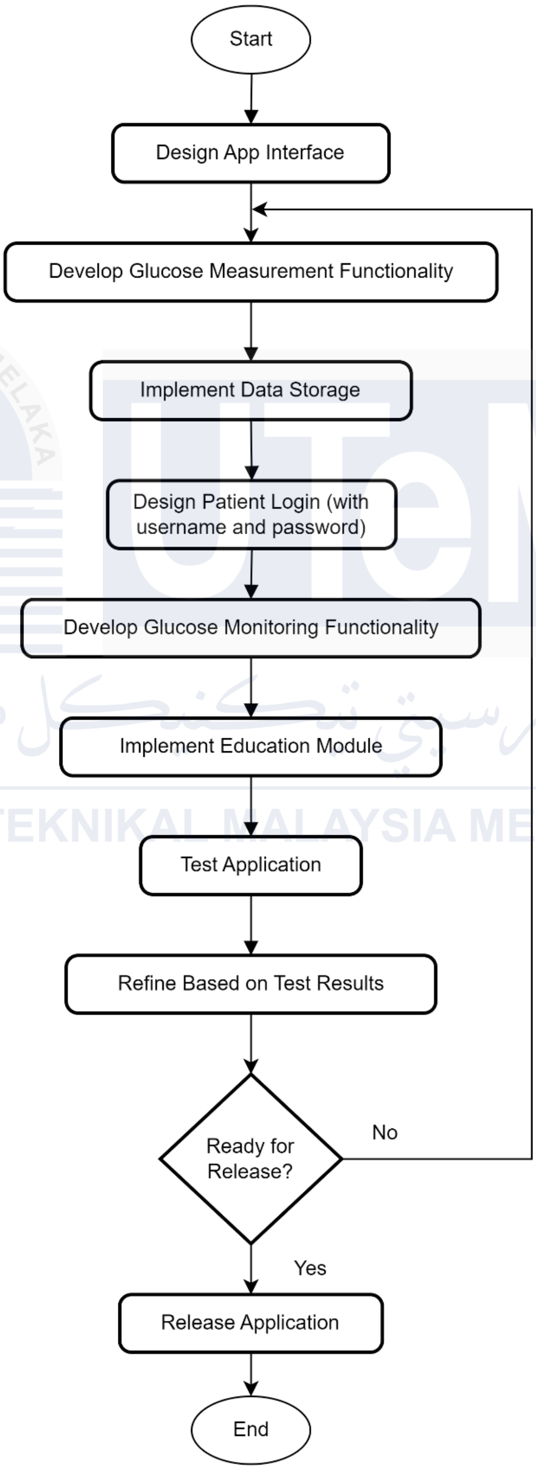

Figure 3.3 Flowchart of developing an Android application

3.5.3 Flowchart of the Blood Glucose Measurement System

The process for measuring blood sugar levels is shown in this flowchart for the glucose monitor system. Initially, it connects to the user's Wi-Fi and requests a finger prick. Upon analyzing the glucose level, the system presents the result on the user interface and classifies it as low, normal, or high. There is an additional buzzer alert for high readings. The system has the option to use Wi-Fi to send the data to cloud services.

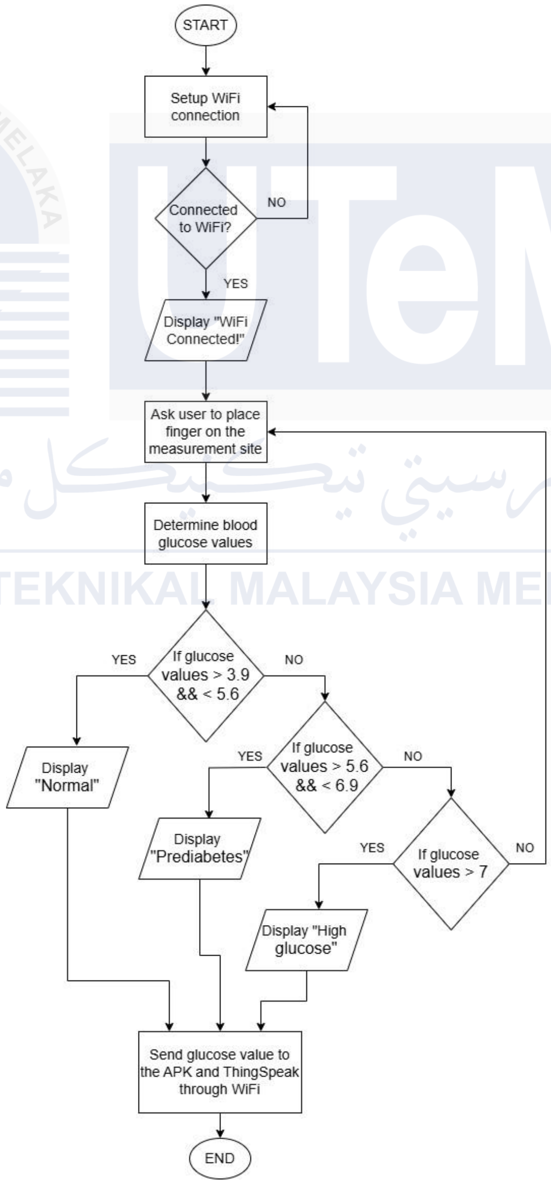

Figure 3.2: Flowchart of blood glucose measurement system.

