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Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE)

**DESIGN AND PROTOTYPING OF A NON-INVASIVE SMART DEVICE TO TEST
HUMAN CARDIOVASCULAR STATUS**

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A dissertation Submitted to the Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), University of Rwanda as partial fulfillment of the requirements for the Master's Degree in Biomedical Engineering.

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DECLARATION

I, **HABIYAREMYE Charles**, declare that this dissertation entitled “**Design and Prototyping a non-invasive smart device to test human cardiovascular status**” is my original work based on research and prototype and has not been submitted for any other degree or professional qualification.

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CERTIFICATE

This is to certify that the project entitled “**Design and Prototyping a non-invasive smart device to test human cardiovascular status**” is a record of original work done by **HABIYAREMYE Charles** (Reference number: 217292372), a MSc. Degree student in Biomedical Engineering. This work has been submitted under the guidance of **Dr. Gerard RUSHINGABIGWI** and **Dr. James RWIGEMA**

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ABSTRACT

Today medical care Technology has taken center stage in people's life. Unexpected heart attacks cause unexpected deaths in humans, which is a problem because patients are not given the right care at the right time. In this project we aim to prevent such sudden death rates by creating an easy body health monitoring system, a handheld electrocardiogram (ECG). In this system, a patient will be equipped with sensors and an android phone application. The sensors in the hardware will detect electrical heart activity especial heart rate and the data is transmitted via WiFi to an android phone application and values are displayed on LCD The system has a cloud database that houses all patient health-related data, and doctors will review the data by using a web application and write prescriptions for medications. If a critical condition exists, the doctor will notify the patient via mobile phone. Patient can move around freely and is continuously under observation. A total of 10 people, six men and four women, received systematic testing for examination of heart rate as part of this study to identify cardiovascular condition.

Results showed that the designed system would be a good way to address the problems with the current wearable ECG smart watch, and the data of new system compared to those from the existing system showed high accuracy. The performance of proposed device is 95% compared to the Blood pressure machine during measurement of heart rate. Both patients and healthcare professionals can benefit from the flexibility and cost-saving options provided by this type of health monitoring system.

Keywords: Electrocardiogram (ECG), Cardiovascular Diseases, Smart monitoring device, Android Phone Application,

LIST OF ACRONYMS

3D Three-dimensional:
ADC Analog Input Pins
API Application Programming
AV Atrioventricular
CAD Coronary Artery Diseases
CHUK University teaching hospital of Kigali
CT Computed Tomography
CVD Cardiovascular disease
DI/O Digital I/O
DNA Deoxyribonucleic acid;
ECG Electrocardiogram
EPS 8266 Espressif Systems
I/O Input/output
IDE Integrated Development Environment
IoT Internet of Things
LA Left Arm
LL Left Leg
MI Myocardial Infarction
MRI Magnetic Resonance Imaging
MVC Model-View-Controller Structure
RA Right Arm
SA Sinoatrial
URL Universal source locator
Wi-Fi Wireless Fidelity

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CHAPTER 1. GENERAL INTRODUCTION

1.1 Introduction

Today medical care Technology has taken center stage in people's lives [1]. Unexpected heart attacks cause unexpected deaths in humans, which is a problem because patients are not given the right care at the right time. As a result, cardiovascular diseases account for approximately 18 million deaths worldwide each year. Every 36 seconds,[2] someone in the USA dies from cardiovascular disease. Heart disease kills approximately 659,000 people in the USA each year [3]. According to the report of the ministry of health, every year, they account for 32% of all fatalities in Rwanda [1]. Most people are unaware of their health status because it has no symptoms, the heart disease primarily caused by artery blockage, which stops blood from flowing to the heart[4]. Pain and discomfort in the center of the chest, arms, or left shoulders, as well as difficulty breathing, are widely symptoms of heart attacks and strokes. This increases the people visiting the hospital, placing pressure on the Medicare health systems[5].

Researchers continue to look for methods to combat this heart disease. In 2012s [6], the scientist came up with a device called wearable ECG smart watch that could be used to measure the patient's parameters of heart and send the results to the doctor without leaving home and then Doctor analyze data, after that provide a feedback to a patient[7]. This was done in order to reduce the high number of patients visiting the doctors and the lack of patient network communication for both doctor and patient while are at hospital and home respectively. The hand movements present a challenge when using a wearable watch device, but an adaptive motion artifact removal algorithm might open up new possibilities for modifying this life-saving device[6]. Thus, there is a growing need for remote health care systems that can help with these difficulties[8]. Generally the ECG tests are carried out by placing electrodes on the human body's chest at specific locations, usually under the right clavicle near the right shoulder within the rib cage frame[4], another under the left clavicle near the left shoulder within the rib cage frame, and finally on the left side below the pectoral muscles on the lower edge of the left rib cage Wires connect these electrodes to the AD 8232 ECG and this AD8232 connects to the NodeMCU ESP8266 WiFi module for processing data [9]. There may be a way for the millions of sensors and devices to connect with one another, making it simple for data to be shared between them. By connecting patients and doctors, as well as medical equipment and patient monitoring systems, and integrating them with the network, it is possible to improve quality of life [10]. The reason why the AD 8032 ECG sensor, it is made to extract, amplify, and filter

weak bio potential signals in noisy environments like those brought on by movement or distant electrode placement. then, using Wi-Fi(Wireless Fidelity)a microcontroller's processed data can be uploaded to android phone application and a web server [11].

Finally, the data can be viewed by logging into the ThingSpeak channel from anywhere in the world. However, this time, the patient gives permission for the doctor to access the data. The captured ECG data is then interpreted by a hospital health specialist and there may also be feedback from the doctor to the patient. The signal information received by the doctor could include the heart activities especially heart rate [12].

We were striving to develop a smart device for patient Health Monitoring systems, to allowing customers to reduce their health risks and medical expenses. Because it is expected that by 2030 there would be over 23.6 million fatalities worldwide. Therefore, action must be taken right away to reduce the tension using existing technologies [12]. In this regard, we proposed a Non – Invasive Smart Device to Test Human Cardiovascular Status includes a portable electrocardiogram (ECG) unit for remote areas for individual use. It is a noninvasive, painless medical test that measures the electrical activity of the heart as it contracts.

