D-CARE: A Non-invasive Blood Glucose Measuring Technique for Monitoring Diabetes Patients

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering.

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DHAKA, BANGLADESH

NOVEMBER 2018

APPROVAL

This Project/internship titled **"D-CARE: A Non-invasive Blood Glucose Measuring Technique for Monitoring Diabetes Patients"**, submitted by **Md Mahbub Alam**, ID No: **151-15-5237**, **Swapnil Saha**, ID No: **151-15-4939** and **Proshib Saha**, ID No: **151-15-5041** to the **Department of Computer Science and Engineering, Daffodil International University** has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 5th November 2018.

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DECLARATION

We hereby declare that, this project has been done by us under the supervision of **DR FERNAZ NARIN NUR, Assistant Professor, and Department of CSE** Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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ACKNOWLEDGEMENT

First we express our heartiest thanks and gratefulness to almighty God for His divine blessing makes us possible to complete the final year project/internship successfully.

We really grateful and wish our profound our indebtedness to **DR. FERNAZ NARIN NUR**, **Assistant Professor**, Department of CSE Daffodil International University, Dhaka. Deep Knowledge & keen interest of our supervisor in the field of "*Internet of Things*" to carry out this project. Her endless patience, scholarly guidance ,continual encouragement , constant and energetic supervision, constructive criticism , valuable advice ,reading many inferior draft and correcting them at all stage have made it possible to complete this project.

We would like to express our heartiest gratitude to **Dr. Syed Akhter Hossain**, Professor and Head, Department of CSE, for his kind help to finish our project and also to other faculty member and the staff of CSE department of Daffodil International University.

We would like to thank our entire course mate in Daffodil International University, who took part in this discuss while completing the course work.

Finally, we must acknowledge with due respect the constant support and

patients of our parents.

ABSTRACT

Diabetes is a lethal disease in the world now a days as we all know. One out of eleven adults are now victim of this disease as per WHO. The common two types of diabetes are Type-1 and Type-2 diabetes. It's a must for a diabetes patient to maintain the blood glucose level. It does not mean that the patient must not consume any kind of sugar. Human body needs glucose to work. That's why a well-planned diet is required to control the disease. Here comes two terms related to blood glucose level; Hyperglycemia and Hypoglycemia. Hyperglycemia mean chronically high blood glucose levels and Hypoglycemia is the vice-versa of Hyperglycemia. Hyperglycemia can cause Stroke, Heart attack or Congestive Heart Failure, Kidney disease or even Nerve damage whereas Hypoglycemia can cause Unconsciousness, Severe confusion and disorientation, Seizures or even Death. As there is no cure for this disease, constant monitoring of the blood glucose level has become the most effective solution for this disease. But the invasive method to measure blood glucose level might cause infection and its painful too. That's why non-invasive method has become the most reliable technique to measure blood glucose level and for constant monitoring of the patient.

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CHAPTER 1

Introduction

1.1 Introduction

Diabetes is one kind of disease of the pancreas which is responsible for producing a hormone called insulin. Diabetes happens when the pancreas gland is no longer able to produce insulin or the body can't properly utilize the insulin delivered by pancreas resulting in the high level of blood glucose in the blood stream. However the human body needs some glucose as it provides the necessary energy for the body to work. The prevalence of diabetes was about 8% in 2011, which most likely to rise to 10% by 2030. The alarming news is 80% of diabetes affected people are from low income or middle income countries. In Bangladesh about 10%, in China 9% and in India 8% of the population are affected by the disease [1]. Deaths occurring from Diabetes mellitus in Bangladesh has reached 40,142, which is nearly 5.09% of total deaths according to WHO [2]. As the statistics show, Diabetes is a key reason for death in Bangladesh in recent years. A statistics shows that the prevalence of diabetes in Bangladesh has increased, from 4% in 1995 to 2000 and 5% in 2001 to 2005 and 9% from 2006 to 2010. Such rate will rise up to 13% by 2030 according to International Diabetes Federation [1, 3]. One alarming fact is that the diabetes affected infants and aged people are less cautious about their condition than the adults and middle aged people. Supposedly, middle aged people are more cautious about their condition and it is seen that they are capable of understanding their medical conditions better than the aged people and the younger ones. Non-invasive method for blood glucose monitoring is becoming more of interest to researchers as it has become a must for constant monitoring of glucose level in blood.

1.2 Motivation

Diabetes patients in Bangladesh are increasing day by day. Even if the adults are cautious about maintaining their blood glucose level, the children and the old people are not. Sometimes the adults are also not that cautious. So monitoring the patient's blood glucose level by another person makes sure that the patient gets immediate attention if any emergency situation arrives. This system allows the patient and the observer to be warned about their health when the condition is critical. In this way the patient can avoid any unexpected sickness due to Hyperglycemia or Hypoglycemia.

1.3 Rationale of the Study

A design has been presented to monitor blood glucose level using *Near Infrared (NIR)* light source which is of 940 nm wavelength [4-7] in this project. Intensity of light passed through the finger is used to calculate blood glucose level. Arm, finger and earlobe; these three different probes were used to calculate the blood glucose using 940 nm NIR LED. But finger tips are more preferable than the other two probes. The data obtained from the sensor through the microcontroller subsequently is sent to a web server and also to an observer (any relative/someone taking care of the patient) if the level of glucose in bloodstream is too low or too high. That way a person can always be aware of any serious condition if such condition does arrive. However to determine the exact level of insulin required, the sugar level in bloodstream needs to be determined by an invasive method.