3.6 Process of Designing Education Module

The Android application contains educational modules that seek to equip patients with extensive information and tools to effectively manage diabetes. It includes essential elements such as diagnosis and treatment, promotion of healthy habits, physical exercise, and prevention of complications. The application is designed to improve patients' comprehension of their illness, encourage healthier behaviors, and boost overall quality of life by offering these tools. The modules are designed according to modules created by WHO. Figure below shows the process of designing the modules.

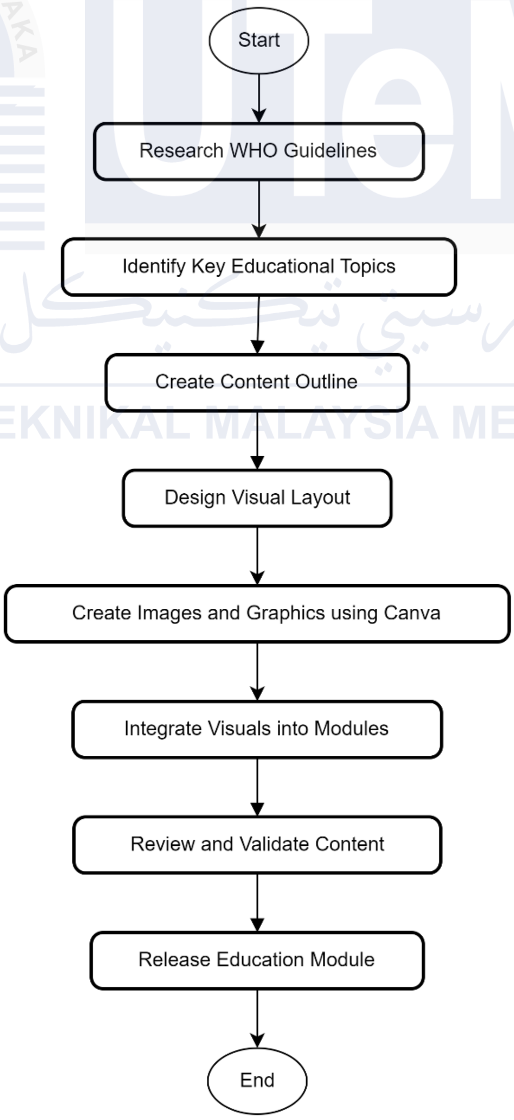

Figure 3.3 Process of designing education modules

To gain evidence-based knowledge, the process begins with conducting research on WHO guidelines for diabetes management. Afterwards, important educational topics are determined, and an organized structure is established to outline the material. The visual layout is strategically created to efficiently showcase the educational material, and Canva is employed to generate aesthetically pleasing visuals and graphics. The images are seamlessly integrated into the module's architecture and then subjected to a comprehensive evaluation to guarantee their precision and relevance. After being validated, the educational module is completed and ready to be released, offering users crucial tools to effectively manage diabetes.

3.7 Software Implementation

Software implementation involves transforming theoretical concepts and models into executable programs that fulfil the required functions. This section introduces the software tools that were chosen based on their suitability for successful implementation.

3.7.1 Arduino Software

Figure 3.3: Arduino IDE

The Arduino Integrated Development Environment (Arduino IDE) includes a text editor for writing code, a message box, a text console, a toolbar with buttons for basic functions, and a set of menus. It connects to the Arduino devices in order to upload and communicate with them. Arduino IDE is simple to use for newcomers while remaining adaptable for advanced users. It is compatible with MacOS, Windows, and Linux. It is used by teachers and students to construct low-cost scientific equipment, to demonstrate chemistry and physics principles, and to begin learning programming and robotics[30].

3.7.2 ThingSpeak

Figure 3.4: ThingSpeak

ThingSpeak is an IoT analytics platform service that allows users to gather, visualize, and analyze real-time data streams in the cloud. ThingSpeak delivers rapid visualizations of data uploaded by users' gadgets. The ability to execute MATLAB code in ThingSpeak allows users to undertake online analysis and processing of data as it arrives. ThingSpeak is frequently used to prototype and test IoT devices that require analytics. ThingSpeak is built around a time series database. ThingSpeak offers users free time-series data storage in channels. Each channel can have up to eight data fields[31].

3.8 Hardware Implementation

In order to take our project from concept to reality, we must complete the hardware implementation phase. It includes choosing, setting up, and assembling the hardware that will allow the system to perform as planned. This section will give an extensive overview of the hardware components utilized and how they work together to create an integrated and useful system. The main hardware that are used in this system are ESP32 and MAX30102.

