JIMMA UNIVERSITY

JIMMA INISTITUTE OF TECHNOLOGY

DEPARTMENT OF BIOMEDICAL ENGINEERING

NON INVASIVE DIABETIC MELLITUS AND HEART RATE MONITORING WITH DISORDER IDENTIFICATION SYSTEM

By Zewdalem Melesse

A THESIS PROPOSAL SUBMITTED TO JIMMA INISTITUTE OF TECHNOLOGY FOR THE FULLFILLMENT OF THE REQUIRMRNTS OF DEGREE OF MASTERS IN BIOMEDICAL “BIOINSTRUMENTATION” ENGINEERING.

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Advisors – Dr. Towfik Jemal

Dr. T. Bheema Lingaiah

June, 2018

Jimma, Ethiopia

Declaration

I confirm the document which is presented in study entitled “Noninvasive diabetic mellitus and heart rate monitoring with disorder identification system” for the fulfillment of degree of master of science in biomedical engineering Submitted to school of biomedical engineering, Jimma institute of technology is my own work carried under the leadership and managment of Dr. Towfik Jemal and Dr. Bheema Lingaiah.

The matter contained in this dissertation has been succumbed neither in part nor in complete to any other university or institute expect as reported in references.

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ABSTRACT

Diabetic disorder is a form of physiological diseases in which our body blood sugar level increases from its normal level. Inadequate amount of insulin production or unusual response of body cells to insulin production results in increasing of sugar level. The status of our cardiovascular system can be monitored by heart rate counting, which indicates the condition of heart. So previous studies and researches aims on monitoring blood glucose level and heart rate condition in isolated way, as a result the relationship between these two parameters (blood glucose and heart rate) was not considered. But this research focuses to consider both parameters together along with the disorders they bring when the measurement is above or below the normal level for a better treatment. The thesis covers, continuous monitoring of blood glucose level and heart rate in isolated way but on the same system using electronic components and Arduino programming code. Measuring blood glucose concentration best suits at 940nm wavelength, as a result the number selected for the measurement. Heart beat sensor is being used for the measurement of heart rate. Both the prototype and simulation (on proteus) of the system is developed for analysis and validation of the final result. Test results of 40 individuals were measured on the system developed, which leads to relate the relationship between the two parameters. The effect of blood glucose and heart beat on cardiovascular system is also being assessed. The reference values in corresponding with the values obtained, none invasive measurement of blood glucose and heart rate measurement accounts 95% similarity which is clinically acceptable.

Key Words: Arduino uno, Blood glucose, Diabetes, Heart rate,

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ACRONYMS

IFG – Inspired Fast Glucose

WHO – World Health Organization

DM – Diabetic Mellitus

NCD – Non Communicable Disease

CVD – Cardiovascular Disease

ECG – Electro Cardiogram

Bpm – Beat per minute

PCG – Phonocardiogram

HR – Heart Rate

BP – Blood Pressure

NIR – Near Infra-Red

FPG – fast plasma glucose

OGTT – oral glucose tolerance test

HHNS – Hperosmolar Hyperglycemic Nonketotic Syndrome

PAD – Peripheral Arterial Disease

PLS – Partial List Square

IEEE – Institute of Electrical and Electronics Engineers

HRM – Heart Rate Monitoring

KUET – Khulna University Engineering and Technology

IOT – Internet of Things

GOD – Glucose Oxidase

POD – Glucose Peroxide

IMS - Intelligent Mechatronic Systems

IFG – Infra Red Fasting Glucose

T2D & T1D – Type 2 and Type 1 Diabetes

LED – light emitting diode

LCD – liquid crystal display

CHAPTER ONE

INTRODUCTION

1.1 Background

Because of the effect of globalization and epidemiologic transition non communicable diseases become disasters in public health around developing countries; but less evidence and data about diabetes and cardiovascular problems[1]. Although the majority of mortality is because of none communicable diseases in developing countries, their health system even do not cop up with this problems. So, designing and implementing different approaches needed to address all the problems[2][3].

Diabetic disorder is a form of physiological diseases in which our body blood sugar level increases from its normal level. Inadequate amount of insulin production or unusual response of body cells to insulin production results in increasing of sugar level. [4]. Estimations of the world health organization showed that 333 million patients in the word by the year 2025 which was previously 135 million by the year 1995. In developed countries non-communicable disease, diabetic mellitus is common since 2007. During this time 246 million patients were assumed to be available which were 194 million by the year 2003[5]. By the year 2000-01 a study was done involving 15640 adults between the age 35 and 75.the result showed that the prevalence of the disease was 5.5% and inspired fasting glucose was 7.4 [6]. Epidemiological study indicated that the increase in DM to be 9.7% and pre diabetes 15.5% which showed that 92.4 million adults were with the disease[7]. 22% of the diabetic patients they needed to see a cardiologist and 50% had cardiovascular disease according to studies done in recent time[8].

The symptoms of diabetic mellitus may include the following;

- ✓ Frequent urination
- ✓ Excessive thirst
- ✓ Unexplained weight loss
- ✓ Extreme hunger
- ✓ Sudden vision changes
- ✓ Tingling or numbness in hands or feet
- ✓ Feeling very tired much of the time
- ✓ Very dry skin
- ✓ Sores that are slow to heal
- ✓ More infections than usual

Under sub Saharan Africa, Ethiopia itself leveled at fourth place with the highest diabetic population. Year after year, medical admission related to this disease is getting grown in major health centers and hospitals. So prioritizing this situation to decrease the prevalence of the disease is the best method and mandatory in solving the problem[9].

R.no	Hospital name	Number of diabetes in 2017
1	Shanen gibe hospital	3060
2	Sexema hospital	2700
3	Agaro hospital	3480
4	Omo nada hospital	2400
5	Limu genet hospital	3600
6	Seka hospital	2900

Table 1 Jimma zone hospitals diabetes patient statics 2017

Per a day, monitoring the patient's blood glucose and knowing the level of measurement results in for casting the appropriate diet and medical treatment and also good for management of diabetes. Regulation of blood glucose level can be done by proper diet management or injection of insulin. Periodically measuring the level of blood

glucose is vital for treatment of diabetes. Glucose meter is currently used as a glucose level indicator invasively which is liable to afflict some degree of pain and capable of causing skin injury[10][11]. Measuring and developing blood glucose noninvasively will be a turning point for diabetic patients with an advantage of relief from pain and comfort since there is no finger puncturing. The non-invasive methods of glucose monitoring reduce the difficulties involved in glucose measurement and hence reduce the cost of healthcare[12]. Absorption and transmittance are the methods of noninvasive technique of blood glucose which gives dissimilar absorption spectrum with wavelength. The replacement of blood with other fluids which contain glucose like saliva, urine or other fluids is another option for painless control[13].

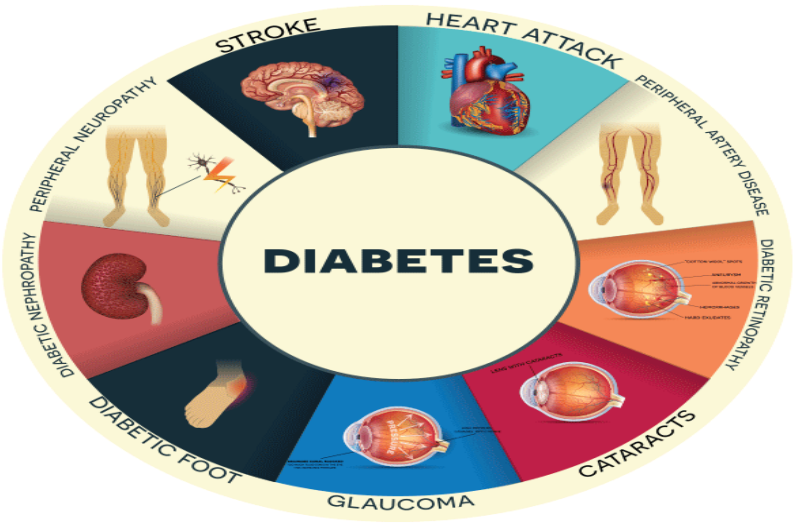


Figure 1 complication of diabetic mellitus [14]

Table 2 Type one and Type two Diabetes difference

	Type one diabetes	Type two diabetes
Phenotype	Happens early age and adolescence	Happens in older age, above 40
	Mostly thin and normal weight	Mostly obese people
	Ketoacidosis	No ketoacidosis
	Administration of insulin is must	Administration of insulin not

		mandatory
	By autoimmune attack pancreas is destroyed	By autoimmune attack, pancreas is destroyed
	Deficiency of insulin in total	Comparative insulin deficiency
	insulin injections	➢ healthy diet and increased exercise ➢ hypoglycemic tablets ➢ insulin injections
Genotype	More prevalence in relatives	Comparatively less in relatives
	Identical twin ; < 50% concordance	Identical twin studies: >70% concordance

People with both type of diabetes; type 2 diabetes and type 1 diabetes mortality is due to the prevalence and increase of cardiovascular system. Nearly 12% of all diabetes around the world cases are type 1which need to take insulin for the rest of their life so that easy to manage the sugar level[15].

