UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Design and Implementation of an IoT-Based Diabetes Remote Monitoring system

By:

Gaspard Nelly Uwumuremyi

Masters of Science in Internet of Things in Wireless Intelligent Sensor Networks

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Title: Design and Implementation of an IoT-Based Diabetes Remote Monitoring system

By **Gaspard Nelly Uwumuremyi**

Reg. No**: 219013749**

A dissertation submitted in partial fulfilment of the requirements for the degree of masters of science degree in internet of things: wireless intelligent sensor networks In the College of Science and Technology (CST)

Supervised by:

Dr. Celestin TWIZERE

Dr. Gerard RUSHINGABIGWI

June 2021

DECLARATION

“I, Gaspard Nelly Uwumuremyi, hereby declares that the Master thesis entitled "**Design and Implementation of an IoT-Based Diabetes Remote Monitoring system**" is a presentation of my original research. Wherever contribution of others is involved, every effort is made to indicate it clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

I have read the University’s current research ethics guidelines, and accept responsibility for the conduct of the procedures in accordance with the University’s Committee.

This work was done under the supervision of Dr. Celestin TWIZERE, and Dr. Gerard RUSHINGABIGWI.

Gaspard Nelly Uwumuremyi **Reg.no: 219013749**

Signed …………………

Date……………………………………

BONAFIDE CERTIFICATE

This is to certify that the project entitled **"Design and Implementation of an IoT-Based Diabetes Remote Monitoring system"** Is a record of original work done by Gaspard Nelly Uwumuremyi with registration number **219013749** in partial fulfilment of the requirement for the award of masters of sciences in Internet of Things in College of Science and Technology, University of Rwanda, Academic year 2018-2020

This work has been submitted under the guidance of **Dr. Celestin Twizere** and **Dr. Gerard Rushingabigwi**

Supervisor 1: Dr Celestin TWIZERE **Supervisor 2: Dr Gerard RUSHINGABIGWI**

Signature: **Signature:**

The Head of Masters and Trainings

Names: Dr Didacienne MUKANYIRIGIRA

Signature: ……………………………………….

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ABSTRACT

Real time diabetes remote monitoring aimed at detecting blood glucose level, Heartrate, Blood pressure and Body temperature with Internet of Things (IoT) Technology. Typically, it is a self-diabetes management system intended to perceive the concentration of specific molecules namely hyperglycemia and with other diabetes' parameters. We discussed and analyzed data collected by biological sensors. Microcontroller (Arduino Uno) has been used for data filtering and transfer sensed data to the cloud through IoT communication protocols. An IoT-based web-application has been developed and linked Node-Red dashboard in order to manage and connect patients with their physicians. Based on measurements collected by the sensors, the physicians may provide the assistance at real time to the patients from user-friendly interfaces dashboard. The previous researchers, introduced the usage of Telephone for Mobile-Health (mHealth), this IoT system integrated of mobile phones and computers with sensor based. The system was designed and tested in such a way that Doctors can access patients' data in a mobile and web-based application. Diabetes remote monitoring system is a tool for careful management of diabetes disease which may build up from the elevated blood sugar. The assistances were provided by doctors, and the patients access their feedbacks via patient's panel of the application, and to their e-mail's accounts and also by telephone call. The existing literature showed that the over-increasing blood glucose leads to many complicated risks such as Stroke, Heart diseases such as cardiovascular diseases. This research contributes to the health sector by filling the gap between clinicians and patients, which was caused by the lack of real-time healthcare, and it may lead to the loss of lives. This Diabetes Remote Monitoring System (DRMS) intelligently operates by identifying and understanding in advance connected devices in heath industries for diabetic's patients. The thesis focused on benefits of diabetics through IoT devices to manage the above parameters. By the results, we encountered real-time data transfer from patient to the clinicians. Diabetics in critical status at fasting:80-139mg/dl; >85 bpm, 120-180 mmHg (Systolic), 80-120 mmHg (Diastolic) 36^{o}C-37.9^{o}C or $\geq$ 37.9^{o}C, Blood glucose, Heartrate, Blood Pressure and body temperature measurements respectively.

The calculation of Correct Dose Insulin has been evaluated based on real time measurements.

Key words: Blood Glucose, Heartrate, Blood pressure, body Temperature, Diabetes, Real-Time, MQTT, Internet of Things, Physicians, DRMS

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List of the Acronyms

AACE: American Association of Clinical Endocrinologists

ADA: American Diabetes Association

AHA: American Heart Association

AI: Artificial Intelligent

BG: Blood Glucose

BP: Blood Pressure

CSV: Comma Separated Values

DM: Diabetes Mellitus

DRMS: Diabetes Remote Monitoring System

EAC: East African Community

EASD: European Association for the Study of Diabetes

ECG: Electrocardiogram

GUI: Graphic User Interface

HR: Heart Rate

HTML5: Hipper-Text Mark-up Language

IBM: International Business Machines Corporation

ICT: Information Communication Technology

IoT: Internet of Things

ISF: Insulin Sensitivity Factors

IT: Information Technology

MQTT: Message Querying Telemetry Transfer

NCDs: Non-Communicable Diseases

RDA: Rwanda diabetes Association

TDD: Total Daily Dose

VPN: Virtual Private Network

VPS: Virtual Private Server

WHO: World Health Organization

WiFi: Wireless Fidelity

WSN: Wireless Sensor Networks (WSN).

CHAPTER 1. INTRODUCTION

1.1 Introduction

Diabetes is one of Non-Communicable Diseases (NCD), which is mainly characterized by a high blood sugar level known as hyperglycemia. The numbers of persons who are suffering from chronic diseases are incredibly increasing and the world counts a huge number of deaths. This research is mainly focusing on Diabetes Remote Monitoring. According to a report by the World Health Organization, Diabetes is a chronic disease that globally kills many people and seems to be increasing at a higher rate. Through the help of IoT, a small number of doctors can help many patients including people living with diabetes. The study focused primarily on helping diabetics to send measurements from sensors, such as glucose meters, heart rate, blood pressure, and body temperature, at the right time in real time. The Diabetes Remote Monitoring system also will be easier for the doctors to get the patient's information, with real time remote monitoring and assess them, with the help of technology, it is actually not necessary for the patients to travel from their home villages for visiting the clinics then looking endocrinologists, for doing medical examination of diabetes checkups unless you have accredited the official appointment provided by doctors. The aims of this system architecture, is to develop a new approach which will solve the problem of the long queue appeared at the diabetes hospitals while doctors are lowered compared to the patients. Longer a person lives with undiagnosed and untreated diabetes, the worse their health outcomes are likely to be, as published at WHO website (WHO, 2020a). In an effort to help people with diabetes, to prevent inherent deaths, from its complications, we have included how the patient can give or measure heart-beat, blood pressure and temp because it has been shown to be among the leading killers, especially diabetics.

1.2 Background and Motivation

1.2.1 Background

The world has been plagued by a number of diseases, which have claimed lives. These diseases have claimed the lives of the world's population, including Non communicable diseases.

Diabetes is a major chronic disease which is challenge for human health and development in the 21st century. People living with diabetes, access to affordable treatment, nearby diabetes clinics/hospital, is critical to their survival.

The World Health Organization (WHO) showed that from 2000 to 2016, the number of people dying diabetes, due to the lack of real-time healthcare, increased by 5%, although it was found that from 2000-2010 it had decreased, but by 2010-2016 the number of deaths due to diabetes or premature increase (WHO, 2020b)

Many people around the world continue to lose their lives due to non-communicable diseases NCDs, including High blood glucose, a graphic from the WHO report,(WHO, 2016) which shows how people have died from high blood glucose.

HIGH Blood Glucose AGE-standardized mortality rates per 100 000 released By WHO region, aged 20+

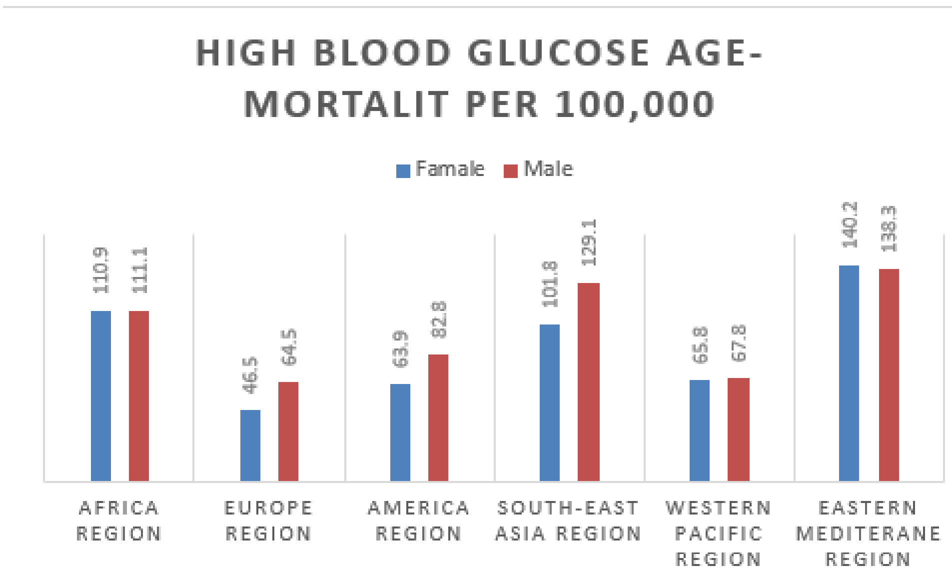


Figure 1 1: High Blood Glucose age-standard mortality worldwide, Age 20+ (Source: WHO, 2016)

In 2013, 380 million people worldwide had diabetes, and almost 629 million are expected to have it by 2045. This incurable disease is largely preventable but remains responsible for millions of deaths annually and many more life-threatening complications (Elflein, 2019).

According to the Diabetes Atlas the prevalence of diabetes in Rwanda is about 3.16% of the population with 1,918 diabetes related deaths per year.

Here is a picture of how the East African Community (EAC) diabetes slayed people based on the WHO report on how countries have come to terms with the prevention of NCDs, and the severity of diabetes and related diseases, and the severity of diabetes and related diseases like heart attacks that are at the forefront of population killings, which is the main reason for this research study, to control these diseases through real-time monitoring with Internet of Things concepts.

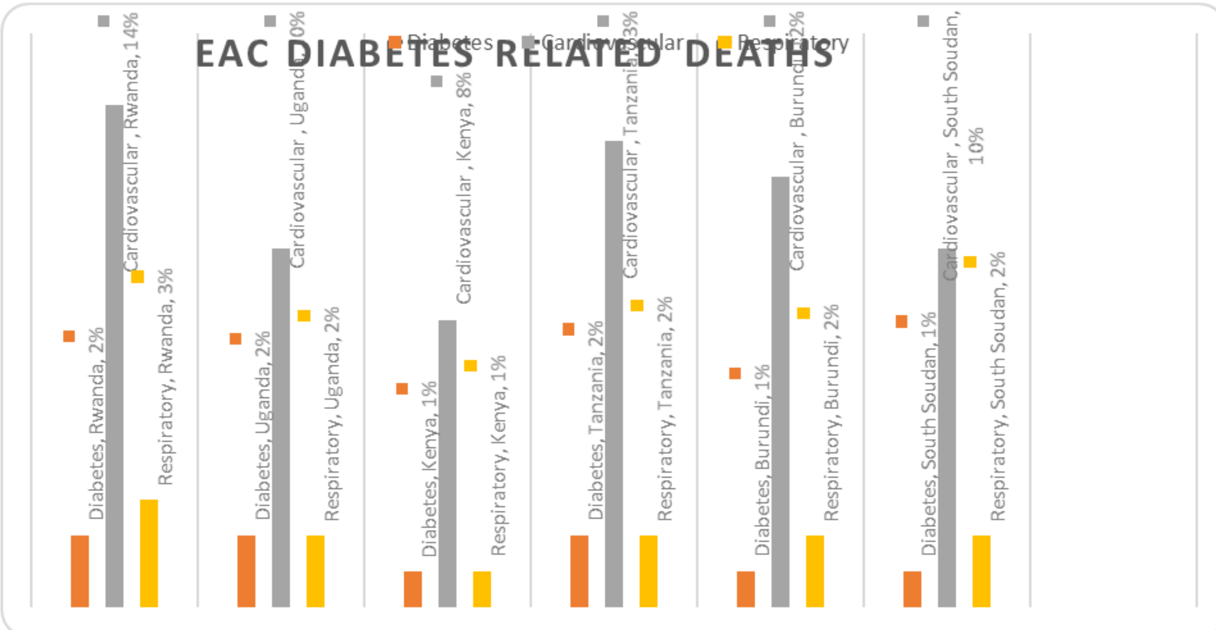


Figure 1 2: Diabetes and its related diseases mortality rate in East African Community (EAC) Source: WHO,2019

According to WHO, physician density report showed that 40% of their member states are less than 10 medical doctors over 10 000 populations globally. World Health Organization reported that: “The African Region suffers more than 22% of the global burden of disease but has access to only 3% of health workers and less than 1% of the world’s financial resources.”

Diabetes self-management and remote monitoring system assists people to overcome the deaths caused by this incurable disease also to its complications as International Diabetes Federation had mentioned in (Meuleneire, 2008).

This study focuses on how patients can access medical services without visiting the hospital.

The 4.0th Industrial Revolution is focusing deeply on interconnectivity ecosystem, automation, Artificial Intelligence and the real-time data mining. This revolution involves Industrial Internet of Things and smart manufacturing that advocates physical production and operations with smart digital technology, machine learning, and big data that generated by sensing technology in order to create a better-connected ecosystem. IoT as a network of interconnection of Things/devices such as sensors, actuators, microcontrollers, software and communication protocols with the ability of transfer data without Human-to-Human or Human-to-computer intervention.

This is one of the things that will help us to do better and complement our research in order to help diabetics control their blood glucose level in a way that is remote or appropriate for their families without having to go to clinics.