3.8.1 ESP32

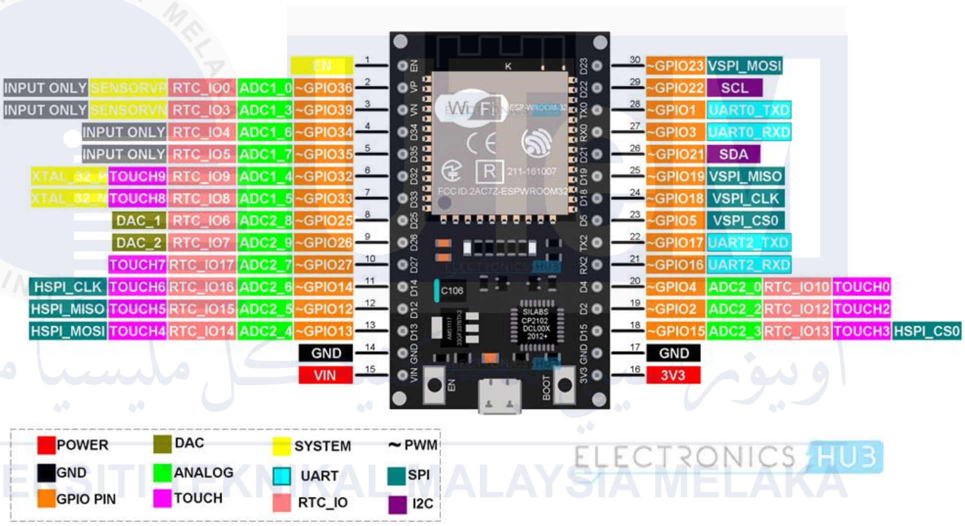

Figure 3.6: ESP32 with its pinout references

The ESP32 is an electronic component that gives embedded devices, or Internet of Things devices, Wi-Fi and (in certain models) Bluetooth connectivity. Although ESP32 is only the chip, the manufacturer also frequently refers to the development boards and modules that contain this chip as "ESP32." A single core Tensilica Xtensa LX6 microprocessor powered the original ESP32 chip. With a clock rate of more than 240 MHz, the processor processed data at a comparatively fast pace[32].

3.8.2 MAX30102

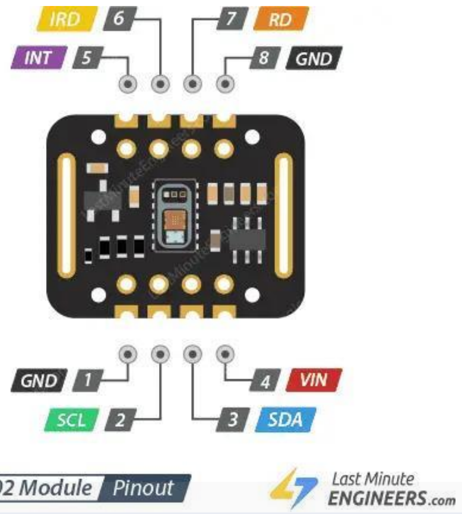

Figure 3.7: MAX30102 with its pinout references

The MAX30102 is a biosensor module that combines heart-rate monitoring and pulse oximetry. Internal LEDs, optical components, photodetectors, low-noise circuitry, and ambient light rejection are all included. In order to facilitate the design-in process for mobile and wearable devices, the MAX30102 offers a comprehensive system solution. The internal LEDs of the MAX30102 are powered by a separate 3.3V power source in addition to a single 1.8V power supply. Through a common I2C-compatible interface, communication is established. Software can be used to completely disable the module with no standby current, leaving the power rails operational constantly[33].

3.9 Summary

This chapter discussed the proposed methodology in order to develop a diabetic care system with a health education module. To make sure the process of project implementation succeeds, a flow chart of the project's progress was created. Before starting the project, the components, both in terms of software and hardware, were chosen. It is critical to carefully choose all components in order to ensure that future project developments are successful.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter provides an overview of the results obtained from the creation and evaluation of the diabetes care system, which utilizes IoT technology and an Android application package. The system's goal was to improve diabetes management through continuous monitoring and data analysis. This chapter will focus on the hardware analysis and the resulting data generated by the glucose sensor MAX30102. The outcome of the project can be observed through the notifications sent to an Android application, and the data may be visually represented using ThingSpeak.

4.2 Android Application Development

The Diabetic Care System Android application has been developed as a key component of the project, with the goal of providing users with an easy and accessible platform for monitoring and managing their blood glucose levels. The application was created with Flutter, a modern cross-platform development framework, to provide a consistent and responsive user experience across many devices. The development approach included designing a compelling user interface, integrating real-time glucose monitoring capabilities, and introducing educational features to raise user understanding of diabetes care.

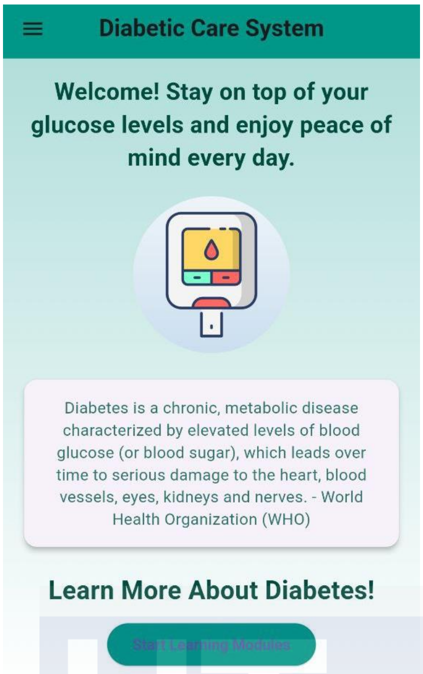

Figure 4.1: Home Dashboard of Diabetic Care System Android Application

Figure 4.1 shows the Diabetic Care System Android application's home dashboard. This dashboard serves as the user's initial interface, displaying a welcome message as well as an educational summary of diabetes from the World Health Organization (WHO). Key features include access to diabetic education courses via the "Start Learning Modules" button.