On the prevalence of stroke and CVD, America has studied and found that 68% CVD and 16% stroke deaths related to diabetes which is four times higher than those without diabetes[16]. Diabetic mellitus and CVD are related in many ways, for example, patients with T2D with no back history of heart effect have similar risk of artery disease as no diabetic patients with a back history of heart problems; showing to consider diabetes as a coronary heart disease risk equivalent[17]. Obesity hypertension also cause for increasing the risk of CVD, specially for diabetic patients[18].

The status of our cardiovascular system can be monitored by heart rate counting, which indicates the condition of heart [19]. Heart beat/rate can be measured in home but it is better if it is measured in controlled condition like heart voice and blood measurement[20]. Our heart pumps oxygen-rich blood to our muscles and then to carry cell waste products away from our muscles. The frequency of our heart working increases as we use our muscle more, as a result heart beat became faster and deliver more blood

throughout our body. Monitoring heart rate using an instrument takes heart beat as a sample in order to calculate beat per minute, as a result it will be easy to track heart condition[21].

Electrical (with an average of its cost, 150$) and optical (with an advantage of its cost 20$) ways of developing heart monitors are available currently around the world. Heart rate of human is about 70 beat per minute for adult males and 75 beat per minute for adult females. Based on fitness, age, and genetics and so on, heartbeat of individuals is different. As an example athletes are with less resting heart beat[21].

Affected by a number of cofounders, for heart rate measurement; sources of variability occurs which include physical factors, environmental factors body measurement or others[22]. Watching all these problems, it has been recommended that sufficient information should be provided while reporting heart rate data [23]. These include:

(i) Before measurement resting period;
(ii) Environmental factors;
(iii) Measurement method;
(iv) Measurement number;
(v) Measurement duration;
(vi) Body position
(vii) Observer nature (i.e., physician, nurse).

To standardize the status of measurement, careful follow up is mandatory. Alcohol, nicotine, and coffee consumption should be avoided in the hours preceding measurement. Other points like room temperature, should be comfortable and background noise, should be avoided. The patient relax as much as possible and to refrain from talking until the procedure end. A minimum of 5 minute rest is needed to complete stable hemodynamic conditions. HR should be measured over a 30 second period by pulse palpation. And also two measurements in the sitting position must be obtained because blood pressure (BP) is more frequently measured in that position, and at the end of each BP measurement heart rate is measured [24]. Isolate system to monitor both

parameters is time consuming and need further laboratory analysis. And also the effect of one on the other is not known immediately.

The following are disorders of blood glucose and heart rate;

- Hyperglycemia/excessive blood sugar (higher than 200mg/dl)
- Hypoglycemia/shortage of blood sugar (less than 70mg/dl)
- Normal blood glucose level 72 – 138mg/dl
- Near to hyperglycemia 138 – 200mg/dl
- Bradycardia/ slow heart rate (below 60 beats per minute)
- Tachycardia/higher heart rate (above 100 beats per minute)

1.2 Statement of the problem

One of the causes of mortality globally/around the world is the diabetic mellitus. However the current way of monitoring blood glucose is biochemistry method (GOD and POD method) and finger pricking which brings discomfort, fear and pain to patients since they have to monitor their blood glucose level severally within a day [25]. Additionally, over 15 million deaths and several million people are disabled globally accounts for cardiovascular disease. During the year 2012, world health organization announced that 9% of all deaths in Ethiopia is because of cardiovascular disease[26]. So it is better to monitor heart rate continuously for all types of patients, especially diabetic's patients. Previously monitoring blood glucose level and heart rate condition was done in isolated way, as a result the relationship between these two parameters was not considered. So it is better if we consider both parameters together along with the disorders they bring when the measurement is above or below the normal level for a better treatment and health care.

1.3 0bjectives

1.3.1 General objective

The objective of the thesis is to design a non-invasive monitoring of diabetic mellitus (blood glucose value) and heart rate with disorder identification system.

1.3.2 Specific objectives

- ✓ To describe how monitoring of blood glucose and heart rate are useful for patients.
- ✓ To design a system that uses a microcontroller and other electronic components in order to monitor these parameters continuously.
- ✓ To design a system that identifies disorders of heart rate and diabetic mellitus.
- ✓ To explore how non-invasive measurement of blood glucose and heart rate overcome the barriers of invasive monitoring.
- ✓ To explore the relationship and effect of blood glucose and heart rate on cardiovascular problems.

1.4 Significance of the study

Unless diabetes is experiencing hyperglycemia or hypoglycemia, many of them do not notice particular symptoms. These disorders can destroy some organs of the body which results in complication of diabetes like the following;

- ✓ Heart attack or stroke
- ✓ Kidney complications which may result in regular dialysis
- ✓ Blindness/eye problem
- ✓ Erectile dysfunction which may result in sexual life
- ✓ Blood circulation problems.

To remove all this problems controlling blood glucose and measurement of heart beat is vital/important[27] So this thesis is good and fulfills the objective of measuring blood glucose monitoring regularly without fear as it is noninvasive way of measurement.

The additional impact of the research is to improve a system that identify some disorders, these parameters (blood glucose and HR) brings to the patient. so that it will be simple for the person who is doing the examination as it minimize the time that take another testing period. More over the relationship between these two parameters are going to be analyzed so that the effect of one on the other will be distinguished.

Physicians also can decide quick decisions depending on the result they found rather than committing further laboratory analysis.

1.5 Scope of the research

The thesis or study is going to cover, how to monitor blood glucose level and heart rate continuously in isolated way but on the same system (microcontroller) non-invasively. And the result of parameters displayed on the screen. Program code is loaded on the microcontroller so that the system works automatically. Diabetic mellitus patient's analysis will be carried out in Jimma zone hospitals using the system developed non-invasively as well as invasively in corresponding to the result from the previous measure.

1.6 Organization of the thesis

Five chapters are organized under this thesis. The chapters will be listed as follow for quick overview of the whole research.

Chapter one – is the introduction which discusses concept of diabetic mellitus and heart rate monitoring. For diabetic mellitus we are going to measure blood glucose level inside the blood and for CVD, we are going to measure heart rate of the patients. Here the relationship between these parameters also overviewed. Then what initiates to do the research and goal of the research is being discussed, following the importance and scope of the research..

Chapter two – is a literature review that reviews different journals and literatures which are related to the topic. Here reviewing the gaps and the points attempted to be addressed has been the main part of the chapter.

Chapter three – methodology and material used which discussed spectroscopic method for blood glucose level measurement. As a light source an infrared light and as a light detector, photo detector is being used. Analog to digital conversion is done by the inbuilt system of the microcontroller and then a code is being added so that we can measure both values. For noise reduction/minimization a filter is being used. Then the values will be

displayed and sample of individuals were taken just to find a regression formula which is used for Ardino programing.

Chapter four – is the result and discussion part that the output of the final result will be displayed and also discussions made on how it was done. For validation we have taken 40 individuals to be monitored invasively and noninvasively and see the difference. Heart bit also measured corresponding to each individuals which helped us to conclude the relationship between the parameters. And finally error analysis is made using Clarke error grid.

Chapter five – is the conclusion part that summarizes the thesis and also indicates the future scope to make the research in progress in bringing new outcomes.

CHAPTER TWO

LITRATURE REVIEW

2.1 Near infrared spectroscopic centered blood glucose measurement noninvasively: physiological effect, time drift

In the year 2010 Simon and his coworkers from china aimed at developing noninvasive measurement of blood glucose using infrared spectroscopy. Here under the same environmental state and sometime drift as well as machine drift, the near infrared spectroscopy obtains glucose concentration up to 200% difference which limits the development of the non-invasive blood glucose measurement. In order to show the advantage over using absorbance for glucose concentration, partial least regression was used. And also none diabetic individuals were also diagnosed as they needed it to consider it with the one that affected by the disease.