This device will assist people in reducing deaths and the number of patients, such as the elderly and the disabled, who frequently visit hospitals. As a result, they will find it helpful in monitoring their health, and it is anticipated that the system will enhance quality of life in terms of early diagnosis. [13].

1.2 Problem statement

Most of the time, people are unaware of their health status, particularly when it comes to cardiovascular diseases. As a result, cardiovascular diseases account for approximately 18 million deaths worldwide each year. Every 36 seconds, someone in the United States dies from cardiovascular disease. Heart disease kills approximately 659,000 people in the United States each year [3]. Every year, they account for 32% of all fatalities in Rwanda. To combat the problem, questions remain as to what form and properties systems can be used to be easily accessible by the public in order to make healthcare truly available to anyone, anytime, and anywhere[9]. There is a strong need to research and developed systems that can answer these questions; we believe that this will eventually lead to a shift from medical systems for patients to health systems for citizens [2]. We intend to use a non-invasive smart device to test Human Cardiovascular status. This includes a portable ECG device that is simple to use to monitor heart activities even in remote locations, which will be preferable for both patient and doctor, using wireless communication WiFi. This system could facilitate patient to be hospitalization at home. While doctor can use it in hospital to monitor multiple patients at a same time on the web page from remote location. In addition, doctors may be able to provide feedback.

1.3 Research Questions

The following questions are the baselines which guided this study:

1. How non-invasive smart device will be developed for real-time human cardiovascular status?
2. How architectural concept will be implemented as a proof-of-concept prototype?
3. Will the developed system able to record, store and send data captured to the doctor for diagnostic analysis?

1.4 Objectives

1.4.1 General Objective

The aim of this project is to design and prototyping a Non-Invasive Smart Device that can be used to monitor Cardiovascular Status.

1.4.2 Specific Objectives

To achieve the general objective of this project, the following specific objectives are used as guiding points:

- ❖ To develop a non-invasive smart device for real-time monitoring human cardiovascular status.
- ❖ To Implement this architectural concept as a proof-of-concept prototype
- ❖ To record, store and send captured data to the Doctor for therapeutic, diagnostic analysis and treatment.

1.5 Study Scope

This study was conducted using 3-lead ECG, aiming to design and prototyping a smart device for assessing cardiovascular health in people. The system was capable of detecting, amplifying, filtering, and processing data before sending it to an online platform. The web application works via WiFi for remote monitoring. The doctor can then use this platform to diagnose and examine the processed data. If any abnormalities are found, the doctor may inform the patient right away or offer pertinent advice. In this system, a patient will be together with hardware having sensors, android phone application. The best of this study is not only to reduce the number of people visiting hospitals also create a low-cost ECG monitoring machine that is portable, available, and affordable, but also to provide a complete solution of recording, monitoring, and report generation for people living in remote areas, so that they never suffer from under diagnosis of a heart problem.

1.6 Significance of the Study

The significance of this study, personalizing home pre-medical checkup systems. By enhancing the usability and caliber of the Smart ECG device and bringing down the price of the device, the designed system can help patients with cardiovascular diseases. The system can help users improve their quality of life and better manage their cardiovascular conditions. The system may also be able to transmit the recorded ECG signal via WiFi to the web server and smartphone.

This time, the patient won't need to visit doctor's office; the doctor will give them feedback immediately. Patients who live a long way from the hospital and have weak bodies will especially benefit from this. They will get the necessary advice at home.

1.7 Organization

This thesis report has four chapters. The project's general introduction is covered in the first chapter. The second chapter provides a brief overview of earlier related research as well as the gaps found. The third chapter describes Different methodologies used to conduct the research.

The fourth chapter provides the implementation of the proposed system. The fifth chapter of conclusion, recommendation and suggestions for the work to be done in the future.

1.8 Summary

In this section's introduction, we discuss the prevalence of heart disease both globally and domestically. We also talked about the problem that exists until now, which is not knowing how people stand on heart disease, and they learn when they visit doctor. We also showed how researchers have been trying to fight this heart disease and the weakness of their system. We are proud to show our contribution in the fight against heart disease, where this study proposed to create a device that could be used to measure the heart condition of a person at home, and send the measurements to the doctor. This system might include physiological data that is stored, processed, and communicated locally using devices like smartphones.

This system could help people to reduce the death rate due to cardiovascular diseases, prevent, manage, and stay as healthy as possible and also reducing the big number visiting to the hospitals. The experimental results show that the device is precise, inexpensive, easy to use, and useful.

CHAPTER 2. LITERATURE

2.1 Introduction

This part provides essential background information for this thesis, the theory comprises general information on the anatomy of the heart, ECG signals, and the methods currently in use for the identification of cardiovascular disorders [2]. We wrap it off with research that identifies other perspectives to be undertaken for preventing certain cardiovascular illnesses more successfully.

2.2. Cardiovascular system

Blood-vascular or circulatory systems are other names for the cardiovascular system. It is composed of a closed network of blood vessels known as arteries, veins, and capillaries, as well as the heart, a muscle pumping apparatus [1]. The muscular organ that circulates blood enriched in oxygen throughout the body is the heart. Each of the four chambers in the heart has two sides. The two "mirrored" sides of the heart are connected by different circular systems. But they both pump in time with one another, rhythmically. The chambers are as follows: the left and right ventricles, where blood is propelled out through the body for circulation; and the right and left atriums, where blood enters. The illustration below demonstrates how the left and right sides are connected to various blood veins, with the right-side supplying blood to the lungs and the left side to the rest of the body [14]. The electrically polarized cardiac cells that make up the heart are dormant. This basically indicates that the interior of the cell is negatively charged while the exterior is positively charged. To keep this charge, ions are pushed into cells through unique ion channels in cell membranes. Cardiac cells may lose their intrinsic charge during the depolarization process. The heartbeat is created by the depolarization of some cardiac cells, which happens on its own.

In contrast, some cells will need to be "pushed" into this state. The cells return to their initial condition through a process known as repolarization when the depolarization procedure is finished. These two conditions of the cardiac cells are what keep the heart from stopping beating [15].

2.2.1.1. Electrical conduction in Heart

At the top of the right atrium, the Sinoatrial Node (SA node) produces the electrical impulse that is then sent to the ventricles via multimodal routes, the AV (Atrioventricular) node and AV bundle system, and Purkinje system pathways in the ventricle's left and right bundle branches.