1.4 Research Questions

From the time of discovery of diabetes in 1889 by Joseph von Mering and Oskar Minkowski, the only way of measuring blood glucose level was the traditional invasive method. Even now most of the diagnostic center uses invasive technique to measure blood glucose level in the blood stream. As it seems the invasive method is not suitable for constant blood glucose measuring hence monitoring.

That's why non-invasive method has become the most popular method among the researchers for constant blood glucose monitoring. The non-invasive method offers a lot than the traditional invasive method of blood glucose monitoring.

Some key reasons for using non-invasive method,

- No pain during the procedure
- No risks of infection
- Allows to monitor glucose level in blood in real time
- Most suitable method for constant monitoring of blood glucose monitoring

1.5 Expected Output

The goal of our system is to monitor a patient's blood glucose level in real time by non-invasive technique. As the invasive method involves pain and risk of infection, non-invasive method for blood glucose measuring seems to be the only way for constant monitoring of the patient. In this way the patient and the observer will be ready every time if any unpleasant situation comes up and will be able to take actions accordingly.

1.6 Report Layout

This report contains five chapter in which we described all necessary things of our project. This section consists of preview of all the chapters.

1. Chapter one consists of introduction, motivation and expected outcome of our study.
2. In chapter two the related research work is discussed. This chapter also provides problem scopes of the research.
3. Chapter three consists of requirements of the proposed system, system

architecture and system flow diagram.

4. Chapter four of this report describes our proposed system design, implementation and testing.
5. Lastly in chapter five we discussed about conclusion, limitations, comparison and future study.

CHAPTER 2

Background

2.1 Introduction

In the context of 21st century, Diabetes is one of the most lethal diseases from which millions of people of different age levels are suffering. It is imperative for a diabetes patient to maintain the blood glucose level all the time as there is no stable solution for this disease. However, the infants and the elderly, suffering from diabetes might not have the notion of maintaining the level of sugar in their blood. So constant monitoring of the patient has become the most feasible 'solution'. But the traditional method for measuring blood glucose level is not a viable option for constant blood glucose monitoring. Even if this invasive method is more accurate, it is painful and also there is a risk of infection, although minimal. That is why the non-invasive method seems to be a reasonable option for ongoing monitoring of blood glucose. For constant remote collection and monitoring of the data obtained from the diabetes patient, an IoT based non-invasive monitoring system has been proposed in this research that can be a great aid besides the invasive method for constant monitoring purposes.

2.2 Related Works

Through literature review, some works based on the above mentioned method

have been identified. In those research works, the main objective has been to measure the glucose level and the proper insulin dose. The widely used method to calculate glucose level in blood is an invasive technique that is painful, high-priced and threat in spreading infectious diseases. Over a long period of time, the invasive technique consequences in damage of finger tissues. As an alternative, the noninvasive approach may be used which helps frequent checking out, relieves ache and discomfort caused by common finger pricks [4, 8-15]. R.A. Buda and M. Mohd. Addi et al. [8] has proposed a system, in their research work, where they have developed non-invasive blood glucose monitoring device to observe glucose concentration in blood, to show the glucose level and the proper insulin dose, resembling the body mass index (BMI) of the user. They showed 4% - 16% accuracy in glucose detection. M. A. Aizat Rahmat et al. [9] proposed IoT based non-invasive glucose monitoring technique where they put fingertip into *Near Infrared (NIR) LED* to calculate blood glucose and the glucose concentration of the blood. They displayed glucose reading on LCD display and showed it to the family and the doctor via SMS and Android Application for monitoring patients remotely. According to them, at least 88.89% accurate results are given by the developed method. Based on 7 assessments the work had average 7.20% percentage error of glucose reading in comparison to their proposed method with invasive method.

2.3 Research Summary

In this study, we tried to identify the main problems related to diabetes and a system which offers a feasible solution to it. We found out, most of the patient affected by diabetes in Bangladesh are not as concerned about the disease as they should be which sometimes causes an unexpected and sudden illness related to the disease. That's why we proposed a monitoring system for the patient. The system uses Microcontroller (Arduino Uno), GPS module and blood glucose measuring sensors (FGA10 and NIR). After measuring the blood

glucose in real time, the data is sent to the server. Then if any critical condition arrives, an observer of the patient and also the patient also gets a notification of the condition and suggest to take immediate action as required.

2.4 Scope of the Problem

Our study mainly focuses on measuring blood glucose and monitoring of the patient. So that whenever the blood glucose level is critical (high or low), the patient can take necessary medications in time.

One less thing to worry about

This study's one of the core expected outcome is to make the patient worry less. When the patient knows that the level of glucose in his/her blood stream is being monitored, he/she will be less worried all the time.

Less chance of infection

The traditional invasive method for blood glucose measuring has a greater chance of infection. Where non-invasive technique does not involves any side effects at all.

No pain

Invasive method for blood glucose measuring involves needle. So there is pain no matter what the diagnostics center tells you. But as non-invasive method does not involves any kind of needle, the patient does not feel any kind of pain.

2.5 Challenges

Working with sensitive sensors

As all the sensors were really sensitive to work with, it was really hard to

determine the output. In the process we made some serious damage to some of the sensors. Sometimes the outputs were too confusing for us to deal with.