Healthy subjects and glucose solution was used as experimental data with a range of wavelength between 905 – 1701nm. For preparing different concentration of glucose, they have dissolved d-glucose in deionized water and as a container; they have used a thermo-resistant Petridis as it has high temperature resistant and good optical clarity. From 64 readings per sample, the average values are recorded. Calibration was carried out before each measurement against background and reference. On voluntary subject's part, fasting over night before the first near infrared and first finger prick in the morning of 36 healthy subjects, 8 male and 28 female, were carried out. The subject group comprised eight males and 28 females, all of whom were non-diabetic.

Higher absorbance spectrum was provided by pure water and higher glucose concentration represented lower absorbance spectrum as a result. According to their investigation, 1180nm was selected as it distinguished absorbance and located in the region of overtone [28].

In this research the accuracy is about 89%. And the method used is the absorbance method which needs very careful analysis and more of numerical which may lead to a

complicated values and results. And it does not incorporate additional parameters so that the condition of other organs is not considered.

2.2 Noninvasive glucose monitoring optical bases – sensor prototype

In the year 2016, Jaspreet and Shaqyri aimed in measuring blood glucose level of human body using spectroscopic method. In vitro and in vivo tests were conducted using transmission spectroscopy. Prototype system was established that quantifies the glucose level on the human body. The developed prototype has been tasted on real human body and the measurement was recorded.

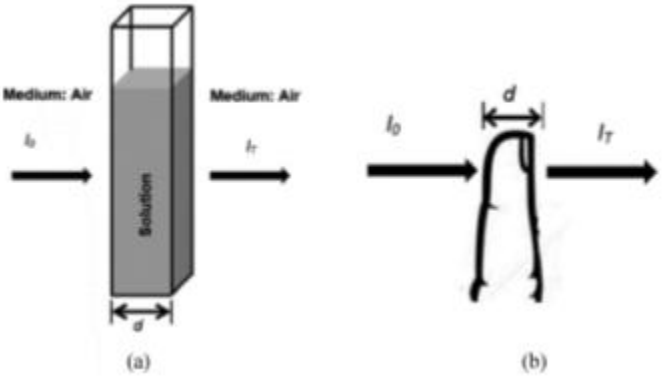


Figure 2 spectroscopy of transmission (a) solution passing light beam. (b) Light beam when passing through finger tip

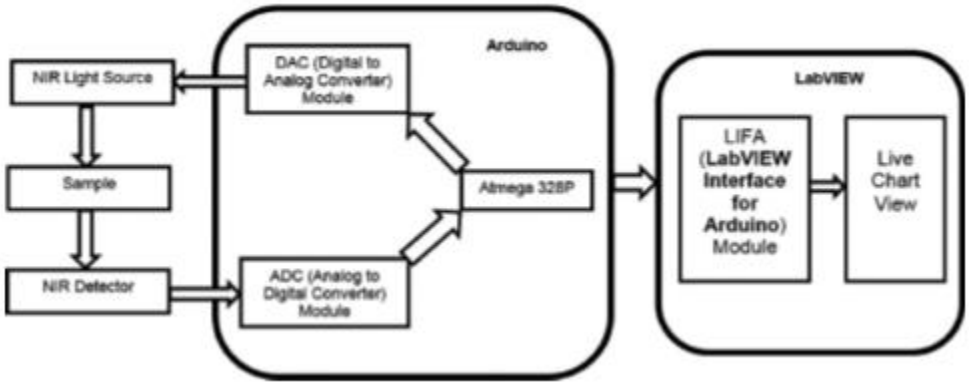


Figure 3: noninvasive glucose monitoring sensor system block diagram.

So, sensor output voltage and glucose concentration association demonstrated, as glucose concentration increases sensor output voltage increases, which have been carried out by in-vitro experiments. The system was tested in two parts, In-vitro testing and In-vivo testing. For in vitro testing;

- Concentration of both solutions were similar
- Reference reading taken from the solvent
- Initially 111mMole and show increment
- Reading was recorded
- Glucose sensor prototype show promising future and CCS compiler was used [29].

The research used absorption method like the above method and accuracy is equal to 92%. And also the paper used more interfacing software like Lab view which is not short and brief and does not integrate other parameters. Lastly the method is not cost effective as compared to other researches.

2.3 Monitoring of heart rate by using a microcontroller

In the year 2007, Mohamed Fazari and his coworkers aimed at developing of heart rate measurement using a microcontroller which brings an advantage of portability over other types of measurements. They explained that, how to analyses heart rate signals using a microcontroller and also investigated the application of it for real time analysis of ECG signals. Simulated ECG signals have been tested using the system and the logical approach has reduced overall memory size so that overall diagnosis time and the amount of data handled are also minimized[30].

There system also designed to include the following attributes;

- ECG signal diagnosis
- Real time ECG processing
- Remote control of a patient and transportability

They have been tested the logical algorithm using a simulated ECG signal and additionally the diagnosis bytes associated with each heart signal is being verified.

This researchers were measuring heart rate only which may not reduce the hospitalization and assistance cost paid for another test like blood glucose. And also measuring heart rate only will not secure the overall status of life.

2.4 Near infrared laser diode spectroscopy based noninvasive glucose estimation

To relate the amount of glucose level in blood, Boatema and his collogues aimed in designing in measuring blood resistivity using finger plethysmograpy. The device construction consist of: laser Diode around 650 nm wavelength, Laser Driver, Voltage regulator (2), step-down transformer (9v), Bridged rectifier circuit, photo detector (2), amplifier, ADC, microcontroller (Arduino Uno) and LCD to display the signal intensity. The device has been constructed in such a way to insert right index finger of the subject in-between the laser diode source and the photo detector. The signal intensity (V) were measured and different known glucose concentration as well as the in vivo calibration and the regression equations was obtained to help estimate the best fitting model (linear curve) and estimated values were correlated in validating the device with the biochemistry method.

By the process of signal intensities transmitted or reflected by cornea, dermis/epidermis layer and others of which arterial/venous blood taken into account, a noninvasive glucose measurement has been proposed. To overcome this barriers, they have used the following steps;

- In estimating regression equation, they have used a known glucose concentration to plot the best fitting curve
- From diabetic and none diabetic individuals, collecting noninvasive signal intensity using the proposed kit
- By taking blood sample, GOD and POD method, estimation of blood glucose concentration done of which is the same subjects

- Based on the correlation between measured blood glucose values and noninvasive signal intensities, computing the values

In this paper a laser diode is used which remains still an unproven method to some extent in predicting the concentration of blood glucose estimation. The calibrations of the prototype were done by comparing the signal intensity obtained in ADC with the biochemistry testing method called GOD and POD method. The accuracy of the measurement is low.

2.5 Using fingertip through IOT, monitoring heart rate

In the year 2018 from India, varum goel and his collogues aimed on developing a technique of measuring the heart rate through a fingertip so that the result displayed on LCD and over the net using a local server. During their study, finger print sensor through the microcontroller used to relate the patient's heart rate where the data transferred using a local server and globally.

- A local server is created by html page and
- Global server is connected via Think Speak software.

Think speak provides a good platform for storing and analyzing data through Wi-Fi module. Since a normal heart beat of a person is 72 approx. if it is less than 60 then it will show Bradycardia and if it is greater than 90 then it will show Tachycardia. The heart beat is shown in the form for graph where x axis represents time and y axis represent heartbeat [31].

Figure 4 heart beat with respect to time on Things peak

This paper is more of instrumental and similar to our paper except that it uses internet service which may limit the service to urban areas. And also a little bit different from ours in that our system is applied to areas that internet access is not accessible and is more of program oriented and incorporates blood glucose level detection and disease identification.

Table 3 **summary of related literature**

Year	Research work	Authors	Method	Result
2010	Study of measurement of glucose concentration by designing near infrared device	Dino Sia	➢ Used a wave length of 1450-2050nm ➢ Measures transmittance through solution	Provides glucose measurement of glucose value.
2011	Heart beat measurement in the role of health and disease	Kumar.T.M and his collages	Follow up of patients	➢ HR as a danger for cardiovascular mortality .