The synchronized contraction and relaxation functions of the atria and ventricles are activated by this cardiac impulse, creating contracting forces in the ventricular muscle that move blood from the atrium to the chambers of the ventricles [10]. The two ventricular chambers then ensure appropriate blood flow throughout the body's circulatory system by supplying blood to the pulmonary circulation system via the right ventricle and the peripheral circulation system via the left ventricle [17].

2.2.1.2. The Cardiac cycle

The cardiac cycle lasts approximately 0.8 seconds and consists of complete relaxation and contraction of both the atria and ventricles. Blood flows passively from the veins into the atria and past the atrio-ventricular valves into the ventricles, beginning with all chambers in diastole. Following depolarization of the atria, the atria begin to contract and pump blood into the ventricles [18]. The ventricles begin to contract, increasing pressure within them. In the ventricular ejection phase, blood pushes open the two semilunar valves and moves into the pulmonary trunk and aorta when ventricular pressure exceeds the pressure in the two major arteries [19]. Following ventricular repolarization, the ventricles begin to relax and the pressure within the ventricles begins to fall. When the pressure in the atria falls below that in the ventricles, blood flows from the atria into the ventricles, opening the atrioventricular valves and completing one heart cycle. For the sake of simplicity, the heartbeat has three distinct events that produce the ECG's characteristic waveforms, which include the P-wave, T-wave, and QRS complex [20].

Table 1:2.1 Lists of the various cardiac cell types with descriptions of each

Cell type	Function
Pacemaker cells	Cells that continuously depolarize and repolarize are known as pacemaker cells. 60 to 100 times per minute are involved in this. The autonomic nervous system's activity, however, affects how quickly this rate changes.
Electrical conducting cells	a person's heart's "wiring." These cells will control how the myocardial cells depolarize in response to the pacemaker cells. In both the atrium and the ventricles, these cells form a "conducting system."
Myocardial cells	The heart's muscles are contracting. The strongest cells in the heart are those mentioned above. The depolarization and repolarization of these cells is what generates a heartbeat.

2.2.2. Blood Vessels

A blood vessel is a conduit that permits blood to circulate throughout an animal or human body. The arteries and the tiny branches they have, called arterioles, are the blood vessels that carry blood away from the heart. Small branches known as venules gather blood from various organs and join to produce veins that carry it back to the heart [21]. The capillaries, which connect the arterioles and venules, are tiny, thin-walled blood channels that facilitate the exchange of nutrients and wastes between the blood and bodily tissues. In particular, cardiovascular diseases like coronary artery disease (CAD) and myocardial infarction (MI), aortic disease, heart arrhythmia, heart failure, heart valve disease, congenital heart disease, cerebrovascular disease, and stroke are regarded as the leading cause of death worldwide [22]. People also become more anxious as food and lifestyle trends change worldwide.

2.3. Existing techniques to combat the heart diseases

Between 1895 and 1900, scientists developed X-rays, echocardiograms, CT scans, and MRIs as tools for monitoring cardiac problems. But most of these tools are expensive, bulky, time-consuming to use, and infrequently unavailable.

2.3.1. Echocardiogram

A high-resolution image of the heart can be viewed during an echocardiography [23]. The image, which is a moving picture of the heart that provides details on its structure and operation, can help cardiac specialists in the identification of a number of heart conditions [24]. Neither test is supposed to hurt the patients. It is a minimally invasive medical gadget with few adverse effects and no radiation [23]. The test may take up to an additional 20 minutes, depending on the precise information needed. During an echocardiography, a cardiac expert can examine the following things [25]: size, thickness, valve function, conductivity, clot, and damaged areas of the heart.

2.3.2.X-ray

An imaging test called an X-ray uses radiation to produce pictures of the body's organs, tissues, and bones [26]. All chest organ abnormalities can be discovered with an X-ray. Additionally, it may detect air or fluid in your lungs [27]. When a patient exhibits signs of pain and shortness of breath, a doctor will typically request an X-ray of the inside of the chest. Radiation from x-rays has the potential to cause cancer [27], which is a downside. Pregnancy is not a good time to get an X-ray [26]. Because radiation can harm your unborn child, this is necessary. Inform your doctor as soon as you suspect being pregnant.

2.3.3. Computed Tomography (CT) Scan

CT scan uses X-rays to take numerous detailed images of your heart and blood vessels. These images can be combined by computers to form a three-dimensional (3D) model of your entire heart [28]. Cardiac CT scans are not without risk. In rare cases, the contrast dye may cause kidney damage, especially in people who have a history of chronic kidney disease. Before the exam, your doctor or the imaging center may perform a blood test to assess your kidney function. Some people may be allergic to the contrast dye in rare cases. If you have a known allergy, you may still be able to receive contrast if you receive medicine ahead of time [29]. Because the test uses radiation, there is a very slight risk of cancer, especially in people younger than 40 years old who undergo multiple CT scans. Discuss with your doctor and the technicians performing the test whether you are pregnant, may be pregnant, or are breastfeeding.

2.3.4. Magnetic Resonance Imaging (MRI)

A magnetic field and radio waves produced by a computer are used by magnetic resonance imaging (MRI), a piece of medical imaging equipment, to produce precise images of the organs and tissues in your body. Large, magnetized tubes make up the majority of MRI machines[21]. These machines were bulky and expensive, and some of them even used radiation, which is dangerous to human life. Another scientist created the Electrocardiogram in the 1990s as a new tool for detecting heart disease.

2.3.5. Basic Concepts of Electrocardiogram (ECG or EKG) Machine

Since William Einthoven first developed the electrocardiogram (ECG) in 1901, it has been widely used to capture the heart activity [30]. This has made it possible for medical professionals to more accurately detect and diagnose heart abnormalities like cardiac arrhythmias, myocardial infarction, and heart failure. Using waves and peaks, the ECG signal is made up P, Q, R, S, and T waves, and every wave shows a function of the heart[20]: Atrial depolarization, ventricular depolarization, and ventricular repolarization are the three electrical heart events that the ECG documents. The P wave, the QRS complex, and the T wave are the electrocardiographic correlates of these events, respectively.