Working with new sensors

The sensors (FGA10 and NIR) used to measure diabetes were new to us. As we did not have the proper datasheet of any of the sensors, it was really hard for us to use appropriate resistor. We did not have any guidelines or help from various IoT experts as they were not familiar with the sensors.

Budget

The original sensors were really costly for us to work with. But we tried to replace them with the best next sensors we could get our hands on. And the results were not as bad as we expected. But the sensors seems to get damaged by a little miss use of them.

CHAPTER 3

Requirements analysis for the Proposed System

3.1 Introduction

Requirement analysis is consisting of some approaches taken to work out specific options, demands, expectation by communication with the system users. It needs combination of hardware, software.

3.2 Block Diagram of proposed work

Noninvasive glucose have been measured by Near Infrared (NIR) Sensor. NIR with 800-1700nm wavelength is suitable for measuring continuous glucose level. NIR sensor transmits continuous wave; a photodiode with 1550nm wavelength receives these continuous waves. After noise filtering and amplifying, these wave signals are converted into a suitable voltage value and the microcontroller converts these voltage value to an equivalent glucose value. This glucose value is displayed with a LCD monitor. The Microcontroller also sends this value to a server using a GSM module (sim

808). Observer can observe this glucose level obtained from the patient by using a smartphone. And in critical situation, emergency SMS is also sent to an observer. Figure 3.1 describes the block diagram of measuring and monitoring procedures.

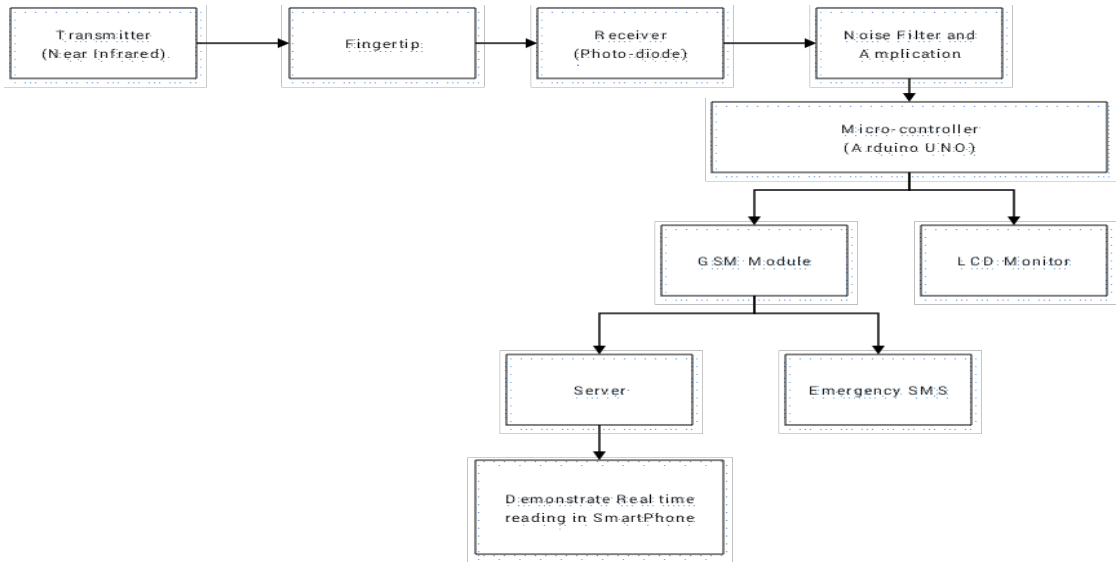


Figure 3.1. Proposed block diagram of non-invasive blood glucose monitoring system

3.3 Architecture of the system

Figure 3.2 shows how the proposed system works through a diabetes patient and observer of this patient. Patient's fingertip is placed between the glucose measuring sensors that measure glucose value through the aid of microcontroller. The patient can see his glucose reading in the LCD display and observer can monitor the patient's glucose condition through a smartphone and also gets notified with SMS when patient's glucose level reaches at a worrying level.

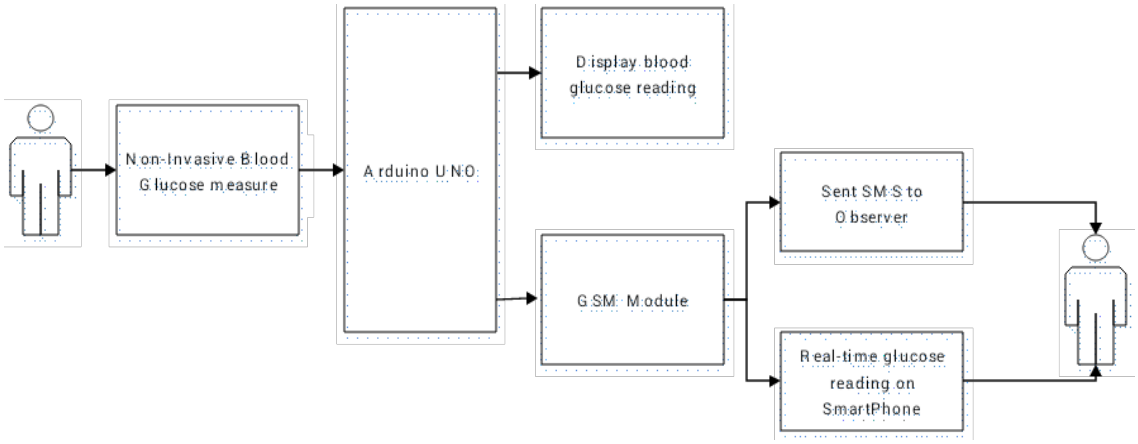


Figure 3.2: Proposed architecture of the proposed system

3.4 Flow chart of proposed system

Figure 3.3 illustrate the flow chart of the proposed system. Firstly, NIR sensor is powered up. Now to measure blood glucose, patient's finger has to be placed between NIR sensor and photodiode sensor. NIR sensor generates optical wave to photodiode and attenuated light wave is then measured and converted to signal by Photodiode sensor.