The study is based on the development of an IoT-embedded system that works closely with current devices such as smartphones, tablets and computers, allowing patients and physicians to exchange real-time information.

The glucose-sensor was able to take blood glucose levels, the data were filtered by the microcontroller and the measurements are able to reach the smartphone, computers (desktops and laptops) as end devices, using WiFi connectivity.

According to Davies, Alessio, et al. (2018) Davies, Alessio, et al. (2018), type 2 diabetes (T2D) management has generated a strong interest in the concept of a patient-centered medical approach, a strategy also supported by the American Association of Clinical Endocrinologists (AACE). The choice of diabetes therapies must be individualized based on attributes specific to both patients and the medications themselves (Davies, Alessio, et al., 2018).

Some of the tools that can be used to help patients with a variety of ailments but do not have the possibility to rush to the hospital immediately, including Telephone.

1.2.2 Motivation

The integration of telehealth in Rwanda, some of physicians were united together and offering remote health services, also allow people to book the appointment to the medical doctors and nurses. The automation telephone system has been taken as one of effective tools supportive to those who are chronically ill of diabetes (Meuleneire, 2008).

The remote diabetes monitoring system IoT-based will support patients to self-monitoring of hyperglycemia. Noninvasive method was reviewed using new infrared LED placed on fingerprint to measure intensity of receiving light, then send data related to glucose level via mobile phone application with WiFi communication protocol (Alarcón-Paredes et al.,2019). This method seems to be a good way to help the patient to know his or her blood glucose level unfortunately there are the errors in experiment measurement of the other and it is more expensive it does not show how the doctors can help the patient at real-time

Davies et al. (2018) have demonstrated the reduction of long-term complications based on early glucose monitoring, this have been selected as self-healthcare system which is most benefits to the patients. The real time glucose monitoring provides notifications which help patients to complete his/her responsibilities given by doctors based on glucose level in blood.

The Internet of Things (IoT) based communication was used for reliable information between physicians and patients. It is an interactive technology which overcomes barriers but the bridge from in body (Glucose molecules in blood) to clinical center or Diabetes Associates. As patients' data should be protecting as his/her privacy the physicians will directly access patients' data using publish and Subscribe concepts.

1.3 Problem Statement

Diabetes is one of the leading causes of death in humans around worldwide. Consequently, It is caused by high blood sugar levels and its complications.

In recent years, the World Health Organization has reported that diabetes has killed a large number of people, with 1.6 million deaths worldwide in 2016. Alternatively, It is estimated that the number of people living with diabetes is about 425 million all over the world. For instance, It is predicted that by 2045, the number of diabetics will reach 629 million (Elflein, 2019).

The following is a diagram showing how in 2019, many billion of US dollars were given for diabetes worldwide expenditure by regions. All of these costs have been covered due to a lack of quality care for patients and the lack of timely follow-up, which leads to death.

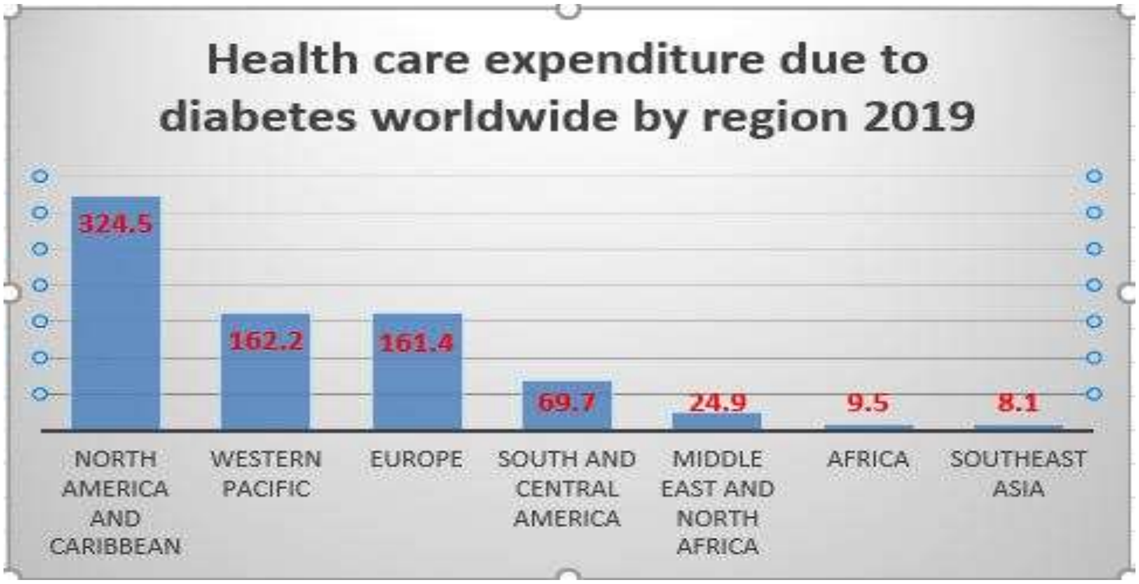


Figure 1 3: Health care expenditure due to diabetes worldwide by region 2019 (Source: WHO, 2016)

The Global report on Diabetes of WHO (WHO, 2016), found that many diabetics do not have access to managements and blood sugar controls and thus endanger their lives including death. To get services to diabetics, clinics requires a long journey and it takes a lot of money too. At the clinics, there is a long queue waiting for doctors and they are also not enough compared to the patients.

Writer (2019) shows that in Kenya, 45% of adult with diabetes disease and 72% of Kenyan children and adolescents have poor control which develop many complications and death while could be preventable using Remote monitoring system connected to their smartphones and computers.

The previous research done in Sub-Saharan on Remote health monitoring have proved that many people are facing healthcare problems, where many of people lose their lives due to the lack of early healthcare caused by few numbers of clinics and physicians.

In the report, government officials point out that they are a global threat and with that, actions should be taken to reduce the death toll from their blood glucose levels, as it is a part of the 2030 Agenda for Sustainable Development signed by Member of States to reduce premature mortality from Non-communicable Diseases (NCDs).

One of the most common problems diabetics have, especially those with type1 diabetes, is to know their glucose level, since they need to balance their insulin.

Mobile-Health care for diabetes remote monitoring have been introduced in Kigali city by a few researchers (Uwimana et al., 2019), but the process of disseminating this information to physicians takes a lot of time and can lead to loss of life. With the advancement of technology today it is appropriate that it be used to address some of the most pressing issues in the health sector.

That is why I would like to do research on how to collect and connect the information of a diabetic patient with a health care provider or clinic depending on their choice sorted for the purpose of managing the patient's information at real time.

As usual, there are many ways to diagnose diabetes, including the use of blood drops and the use of Near-infrared detection. Unfortunately, the country under development, where diabetes clinics are very few, patients often have problems getting medical services or doctor's advice. IoT system is needed to help all diabetics, whether urban or rural, and very easy for use and affordable for everyone

Although these technologies diabetes self-management exist, but there is no system to help and to monitor diabetics wherever they are using low-cost technology especially in Africa.

With the help of Internet of Things (IoT) technology we can achieve to our goals and sustaining people with diabetes healthcare.

The previous studies, did not specify clearly the diabetes remote monitoring, by allowing patients to give their real-time health status, especially blood glucose level, blood pressure, Heart rate and also body Temperature.

Research showed that self-monitoring using innovative technology could be a key challenge to overcome premature death. Unfortunately, Rwanda and in whole sub-Saharan countries are not availing to promote and adopting the technology system to monitor and manage diabetes disease.

The current glucose meter which are using, provide the incomplete information, because it does not cover the all main parameters, while are the key challenge to increase blood glucose.

The diabetes patients’ data/measurements, currently are unavailable due to the system who can’t allow user to store her or records.

1.4 Study Objectives

The purpose of this study is to assess the factors diabetes based on blood Glucose level and diabetes complications.

1.4.1 General objectives

As diabetes could be display in two different types (Type1 and type2), this study has generally to make:

Real time diabetes remote monitoring system by building strong communication between physicians and patients.

1.4.2 Specific objectives

The Internet of Things aims to connect the physical objects with electronic devices. The specific objectives are cited as following and described below:

i. Detect glucose level (Hyperglycemia) into blood using Glucose meter;
ii. Providing Heart rate, Blood pressure and Body Temperature measurements into the system;
iii. Design and implement web system application with node-red and design a direct real time view with Grafana;
iv. Design and develop data storage managements;
v. Provide real time clinic’s appointment.

Based on sensing technology raised in revolutionary industrial Technologies, Internet of things is now applied in Health sectors. Health monitoring, had made immense impact by reducing deaths caused by different diseases. The measurements of curtains particulars molecules in blood have been tested for diseases monitoring and diverse technology have been adopted. As diabetes disease is one of **non-communicable diseases** (NCD) also were scrutinized with various systems. This study will use glucose sensor to detect glucose level (Hyperglycemia) into blood, in addition it will advise patients based on preprocessing (at edge computing) of data sensed to manage his/her insulin in body. Diabetes remote monitoring using Internet of Things concepts it is aimed to realize diabetes status within digital format or electronic form from analog format. Ensure patient's data could be monitored by recognized clinics or his /her doctor in custody so that they could provide immediate assistance. Create Health embedded device which is capable of collect data to be stored locally and send them using Internet of Things protocols. As diabetes shall bring many complications, with this system we would like to help patients to avoid other side effects (diabetes' complications). Rwanda diabetes Association (RDA) like other worldwide diabetes' Associations and/or Federations, they provide some facilitations to their members (Uwimana et al., 2019), which means that they try to figure out how their could help people with diabetes problems. The system will allow diabetes patients to access his/her life cycle of glucose into blood. It will check diabetes behavior, and as it is sensor based, it will also help patients as self-consultancy and self-care. The doctors or diabetes' Clinics will be able to appear while the patient is showing signs that may be life-threatening because this system will be real-Time monitoring, which means, doctors will assess patients wherever he/she is. Create statistical data of patient, based on statistical records, the analysis will be made and it will lead to a firm decision. Finally, this system will provide end-to-end encryption for patient's data privacy. Patient will send data as publisher and clinics and physicians will be both publishers and subscribers.

1.5 Hypothesis

Diabetes Remote monitoring looks forward to helping diabetics reach out to their doctors as soon as possible and be able to get help or feedback right away.

Diabetics will be able to get the appointment based on their measurements.

1.6 Study Scope

The study is limited to the target of people who are suffering diabetes by focusing on Rwanda Diabetes association members. It will be limited to help diabetics to share their data remotely and having appointment at real time.

The study uses and limited Node-red dashboard, Grafana for data visualization and analysis. The additional on this research we used fitBit Studio for designing smart watch which help us to measure Heart rate and Steps. The complete watch will be done at future research

1.7 Significance of the Study

The study is determining, the key features that help diabetic's patient for self-monitoring.

The study will contribute in state measure to help people living with diabetes by monitoring all patients. This will reduce the long queue that appears at diabetes hospitals. It also helps patients to thrive by wasting money and time wasted when patients took long walks going to the doctor or clinics.

1.8 Organization of the Study

This research thesis is organized as the following: The Introduction chapter discusses little more about Diabetes remote monitoring system, it highlights by touching on Diabetes rate, diabetes mortality by worldwide region, East African Community (EAC) region and locally (in country). It is also touching on the motivation for conducting this research. This chapter presents problem statements the objectives of the project and the proposed solution. The chapter 2, which is about Literature Review, discusses on the previous related research mainly focus on Internet of Things (IoT) projects done for diabetes remote monitoring, e-health and telehealth or telemedicine. The chapter 3 known as Research Methodology discusses research design, system block diagram of this project, we discussed also the research tools to complete this project. The chapter 4, System Analysis and Design discusses the existing system and shows the new system architecture and data flow of the project. Then chapter five, presents the data results sent by the patients using node-red dashboard or using MQTTBox with specific topics. Data are stored in database and provide real time notification from endocrinologists of the clinics. Finally, chapter 6, which is Conclusion and Recommendation, highlights on usability of this research project and recommend for some future works for better of human health.

1.9 Summary

After considering the background of diabetes mellitus in worldwide regions, east African region and in Rwanda country position, we find that it's valued to conduct a system which is based on Internet of Things (IoT). In this chapter, we touched to general background of Non-communicable Disease focus on Diabetes. Moreover, the motivation of the study, problem statement, and the objectives of this research were introduced in this chapter. As pointed in the objectives of the study, this is for connecting patients and clinicians at real-time using IoT technologies.

CHAPTER 2. LITERATURE REVIEW

This chapter is discussing the theoretical and empirical literature of the study and this chapter describes the conceptual framework of this research.

Nowadays many researchers are very interested with real time solutions, looking for ways to help different people, such as children, the elderly and people with various disabilities to get better services through technology, such as Internet of Things, where some can get remote health services. A remote e-healthcare system with the help of medical equipment, which help patients used by these healthcare providers, where they could respond to the patient who asked for help (Brown, 2001).

The web application was developed by Raj et al. (2018) so that patients who are at long distance from their clinics or who are remotely, they could use their system known as e-Health telemedicine, which helps those who want to monitor their Pulse oximeter, Electrocardiogram (ECG), Blood pressure and body temperature where the system will help doctors and patients to communicate in a way remotely and it seems to help users of this system.

According to Mercedes et al. (2008) and Neuffer (2019), resting heart rate might be directly associated with the development of diabetes."

In a study conducted in China, in 2004 and 2008, on 53,817 adults, 1766 were diagnosed with type 2 diabetes. Their study found that heart rate was correlated with type 2 diabetes commonness, as those with heart rates from 67 to more than 86 beats per minute, were all at higher risk for developing diabetes than those with heart rates of 67 bpm or lower.

The relationship was also present for participants with systolic BP of 140 mm Hg or more and diastolic BP of 90 mm Hg or more, especially in those with heart rates of more than 86 bpm (HR = 1.38; 95% CI, 1.13-1.67).