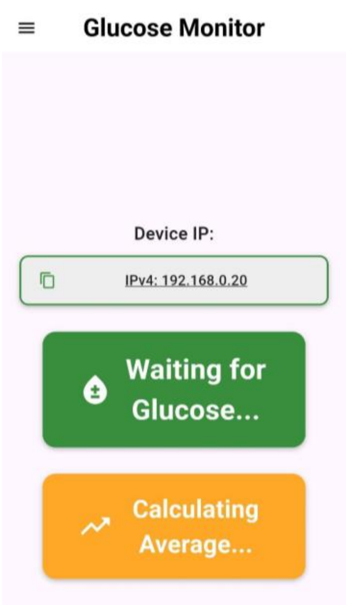

Figure 4.2: Glucose Monitor Dashboard of Diabetic Care System Android Application

The Glucose Monitor Dashboard is an essential element of the Diabetic Care System Android app, allowing for real-time monitoring and analysis of blood glucose levels. This feature is made possible by smooth integration with the ESP32 microcontroller and the MAX30102 sensor, which continuously transmit glucose-related data to the application. When data is received, the system analyzes and determines the average glucose levels during a given time period. This feature enables users to track trends in their blood glucose levels, which is essential for efficiently controlling diabetes.

4.3 Education Module in Android Application

The Education Modules of the Diabetic Care System Android app are intended to equip users with vital knowledge for efficient diabetes management. These modules are based on WHO requirements to ensure that the content is authentic, reliable, and meets global health standards. Figure 4.3 shows the education modules in the android application.

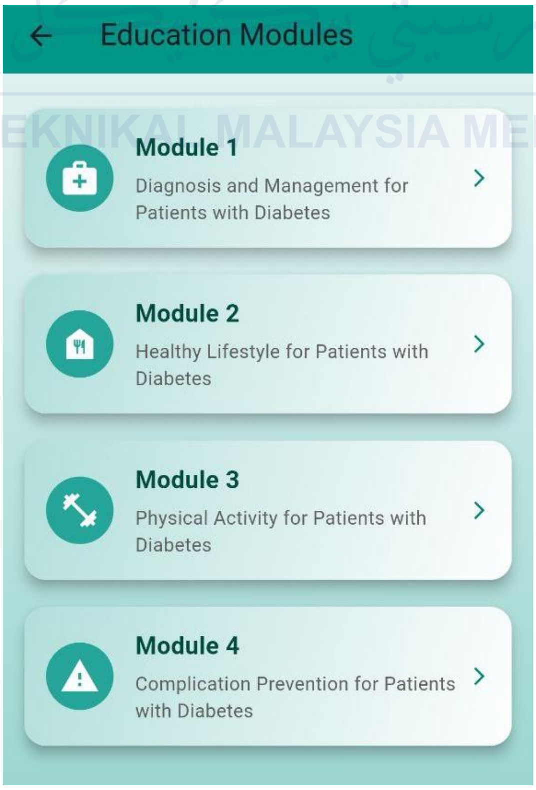

Figure 4.3: Education module of the android application.

The modules are arranged into four sections, each addressing a fundamental aspect of diabetes care. As shown in Figure 4.4, Module 1: Diagnosis and Management for Diabetes Patients covers the essential principles of diabetes care, such as, recognizing symptoms, seeking prompt diagnosis, and implementing successful management measures. This module is especially useful for those who have recently been diagnosed with diabetes, as it provides them with a solid basis on which to build their health.

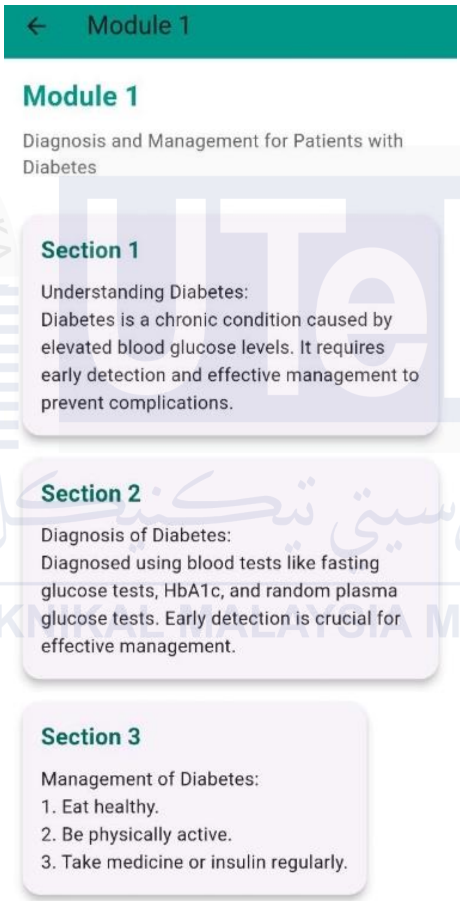

Figure 4.4: Module 1

As shown in Figure 4.5, Module 2: Healthy Lifestyle for Diabetes Patients highlights the importance of balanced nutrition and dietary habits in achieving stable blood glucose levels. It advises on meal planning and promotes healthier eating habits. Meanwhile, in Figure 4.6, Module 3: Physical Activity for Patients with Diabetes emphasizes the need of regular exercise in regulating blood sugar levels and promoting general well-being. This module provides practical advice for adding physical activity into your everyday routine.