2.3.5.1. Waveform of the electrocardiogram (ECG)

Each heartbeat displayed is a series of electrical waves with peaks and valleys. The ECG primarily provides two types of information. The length of the electrical wave passing through the heart determines whether the electrical activity is normal, slow, or irregular. The amount of electrical activity passing through the heart muscle, which helps determine whether certain parts of the heart are too large or overworked, is the second factor[31]. An ECG signal has a frequency range of 0.05–100 Hz and a dynamic range of 1–10 mV. ECG analysis performance is based on the accurate and dependable detection of the QRS complex as well as T- and P waves.

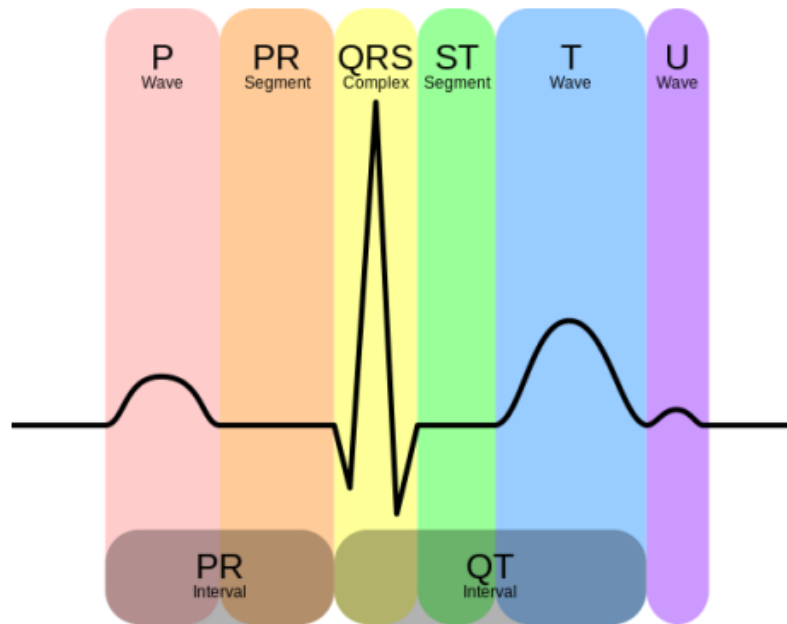


Figure 1:2.1. ECG waves indicating the depolarization and repolarization of the atrium and the ventricle [32]

P wave

The electrocardiogram's P wave denotes atrial contraction.

QRS complex of wave

The complete depolarization of the ventricles is represented by the Q R S complex.

The Q wave, R wave, and S wave are all included in the QRS complex, as the name suggests.

These three waves happen quickly one after the other.

- Q wave: The downward inclination just before ventricular contraction
- R wave: when ventricular contractions are at their strongest.
- S wave: Immediately following the ventricular contraction, the downward deflection.

T wave

The T wave is a visual representation of the ventricles' repolarization, or the period following a heartbeat when the heart muscles revert to their resting negative condition. Leads often have a positive T wave. Certain disorders may be indicated by negative T waves.

U Wave

It is a very small wave that follows the T wave. It stands for the delayed repolarization of the papillary muscles or Purkinje fibers.

The interval

The interval is the amount of time that passes between two specific ECG events. The intervals that are usually measured on an ECG are the PR, QRS, QT, and RR intervals. The QRS interval is also referred to as the QRS duration.

The PR interval

The time between the onset of atrial and ventricular contraction is measured by the PR interval. Typically, the PR interval ranges from 0.12 to 0.22 seconds.

QT Interval

The Q T interval is a measure of the full depolarization and repolarization of the ventricles. A prolonged Kuttly interval raises the danger of ventricular arrhythmias and abrupt death. It signifies the change from the beginning to the finish of the depolarization of the ventricles. Anywhere between 0.4 and 0.44 seconds.

PQ interval

There are no accepted physiologic explanations for the PQ interval's mild heart rate reliance, despite the fact that this relationship is well known. PQ dynamics is an obvious choice for concurrent non-invasive assessment of atrial anomalies, including the risk of atrial fibrillation.

QRS interval

The time it takes for a stimulus to propagate throughout the ventricles is measured by the QRS interval, which is normally less than 0.10 seconds.

The Segment in ECG

A segment is the distance between two particular ECG locations that should both be at baseline amplitude. The segments on an ECG are the PR segment, ST segment, and TP segment.

The ST segment

The S T section illustrates the complete depolarization of the ventricles. Elevation or depression of this section may indicate ischemia of the heart muscle.

The PR segment

Starting at the P wave's conclusion and finishing at the start of the QRS complex.

The TP segment

The TP segment of an ECG is the region between the end of the T wave and the beginning of the P wave. The TP segment should always be at baseline and used as a reference to assess if the ST segment is elevated or depressed because there are no specific illness situations that elevate or depress the TP segment.

2.3.5.2. ECG component parts

On a typical ECG, there are 12 leads. Six of the leads are referred to as "limb leads" since the wearer's arms and/or legs are connected to them. The final six leads are known as "precordial leads" due to where they are located on the torso (precordium). The formal names of the six limb leads are Lead I, II, III, aVL, aVR, and aVF. The letter "a" stands for "augmented," as these leads are determined as a result of adding leads I, II, and III together. The six precordial leads are leads V1, V2, V3, V4, V5, and V6. The image below shows a typical 12-lead ECG trace. The various ECG components are described in the sections that follow.