2013	The result of diabetics on CVD	Saldanha A. and his collages	An update	Investigated the impact of the disease on CVD
2015	GSM alert system monitoring of heart beat	Ufoaroh S.U his colleagues	Sensor used to sense heart beat and measurement	Provided the required device
2016	Measuring noninvasive way of blood glucose using NIR	Parag Narkhede and others	Optical technique.	Developed measurement non-invasively
2016	Study of measuring noninvasive way of blood glucose using	Kalaiselvi.P and et al…	Follow up and recording of consecutive values	Review the various noninvasive blood techniques and devices

CHAPTER THREE

METHODOLOGY AND MATERIAL

3.1 Methodology

For blood glucose monitoring, spectroscopic technique is used. Both when emitting and absorbing light, spectroscopy of objects can be studied based on wavelength spectrum and also a given species can be assesses its concentration using the technique[32].

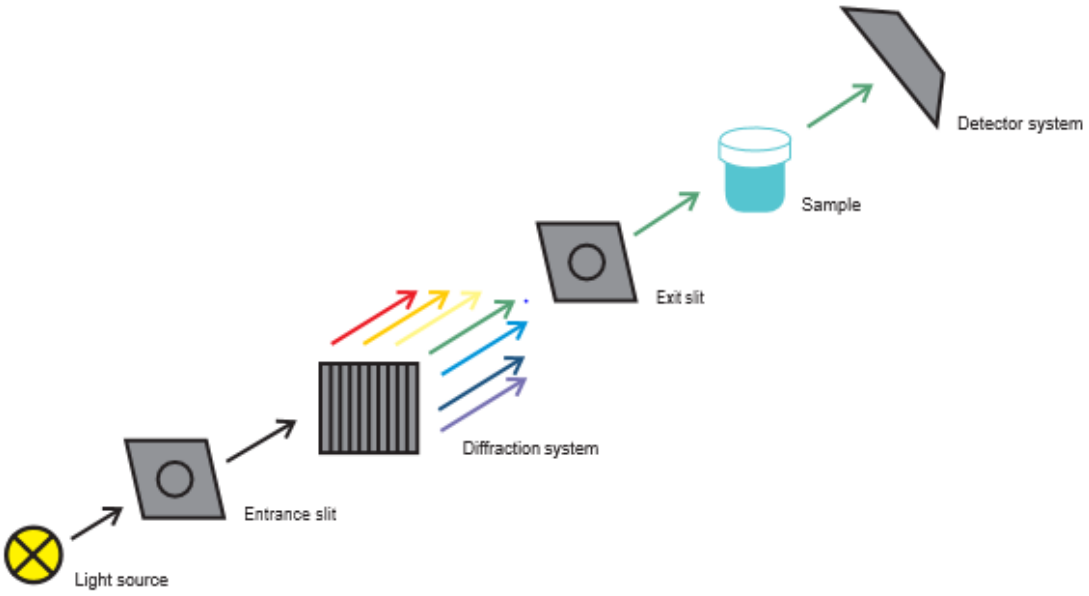


Figure 5 spectrophotometer parts

- Containing a wide range of wavelength, white light is directed towards the entrance slit.
- Light passes through a prism
- By using the exit slit specific wavelength selected.
- The selected range is directed to a sample and, the transmitted light is finally directed towards a detector system.

The base of the research is focused on near infrared technique that 940nm wavelength is being selected as it has high signal to noise ratio and also attenuation of optical signal of constitutes of blood like water and platelets is minimum. So depth of penetration and concentration of glucose can be predicted. Sensing unit comprises of;

- NIR emitter
- NIR receiver

Both are positioned on the measurement site (fingertip).

- Then the light interacts with the glucose molecule, some light gets absorbed depending on the glucose concentration of blood and remaining part is passed through the fingertip. The amount of blood glucose concentration can be affected by the amount of NIR light.
- Then the noise is filtered and amplified followed by direct interfacing of Ardino and displaying on the LCD.