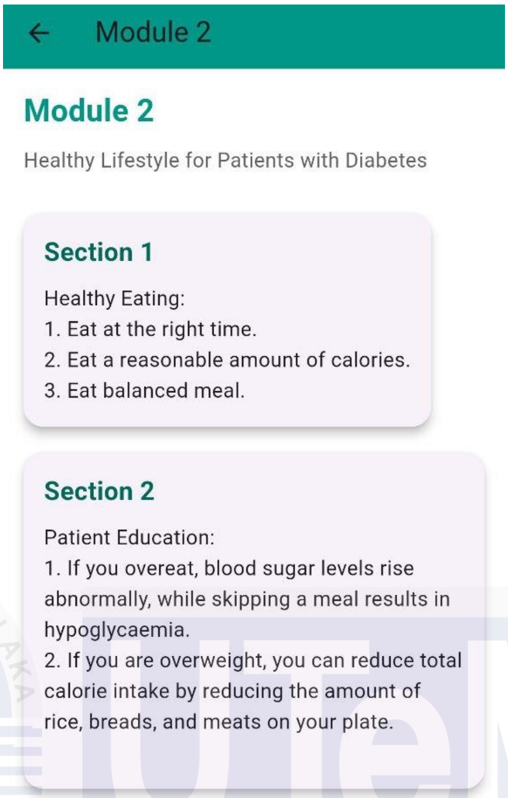

Figure 4.5: Module 2

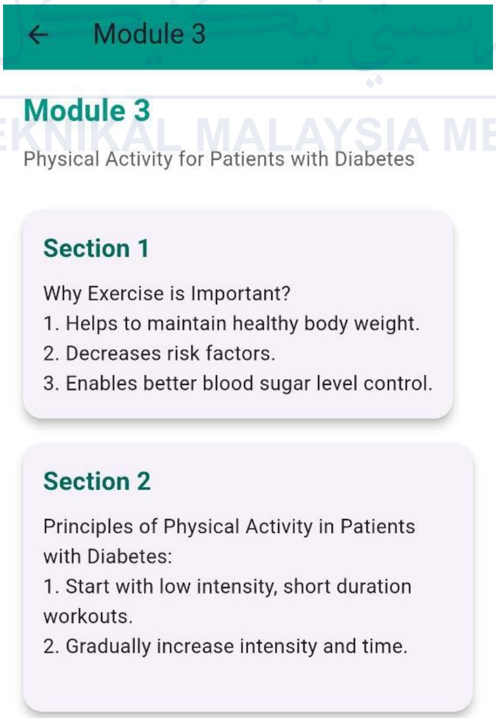

Figure 4.6: Module 3

Finally, Module 4: Complication Prevention for Diabetes Patients as in Figure 4.7, educates users on how to avoid diabetes-related problems. It discusses issues including monitoring health indicators and taking precautions to ensure long-term health. Together, these modules offer a comprehensive training experience, providing users with the knowledge and tools they need to manage their diabetes efficiently and confidently.

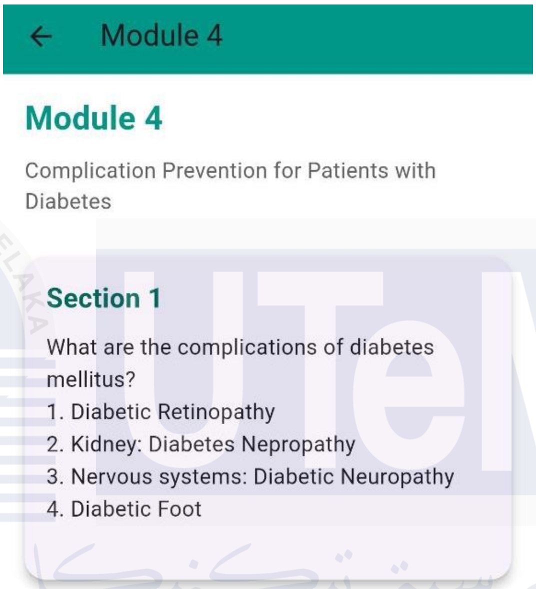

Figure 4.7: Module 4

4.4 Hardware Development

The hardware development of this project focused on developing an efficient and stable platform for real-time glucose monitoring. This requires proper collection, processing, and transmission of glucose-related data through the integration of numerous hardware components such as sensors and microcontrollers. The goal is to create a system that is not only effective, but also user-friendly and appropriate for daily use.

In this hardware development project, the ESP32 microcontroller is seamlessly connected with an LCD display, a buzzer, and the MAX30102 sensor to form a non-invasive blood glucose monitoring system. Figure 4.8 shows the internal components securely attached within the housing. Figure 4.9 illustrates how the circuit has been adjusted to fit into the final design case.

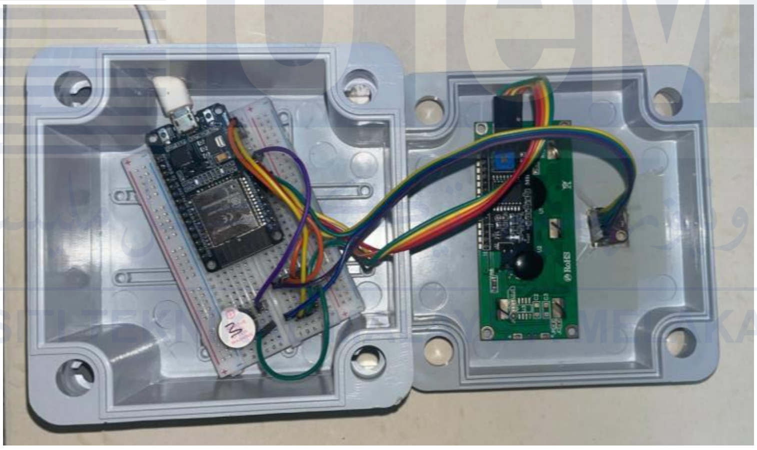

Figure 4.8: Internal components attached in the case.