It has been found that the relationship between heart rate increases significantly in middle age and diabetes and death rates in old age. This relationship is mainly strengthened by post-glucose uptake during heart rate (R. C. Mercedes, L. Yan, et al., 2008)

The Non-invasive glucose level monitoring has been investigated using spectroscopy method as they pointed to Raman and Infrared spectra. Glucose level were monitored using Raman spectroscopy, where this method has ability of predicting blood glucose concentration with high and more accurate on its data sensed in Raman peaks (Li et al., 2019). With sensing technology (Gao et al., 2016), non-invasive wearable glucose-sweat sensing of using wireless communication where Bluetooth-enabled technology was studied and being used in the system as key for communication model by transferring data accordingly. This approach seems to be possible to the people who can excrete sweat form their body which is very limited for elderly and other chronically ill.

Davies, D’Alessio, et al. (2018) demonstrated the reduction of long-term complications based on early glucose monitoring, this have been selected as self-healthcare system which is most benefits to the patients because patient may take measurements through this system as discussed. The real time glucose monitoring provides notifications which help patients to complete his/her responsibilities given by doctors based on glucose level in blood.

The automation telephone system has been taken as one of effective tools supportive to those who are chronically ill of diabetes and Internet Things (IoT) based communication was used for reliable information exchange between physicians and patients. It is an iterative technology which overcomes barriers from in body (Glucose molecules in blood). Moreover, they have found that, the integration of the Internet in such application system helps a large number of people to be connected. In addition, they see Telephone care as a broad tool that can be used to connect patients with their healthcare providers (Meuleneire, 2008). The automated calls were introduced for extending the self-management. Author, did not care about Real time data Acquisition and more other issues.

Non-invasive method was reviewed using new infrared LED placed on fingerprint to measure intensity of receiving light, then send data related to glucose level via mobile phone application with WiFi communication protocol, and data are sent remotely to the cloud server ThingSpeak (Aizat Rahmat et al., 2017). This system does not show how doctors can help a patient when they are in critical condition, however the doctor may find that the patient has increased or decreased his or her measurements in the ThingSpeak’s dashboard.

In the research by Uwimana et al. (2019) the system does not have the capability to send sensed data, using the internet pathway, however, adding IoT concept, it would help because it does not require the patient to first sit down and text first because it also takes a lot of time.

According to Uwimana et al., (2019), home self-healthcare would like to be automated using a smartphone as shown by young people who like to use smartphones and it becomes more productive. Unfortunately, this system does not have the capability of sending real time data and did not mention where physicians may reply the patients. The integration of sensing technology and adding Internet of Things concept would help because it does not require the patient to first sit down and text, this may result to wrong or false information either typing errors or misread what glucose-meter measured moreover it also takes a lot of time. Real-time monitoring has been evolved through Wireless communication, these days the research is getting more and more advanced, and we are using sensors, a fast, low-cost, low-power, high-speed communication is Wireless Sensor Networks (WSN). Smartphones are among of tools that help us connect, display and access all this information at the right time (Real-time). Valenzuela et al. (2020), designed the algorithm to support elderly diabetics to report to their doctors' in charge, the critical condition of illness. This is based on wireless Sensor communication with WiFi channel. Moreover, here is the need for in-depth research and improvement at perception layer also use of one microcontroller instead of using two which may result to high delay. IoT allows data processing at fog computing level and deeply general processing with analysis at cloud. Apparently, the noninvasive method is best way in which no one is afraid to take physical measurements, either they are suffering diabetes or want to know what their health is like (Health status), since this method is painless. A study done by Buda & Addi (2014) was Non-invasive glucose level monitoring system which help patient to full visualization of glucose level and Insulin needed based on his/her Body Mass Index (BMI). Patients' data are displayed in local device; however, it is important that doctors have access to patients' measurements; consequently, they may give advice.

Glucose level monitoring have been detected using laser and RPi camera as 3D-Printed thereafter data acquisition, processing was made using Neural Network as part of Artificial Intelligent (AI). The output was displayed using Smartphone, unfortunately this could not determine which type of diabetes, either is types one or type 2.

According to Bajer (2017) they proposed three tools known as Elastic search, Logstash and Kibana (ELK) which can be used for the collection large amount of log data from patients, then processed and transferred using embedded devices to Data Hub which is local data Acquisition devices. At this stage data are preprocessed for filtering and basic analysis before transferring them to the cloud.

Rghioui et al. (2020) showed that the use of a pedometer, which helped diabetics to know their physical activities, the use of smartwatches was to be able to identify the activities of a diabetic patients. They were found that is recommended to use smartwatches for measuring patients' activities because they can control or monitoring blood glucose levels.

Figure 2 1: Smartwatch for diabetes (pedometer) source: Google.rw

All of this has been done to help the health sector and government to identify people who could lose their lives due to the lack of real-time monitoring. Most deaths from diabetes disease can be prevented once the patient's status is known early.

M-health shows that diabetics possess Glucose meter at their home residence are present 99.2%, thermometer for temperature measurements are 27.7%, and those holding blood pressure machine are 13.2%. The Heart rate was note considered in this research. With them the reporting style shown in their research are logbook method which represent 93.4%, short message text 22.3% and with internet integration using email and social media at 4.1%. The real time data transfer used in the previous research is phone call, which appears to be at rate of 69.4%. This suggests that some information may be problematic when logbooks are damaged in various ways. What’s more, during the reporting period it appears that using phone call would prevent the patient to send his or her measurements on time, if he/she misses the doctor’s phone (Uwimana et al., 2019).

Scheen (2016) states that it is better to take a concern on heart rate measurements as it known well to increase high risk of heart failure for people living with Type 2 diabetes (T2D).

CHAPTER 3. RESEARCH METHODOLOGY

This chapter consists of the research design, and tools used for completing this study. It also presents the study flow activities and process.

This research is based on previous literature and making an IoT-embedded system for glucose levels detect, blood pressure, Heart rate, and temperature measurements.

3.1 Research design

The Neutrality was used during this study. Neutrality have been used by assuming the reality on the measurements collection (Sollund, 2008). In this study we expected to collect data from biological sensors such us Glucose meter, heartrate, blood pressure and body temperature. Moreover, we used Descriptive and Correlation research, for system information management and analysis. The data collected are complementally with previous statistical data to provide accuracy decision (Https://www.wssu.edu/, n.d.). ten Thousand

The study targeted the people living with diabetes, which are located in different area of locations. The Generalization research, have been used by applying the rules of assumption on big population, so that the output may cover the large population.

Glucose-sensor collect the vital information of patients as we are targeting about glucose molecules in the blood. The data received are to be send into the system then processed through the system that has the ability of send data to the diabetes' clinics servers. The transmission of these data is free using the Message Queuing Telemetry Transport (MQTT) technique, which helps the user to record the measurements he or she has received using standard devices that do the work but are incapable of transmitting that data. The dashboard that designed for Graphical User Interface (GUI), it helps the users to enter the measurements into the system, which was developed using JavaScript programming language and Hyper-text Markup Language (HTML5) integrated in Node red. Node-red is an environment development of IBM, which connects hardware devices, APIs and online services as part of the Internet of Things. This system will have Wireless communication WiFi as communication protocol.

System design and logical flow, the flowchart of this system was created and illustrated in the eDraw Max software.

This research is based on logical flow, I hope that I am based on a common problem in the exchange of information between the patient and his or her doctor. This research is based on logical flow, I hope that I am based on a common problem in the exchange of information between the patient and his or her doctor. According to a WHO report, there are many premature deaths from Non-Communicable Diseases (NCDs) including Diabetes Mellitus (DM).

Diabetes can be monitored for efficient management control; sensors can provide a large range of information about the patient's psychophysical status and performance.

Using mostly sensors which are commonly used to sense the blood glucose, usually insulin calculation for high blood sugar correction, and other medical parameters related to two types of Diabetes.

The entire sensor drivers at patient side will collect the data and Fog computing will be considered for the privacy benefits purposes. The data are usually collected by professional embedded devices approved by Food and Drug Administration (FDA) or other recognition organization. In this system we use IoT tools, for publishing data in place of direct sensors, data are recorded in the system easily by the users of this system where we have made a friendly user Interface, the other way is that MQTTBox can be used to publish data at known, conventional or agreed topics.

Data protected by encryption strategies (Patient's Data privacy), for privacy patient will use his/her own dashboard with username and password. Furthermore, the system is linked to his/her email for getting notifications.

Real time notification, patient and doctors are getting notice or warning throughout via system dashboard and/or email a message will be generated at specific critical information from glucose device.

For data analysis, the **descriptive statistics** which describe the previous situation on how often Non- communicable Diseases (NCDs) were communicate to their doctors remotely and **inferential statistics** to predict how remote communication with clinics or doctors will be very closely. The research highlight to Diabetes disease which is one of leading diseases in killing a large number of people.

3.2 Block Diagram

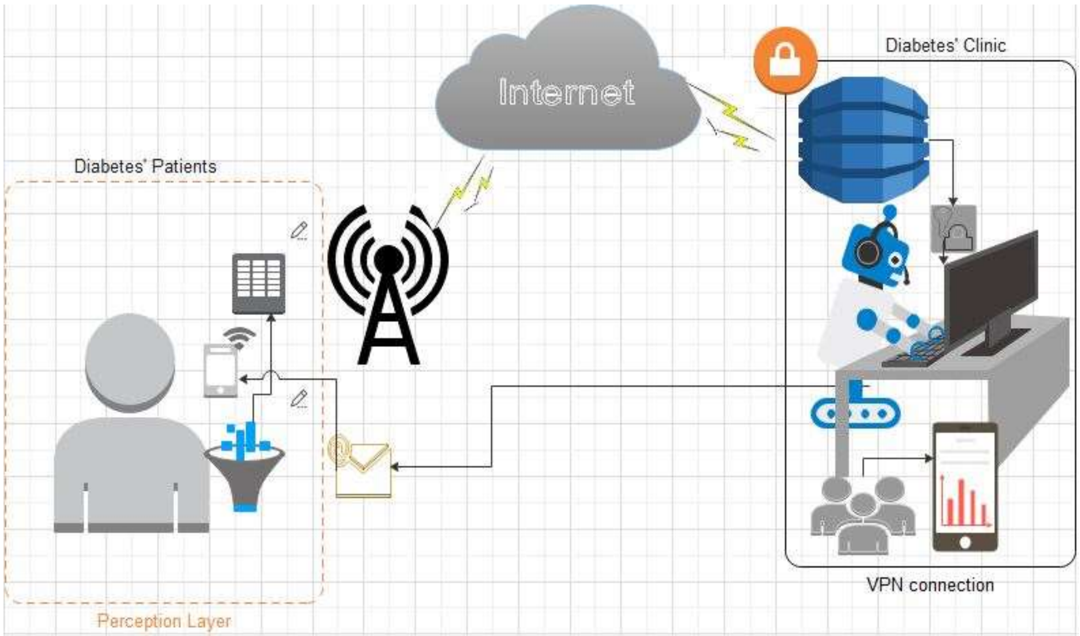


Figure 3 1: Block diagram of the proposed system

Based on this system block diagram, the first section block it is patient's perception. On the perception layer is where the patient will be able to use a recognized glucose meter for blood sugar measurements which will determine the real-time status of glucose in the blood of the diabetic.

Subsequently the data is collected, the preprocessing and filtering of the data are being done and stored in the local database center, in which our system is using InfluxDB and Grafana for data controlling.

With the network layer, the data are being transmitted via the system by using Internet with different technologies channel. Furthermore, the data are sent to the central data-center for farther analysis, we used mqtt-dashboard.com as MQTT broker. The reason for using MQTT is that the patient and the doctor can work for the MQTT client and be able to send his or her daily measurements and the Doctor may want to be able to provide feedback at a specific topic by using MQTTBox. All patient data goes to the Clinical server with the highest security department for the data privacy. Doctors and/or other physicians can access dashboard panel by entering the right credentials, for patient's data, once it is necessary, they may immediately send a message to the patient for appointment.

3.3 Research Tools

This research, conducted using IoT tools, Fitbit simulator has been used to create a Smart watch as wearable device that help in capturing of diabetes measurement for non-invasive. The simulator used is fitBit studio for Heart rate measurements and steps. The Fitbit simulator is a useful and greater IoT tool which is including health simulation parameters such as Heart Rate, it is one of leading smart watches simulators.

Glucose meter: Measured using a glucose meter, the patient can enter the system where it is designed as a dashboard and the data can be transferred to the clinics

Blood Pressure: The patient must also take his or her blood pressure measurements and incorporate them into the system dashboard to make it easier for them to reach the doctor immediately.

Heart Rate: With the help of fitbit simulation, we have been able to create a smart watch that can measure the heart rate, not only that, we realized that it was not enough then, we wanted the patient being able to enter the data find into the system or heart beat measurements.

Temperature: Diabetics also have the problem that their bodies can have high temperatures which can cause them problems. We found it important that the patient provide his Temperature measurements

Hardware used for prototype are: Arduino Uno, ESP8266 as Microcontroller, Pulse Oximeter, LM-35 and Glucose meter.

System design Tool: We design this system with **Node-red**, which is an IBM tool that helps create IoT nodes, which helps us to design user dashboard easily.

Data storage: The database of this system we used **influx_db**, because it is one of the tools that help IoT devices to be integrated easily and able to store data in a secure way. This **influx_db**, is also a database source that helps us to connect the patient's data into **Grafana** dashboard.

MQTTBox: is one of the IoT tools used for data publish and subscribe with conventional topics between different destinations.

Communication Module: Data are transferred through WiFi module.

CHAPTER 4. SYSTEM DESIGN AND ANALYSIS

In this chapter we are going to look at how DRMS, the equipment used, and how it is monitored since its inception, the software we have used and how it will help the patient to provide her/his health information to the doctor or hospital (at Diabetes's Clinic).