In the subsequent steps noise frequency of the signal from NIR is reduced through noise filtering procedure and the signal is amplified through amplification procedure to expand the weak signal. After the conversion of signal into electrical current value, Arduino converts this current value into a relative glucose value.

This glucose value is then compared with some condition, and according to condition the derived glucose value is displayed in LCD monitor with categorized level such as *dangerously low, low, normal, high and very high*. Observer also can see this categorized glucose level and glucose value. When glucose level is dangerously low or low or very high then a SMS is sent to the observer to take care of the patient. All glucose reading is stored in a database before terminating the system.

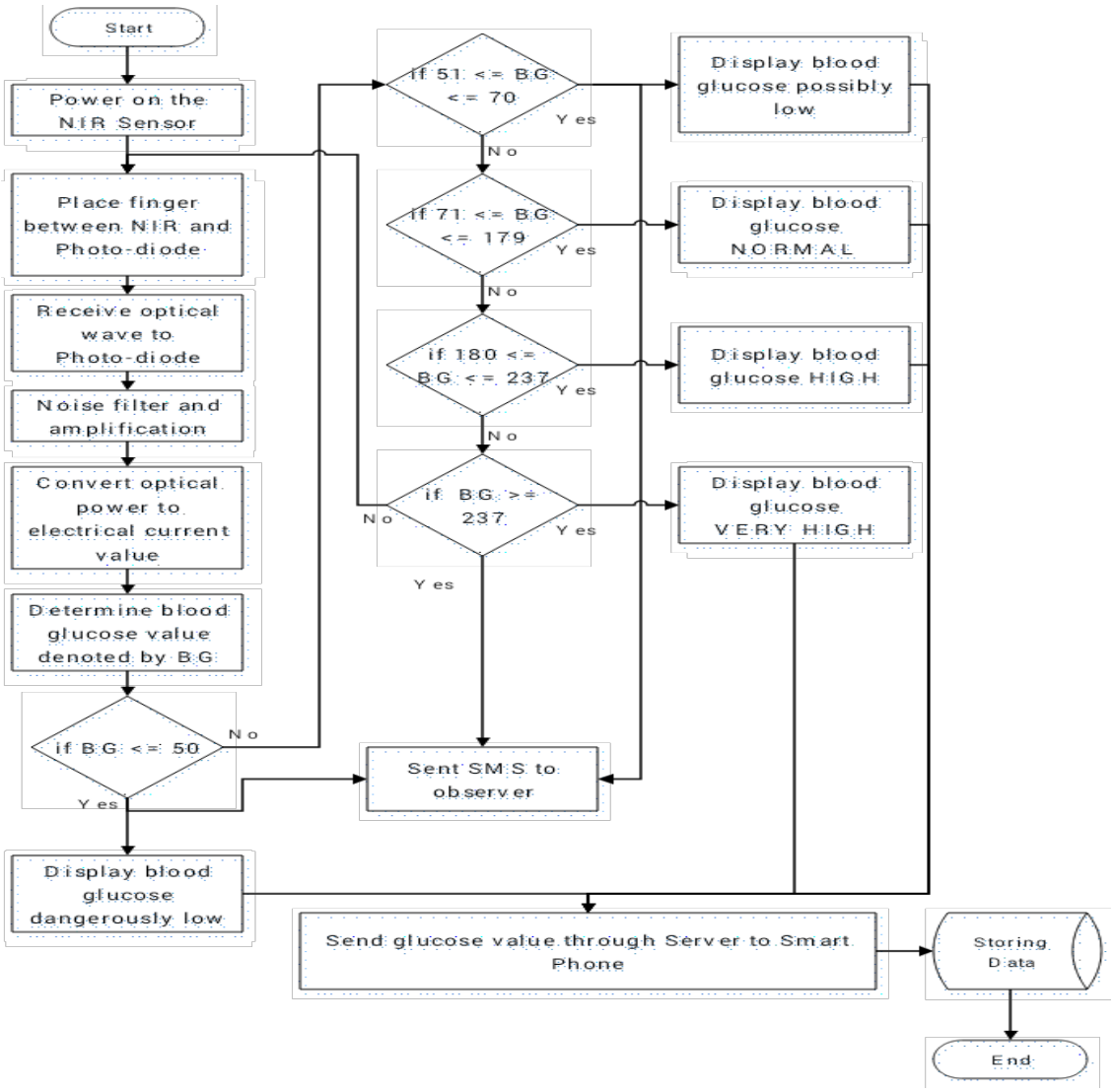


Figure 3.3: Flow chart of working procedure of the proposed system.