Figure 4.9: Final design casing box.

4.5 Result

This section describes the results of the hardware and software integration for the non-invasive blood glucose monitoring device. The results include system operation, sensor accuracy, display outputs, and the buzzer and LCD's reaction behavior. In addition, performance tests were undertaken to assess the device's accuracy, reliability, and real-time responsiveness.

This project uses the MAX30102 sensor to detect hemoglobin levels in the patient's blood. MAX30102 consists of two components: an LED emitter for passing light to the patient's finger and a photodiode for capturing light intensity. The amount of light caught by the photodiode affects the voltage output in the form of an analog signal that is sent to the ESP8266 microprocessor. The data processed by the microcontroller will be displayed on the LCD and transmitted to the ThingSpeak that has been integrated in the android application.

If the blood glucose level (3.9 – 5.6) mmol/dL, the LCD will display "Normal" as the value is in the normal range. Next, when the blood glucose value (5.6 – 6.9) mmol/Dl, the LCD will display "Prediabetes" and if the blood glucose level value is above 7 mmol/dL, the LCD will display "High glucose". There is pop-up notification for each value that the android application received and the apps also provides users warning if the blood glucose is in prediabetes and high glucose range. Figure 4.10, 4.11 and 4.12 show the pop-up notification that is sent to users. The users may know their blood glucose level is either normal, prediabetes or high by having this notification system delivered to their mobile phone.

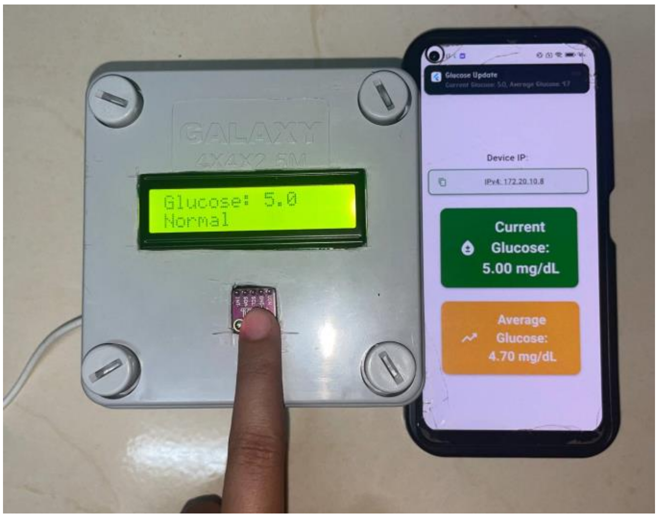

Figure 4.10: When blood glucose is in normal range, there will be no warning notification.

Figure 4.11: When blood glucose is in prediabetes range, there is a warning notification.

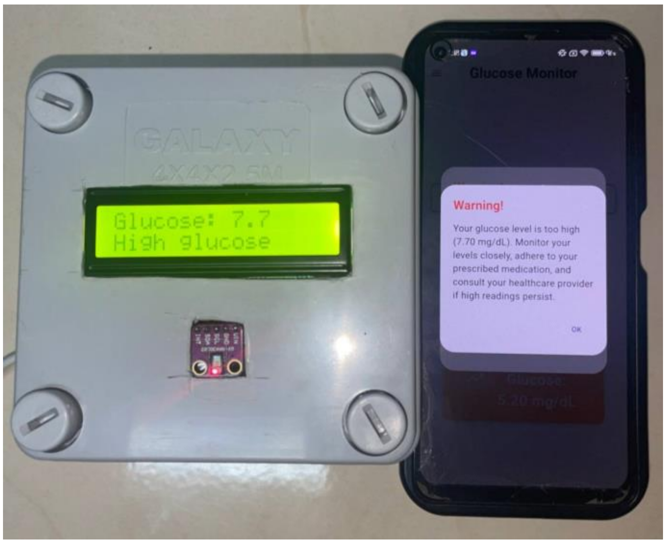

Figure 4.12: When blood glucose level is in high range, there is a warning notification.

The project was intended to show real-time sensor information on LCD screen, but ThingSpeak was integrated in the android application as a cloud-based data logger to improve data accessibility and long-term monitoring. This enables real-time storage, display, and remote access to recorded blood glucose values.

ThingSpeak is an IoT analytics platform that collects data from the ESP32 microcontroller and sends the results, such blood glucose levels to a cloud server. The saved data can be accessed via a web interface or in the android application itself, allowing users to easily track their health patterns over time. Figure 4.13 shows the real-time chart of ThingSpeak in the android application.