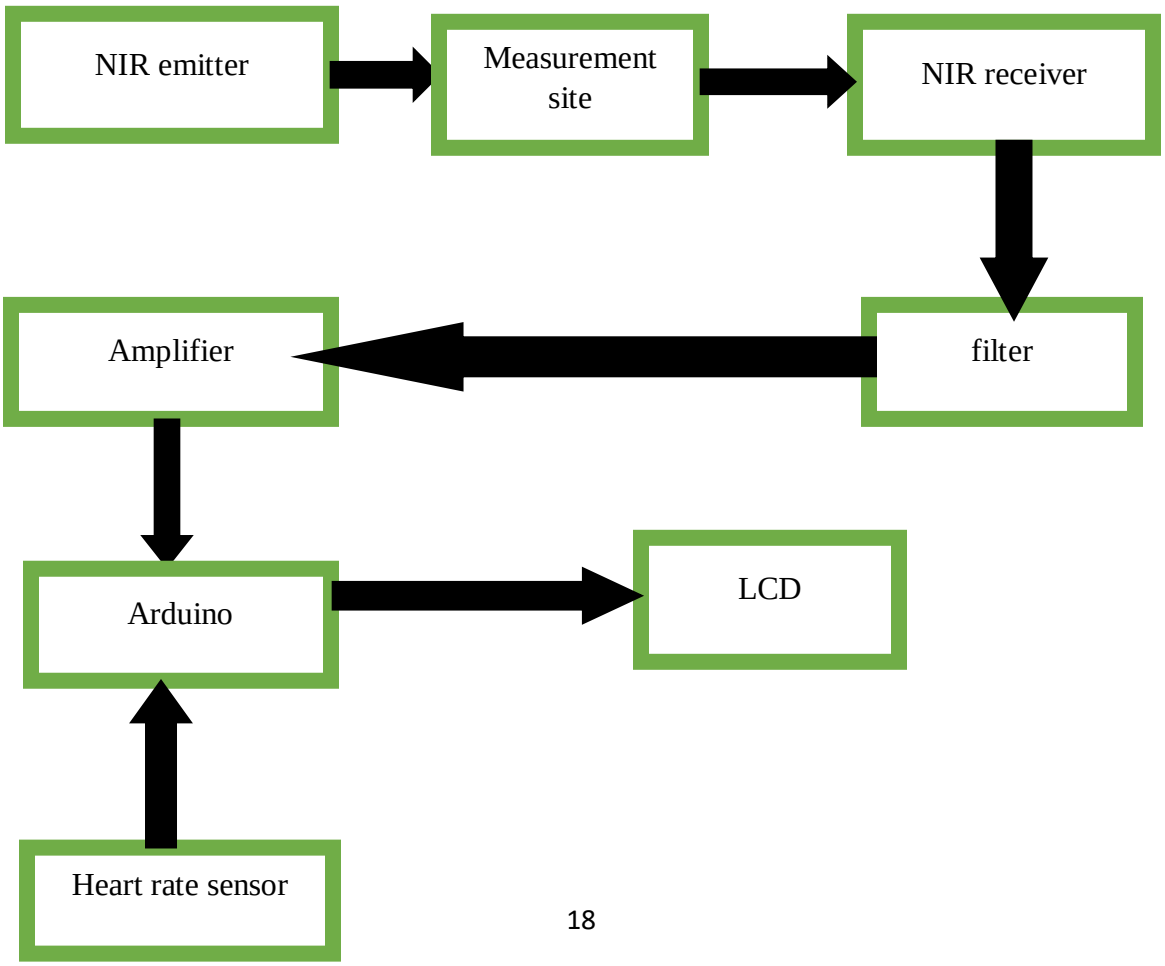


Figure 6 Block diagram of noninvasive glucose level and heart rate measurement

3.2 System design

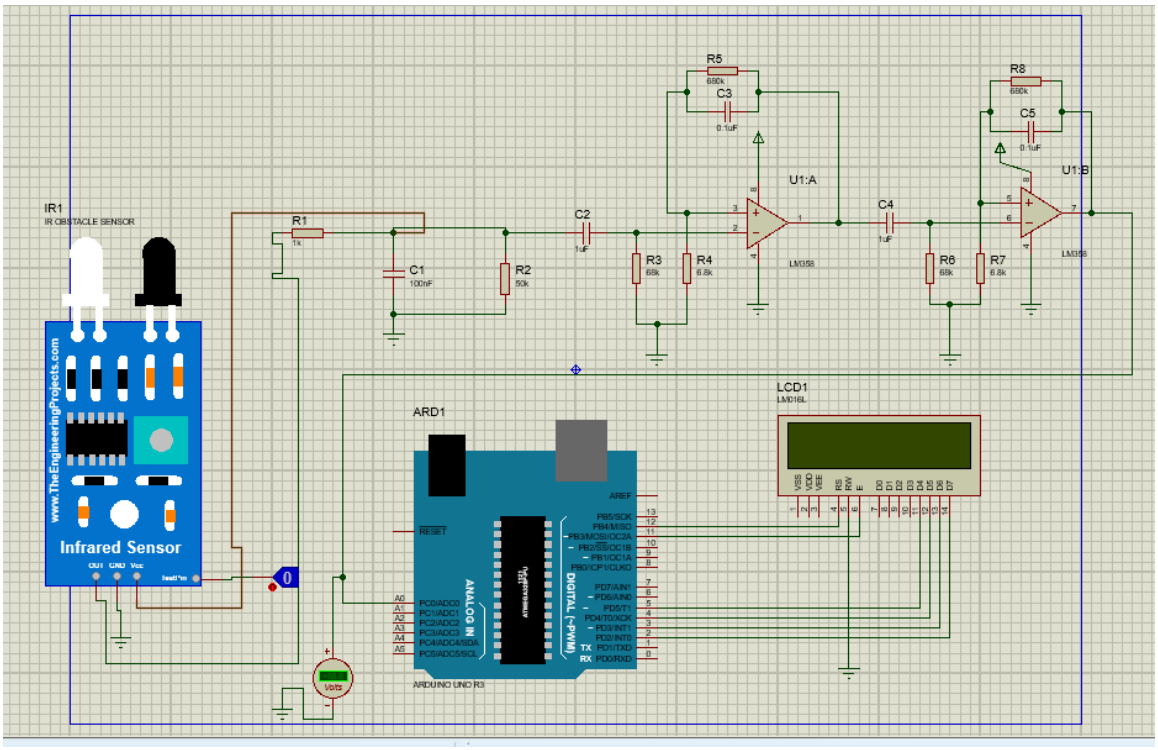


Figure 7 circuit diagram of blood glucose level

The ciricut diagram cosists of;

- Filtering stage and
- Amplification stage

Electrical current from the detector changed into voltage by placing load resistance R=50kilo ohm at the anode side of photodiode.

- Cut-off frequency of high pass filter =2.34 Hz and
- Low pass filter 1.59 kHz.

$$LPF = 1/ (2\pi R1C1)$$

$$=1/ [2\pi (1*10^{3}) (100*10\text{^}-9)]$$

$= 1.59$ kHz

$HPF = 1/ (2\pi R2C2)$

$=1/ [2\pi (68*10^3) (1*10\text{^}-6)]$

$= 2.34$Hz

Voltage gain = 1 + (Rf / Rin)

$=1 + [(680*10^3)/ (68*10^3)]$

$=101$

- Output voltage connected to A0
- Digital value measured using digital multi meter
- Actual glucose level is determined using polynomial regression equation. The equation is formed invasively using glucometer

3.3 Procedures for measuring blood glucose;

Step 1 24 individuals selected and monitored

Step 2 the values are tabulated. (Non-invasive using the proposed method and invasive way using glucometer)

Step 3 values compared, here the values of the noninvasive method displayed in multi meter at the output part of the circuit in mv. And the invasive one in mg/dl

Step 4 a regression formula developed from the values. So from that formula developing a program for blood glucose level monitoring

The following diabetic individuals were taken in order to find the regression formula which is a polynomial, used for handling separable data. 24 individuals were measured their glucose level invasively in laboratory along with the analog voltage measured using the proposed system.

Table 4 Analog voltage vs. glucose level using glucometer

Patient number	Analog voltage measured in multi meter (mv)	Glucose level measured in glucometer (mg/dl)
1	499	142
2	509	146
3	519	156
4	519	157
5	548	177
6	524	159
7	543	209
8	568	133
9	573	179
10	583	224
11	592	175
12	597	187
13	607	196
14	627	191
15	695	167
16	735	220
17	612	244
18	847	247
19	833	248
20	867	276
21	935	302
22	999	321
23	1136	338
24	1538	516

The following is the formula for calculating quadratic regression;

$a\ x^2 + b\ x + c$

$a = [[\Sigma x^2 y * \Sigma xx] - [\Sigma x\ y * \Sigma xx^2]\} / [\Sigma xx * \Sigma x^2x^2] - [\Sigma x\ x^2]^2]$

$b = [[\Sigma x\ y * \Sigma x^2x^2] - [\Sigma x^2y * \Sigma xx^2]] / [[\Sigma xx * \Sigma x^2x^2] - [\Sigma x\ x^2]^2]$

$c = [\ \Sigma y / n\ ] - [\ b * [\ \Sigma x / n\ ]\ ] - [\ a * [\ \Sigma x^2 / n\ ]\ ]$

Where,

$(\Sigma x\ x) = [\Sigma x^2] - [(\Sigma x)^2/ n]$

$(\Sigma x\ y) = [\Sigma x\ y] - [(\Sigma x * \Sigma y) / n]$

$(\Sigma x\ x^2) = [\Sigma x^3] - [(\Sigma x^2 * \Sigma x) / n]$

$(\Sigma x^2\ y) = [\Sigma x^2\ y] - [(\Sigma x^2 * \Sigma y) / n]$

$(\Sigma x^2x^2) = [\Sigma x^4] - [(\Sigma x^2)^2/ n]$

x and y – analog and blood glucose variables

a, b and c – quadratic equation coefficient

n - Patient number

(Σx)- The sum of analog voltage

(Σy) – The sum of glucose level

(Σx^2) - The sum of square analog voltage

(Σx^3) - The sum of cube of analog voltage

(Σx^4) – The sum of power four of analog voltage

$(\Sigma x\ y)$ – The sum of the product of analog and blood glucose level

(Σx^2y) - Sum of Square of analog and blood glucose level

Finally we get the following polynomial formula that relate both column's

y = (8*10^-5) x2 + 0.1873x + 46.131

For heart rate monitoring, the system designed consists of a heart rate sensor and an Ardino microcontroller. LCD showed as the final result. Here a program is loaded on the microcontroller.

3.4 Procedures for heart rate monitoring

Step 1 using the developed device, heart rate of the above individuals was monitored and recorded in front of the corresponding values of the blood glucose.

Steps 2 relationship between the parameters was analyzed, implies that normal blood glucose value vs. normal HR, above and below HR and the like.

Steps 3 physicians and other health professionals were involved to validate the values with the reference values.

3.5 Material used for blood glucose level measurement and heart rate monitoring

Ardino uno ;

- Focused on the ATmega328 (datasheet).
- Has 14 digital input/output pins
- 16 MHz ceramic resonator,
- Power jack, an ICSP header, and also a reset button[33].

LED IR-333A;

- High strength diode
- Molded in a blue clear plastic set
- Matched with phototransistor, photodiode and infrared receiver module.
- 940nm wavelength[34]

PT333C;

- High speed and high sensitive NPN silicon and NPN
- Molded in a standard 5 mm package
- Sensitive to infrared radiation[35].

Pulse rate sensor;

- Heart-rate sensor for Arduino.

LM358N;

- Two independent, high gains, internally frequency operational amplifier
- Operate from a single power supply over a wide range of voltages
- Operation from split power and the low power supply current drain is possible independent

Resistors;

- Of different values;

  330ohm, 1k, 50k, 68k, 6.8k 680k

Wires and connectors;

- Used to connect circuits and LCD interfacing

Capacitors;

- Of different values;

  0.1mico farad and 0.22 micro farad

Breadboard module;

- Used to make momentary circuits
- electronics and test circuit designs

- Electronic elements inside the electronic circuits can be substituted by inserting the station and leads into holes and later joining it with the help of appropriate wires[36].

LCD Display;

- Present textual information to user
- Here 16x2 LCD Module
- Capable of displaying 224 different characters and symbols[37]

Potentiometer;

- Three-terminal resistor with rotating adjustable voltage divider
- Used as brightness control**.**

3.6 Interfacing the Arduino and the LCD

LCD display contains two parts under its process of displaying;

- Wiring and
- programing

Where the program being included on appendix part. But we can see the wiring part as follows.

3.6.1 Wiring;

Sistine (16) pins are available under an ordinary LCD display that control different features of the screen. The microcontroller is with two output voltages of 5v or 3.3v where the LCD power with wiring VSS and VDD to one of the output. Contrast of the screen by wiring resistor to V0. The RS to pin 12, R/W to the ground, and E to pin 11 of the Arduino.

Pin 15 to ground and pin 16 to 5v so that the backlight will power. Laptop USB connecter can be connected to the VIN and ground pins on the Arduino.