3.5 Use case diagram

Figure (3.4) shows use case diagram of our designed system

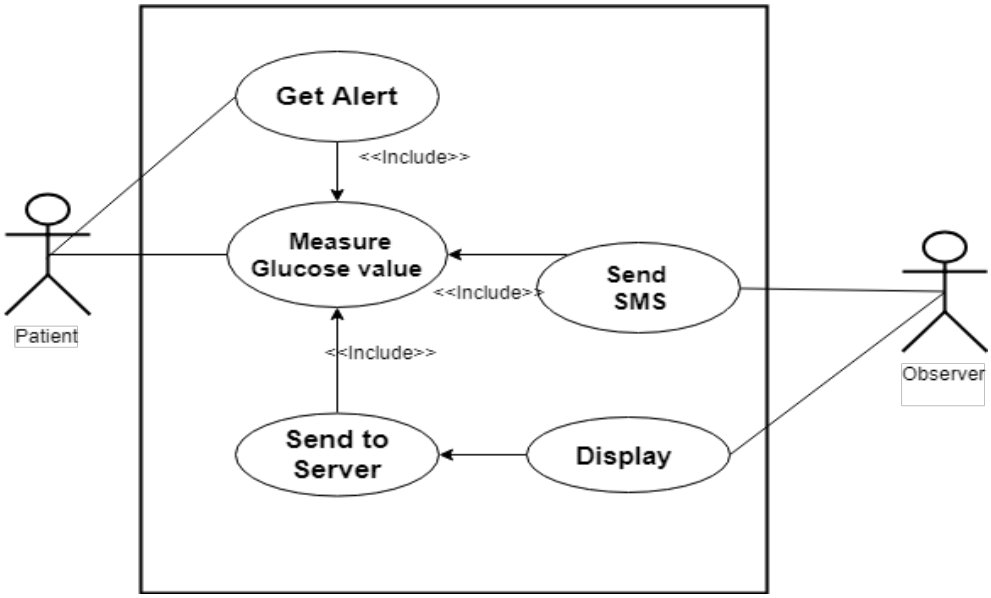


Figure 3.4: Use Case Diagram of proposed system.

3.6 Use Case Description

For Measuring Glucose Value

TABLE 3.1: USE CASE DESCRIPTION-MEASUREMENT OF GLUCOSE VALUE

Use Case Name	Measuring glucose value of the patient
Trigger	Patient must be triggered the sensor through finger for getting the value.
Pre-Condition	System devices must be powered on.
Basic Path	First the sensors transmit and receive the signal through fingers and the microcontroller will transfer these voltage signal to an identical glucose value.
Post Condition	Reading is sent and stored in server.
Exception Path	Probability of perishing the sensor.

For Getting Alert from System

TABLE 3.2: USE CASE DESCRIPTION-GETTING ALERT FROM SYSTEM TO PATIENT

Use Case Name	Getting alert from system to patient
Trigger	When the glucose level is calculated.
Pre-Condition	Displayable devices must be linked up with patient.
Basic Path	Microcontroller transforms the value from signal and sends it to display to the patient.
Post Condition	Successfully displays the value.
Exception Path	Fails to display.

For Sending Glucose Value to Server

TABLE 3.3: USE CASE DESCRIPTION-SENDING VALUES TO SERVER

Use Case Name	Sending values to server
Trigger	When the glucose level is calculated
Pre-Condition	System devices must be connected with internet.
Basic Path	Microcontroller transfigures the value from signal and sends it to the server.
Post Condition	Successfully stores the values on server.
Exception Path	Fails to store.

For Displaying Real Time Value to Observer

TABLE 3.4: USE CASE DESCRIPTION-DISPLAYING REAL TIME VALUE TO

Use Case Name	Displaying real time value to Observer
Trigger	When the glucose values is stored on server.
Pre-Condition	System devices must be connected to the server.
Basic Path	Server stores the values and then real time value is fetched up by devices to show
Post Condition	Successfully shows the real time glucose value.
Exception Path	Fails to show.

For Sending SMS to Observer

TABLE 3.5: USE CASE DESCRIPTION-SENDING SMS TO OBSERVER

Use Case Name	Sending SMS to Observer.
Trigger	When the glucose level is predicted.
Pre-Condition	System devices must have the ability to send SMS.
Basic Path	Microcontroller transmutes the value from signal and sends it directly to the Observer.
Post Condition	Successfully sends the SMS.
Exception Path	Fails to send SMS.

3.7 Equipment's for Proposed System

- ESP 12-E Wi-Fi IoT Development Board
- 0.3mm InGaAs pin Photodiode Sensor
- Near Infrared (NIR) Sensor
- Buzzer
- LCD
- GSM Module (Sim 808 v3.2)
- Android Studio
- Arduino IDE

3.7.1 ESP8266 (ESP-12E) Wi-Fi Development Board

It is a low-cost Wi-Fi module based microcontroller that built in one board platform which is expansive to use in IoT (Internet of Things) based applications. The board is predicates by the extremely in style ESP8266 Wi-Fi Module chip with the ESP-12 SMD footprint. All the required elements for the ESP8266 (ESP-12E) is already embedded by this Wi-Fi development board to program and transfer code. It's a intrinsic USB to serial chip transfer codes, 3.3V regulator and logic level device circuit thus we will right away transfer codes and connect our circuits. This board contains the ESP-12E chip with a 4MB nonvolatile storage thus no worries for long project codes. This microcontroller board will simply be programmed mistreatment the Arduino IDE programming package.