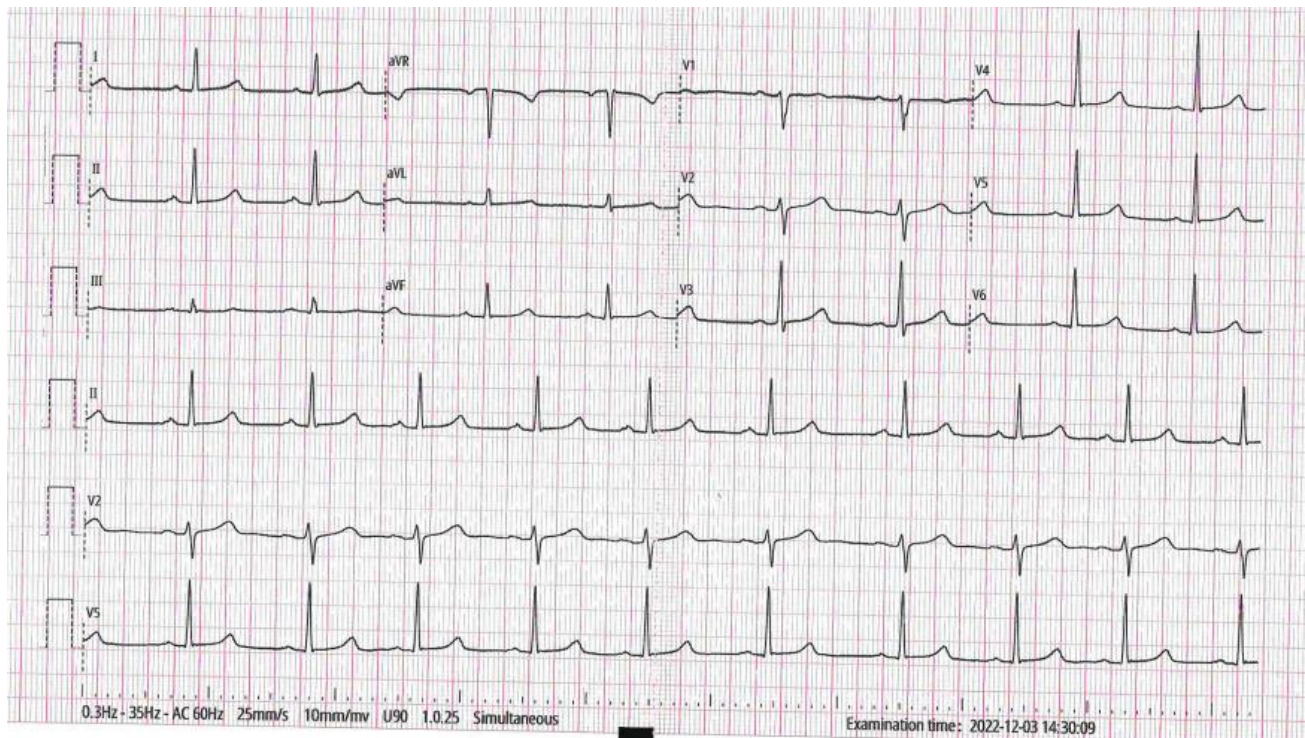


Figure 2: 2.2 Normal ECG contains waves, intervals, segments and one complex

The electrocardiogram (ECG) signal, which was discovered in 1901 by Dutch physician William Einthoven, is the most widely used and easily accessible bio signal in both humans and animals. ECG is the most effective non-invasive diagnostic technique in cardiovascular physiology for analyzing the function of the heart, and the information extracted from the different ECG wave intervals can indicate abnormalities of the cardiac system in various pathological conditions [33]. The ECG signal is made up of P, Q, R, S, and T waves, and every wave represents a function of the heart: the P-wave represents atrial depolarization, the Q-wave represents interventricular septum depolarization, the R-wave represents ventricle depolarization, and the S-wave represents final ventricle depolarization, and also The T wave indicates ventricular myocardium repolarization [17]. After conducting research on existing techniques used to test cardiovascular diseases, I discovered that some of them use radiation, which can harm human cells. Radiation can cause DNA mutations and, as a result, cancer later in life[34]. CT scans are thought to be responsible for 0.4% of cancers in the United States. Some scientists believe that as the use of CT scans in medical procedures increases, this level will rise [35]. According to my research, by the age of 75, radiation increases the risk of cancer by 0.6 to 1.8%.Each procedure comes with its own set of risks, which vary depending on the type of radiation and the part of the body being imaged[36]. Another existing techniques of detecting cardiovascular diseases, which takes a long time to complete the test (about 20 minutes), so I chose a short-term technique which is the ECG (about 5 minutes).For ease of analysis, existing techniques typically print results on paper[35]. In 2012s, the scientist came up with a device called wearable ECG that he could use to measure the patient's parameters of heart and send the results to the doctor without leaving at home and then Doctor analyze data, after that provide feedback to a patient. This was done in order to reduce the high number of patients visiting the doctor and the lack of patient network communication for both doctor and patient while are at hospital and home respectively. The hand movements present a challenge when using a wearable watch device, but an adaptive motion artifact removal algorithm might open up new possibilities for modifying this life-saving device[6].

2.4. Gaps existing in current Technology used to monitor cardiovascular status.

The following are disadvantages apply to the wearable watch ECG: Keeping electrodes firmly attached to the skin can be challenging, higher impedances and more unstable signals, more prone to mains interference and movement artifacts than sticker electrodes, and uncomfortable to the wearer. According to our findings, there may be a relatively cheap, small size tool that is widely available that could be used to identify heart disease in people who are not in a clinical setting. We promoted the development of a system that could aid in reducing mortality rates and heart disease using a portable ECG device as one of the accuracy-related parameters. This device uses electrodes to detect electrical heart signals, an AD8232 to amplify and filter the heart signals and NodeMCU ESP8266 with WiFi Module to process the data. The device uses sticker electrodes with a powerful gelled adhesive; the reasons these electrodes selected so well are as follows: Low impedance to reduce the noise produced while recording signals, highly effective signal, superior to dry electrode in terms of resistance to mains interference and movement artifacts (even when the subject is moving, the impedance is low.), recordings are stable for long period. Through a WiFi connection, this device could be linked to the cloud database for continuous user data recording and to an Android phone application. A patient will then be able to send to doctor information about cardiovascular health. The doctor reviews the patient's data for therapeutic, diagnostic, and treatment purposes. If a critical condition exists, the doctor will notify the patient via mobile phone.

2.5. Summary

This chapter provides an overview of the cardiovascular system and how it works. And we demonstrate how to prevent heart diseases. We have also demonstrated the global nature of heart disease. In this chapter, you find techniques used to monitor the heart status, from the 1990s to 2012. Until now, the latest technique used is the wearable ECG smart watch, which is worn on the wrist and its weakness just showed. We put forth an alternative that might support it, where the motion artifact makes the signal unstable for the existing techniques while the new one does not have any issues with motion. due to the electrodes' secure attachment to the skin. This has made it possible to more accurately detect and diagnose heart abnormalities like cardiac arrhythmias, myocardial infarction, and heart failure. Each heartbeat displayed is a series of electrical waves with peaks and valleys. The length of the electrical wave passing through the heart determines whether the electrical activity is normal, slow, or irregular. An ECG signal has a frequency range of 0.05–100 Hz and a dynamic range of 1–10 mV.