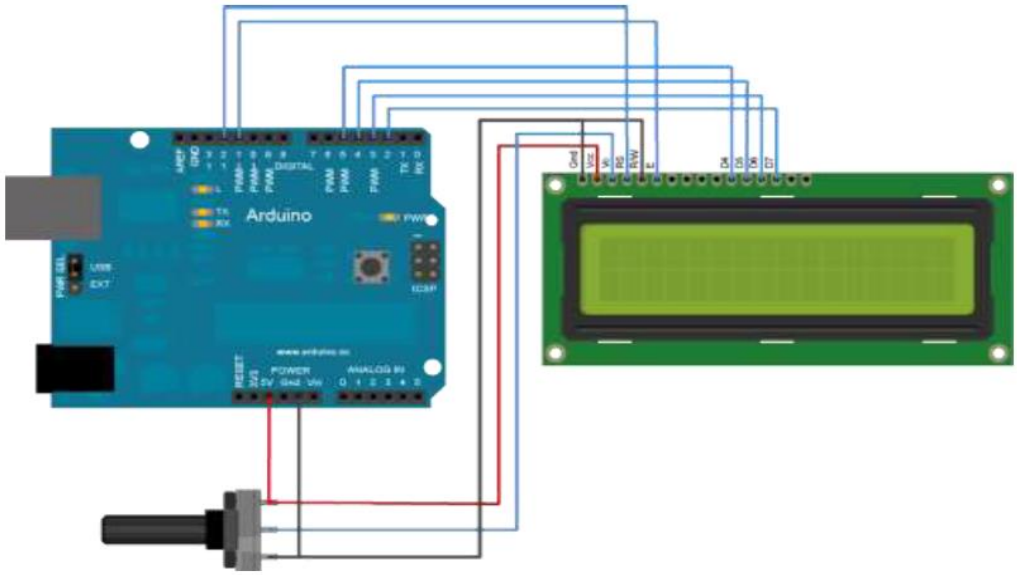


Figure 8 interfacing of ardino and the LCD

No. of pin	Representation	Purpose
1	vss	Ground
2	vdd	Power Supply
3	V0	LCD power supply
4	RS	Selecting displaying data
5	R/W	Reading or writing
6	E	Enable Signal
7	DB0	
8	DB1	
9	DB2	

10	DB3	Data signal display
11	DB4	
12	DB5	
13	DB6	
14	DB7	
15	LED- (K)	LCD as negative
16	LED+ (A)	LCD as positive

Table 5 the pins and description of each function

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Final simulation

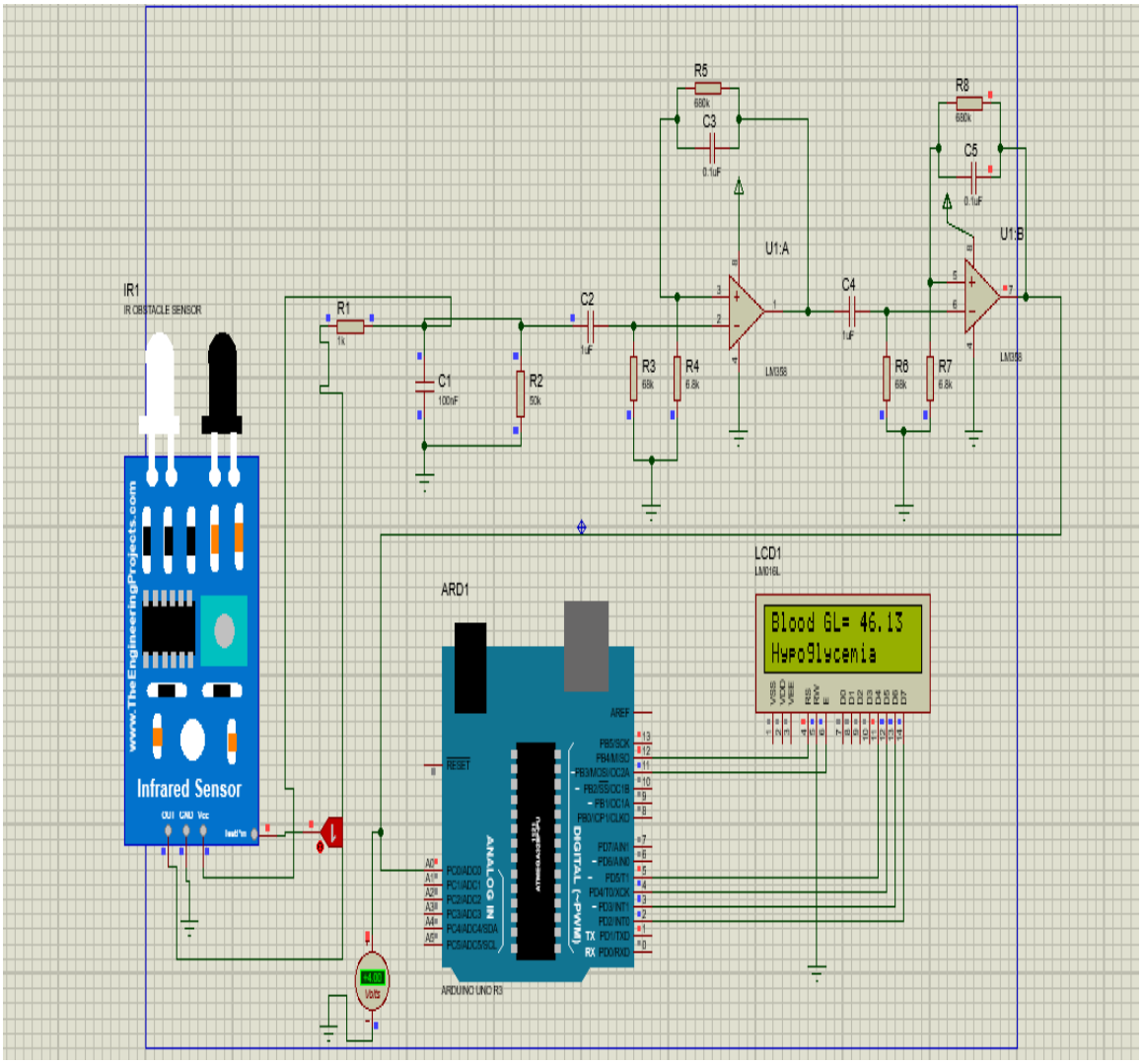
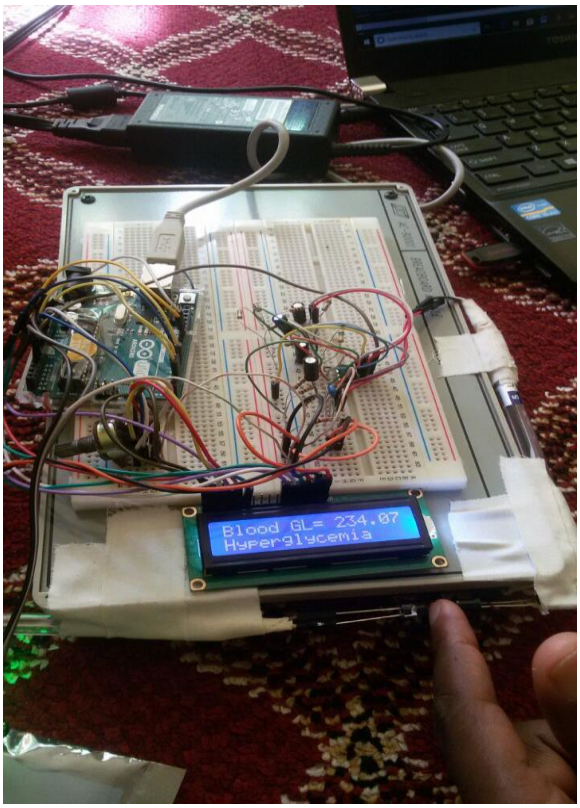


Figure 9 simulation of the final circuit



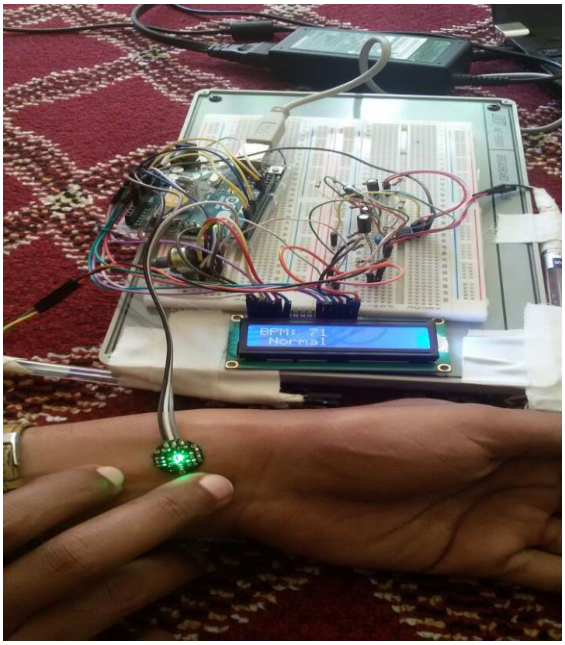


Figure 10 prototype of the designed system measuring blood glucose and heart bit.