4.1 System Design

4.1.1 System design architecture

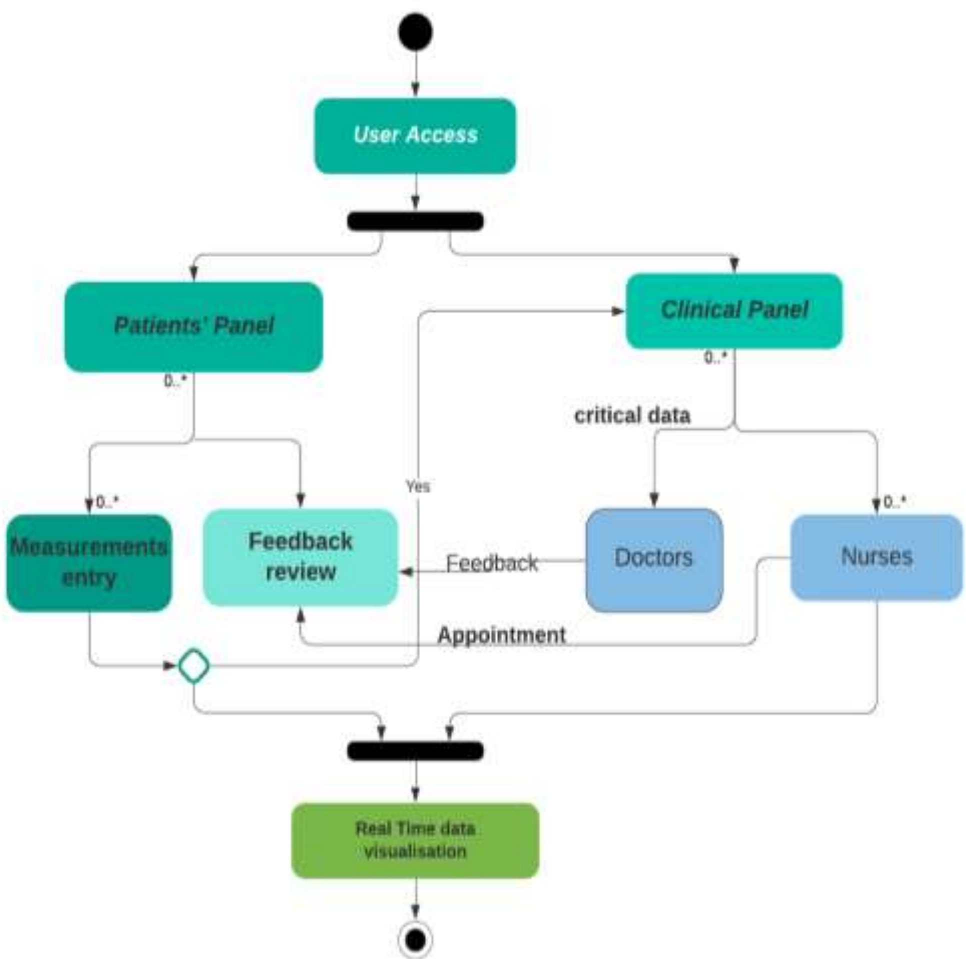


Figure 4. 1: System usability between Physicians and Patients

The way this system works based on this system architecture, as usual with every device in IoT, has its own configuration and identifications, so it helps the patient to easily send his or her measurements to the doctor.

Based on the findings of this study, we are using two types to send his/her measurements to the physicians; (1) User interface, as first types is a panel that helps the patient to be able to input and send data into the system namely: Blood Glucose level, Heart rate, Blood pressure and body temperature taken using standard devices used in diabetes testing. The patient needs to know if his or her measurements have reached the doctor or the clinic, by knowing which patient the patient can get feedback from doctors in the patients ‘panel. The patient can also get his or her measurements via email so that he or she can also have a history of his or her condition. The evolution of his/her diabetes status, the patient will have the access on his or her measurements at real time. Furthermore, the patient can use other highly reliable methods so far, we have used in place of using sensors System Design due to the circumstances we were not able make the prototypes and do the implementation of the device we wanted to design. (2)The second method I am talking about is the use of Message Queuing Telemetry Transport (MQTT), where the patient is also able to send his or her measurements to the clinic or to the doctor who cares or monitors his or her daily life.

According to(MQTT.org, 2017) website: “MQTT is an OASIS standard messaging protocol for the Internet of Things (IoT). It is designed as an extremely lightweight publish/subscribe messaging transport that is ideal for connecting remote devices with a small code footprint and minimal network bandwidth. MQTT today is used in a wide variety of industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.”

According to (Businesswire.com, 2018)“MQTT is a publish / subscribe messaging transport protocol optimized to connect physical world devices and events with enterprise servers and other consumers. It is designed to overcome the challenges of connecting the rapidly expanding physical world of sensors, actuators, phones, and tablets with established software processing technologies”.

According to the MQTT definitions, we used the MQTT box to allow the patient and the doctor to have a place to exchange information.

MQTT ws designed for connecting IoT devices from different remote locations, it is composed with three main sections to perform messeges transaction from one device or from the sourceto another devices called destination.

With MQTTBox, we configured a MQTT client for publish and subscribe. By mutual arrangement, we decided that the patient should be a publisher because he or she will input the main indicators of blood glucose, heart rate, blood pressure, and body temperature. Each of this indicators, it has his specific and unique Topic.

4.1.2 Topics and Blocker

In MQTT, the topic in Internet of Things, it is referring to an UTF-8 string that the MQTT broker uses to purify messages from connected devices either publisher's device or subscriber's devices which called Clients. The topic may consist of one or more topic levels.

Topics used in this research thesis are four as key parameters studied for diabetes limited on Blood Glucose, Heart rate, Blood pressure and Body Temperature.

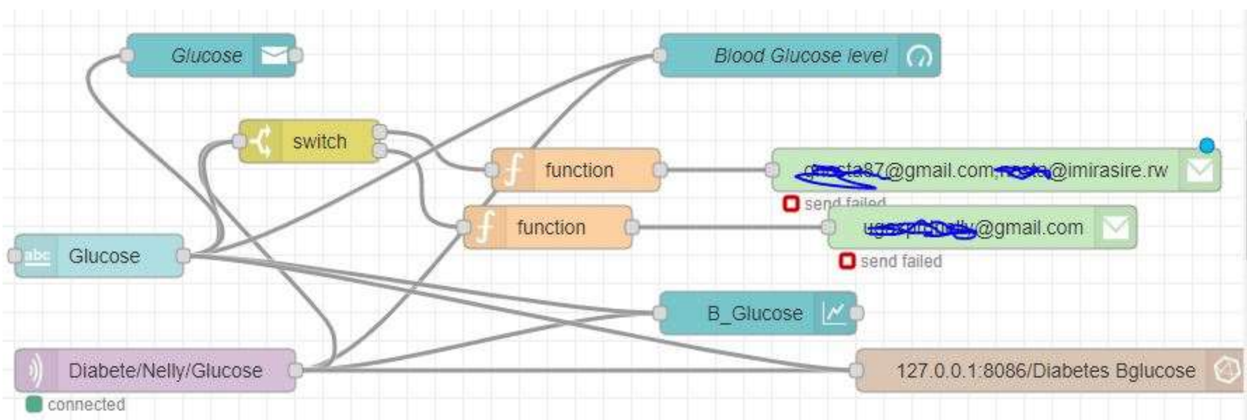


Figure 4. 2: Glucose configuration nodes with mqtt Topic

When we designed this system, we use the mqtt-dashboard.com broker to help us send our data to the database.

mqtt-dashboard.com: is cloud based server that enables IoT applications for data transfer and receiver for free of charge.

4.1.3 System Flow chat

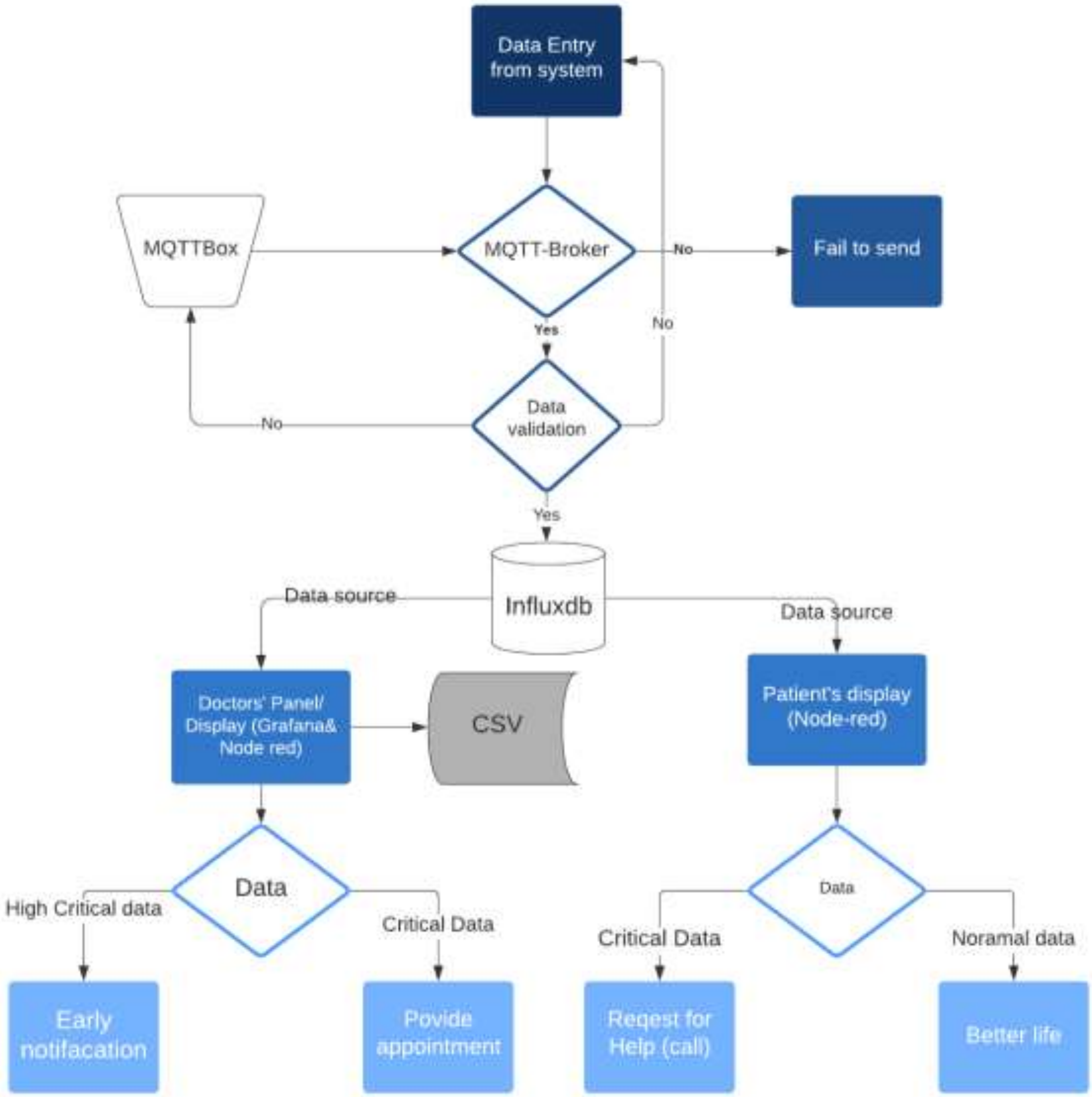


Figure 4. 3: Flow chat of the system designed in edraw Max

The DRMS, is logically structured in which data are systematically flow from source of the data to the destination accurately. Figure 9, show the ways data will pass through data entry (from perception) either sensor direct data or inserted data through input forms designed in the system which shown in Figure 10.

Secondary, diabetes 'data will be shared through MQTT system, in this research we used MQTTBox for data share or transfer into the application.

Data measured from the sensor are validated before stored into database. The sender should have access to a specific Topic to be verified by MQTT-broker. Once topic verified, data provide the provide privacy, integrity with reliability. In figure 11, shows the interface of MQTT-Box with specifics topics of every parameter.

In Addition, patient's data are stored privately into Influxdb, for making dataset of diabetics based on four parameters measured in this thesis.

From storage, influxdb, we developed and used API which helped users to access data from database to Node-red and access them to Grafana. With Grafana, data are visualized in plot and in CSV file which help physicians to make deep analysis of patients.

The system provides patient's panel where patients enter their physiological signs measured and send them to the clinicians. With patient's panel, he/she will be able receive Doctor's feedback and access live chart of his/her measurements. Moreover, system will provide email notification for patient's measurements, telling him or her to go at clinic for further checkup. Patient could make call for requesting an appointment or for help.

With the application, doctors may access the patients 'data in clinic's dashboard and doctor's panel to give feedback to the patients.

4.2 System Analysis

This study focused on the difficulties of patients with non-communicable diseases but we would like to focus on Diabetes.

As mentioned above, some diabetics do not have a stable and reliable method that can allow the patient to send his or her health status to his or her doctor at real time. Moreover, doctors were not able to give patients the feedback remotely.

This system will allow patients to provide measurements or parameters of their illness in the dashboard. at the perception layer with the current sensor or existing devices that are able to measure the blood glucose known as the "Glucose meter" so far do not have the time to send the measurements taken to the doctors, the patient will immediately take the measurements and complete the recording in a system with a user-friendly graphical interface.

Blood glucose levels are the key indicators that will help an analyst in this system to determine the level of patient's diabetes.

Blood glucose levels are taken regardless of when a patient recently ate and taken care of, we found that from 140 milligrams per deciliter mg/dl has diabetes and between 200 milligrams per deciliter or higher indicates that a person has a serious diabetes problem.

After sending the measurements the doctors will provide feedback whether the patient has to do various exercises or if it is better for the patient to come to the clinic. The doctor will be able to get real time notification on his or her email in the form of patient's data privacy and safety additionally could be storage of patient health information.

In IoT technology as it is connected devices anytime and anywhere, data are sent frequently when measurements are taken. The system will filter the data and provide which information to be sent to doctor as early notification in order to avoid congestion of information at doctor's email.