CHAPTER 3. RESEARCH METHODOLOGY

In this part the methods and approaches used to conduct the research are outlined. This includes the steps undertaken to complete the study, the system design methodology, and tools used in data collection, and prototyping of the proposed system according to [19].

3.1 Research Process

Five major stages made up the research process. These phases include a review of the literature, data collection from a pilot study, data collection from the main study, data analysis, and output compilation[1]. To establish an initial background of the existing knowledge surrounding the topic, a critical review of the literature was the first step [37]. By analyzing the literature, it was possible to determine which research questions could be answered and which ones needed to be further investigated. The existing body of recorded work produced by researchers and scholars can be identified and synthesized using a systematic and repeatable method called a literature review[10].

3.2 Research Design Method

We used qualitative research techniques, such as system observation, questionnaires, and journal reading, in this study. The objective was to examine the current system to identify any gaps that could be filled with new technology to make it better[18].

3.2.1.1. Research Site

We concentrated on the hospitals with the appropriate ECG machine for cardiovascular monitoring, during the research study, which was conducted within six hospitals in Rwanda. The research project emphasized on the challenges in which these hospitals are faced and how the ECG is used in these hospitals. For the better achievement of study, there is an need of conducting surveys with a clear focus based on the study's goal [38].

3.2.1.2. Target population

According to Prasad. Et al 2014, The target population for non-invasive smart device was conducted to know their life from the cardiovascular system especially in Rwanda[33]. The target population of this study was the healthcare providers who work in cardiology department in hospitals. A total number of eleven (11) respondents participated in the study.

3.2.1.3. Data collection procedure

Qualitative research methods were applied to the data collection process. People who work for the cardiology service filled out the multiple-choice questionnaires. To make sure that the research goal was achieved.

3.2.1.4. Data analysis

To gauge the respondents' understanding of ECG machines and their practices for using them to monitor heart patients, nine different questions were set. It was possible to select Yes or No as your response to each question. It became clear from the questions we posed from fifth to ninth questions that this essential system could aid in resolving the issues that currently exist. All of the respondents to the questions we posed indicated that the system would be a real help to them in their day-to-day tasks and that it would also provide solutions for the issues that patients who previously visited the doctor's office faced. In the table that follows, the percentage of responses that were answered is displayed.[39]

Table 2:3.1 Asked and percentage of respondents

Q1. Do you work in a cardiology service	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	90.9	10	90.9	90.9
	No	9.1	1	9.1	100
	Total	100	11	100	
Q2. You have been employed here for over two years	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	81.8	9	81.8	81.8
	No	18.2	2	18.2	100
	Total	100	11	100	
Q3. Are you utilizing an ECG device	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	72.7	8	72.7	72.7
	No	27.3	3	27.3	100
	Total	100	11	100	
Q4. Are the ECG readings able to be saved in your system?	Response	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	9.1	1	9.1	9.1
	No	90.9	10	90.9	100
	Total	100	11	100	
Q5. Do you have a system a doctor can use to examine heart parameters without the patient present?	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	No	100	11	100	100
	Yes	0	0	0	0
Q6. Can a patient take their own heart measurements and send them to the doctor?	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	No	100	11	100	100
Q7. Can you assist the patient with everyday tasks if they have a portable ECG machine and can assess their heart parameters at home?	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	100	11	100	100
Q8. Can someone create a system for you that would enable you obtain patient data?	Responses	Percent	Frequency		
	Yes	100	11	100	100
Q9. Is there a method to advise the patient of the results without having them visit the doctor?	Responses	Percent	Frequency	Valid Percent	Cumulative Percent
	Yes	18.2	2	18.2	18.2
	No	81.8	9	81.8	100
	Total	100	11	100	

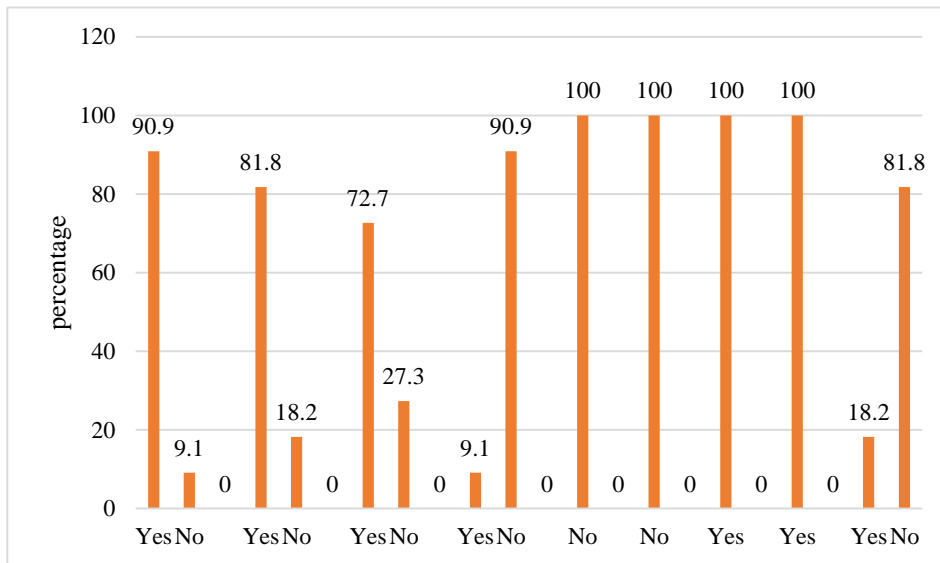


Figure 3:3.1 Histogram of respondents

3.2.2. System Development

The software development life cycle is a prototyping model with a system development method in the context of research methodology. The study built a prototype, tested, and revised until a final, acceptable prototype is attained from which the full system can now be developed [22].The System Development Method used includes the following steps.