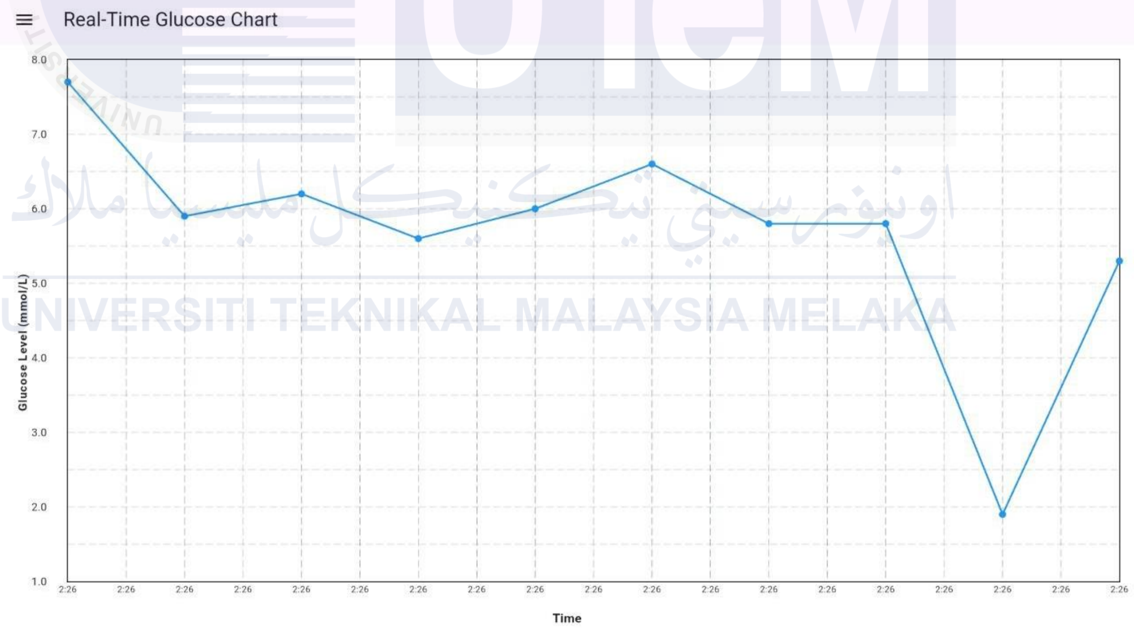

Figure 4.13: Real-time chart of ThingSpeak in android application.

4.6 Result Analysis

This section presents and assesses the project's implementation and testing findings. The acquired data is used to evaluate the system's performance and accuracy. Comparisons with expected results, theoretical predictions, and existing solutions are also examined. Graphs, tables, and charts are used to emphasize important facts, such as trends, variances, or areas for improvement. This analysis validates the effectiveness of the suggested design and provides suggestions for further improvements.

4.6.1 Invasive vs Non-invasive Methods

A number of experiments were carried out to compare the glucose readings obtained from the produced prototype with a commercially available glucometer (SinoCare GA-3), as shown in Figure 4.14. Figure 4.15 shows the value of blood glucose when using invasive approaches. The tests were carried out on 17 non-diabetic persons and two diabetes patients, using both invasive and non-invasive method. The invasive method used the glucometer, while the non-invasive method used the non-invasive blood glucose monitoring equipment.

Figure 4.14: Glucometer device

Figure 4.15: Blood glucose values using invasive method.

After collecting all 19 datas as shown in Table 4.1, the accuracy is calculated for each reading so that the two techniques may be compared using Mean Absolute Relative Difference (MARD). MARD parameter is most commonly used to assess the measurement performance of continuous glucose monitoring (CGM) devices. The lower the MARD number, the closer the CGM readings are to the comparator values. A CGM system with a MARD of <10% is considered to have good analytical performance[34]. Figure 4.16 is the formula for MARD.

$$\mathrm{MARD} = \frac{1}{\mathrm{N}} \sum_{i=1}^{\mathrm{N}} \left| \frac{BG_i - Comp_i}{Comp_i} \right|$$

Figure 4.16: Formula for MARD.

No.	**Subject**	**Glucose concentration measurement**	
		Invasive (mmol/L)	**Non-invasive (mmol/L)**
1.	Person 1	5.2	5.1
2.	Person 2	5.1	5.4
3.	Person 3	4.4	4.7
4.	Person 4	4.9	4.5

5.	Person 5	5.4	5.1
6.	Person 6	5.0	4.9
7.	Person 7	4.3	4.4
8.	Person 8	4.9	5.0
9.	Person 9	4.9	4.5
10.	Person 10	4.7	4.4
11.	Person 11	5.1	5.4
12.	Person 12	5.0	4.8
13.	Person 13	4.3	4.5
14.	Person 14	4.7	4.5
15.	Person 15	5.1	4.9
16.	Person 16	5.2	5.4
17.	Person 17	5.8	5.5
18.	Person 18	7.1	7.2
19.	Person 19	7.6	7.3

Table 4.1: Data collected from 19 persons.

The accuracy needs to be calculated using formula in Figure 4.16, and the result of the calculation will be implemented in Table 4.2.

No.	Subject	Individual MARD values
1.	Person 1	2%
2.	Person 2	6%
3.	Person 3	7%
4.	Person 4	8%
5.	Person 5	6%

6.	Person 6	2%
7.	Person 7	2%
8.	Person 8	2%
9.	Person 9	8%
10.	Person 10	6%
11.	Person 11	6%
12.	Person 12	4%
13.	Person 13	5%
14.	Person 14	4%
15.	Person 15	4%
16.	Person 16	4%
17.	Person 17	5%
18.	Person 18	1%
19.	Person 19	4%

Table 4.2: Calculation for individual MARD values.

After computing the MARD for individual glucose measurements, the total MARD value for the system was found to be 4.5%. This value is substantially lower than the usually recognized 10% threshold, showing that the glucose monitoring equipment is highly accurate. A low MARD number, such as 4.5%, indicates that the system can produce dependable and precise measurements, which is essential for optimal diabetes control.