After taking blood glucose levels, diabetics have heart attack problems that are accelerating the premature death. So, it is in the context this study thought to be measured as well.

Other parameters that are complications we have with diabetes are Heartbeat (Heart Rate), Blood pressure and Body Temperature.

Heart rate is a very serious complication for diabetics because it is one of the most common causes of premature death on diabetics. In this system I have used every possible means to help diabetics to send heart rate to doctor and even doctor is able to see the patient's status so he/she will help patients at real time or help the patients in needed.

CHAPTER 5. RESULTS AND ANALYSIS

Internet of Things systematic algorithm has got a potential impact on the better human life and environment.

During this academic study period, we focused on developing a platform which is based on sensors and to IoT technological protocols. The communication used for data transfer, are wireless medium named wireless Fidelity (Wi-Fi).

This study mainly stands on diabetes remote monitoring system by measuring, four parameters which are Blood Glucose level, Heart rate, Blood pressure and Body temperature.

The measurements were simulated into patient's dashboard and using MQTTbox client free software.

We found that, by the monitoring of blood sugar, patients will be aware of or taking care for insulin sensitivity factor in order to the balance or correction of his or her Glucose level. Measuring Heart rate, it's very important for diabetics because it help to detect their impaired awareness of hypoglycemia. Thus, measuring blood pressure helps patients to know that with up boundaries of his/her blood pressure measurements which is 90mmHg for diastolic, patient is tending to increase hypertension. In addition, monitoring body temperature also, helps the clinicians to make their analysis as the have all physiological signs.

5.1 Software interface

We developed a web-based system where measurements are recorded into a form of application system, using smart-phones, laptops or computer devices responsible for data collecting, computing and information sharing in different technology medium.

The interface for physiological signs studied in this research are reported in the next sub-sections.

5.1.1 Nodered dashboard

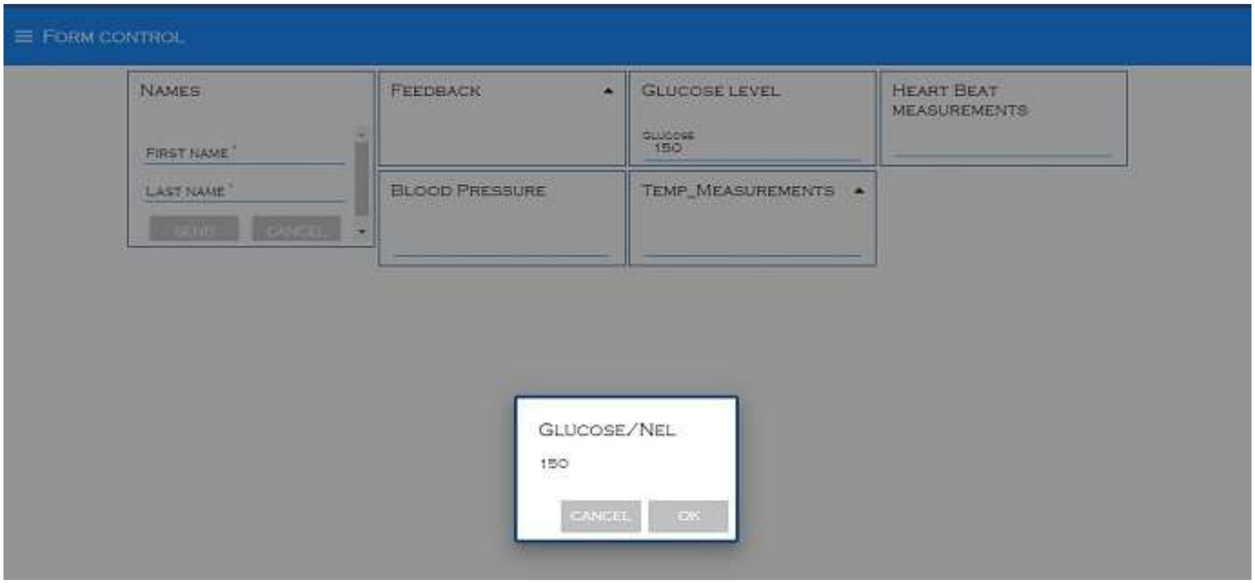


Figure 5. 1: Form control for measurements input with pop up window

In the next figure, Figure 10, this form helps the patients, whatever location to input measurements from the sensors, and send them through the system. Diabetics use the above control to communicate with their doctors (Clinicians). The results obtained from glucose meter, are entered into "Glucose level form". Once patient press Enter Key, he/ she get a pop-up window, requesting him to confirm the measurements to be send. As we have done this research with a strong focus on Blood Glucose level, heart rate, blood pressure and body temperature, where are often found to be assessed continuously for diabetics and send them to the physicians for better examine, and remote monitoring at real time. As you can see in Figure 9, this form has a place to enter names, as well as other parameters mentioned above. Every time before sending data, you should see a pop-up window asking you if what you typed is correct.

This form is for the patient, which is also where the patient can get feedback from doctors.

Another way to send patient measurements is to use MQTTBox as protocol where it appears on the MQTTClients figure.

5.1.2 MQTTBox dashboard

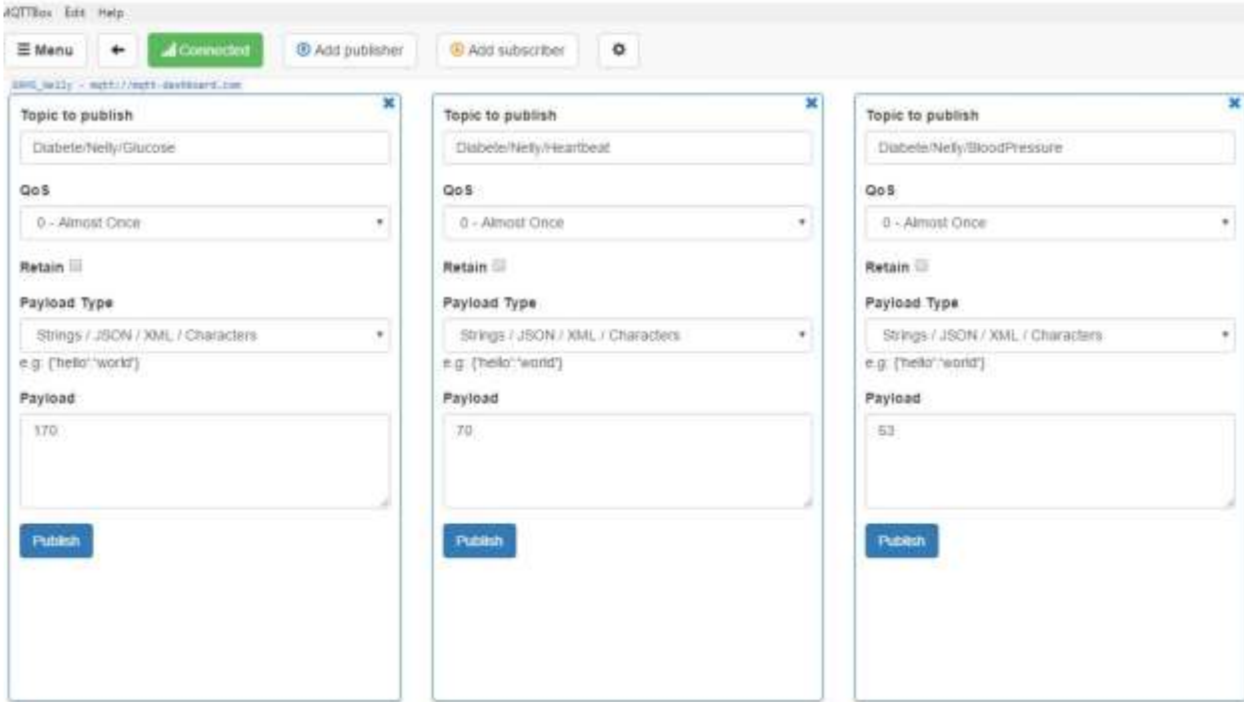


Figure 5. 2: MQTT dashboard used for publishing patient's measurements

The patient, who uses this mqtt-client dashboard must have a topic to follow, in this system we used topics 4, where each measurement from the sensors, has its own topic.

The measurements are live streaming by the system

A. Blood Glucose measurements

Glucose meter measurements, were analyzed for fasting, in range of 100 to 125 mg/dl which show the pre-diabetes and greater than 130 mg/dl for diabetes.

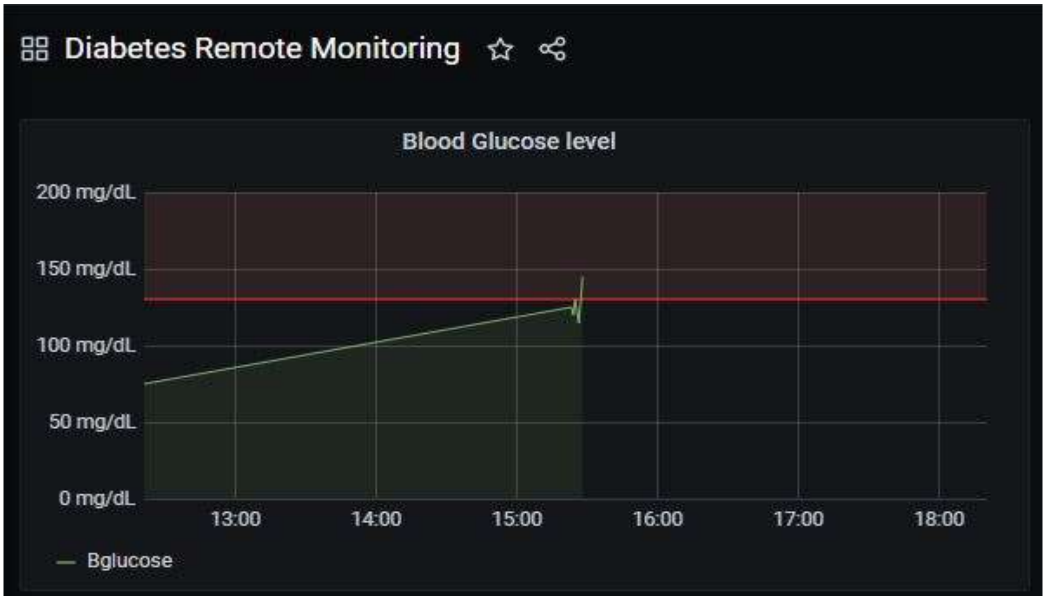


Figure 5. 3: Blood glucose measurements representation

B. Heart Rate measurements

The Heart rate measurements for diabetics have been correlated from 60bpm up to 90bpm and found that above 67bpm show high risk for diabetics.

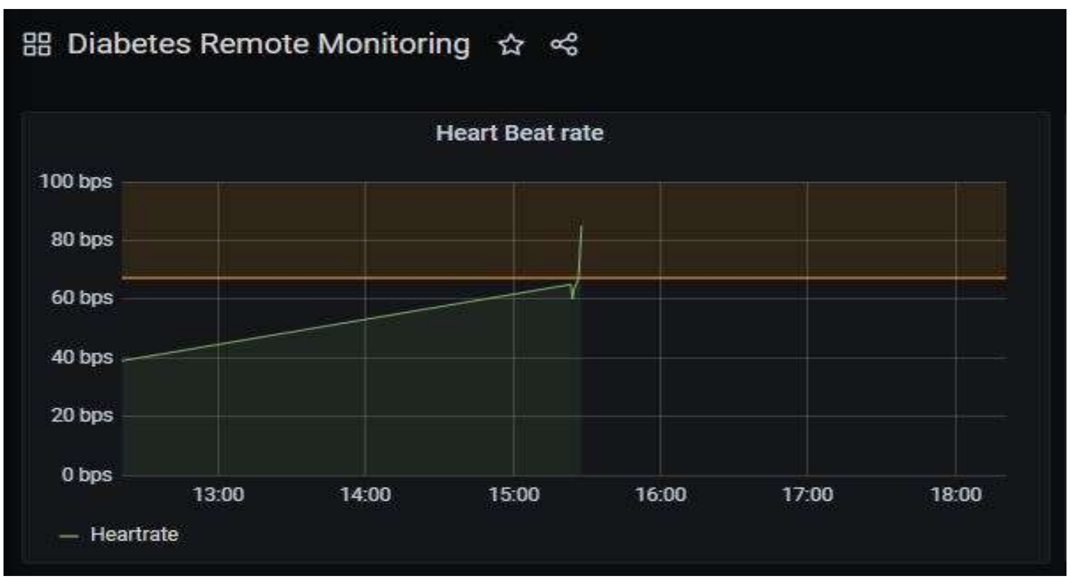


Figure 5. 4: Heart rate measurements from sensors

C. Body Temperature measurements

As shown in (Mercedes et al., 2008), it is good for a diabetic to be able to know his or her body temperature levels so that they can take care of him or her based on his or her temperature. The thresholds used for diabetics was 38ºC for warning and critically was 40ºC.