In figure 3.5, ESP-12E Wi-Fi Development Board. Microcontroller, Wi-Fi

module, flash chip and logic level converter are integrated in a single board.

Figure 3.5: ESP8266 (ESP-12E) Wi-Fi Development Board

3.7.2 0.3 mm InGaAs pin Photodiode 800-1700nm

A photodiode is a semiconductor sensor device that transfigures light into an electrical current. When photons are absorbed in the photodiode, the current is generated. Photodiodes contain optical filters, built-in lenses, and also have large or small surface areas. 0.3 mm InGaAs pin Photodiode (800-1700nm) has high reliability, ultra-low dark current, 800-1700nm spectral range, 0.3mm active diameter.

This sensor is used in medical field, security field and industrial automatic control field and so on.

Figure-3.6: Photodiode (0.3mm InGaAs photodiode)

3.7.3 Near Infrared (NIR) sensor

Sensors which can catch near-infrared rays, electromagnetic waves close to visible light is called near infrared sensor. The principal of near infrared sensor is to detect objects by emitting near-infrared rays and identifying the rate of change caused by the reflection or transmission of light. For our project, Near Infrared (NIR) sensor range is (800-1700nm

Figure 3.7: Near Infrared (NIR) sensor

3.7.4 Buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric (shortly known as piezo). The buzzer informs the situation by making a sound. There are magnetic buzzers and piezo buzzers depending on the structure that making a sound.

Figure 3.8: Buzzer

3.7.5 Liquid Crystal Display (LCD)

Liquid Crystal Display (shortly named as LCD) is an electric display module and find a comprehensive range of applications. A 16x2 LCD is exceptionally fundamental module and is regularly utilized in different devices and circuits. These modules are favored more than seven portions and other multi section LEDs. A 16x2 LCD implies it can show 16 characters for every line and there are 2 such lines. In this LCD each character is shown in 5x7 pixel matrix. This LCD has two registers, specifically, Command and Data.

Figure 3.9: Liquid Crystal Display (LCD)

3.7.6 GSM Module (Sim 808 v3.2)

A Quad-Band module that consists with GSM/GPRS also combined with GPS technology. It is fast and cost efficient .We have used this for sending message to observer

Figure 3.10: sim808 v3.2

Platform of our project

- Platform: Arduino
- Language C
- Tools: Arduino IDE

Arduino IDE

For our project, Arduino IDE has used to run program on microcontroller device for measuring the glucose value.

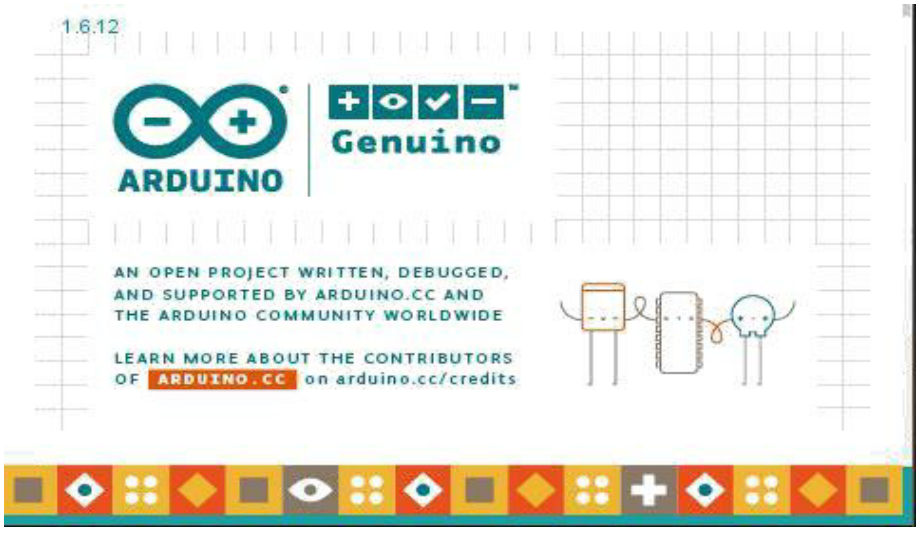


Fig-3.11: Arduino IDE

Arduino is a freely distributed prototype platform which comprises of a circuit board, that can be programed (alluded to as a microcontroller) and an instant programming package called Arduino IDE (Integrated Development Environment).This IDE runs on computer to write, compile and upload program in multiple genres of physical board.

The Arduino Platform has turned out to be exceptionally well known among

hobbyist and developers. Arduino products are freely distributed hardware and software under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL).

Here are some purposes of using Arduino IDE:

- It is freely distributed extensible platform.
- It has a massive community all over the world.
- It is very well known cross-platform IDE.

Platform used in Android Application

Platform: Android

Language: Java

Tools: Android Studio, Java SDK

Android Studio

For our developed system, Android Studio IDE is used to build Android Application.

Fig-3.12: Android Studio

Android Studio IDE (Integrated Development Environment) is officially

known as Android operating system which is provided by Google based on IntelliJ IDEA. By the replacement of Eclipse Android Development Tool (ADT), it is primarily used for Android development.