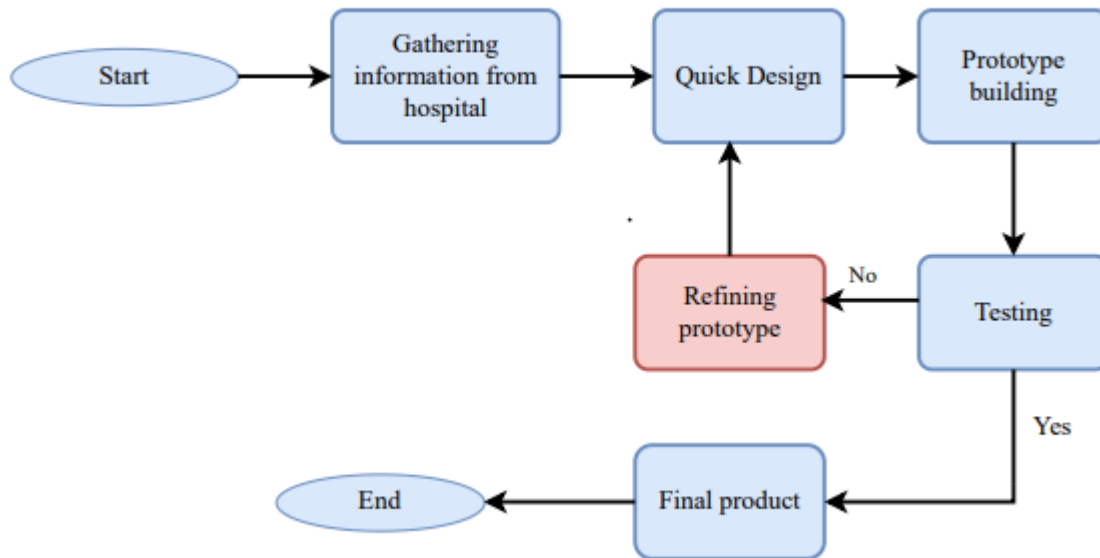


Figure 4:3.2 System development steps

We used the first two blocks of the diagram, information gathering and building prototype for our research. In order to start the process of gathering information, we first went to some hospitals, including King Faisal and CHUK, to investigate the existing system how is working. We observed how they record data and measure human heart activity in order to comprehend the current method of cardiovascular monitoring[40]. Additionally, we read through a number of documents, particularly those that discuss cardiovascular monitoring. We used IoT technology to design a prototype after learning about the specifications for designing a smart device. We used a system with three main components in the prototype such as sensor, an amplifier, and a processing component (Microcontroller)[10].

3.2.3. Structure of research design

The distinct elements that make up the design of the research process for this project are described in this section. The components are a database, a web application and API, an Android mobile application, and an ECG AD 8232 with EPS 8266 device. The methodology choices for each component of the research design are shown in the figure bellow. These choices will be explained and supported in the sections that follow[7].

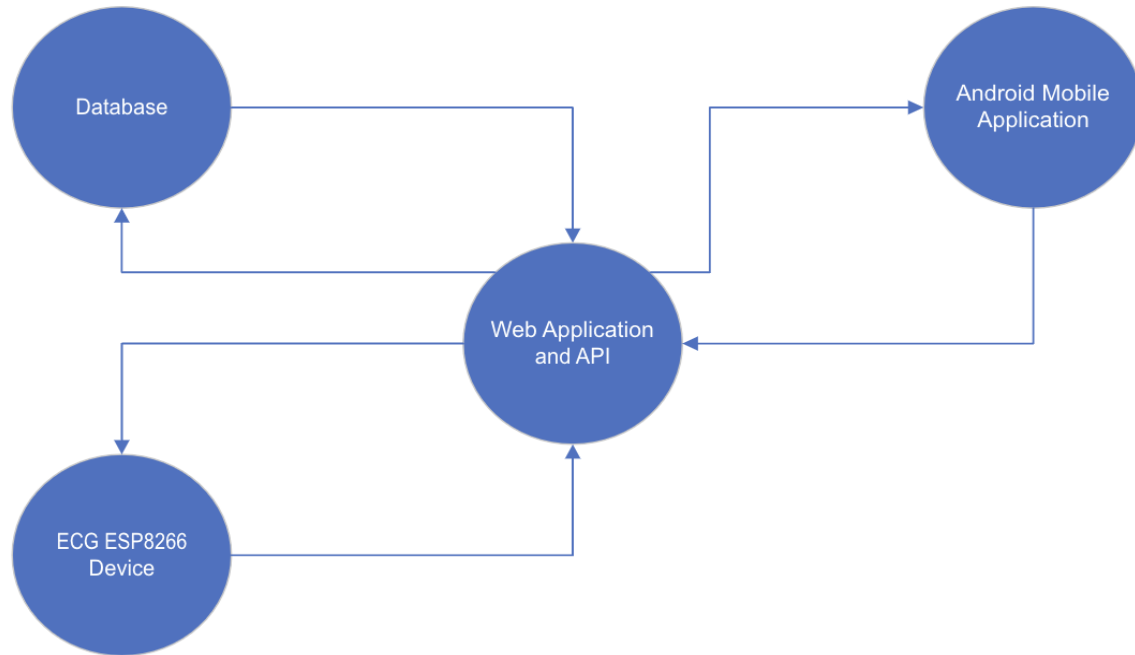


Figure 5:3.3 Structure of research design

All of the aforementioned components are interconnected and have the ability to send and receive requests using the Hyper Text Transfer Protocol. Requests can be made in a variety of ways, including GET, POST, PUT or PATCH, and DELETE.

All of the requests are in various case scenarios for standardization, as follows:

GET Request

1. A GET Request is used to fetch data from a database, Data are transferred using a universal source locator (URL), and Data are exposed as a result of being a part of the URL[13].
2. Only a small amount of data can be sent in a GET request because header data is sent instead.
3. Data in because it is more effective. The URL bar makes the GET request insecure.
4. GET request is bookmarkable.
5. The GET command has no duplicates. It indicates that a second
6. Request won't be taken into account until the first one has been answered.
7. More people use GET request than POST[31].

POST Request

1. Since the data is sent in the body of the POST request, large amounts of data can be sent.
2. Data is not displayed in the URL bar, making the post request secure.
3. You cannot bookmark a POST request.[10]
4. POST requests are not irreversible.

5. Less frequently used than get, POST requests are less effective.

PUT and DELETE were used in this system primarily to update or remove items from the database.

3.2.3.1. Web application

A web application is a website that is dynamic and whose content can be altered. The primary function of this system is to collect patient ECG data so that a specialist can view it.

This web application was created using the Laravel framework and the PHP programming language. We chose Laravel because it is the most well-liked and secure PHP framework. Model-View-Controller Structure (MVC) is used[12].

Model: A component of the MVC framework that communicates with the database

View: A MVC component routes and templates. The pages of the user interface are templates.

Controllers: Consists of the class that contains the methods to execute logic operations and communicate with the model to add or retrieve data from a database[19].