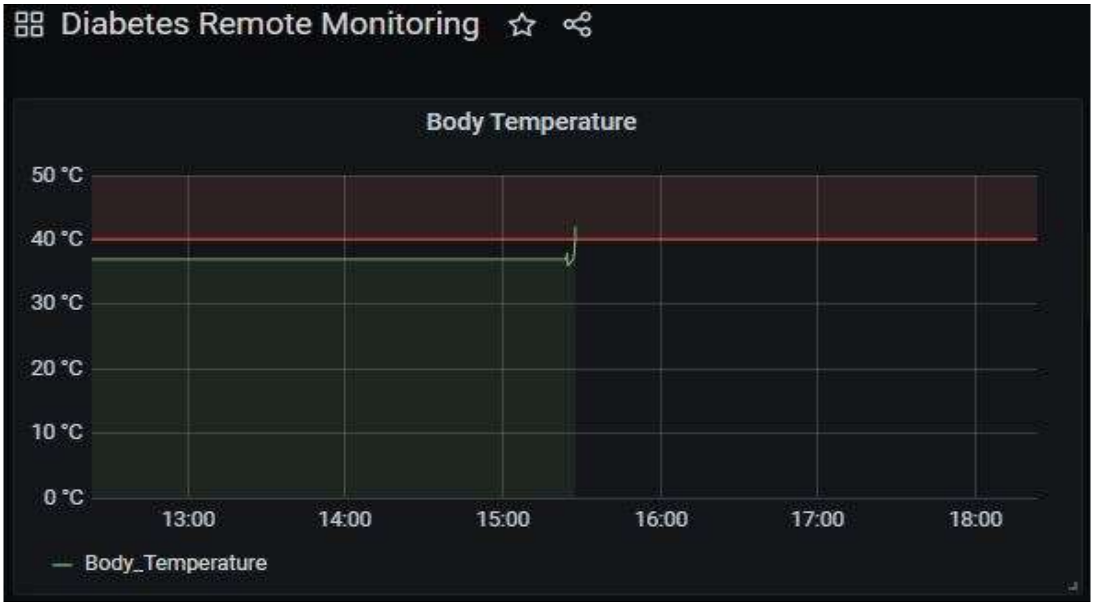


Figure 5. 5: Body Temperature measured from sensor, inserted into the system

D. Blood Pressure measurements

Blood pressure control is more important and considerable parameter for diabetics (Osher & Stern, 2008; De Boer et al., 2017). With self-monitoring Blood Pressure, it is recommended that from 90mmHg of diastolic measurements, patients should be taken care by clinicians.

The following figure shows patients' Blood pressure measurements. It shows real time data, by providing time (date, hours, minutes, seconds) data received.

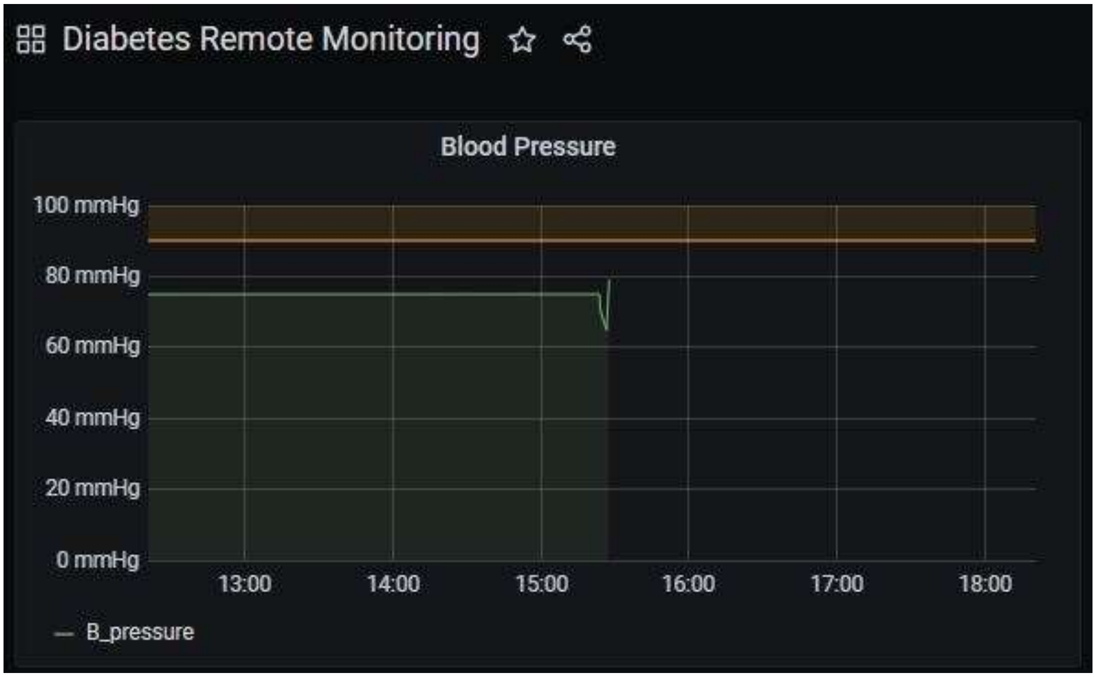


Figure 5. 6: Blood pressure entered in the system by patient

5.2 Software dashboard

The users of this system visualize the data of the patients. The allowed users may view patient's data through the system as shown in the following figure 16.

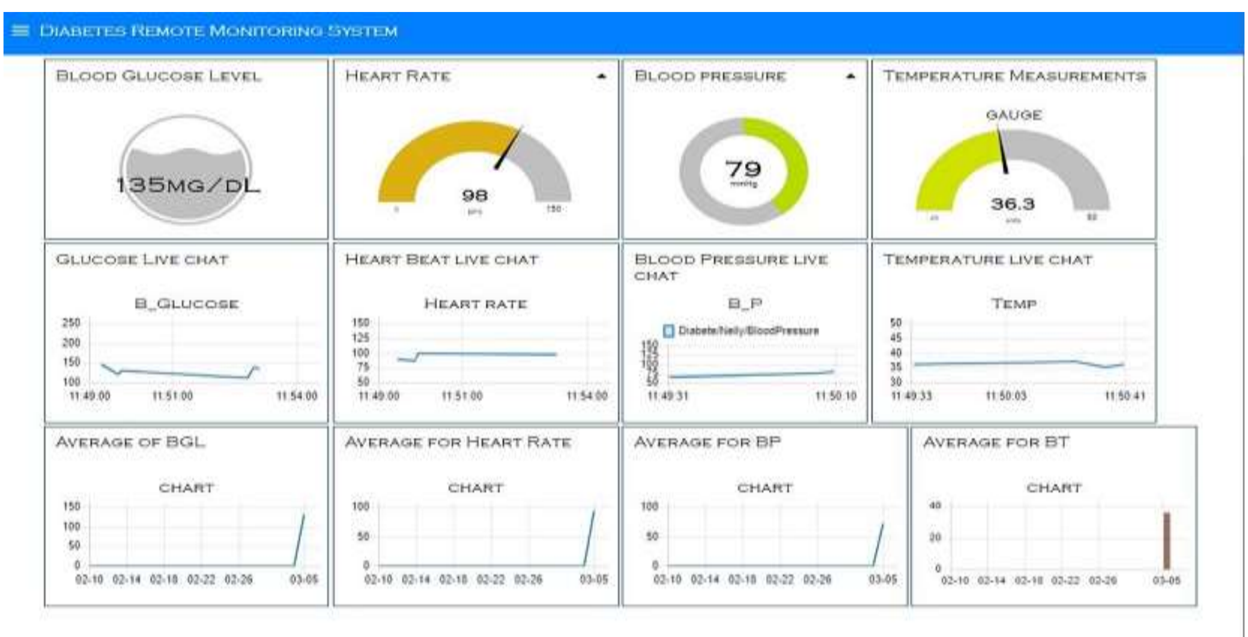


Figure 5. 7: Node red Dashboard view for diabetics

System allow clinicians to visualize all patient's data or measurements from electronic devices into node-red dashboard anywhere and anytime. Doctors access patient into Grafana dashboard for father analysis of each patient. The system provides CSV file from database and display time and measurements data arrived reached into the system. The data collected from sensor are stored into influx database installed in local computer and connected to node red again to Grafana for data source.

Moreover, all data measured from patients, the purpose here is to create a dataset that will help the search engineers to make a prediction of the level of diabetes.

The following figure 17, shows at Grafana data visualization and the way doctors/ clinicians may have right to download CSV file of one of parameters studied in thesis which is Blood Glucose level sent from patient at remote site.

Figure 5. 8: Grafana dashboard at clinic's site, Blood Glucose level measurements (CSV file).

5.3 System reporting

The patient's measurements are made daily, accurately indicating the time, date including hours, the patient was able to send the measurements using smartphones, computer in IoT platform umbrella.

When the measurements made, are extremely critical, which means that the patient has trouble or high measurements that appear to be in urgent need of help, the doctor gets a high-level notification on his or her email, so that he she can immediately provide help or can make an early appointment for that patient. The report of all sent data are accessed from Grafana dashboard of each patient. Doctors access the csv file from there and make his/her analysis depending on diabetic's case. The computers such as desktop, laptop, smartphones and others electronic are available for data collection and receiving from different sources. The diabetics holding these devices, they may use them to record and send physiological data to the physicians for in-depth analysis of patient's status.

The report is based on the measurements given by the patients where the doctor can make a daily, weekly, monthly and yearly report when necessary

The following diagram show the real-time daily report for patient's measurements.

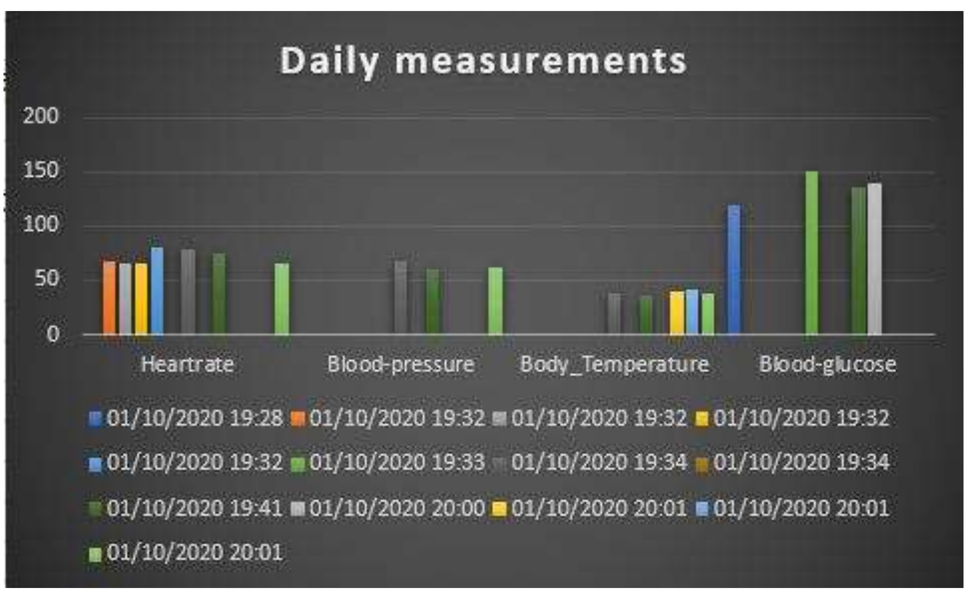


Figure 5. 9: Daily report made by clinicians based on measurements

The system is able to make an average of each day based on the number of times the patient has been able to send or publish data to the system and providing notifications via emails.

Insulin dose calculation

Based on blood glucose levels measurements, the system will determine the amount of insulin dose to be able to balance his blood sugar as he goes up. With this system we find that by applying the formula of determining Insulin Sensitivity Factor (Correction Factor) ISF. By default, we used Total Daily Dose (TDD) of 60 Units insulin and the constant of 1800 rule.

The calculation of correction dose was determined using the following formula:

$$\text{Correctdose} = \frac{(\text{CurrentBG}) - (\text{TargetBG})}{(Correctio\_Factor)}$$

Where:

- ***Correctdose*** is Correction dose insulin for injection;
- ***CurrentBG*** is the current Blood Glucose measured;
- 120 taken as the Targeting Blood Glucose by default;
- ***Correctio_Factor or isf*** is the Insulin Sensitivity Factor;

Insulin, as we have seen, is one of the things that helps diabetics to control their blood sugar. Here we used the above formula so that when a patient has a problem the system helps by providing an email notification telling a patient the quantity of insulin, he/she should take.

5.4 Smart watch

As development accelerates, fitbit has tried to figure out how people can monitor NCDs with a smart watch. Using their fitbit OS Simulator, I was able to create a smart watch that is capable of measuring the heart rate, and counting the steps of user (diabetics).

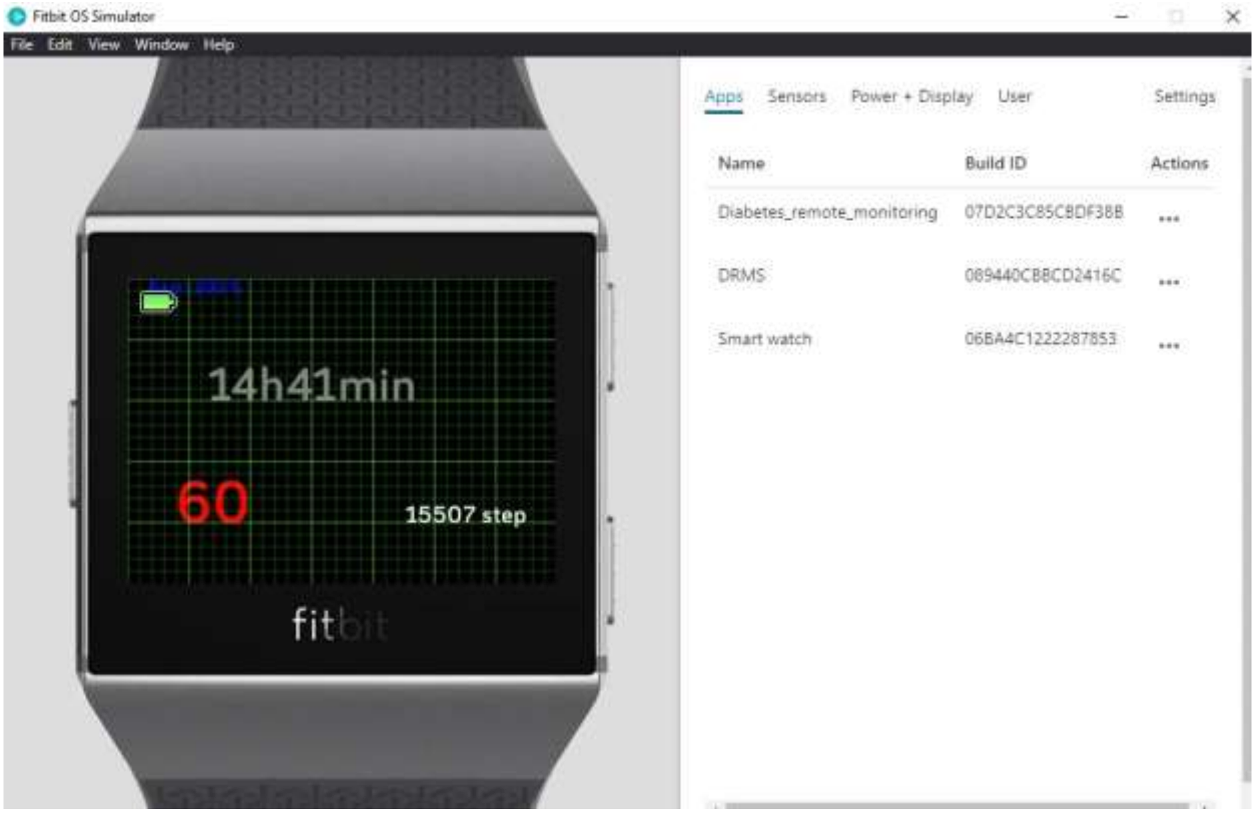


Figure 5. 10: Smart Watch designed for Heart rate Monitoring with Steps count

The smart watch has features including display and send measurements notifications from your body, such as tracking activities blood pressure, heart rate and managing body fitness. This fitbit OS Simulator, it measures heart rate, which display 60 bpm and dynamic steps.