4.6.2 Graph Analysis for Invasive and Non-invasive Method

The glucose measurement analysis compares values obtained with both invasive and non-invasive procedures on 19 patients. The invasive method, represented by the blue line, is used as a standard reference, while the non-invasive method, shown by the red line, is being tested for accuracy. The graph shows a steady pattern between the two systems, demonstrating a high correlation in glucose level monitoring. In most situations, non-invasive results closely match invasive values, while some discrepancies do occur, particularly in patients with higher glucose levels. These modest variances could be due to sensor accuracy, ambient influences, or individual physiological variables. Figure 4.17 shows the graph analysis for both methods.

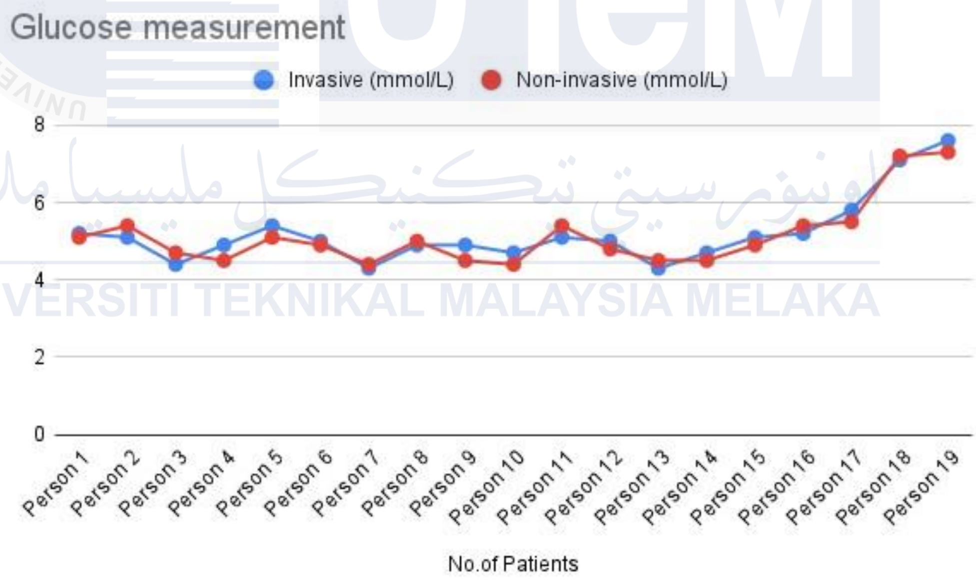

Figure 4.17: Graph analysis for invasive and non-invasive methods.

4.7 Summary

The major hardware components are the ESP32 microcontroller, the MAX30102 sensor for measuring blood glucose levels, and an alert buzzer. The system shows the output on an LCD screen. The components are appropriately constructed and integrated to guarantee that the device is constructed in accordance with the schematic designs and functions properly when placed in the right enclosure. The project also includes the creation of an Android application that will allow users to track their blood glucose levels in real time. The software communicates with the hardware by displaying readings, giving instructional resources for diabetes control, and providing individualized feedback based on collected data.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The development and implementation of the IoT-based diabetic care system, which includes an ESP32 microcontroller and MAX30102 sensor, established the feasibility and usefulness of real-time glucose monitoring. The device, which is complemented by an Android app, gives users an easy and simple way to measure their glucose levels, receive notifications, and follow individualized health instructions. After thorough testing and analysis, the system demonstrated a high level of reliability and consistency in glucose measurement when compared to standard invasive approaches, with minor variances. The seamless integration of hardware and software components results in an efficient user experience, allowing diabetes patients to monitor their condition without the frequent pain associated with traditional glucose testing methods. Furthermore, the ability to offer real-time data visualization and historical monitoring via the Android APK increases user engagement, allowing people to take an active role in their diabetes control.

5.2 Potential for Commercialization

The IoT-based diabetic care system offers a promising commercialization opportunity, meeting the growing demand for low-cost, non-invasive glucose monitoring solutions. Its portability, ease of use, and real-time monitoring capabilities make it an appealing choice for consumers, healthcare providers, and telemedicine services. The integration with an Android application improves accessibility, allowing users to easily track their glucose levels and receive timely messages. This feature appeals to both users with technological skills and healthcare providers looking for effective patient management solutions.

The system's scalability and potential for growth allow it to be used as part of diabetes treatment programs through collaborations with hospitals, clinics, and insurance companies. Furthermore, its low cost and non-invasive features make it ideal for use in developing countries with limited access to traditional healthcare. The system can expand its market reach by getting the appropriate regulatory clearances and certifications, providing a comprehensive and accessible solution for diabetes management around the world.

5.3 Future Works

The future works in the development of a diabetic care system based on IoT and android application package can focus on several key areas such as:

a) Implementing machine learning algorithms for predictive analysis and trend identification could provide users with individualized insights and early warnings.
b) Increasing the system's connectivity with other platforms, such as iOS and cloud-based data storage, could improve user experience and data accessibility.
c) Improve sensor calibration approaches to reduce differences between invasive and non-invasive glucose measurements by employing machine learning-based correction algorithms.

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APPENDICES

Appendix A Gantt Chart PSM 1

ACTIVITY	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Confirmation project's title	PSM Briefing and The Registration						MID TERM BREAK							
Introduction (Chapter 1)														
Research journals (Chapter 2- Literature review)														
Update Logbook														
Survey components and price														
Methodology (Chapter 3)														
Preliminary result analysis														
Presentation PSM 1														

Appendix B Gantt Chart PSM 2

ACTIVITY	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Develop hardware for system								MIDTERM BREAK						
Develop android application														
Update logbook														
Result and Discussion (Chapter 4)														
Collect data														
Result analysis														
Presentation PSM 2														
Submission final report														