4.2 Validation

By the reading of 40 individuals, the final result validated using both methods, invasively or noninvasively. Clarke error grid analysis is being used as an analysis of the accuracy of the glucose measurement. Also the value of heart rate measured by the proposed device also listed corresponding to other values.

Patient number	Invasively obtained glucose value (mg/dl)	Noninvasively obtained glucose value (mg/dl)	Variance (mg/dl)	Heart rate (bits/min)
1	117	118	1	75
2	143	143	0	101
3	112	115	+3	74
4	106	103	-3	74
5	166	169	+3	105
6	193	192	-1	110
7	88	88	0	65
8	108	110	+2	73
9	110	117	-7	75
10	134	151	-17	105
11	245	213	32	115
12	299	252	47	120
13	145	139	6	100
14	211	186	25	111
15	152	111	41	86
16	205	219	-14	116
17	120	129	-9	73
18	157	142	15	102
19	117	122	-5	72
20	164	170	-6	110
21	145	156	-11	104

22	170	161	9	111
23	117	108	5	68
24	110	152	-42	73
25	165	152	13	105
26	310	324	-14	117
27	149	160	-11	102
28	130	104	26	80
29	220	198	22	110
30	129	136	-7	95
31	316	268	48	117
32	131	128	3	75
33	192	220	-28	112
34	148	157	-9	98
35	170	162	8	103
36	145	154	-9	99
37	195	181	14	104
38	92	85	7	80
39	250	235	15	111
40	100	108	-8	84

Table 6 Invasive vs. noninvasive measurement including heart rate of patients

The variance between these values is due to;

- Body parameter variance due to glucose concentration like;
  - Blood pressure
  - Skin hydration
  - Triglyceride
  - Albumin concentration and body temperature
  - Environmental changes like humidity, atmospheric pressure and temperature

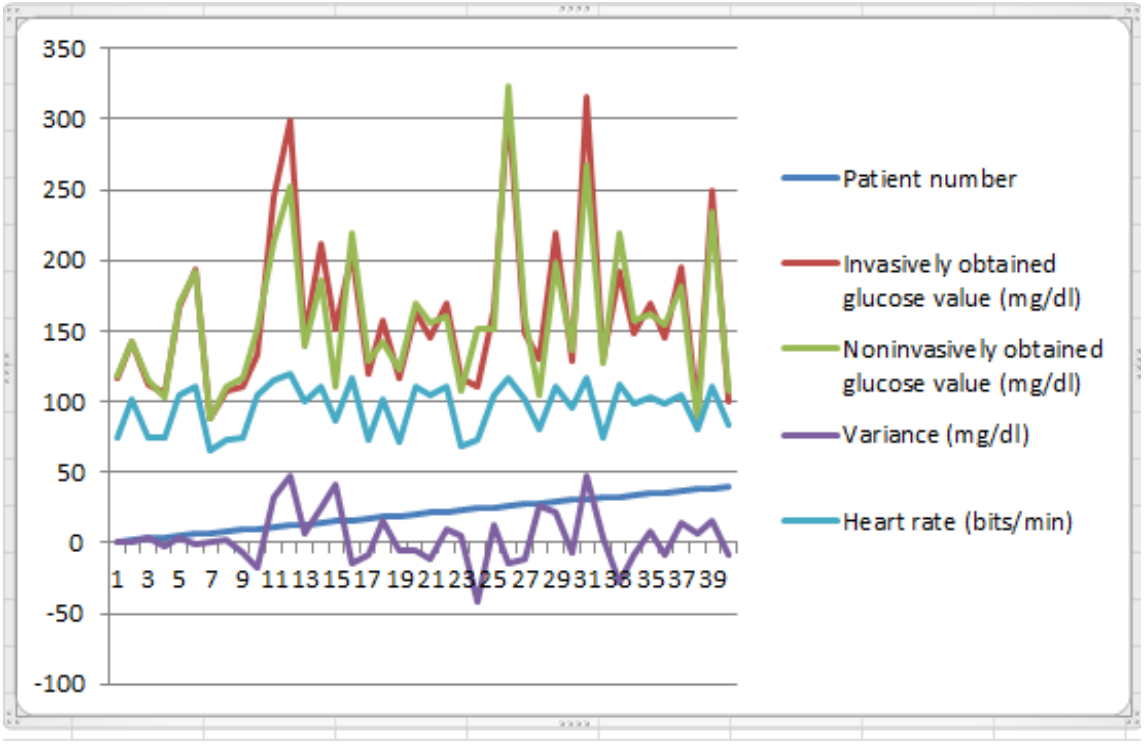


Figure 11 graphical representation of the above table

4.3 Relationship between blood glucose level and heart rate

- ✓ Those who have blood glucose level between 72 – 132mg/dl, had an average heart rate of 78.1 beats / min which is assumed to be a normal range. And from this it is concluded that individuals under this category are risk free from cardiovascular disease.
- ✓ Those who have blood glucose level between 132 – 200mg/dl, had an average heart rate of 104 beats / min which is assumed to be near normal range but need attention and follow up regularly in order to maintain a normal level. And from this it is concluded that individuals under this category are more at risk than the one who are normal and a little bit at risk of cardiovascular disease.
- ✓ Those who have blood glucose level above 200mg/dl, had an average heart rate of 115.4 beats / min which is assumed to be at risk range. And from this it is concluded that individuals under this category are under a risk of cardiovascular disease. They need a regular follow up every day.

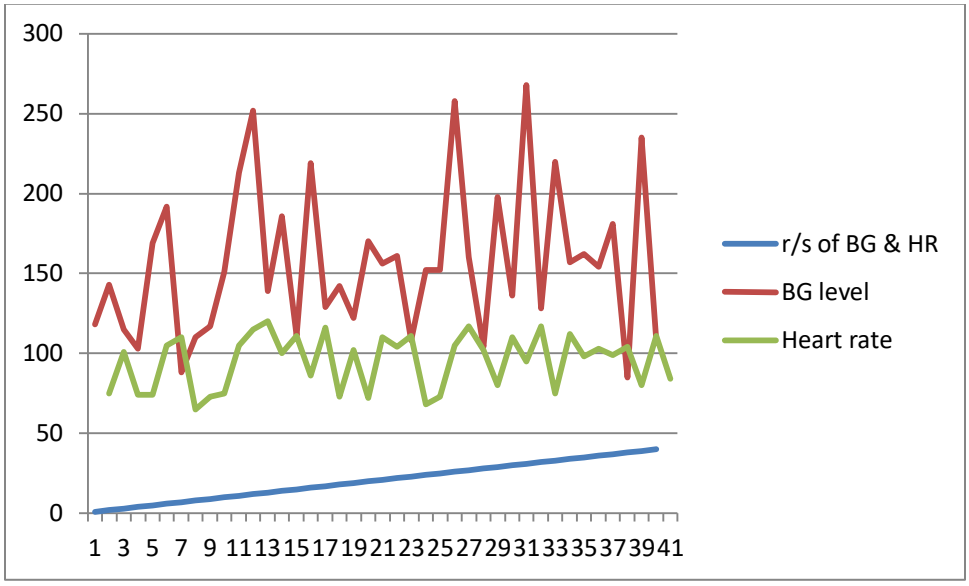


Figure 12 graphs showing the linear relationship of both parameters.

Here heart rate and blood glucose relationship is linear. These means as patients' blood glucose level increase the heart rate also increase and vice versa.