5.5 Diabetes management

Table 1: Diabetes Mellitus results Analysis

People	**Blood Glucose**				**Heart rate**		**Blood Pressure**				**Body Temperature**	
	Fasting		After meal		Normal	Critical	Systolic		Diastolic		Normal	Critical
	Normal	Critical	Normal	Critical			Normal	Critical	Normal	Critical		
Without DM	70-99 mg/dl (3.9-5.5mmol/l)	100-125mg/dl (5.5-6.9mmol/l)	<140mg/dl (7.8mmol/l)	140-180mg/dl (7.8-10mml/l)	50-85 bpm	<85 bpm	<120 mmHg	120-180bpm	<80	80-120	36ºC-37.9ºC	≥ 37.9ºC
With DM	80-139mg/dl (4.4-7.2 mmol/l)	≥ 130 mg/dl	≤180 mg/dl (≤10mmol/l)	≥180mg/dl (≥10mmol/l)	50-85 bpm	>85 bpm	<120 mmHg	120-180 mmHg	<80 mmHg	80-120 mmHg	36ºC-37.9ºC	≥ 37.9ºC

The American Heart Association (AHA, 2015) demonstrate that the maximum heart rate during exercise should be roughly equal to 220 bpm minus the age of the person.

A person's heart rate should fall within this range when exercising at 50 to 80 percent intensity, also known as exertion.

A person's body works individual in different ways and thus the reaction of the body also varies. This affects the generalization of each measurement, which is why we set the range (WHO, 1968).

So we are urging people to have their devices that help them take physiological signs

CHAPTER 6. CONCLUSION AND RECOMMENDATION

The main purpose of this study was to enable technology more accessible, and help diabetics' patients to improve and maintain their health. Here, we took a closer look at how the Internet of Things, can help people with diabetes to manage their blood glucose, Heart rate, blood pressure and body temperature.

We developed a system where patient's measurements are recorded using computer or smartphones and data are stored automatically in database. Furthermore, data are sent to the clinicians' servers connected remotely with email notification. The clinicians can visualize the patient's measurements in user friendly Interface dashboard and make a daily, weekly and monthly report.

The implementation of this project's prototype will help countries to manage this Non-Communicable Disease, mainly Diabetes; thus, minimizing losing their people's health. It will accelerate development due to the saving of money they'd have wasted while taking their time to go to look for doctors at the hospital. The patient will be able to perform self-monitoring and find out his or her condition to help him or her take steps in his or her health. In the development of this system we combined the current IoT technologies. The dashboard is made of JSon and JScript and we did it in node-red and we created view panel for clinics and physicians in Grafana. Data are stored in influxdb, which is the best database tools in IoT and it is linked to Grafana as Data source. All these system features are hosted in localhost machine.

Recommendation

Based on this research is needed to address the issue of deaths from diabetes. There is a need for awareness-raising campaigns on the issue of establishing a project that will help diabetics to communicate their values in a timely manner, and have an immediate connection with clinicians.

We would urge patients to register for a system that will enable them to be monitored by physicians at real-time remotely.

We Research in healthcare requires a lot of time to achieve all the goals set by the researcher, so it is much better if government made easier for those who want to do research in the health sector to get an Ethical clearance certificate.

Proposition to the future research

Even though, there has been a lot of work done in this field and it seems that the research is ongoing, we can say that what has not been done in this current due to the reasons mentioned above future researchers will look at the following:

Design an algorithm that could differentiate diabetes types using Machine Learning for Artificial Intelligent.

We wanted to make our own non-invasive device but due to the COVID-19 corona outbreak, it was not often done because the equipment was not available on the local market and conducting experiment was limited due to the timeline.

For future research related to this study, we prefer to recommend researchers, to include Machine Learning /Artificial Intelligent for predict of diabetes based on parameters studied in this research, and able to express the possible risks or complications to diabetics.

Anticipated Output for the future research

This study aimed to put out an IoT device that can help diabetes patients to determine the level of their blood glucose and other four parameters mentioned above. Moreover, once blood glucose concentration, heart rate, blood pressure and body temperature are detected, the system will also calculate relevant much insulin is needed. Second, is a web-based application to display and manage the user’s information. Last, is the publication paper.

Potential Impact

To the community and country, the project would help contribute to improved quality of life and wellbeing (SDG 3) by availing easy and immediate access to medical prescriptions to a sample of diabetes's patients in Rwanda. The same project has a potential to contribute to the family and national economy by allowing citizens to save money and time that were to be spent to get conventional healthcare services (SDG8) by minimizing direct and indirect cost of healthcare for diabetic patients. Diabetes Associations will be able to determine the status of their members, classifying the patients with high priorities and provide fast assistance.

REFERENCES

1. AHA. (2015). *Target Heart Rates Chart*. https://www.heart.org/en/healthy-living/fitness/fitness-basics/target-heart-rates
2. Aizat Rahmat, M. A., Su, E. L. M., Mohd Addi, M., & Yeong, C. F. (2017). GluQo: IoT-based non-invasive blood glucose monitoring. *Journal of Telecommunication, Electronic and Computer Engineering*, *9*(3–9), 71–75.
3. Alarcón-Paredes, A., Francisco-García, V., Guzmán-Guzmán, I. P., Cantillo-Negrete, J., Cuevas-Valencia, R. E., & Alonso-Silverio, G. A. (2019). An IoT-based non-invasive glucose level monitoring system using Raspberry Pi. *Applied Sciences (Switzerland)*, *9*(15). https://doi.org/10.3390/app9153046
4. Bajer, M. (2017). Building an IoT data hub with elasticsearch, Logstash and Kibana. *Proceedings - 2017 5th International Conference on Future Internet of Things and Cloud Workshops, W-FiCloud 2017*, *2017-Janua*, 63–68. https://doi.org/10.1109/FiCloudW.2017.101
5. Brown, S. J. (2001). *Remote health monitoring and maintenance system*.
6. Buda, R. A., & Addi, M. M. (2014). A portable non-invasive blood glucose monitoring device. *IECBES 2014, Conference Proceedings - 2014 IEEE Conference on Biomedical Engineering and Sciences: "Miri, Where Engineering in Medicine and Biology and Humanity Meet," September*, 964–969. https://doi.org/10.1109/IECBES.2014.7047655
7. Businesswire.com. (2018). *OASIS-Members-Advance-MQTT-Standard-M2M-IoT*. https://www.businesswire.com/news/home/20130425005899/en/OASIS-Members-Advance-MQTT-Standard-M2M-IoT
8. Davies, M. J., Alessio, D. A. D., Fradkin, J., Kernan, W. N., Mathieu, C., & Mingrone, G. (2018). *Dm2 Tratamiento Ada 2018*. *2012*(4), 1–33.
9. Davies, M. J., D'Alessio, D. A., Fradkin, J., Kernan, W. N., Mathieu, C., Mingrone, G., Rossing, P., Tsapas, A., Wexler, D. J., & Buse, J. B. (2018). Management of hyperglycemia in type 2 diabetes, 2018. A consensus report by the American Diabetes Association (ADA) and the european association for the study of diabetes (EASD). *Diabetes Care*, *41*(12), 2669–2701. https://doi.org/10.2337/dci18-0033
10. De Boer, I. H., Bangalore, S., Benetos, A., Davis, A. M., Michos, E. D., Muntner, P., Rossing, P., Zoungas, S., & Bakris, G. (2017). Diabetes and hypertension: A position

statement by the American diabetes association. *Diabetes Care*, *40*(9), 1273–1284. https://doi.org/10.2337/dci17-0026

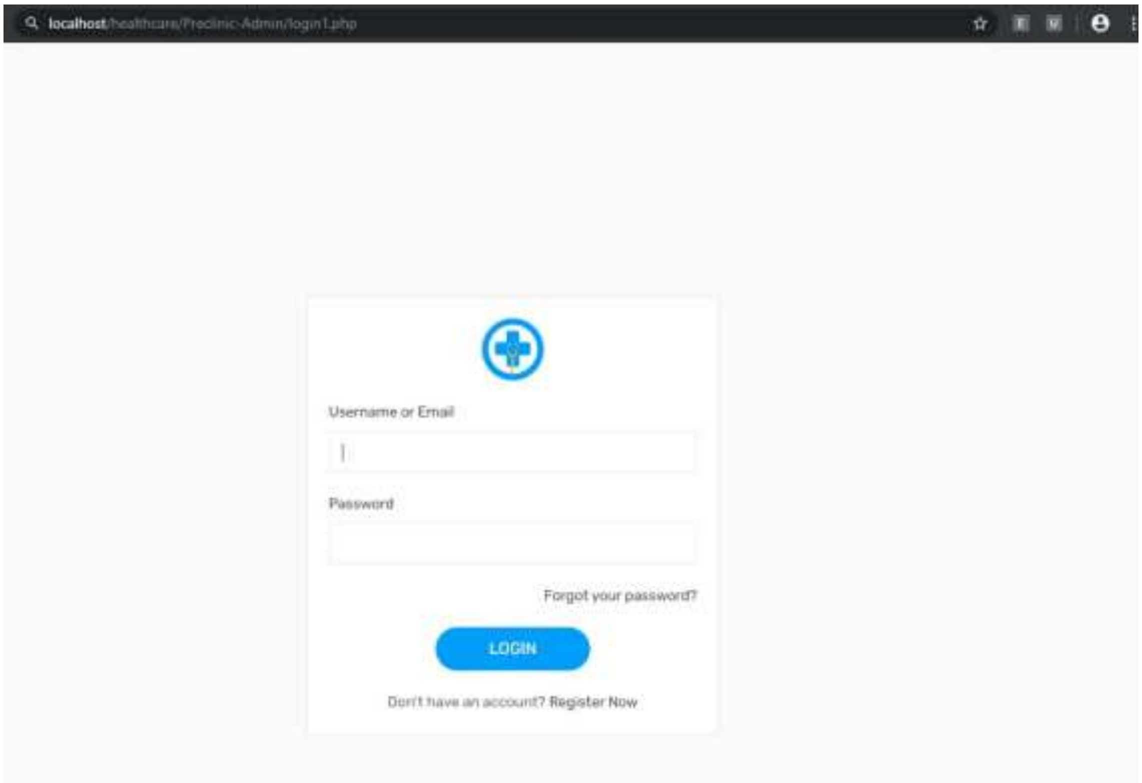
11. Elflein, J. (2019). *Diabetes - Statistics & Facts*. Health & Pharmaceuticals. https://www.statista.com/topics/1723/diabetes/
12. Gao, W., Emaminejad, S., Nyein, H. Y. Y., Challa, S., Chen, K., Peck, A., Fahad, H. M., Ota, H., Shiraki, H., Kiriya, D., Lien, D. H., Brooks, G. A., Davis, R. W., & Javey, A. (2016). Fully integrated wearable sensor arrays for multiplexed in situ perspiration analysis. *Nature*, *529*(7587), 509–514. https://doi.org/10.1038/nature16521
13. Https://www.wssu.edu/. (n.d.). *Key Elements of a Research Proposal Quantitative Design*. Retrieved November 10, 2020, from https://www.wssu.edu/about/offices-and-departments/office-of-sponsored-programs/pre-award/_Files/documents/develop-quantitative.pdf
14. Li, N., Zang, H., Sun, H., Jiao, X., Wang, K., Liu, T. C. Y., & Meng, Y. (2019). ALi, N., Zang, H., Sun, H., Jiao, X., Wang, K., Liu, T. C. Y., & Meng, Y. (2019). A noninvasive accurate measurement of blood glucose levels with Raman spectroscopy of blood in microvessels. Molecules, 24(8). https://doi.org/10.3390/molecules24081500 noni. *Molecules*, *24*(8). https://doi.org/10.3390/molecules24081500
15. Mercedes, R. C., Lijing, Y., Philip, G., Alan, R. D., MetzGer, B., & Martha, L. D. (2008). *Resting Heart Rate in Middle Age and Diabetes Developments in Older Age*. *31*(2). https://doi.org/10.2337/dc07-0874.Abbreviations
16. Meuleneire, F. (2008). Management of diabetic foot ulcers using dressings with Safetac®: A review of case studies. In *Wounds UK* (Vol. 4, Issue 4).
17. MQTT.org. (2017). *MQTT: The Standard for IoT Messaging*. https://mqtt.org/
18. Neuffer, P. (2019). *Higher heart rates related to type 2 diabetes risk in normal-weight adults*. Endocrinology Diabetes. https://www.healio.com/news/endocrinology/20190215/higher-heart-rates-related-to-type-2-diabetes-risk-in-normalweight-adults#:~:text=The researchers found that heart,%3D 1.24%3B 95%25 CI%2C
19. Osher, E., & Stern, N. (2008). Diastolic pressure in type 2 diabetes: can target systolic pressure be reached without “diastolic hypotension”? *Diabetes Care*, *31 Suppl 2*(12). https://doi.org/10.2337/dc08-s262