CHAPTER 4

System Design, Implementation and Testing

4.1 Introduction

Approaches that has been taken for solving our system will be discussed. Our proposed system is for those infants and aged people who have suffered from diabetes. Monitoring is very necessary for them as they often become hypo and they need to take sugar immediately. For this problem we have done this project. Here patients finger have to place between NIR and Photodiode. NIR transmit fiber wave and photodiode converted these wave into current values. Micro controller converted this value with suitable glucose value. Patient can see his glucose level on real time and also we use buzzer for getting alert to patient if he becomes very low. For remotely monitoring we extends our project. We thought for infants and aged people providing glucose value or providing alert is not enough. If one can monitor them on real time that could be a good for the patients. We have used wifi module to send data to server for this observer can monitor the patient through smartphone. We have also used gsm module for notifying the observer when patient's glucose condition is not good.

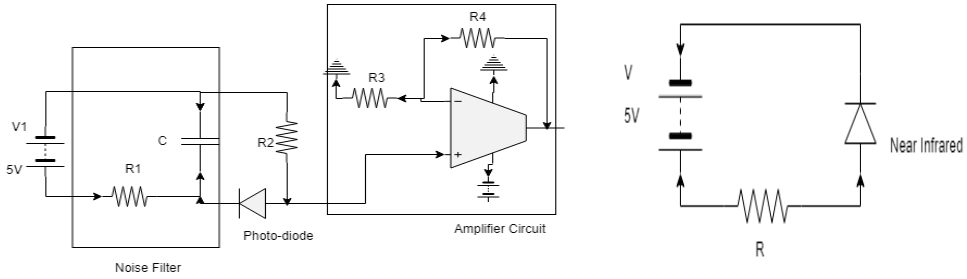
4.2 System Design

The system has been designed in two units:

4.2.1 Blood Glucose Measuring unit

In blood glucose measuring unit there are two circuits as shown in figure 4.1(a)

(Transmitter Circuit) and figure 4.1(b) (Receiver Circuit). Transmitter circuit consists of a noise filter, a photodiode (1550nm) and an operational amplifier (lm358); and receiver circuit consist with a near infrared (800nm-1700nm). Transmitter transmits continuous wave thread light through finger, receiver receives this attenuated light. Firstly noise frequency of this light is reduced by noise filtering components and then it has been amplified to expand the weak signal. After that the intended signal converted into an electric current value. Arduino converts the electric current value into relative glucose value.

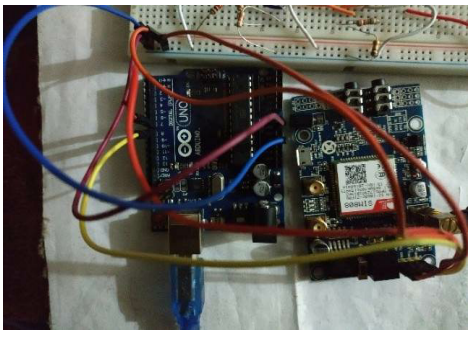


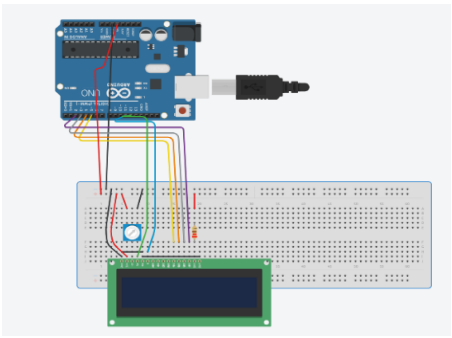
(a) Receiver circuit (b) Transmitter circuit

Figure 4.1: Schematic diagram for measuring blood glucose

4.2.2 Monitoring Unit

Glucose value will be displayed in an LCD display for patient (Figure 4.2(b) shows LCD circuit diagram); also, the value will be displayed through a smartphone apps for an observer (Figure 4.2(a) shows GSM module circuit diagram). GSM module 808 v3.2 has been used as it can send SMS to a cellular and also can send data to server.





(a) GSM module (SIM 808) circuit (b) LCD display circuit

Figure 4.2: circuit diagram for monitoring unit

4.3 Implementation of the Proposed System

Figure (4.3) shows LCD display to display glucose value to the patients.

Figure 4.3: Show glucose value in LCD display

Figure (4.4) shows the data storage on server.