4.4 The clarke error grid analysis (EGA)

It is used to show accuracy of blood glucose value obtained using the developed device compared to the reference value and also it is a standard for determining accuracy[38]. The graph has 5 parts;

Region A;

Values of reference sensor of the values are 20%

Region B;

Values which can be handled but are outside of the 20%

Region C;

Values which brings unnecessary treatment

Region D;

Values that need to be treated seriously

Region E;

Complicate treatment of hypoglycemia for hyperglycemia and vice versa.

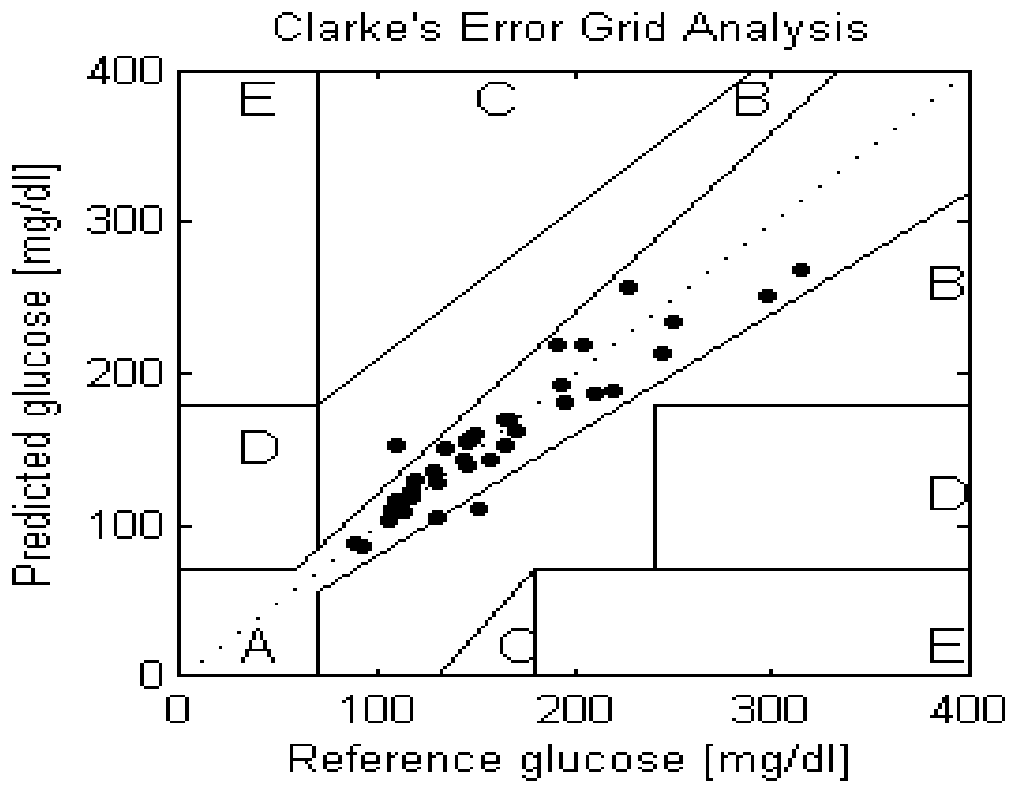


Figure 13 clarke's error analysis

All the glucose values are under region A (95%) except a few. So the values indicate that it's in acceptable range.

CHAPTER FIVE

CONCUSSION

In this thesis an attempt is done to measure blood glucose level continuously along with heart rate monitoring and see the relationship between these parameters. Measuring blood glucose concentration best suits at 940nm wavelength, as a result the number selected for the measurement. Hence a desired depth of penetration can be achieved and actual glucose concentration can be predicted. 24 individuals were involved to formulate a regression formula was developed depending on the reference values which are measured invasively using glucometer and the analog voltage output using multi meter. After the formula was obtained an Ardino program code was developed and uploaded on the circuit. For validation of the thesis 40 diabetic individuals that were willing to be measured were considered along with their heart rate measurement. The results of the values are tabulated in a table and a graph for easy analysis. From the result the blood glucose and heart rate measurements are linearly related. Some disorders regarding both parameters were identified using the system. And finally using clerk's error grid analysis the measurement of accuracy is 95% which is clinically acceptable.

5.1 Future work

For the future these system can be modified by adding other parameters or vital signs like blood pressure, respiration rate, and temperature. And also mobile phone can be used to monitor all these parameters so that it will be so easy for the patient and the physician as an alternative monitoring system to save time.

APPENDIX

The following is the code that developed for the measurement system of the parameters;

```
#include <PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library.

#include <LiquidCrystal.h>

PulseSensorPlayground pulseSensor;  // Creates an instance of the PulseSensorPlayground object called "pulseSensor"

//  Variables

const int PulseWire = A0;       // PulseSensor PURPLE WIRE connected to ANALOG PIN 0

const int LED13 = 13;          // The on-board Arduino LED, close to PIN 13.

int Threshold = 550;           // Determine which Signal to "count as a beat" and which to ignore.

   double lt;                  // Use the "Gettting Started Project" to fine-tune Threshold Value beyond default setting.

                               // Otherwise leave the default "550" value.

LiquidCrystal lcd(12,11,5,4,3,2);

void setup() {

  Serial.begin(9600);          // For Serial Monitor

  lcd.begin(16,2)      // Configure the PulseSensor object, by assigning our variables to it.

   pulseSensor.analogInput(PulseWire);

   pulseSensor.blinkOnPulse(LED13);       //auto-magically blink Arduino's LED with        heartbeat.

   pulseSensor.setThreshold(Threshold);   // Double-check the "pulseSensor" object was created and "began" seeing a signal.


   if (pulseSensor.begin()) {

    Serial.println("We created a pulseSensor Object !");  //This prints one time at Arduino power-up,  or on Arduino reset.

      lcd.clear();

     lcd.setCursor(0,0);

     lcd.print("Ready...");

     delay (5000);

     lcd.clear();

     lcd.setCursor(0,0);

    lcd.print("Please attach");
```

```
    lcd.setCursor(0,1);
    lcd.print("your finger");
    delay(20);
  }
}
void loop() {
int myBPM = pulseSensor.getBeatsPerMinute();  // Calls function on our pulseSensor object that returns BPM as an "int".
                                              // "myBPM" hold this BPM value now.
if (pulseSensor.sawStartOfBeat()) {           // Constantly test to see if "a beat happened".
 Serial.println("♥  A HeartBeat Happened ! "); // If test is "true", print a message "a heartbeat happened".
 Serial.print("BPM: ");                        // Print phrase "BPM: "
 Serial.println(myBPM);   // Print the value inside of myBPM.
  if(myBPM > 85)
  {
    Serial.println("Love you");
   lcd.clear();
   lcd.setCursor(0,0);
   lcd.print("BPM: ");
   lcd.print(myBPM);
   //lcd.clear();
   lcd.setCursor(0,1);
   lcd.println("Tacycardia        ");
 }
 else if(myBPM < 60){
   lcd.clear();
   lcd.setCursor(0,0);
   lcd.print("BPM: ");
   lcd.print(myBPM);
   lcd.setCursor(0,1);
   lcd.println("Bradycardia          ");
 }
 else if (myBPM >60 && myBPM <85){
```

```
  lcd.clear();
   lcd.setCursor(0,0);
   lcd.print("BPM: ");
   lcd.print(myBPM);
    lcd.setCursor(0,1);
   lcd.print(" Normal ");
}
}
 delay(10000);                  // considered best practice in a simple sketch.
 lt=analogRead(A1);
lt=lt*lt*0.00008+0.1873*lt+46.131;
lcd.setCursor(0,0);
lcd.print("Blood GL= ");
lcd.print(lt);
if(lt<73)
{lcd.clear();
lcd.print("Blood GL= ");
lcd.print(lt);
 lcd.setCursor(0,1);
// lcd.print("               ");
 lcd.print("Hypoglycemia");
}
else if(lt>73 && lt<143)
{lcd.clear();
lcd.print("Blood GL= ");
lcd.print(lt);
 lcd.setCursor(0,1);
// lcd.print("               ");
 lcd.print("Bg is Normal");
}
else if(lt>143 && lt<200)
{lcd.clear();
```

```
lcd.print("Blood GL= ");
lcd.print(lt);
  lcd.setCursor(0,1);
 // lcd.print("               ");
  lcd.print("Near Hyperglycemia");
}
else if(lt>200)
{lcd.clear();
lcd.print("Blood GL= ");
lcd.print(lt);
  lcd.setCursor(0,1);
 // lcd.print("               ");
  lcd.print("Hyperglycemia");
}
delay(10000)
```

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