20. Raj, C., Jain, C., & Arif, W. (2018). HEMAN: Health monitoring and nous: An IoT based e-health care system for remote telemedicine. *Proceedings of the 2017 International Conference on Wireless Communications, Signal Processing and Networking, WiSPNET 2017*, *2018-Janua*, 2115–2119. https://doi.org/10.1109/WiSPNET.2017.8300134
21. Rghioui, A., Lloret, J., Harane, M., & Oumnad, A. (2020). A smart glucose monitoring system for diabetic patient. *Electronics (Switzerland)*, *9*(4), 1–18. https://doi.org/10.3390/electronics9040678
22. Scheen, A. J. (2016). Precision medicine : the future in diabetes care ? Department of Medicine. *DIABETES RESEARCH AND CLINICAL PRACTICE*, *April*. https://doi.org/10.1016/j.diabres.2016.04.033
23. Sollund, R. (2008). Tested neutrality: Emotional challenges in qualitative interviews on homicide and rape. *Journal of Scandinavian Studies in Criminology and Crime Prevention*, *9*(2), 181–201. https://doi.org/10.1080/14043850802450138
24. Uwimana, J. D. D., Nyirandegeya, J., & Nisingizwe, E. (2019). *M-health Tools Utilization of Tele-home Healthcare Services for Diabetes Management Among Youth in Kigali City . Demographic profile Study design Existing Tele-home healthcare framework for youth diabetes management in Rwanda*. *2*(3), 213–219.
25. Valenzuela, F., García, A., Ruiz, E., Vázquez, M., Cortez, J., & Espinoza, A. (2020). An IoT-based glucose monitoring algorithm to prevent diabetes complications. *Applied Sciences (Switzerland)*, *10*(3), 1–12. https://doi.org/10.3390/app10030921
26. WHO. (1968). *EXERCISE TESTS IN RELATION TO CARDIOVASCULAR FUNCTION*. https://apps.who.int/iris/bitstream/handle/10665/40688/WHO_TRS_388.pdf?sequence=1&isAllowed=y
27. WHO. (2016). *Global Report on Diabetes*. https://apps.who.int/iris/bitstream/handle/10665/204871/9789241565257_eng.pdf;jsessionid=AFB014CC445D486EDBB8C91B676B4508?sequence=1
28. WHO. (2020a). *Diabetes*. https://www.who.int/health-topics/diabetes#tab=tab_3
29. WHO. (2020b). *Diabetes*. https://www.who.int/news-room/fact-sheets/detail/diabetes
30. Writer, S. (2019, April 30). *Sanofi unveils new digital diabetes patient support program*. CIO East Africa. https://www.cio.co.ke/sanofi-unveils-new-digital-diabetes-patient-support-program/

APPENDICES

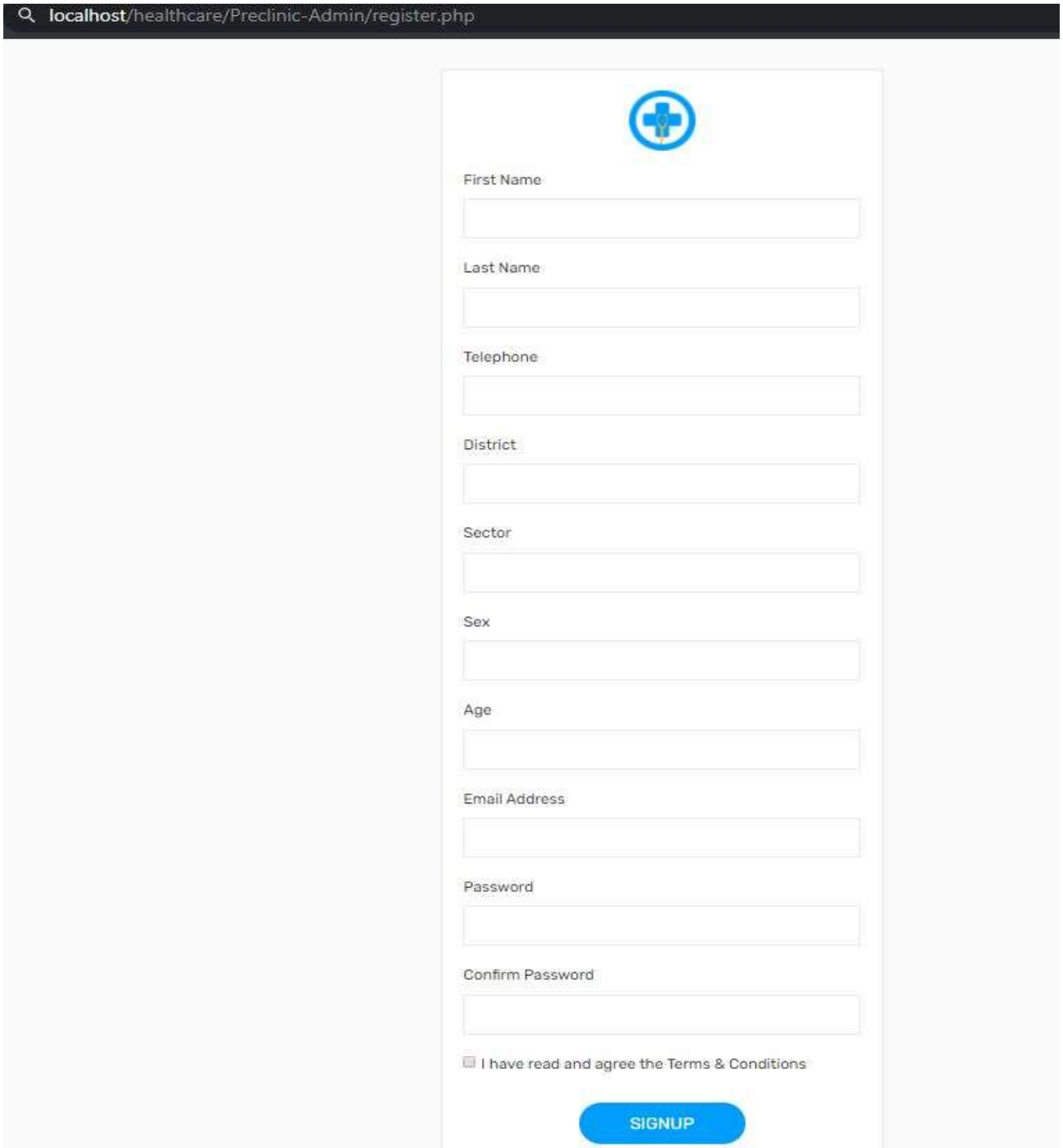
As we have shown, this is a web application-based system and I present system forms

Appendix-1



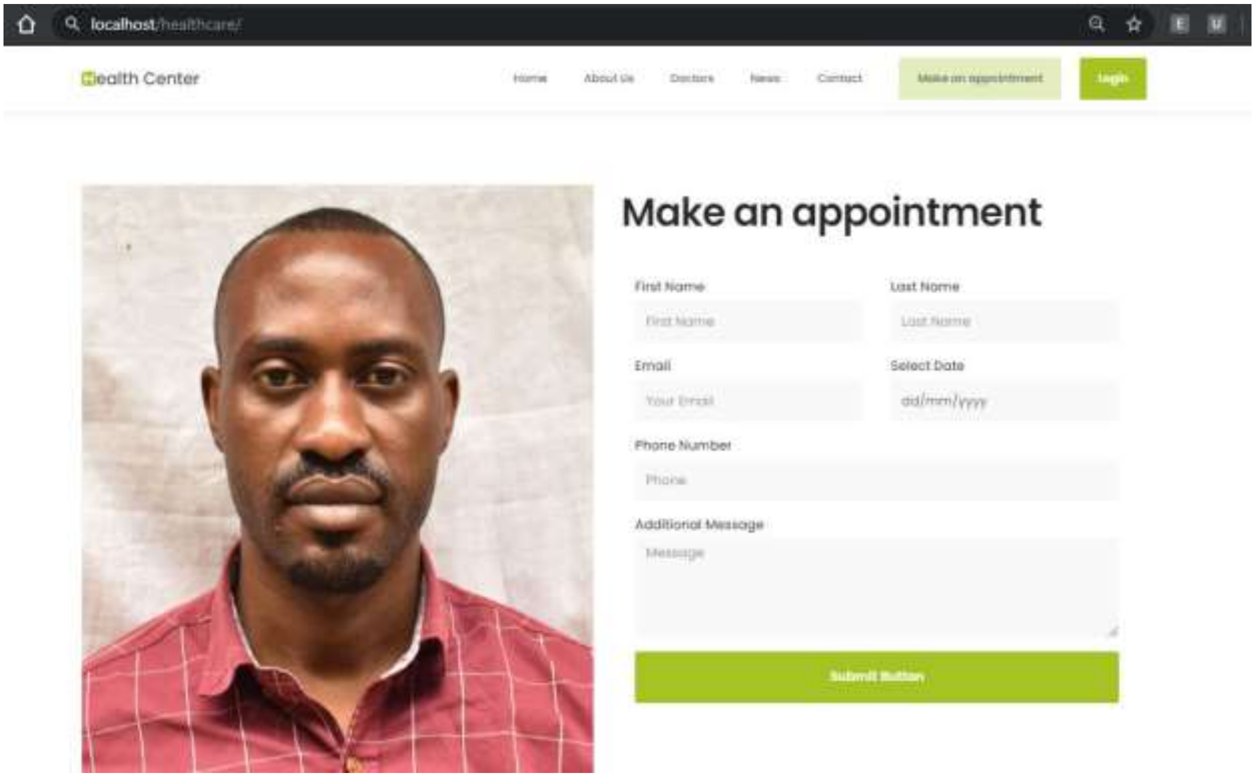
Appendix-Figure 1: Login form of the system's users

Appendix-2



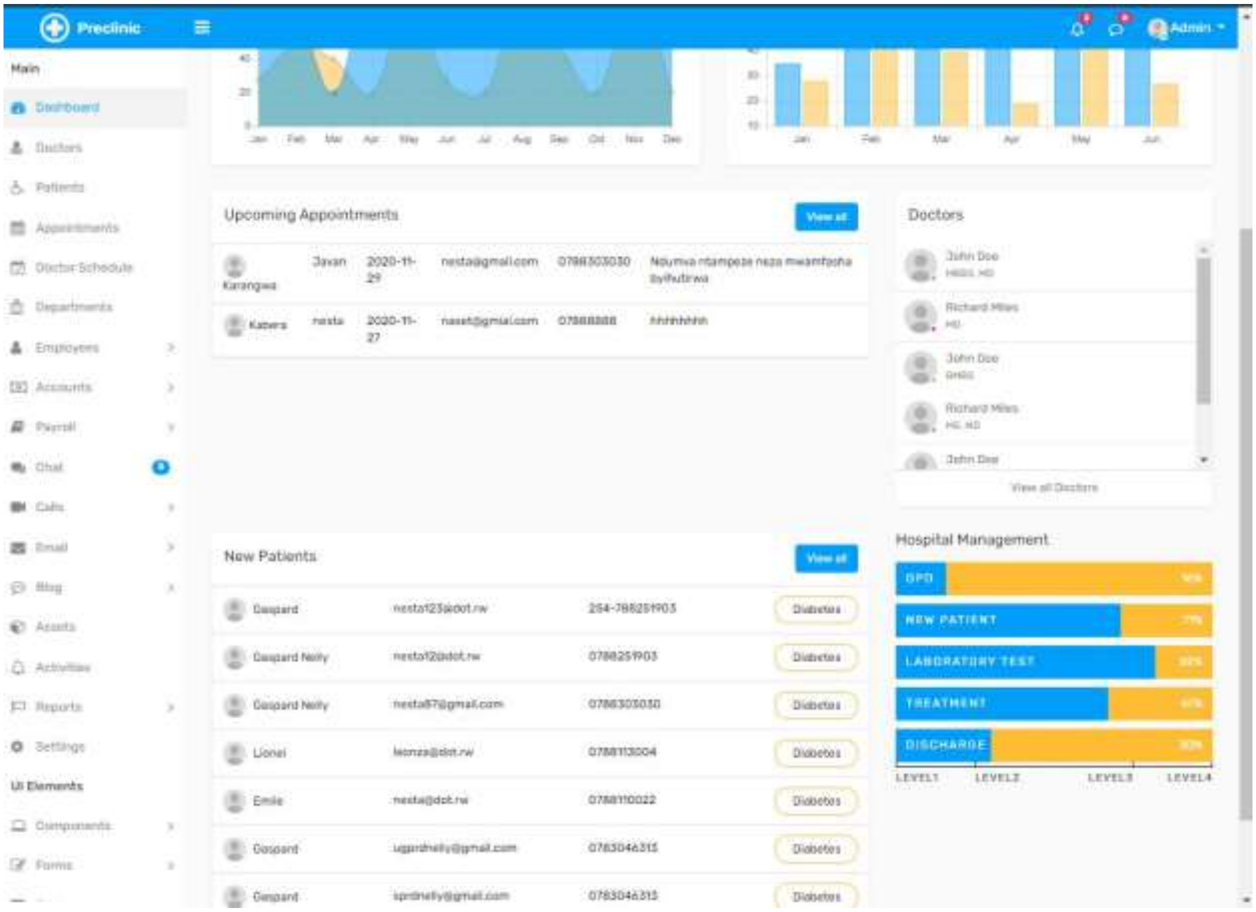
Appendix-Figure 2: Registration form for new user

Appendix-3



Appendix-Figure 3: Appointment form for patients

Admin control panel for clinic/ Preclinic management



Appendix-Figure 4: Web application System admin panel