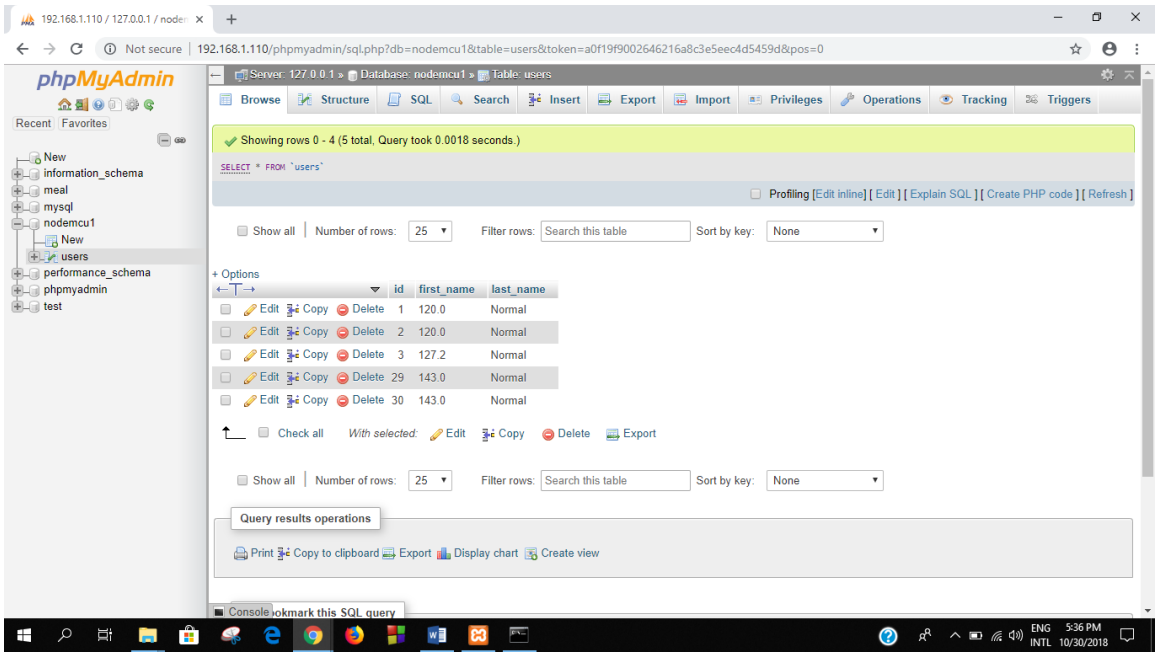


Figure 4.4: Glucose value in server

Figure (4.5) shows messaging function. When patients glucose level is critical it'll send notification to observer to take care of him.

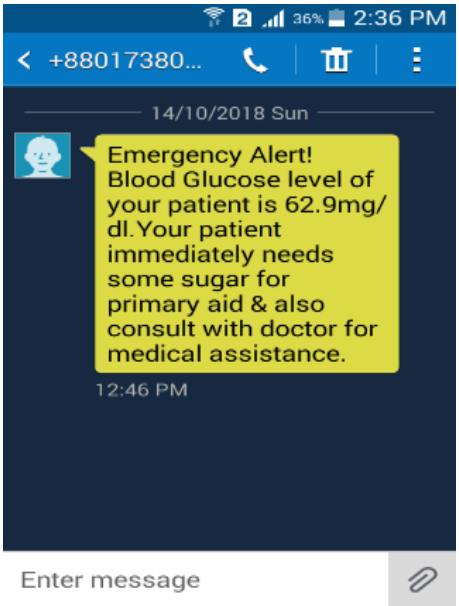


Figure 4.5: Notify observer via sending

message

Figure (4.6) shows the android apps to display real time glucose value to the observer.

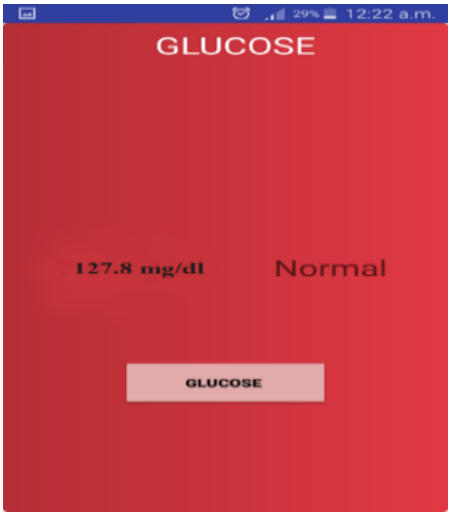


Figure 4.6: Mobile application for display real time glucose value

4.4 Testing

Unit Testing

Unit testing have focused on verifying the least unit of the designed software. White box testing is applied here. Measuring the glucose value is tested and if it give corrects value then value is sent to database for storing data and show in application and also show in LCD display.

Integration test

Integration testing is the black box testing where software is tested. For verifying functionality and its performance integration testing is performed. We have tasted our project by integrating testing. All module that includes with our

software design are tested:

TABLE 4.1: INTEGRATION TEST

Test Case	Expected Result	Observed Result	Test Result
Measuring Glucose value through NIR and Photodiode sensor	Can measure properly	Can measure properly	pass
Sending data to server	Can send properly	Can sent properly	Pass
Retrieve data from server for showing value on application	Can retrieve properly	Can retrieve properly	Pass
Send notification via SMS on observer mobile	Can send SMS properly	Can Send SMS properly	pass

CHAPTER 5

Conclusion, Implication for Future Research

5.1 Conclusions

The IoT based non-invasive method using Near Infrared (NIR) is becoming a very useful option for constant glucose monitoring. As it is not painful and there is no risk for infection unlike the traditional invasive methods, more people are willing to utilize the framework. IoT have been an integral part for number of different sectors, ranging from healthcare to building smart homes [17]. This proposed work can act as a multidimensional health monitoring system as it is capable of combining the monitoring functionality with feature such as notifying relevant information to the patient and the

observer. The constant remote collection of the patient's glucose readings will also help any doctor to take a decision based on patient's health if the patient or the observer decides to discuss the obtained information with the doctor.

5.2 Limitations

The obtained result might contain some errors. As we were not able to work with the actual sensors the errors occurs. Sometimes the server fails to cope up with the real time upcoming data from patient

5.3 Comparison

In most of the related papers, they tried to measure the blood glucose level in the blood stream of the patient by non-invasive technique. Some of the paper showed some notification related research. But none of the paper showed the total monitoring system as we did in our study. This study mainly focuses on the monitoring system of the patient on basis of measuring blood glucose level by non-invasive method.

5.3 Implication for Further Study

The system will be further developed to counter such errors and also to output more accurate value. Add diet plan for diabetes patient based on their glucose level is also another consideration for future development

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