3.2.3.2. ECG Device

It is an Internet of Things (IoT) device that uses the internet to send patient ECG data to a database. The ESP8266 NodeMCU development board was used to construct this device. NodeMCU can establish a WiFi connection. The device or parts used for this device are as follows[12][41]:

1. **The NodeMCU** has wireless connectivity and can access the internet using wireless. It functions best in IoT applications [29].
2. **AD8232 Amplifier:** This part amplifies the signal from the electrodes and feeds it to the NodeMCU[41][42].
3. **Electrodes:** are attached on the body to extract electrical activity of the heart[26].

Arduino IDE (Integrated Development Environment) is used to program the ESP8266[39]. It is necessary to include the ESP8266 board because it comes with default libraries that let us access various chip modules, including the WIFI module. The ESP8266's WIFI module is a crucial component of our project because it's the method by which we insert data into our database. When inserting data into a database, the device makes a GET request. You cannot retrieve your code once it has been uploaded inside the microcontroller. The amplifier on this development board is powered by 3 Volts[43].

3.2.3.3. Mobile application

Patients can view their ECG data on mobile applications, which also makes the data available to the treating doctor. It was created in native React. React Native is a framework created and maintained by Facebook-owned META, which enables developers to create mobile applications using web development languages. During the creation of this application, the JavaScript is converted into Java code [11].

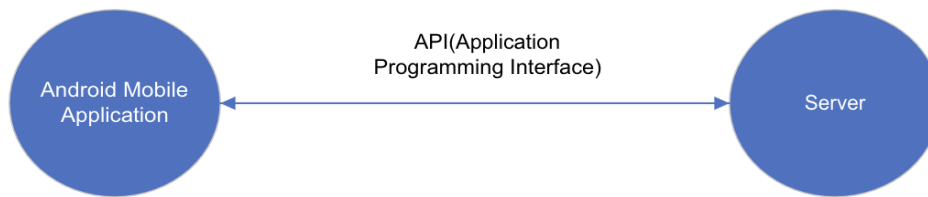


Figure 6:3.4 Mobile application interacts with database

3.2.3.4. Database

Data from patients and doctors are stored in databases. This system uses a relational database called MYSQL, which is SQL-based and has tables that are connected to one another. Data are stored in tables, which contain related data. For instance, a patient table contains information about patients such as names, ages, phone numbers, and emails. Due to the fact that each patient has a specific doctor assigned to them, the ECG table is related to the patient table, and the patient table is related to the doctor table.

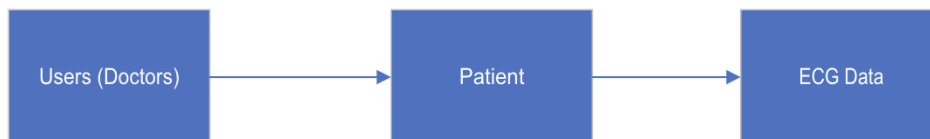


Figure 7:3.5 Relationship between tables in database

3.2.4. System structure

Figure displays the proposed system's block diagram. The Arduino board is connected to the electrode sensors and the AD8232 ECG (NodeMCU 8266). Utilizing Wi-Fi connectivity, the Web Server receives the values from the Microcontroller. The application that is installed on doctors' and patients' smart phones/Pcs can display the heart parameter values.

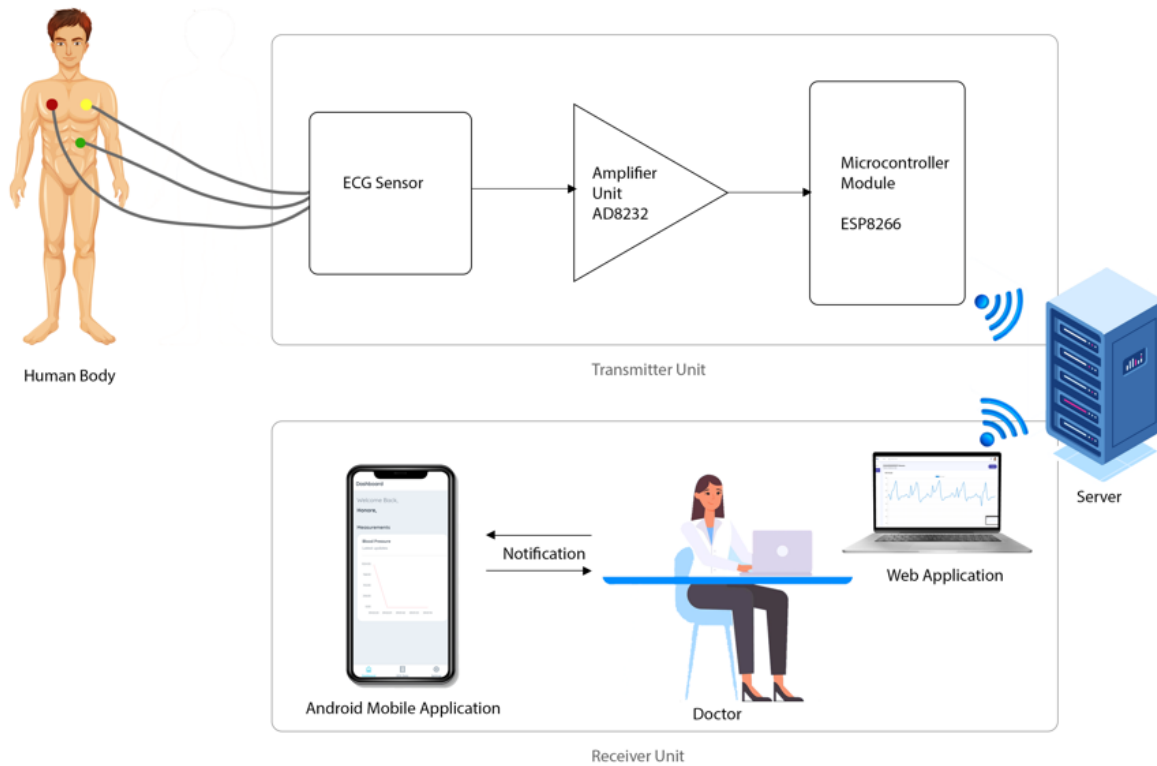


Figure 8:3.6 proposed system

3.2.5. Flowcharts Design of the proposed system

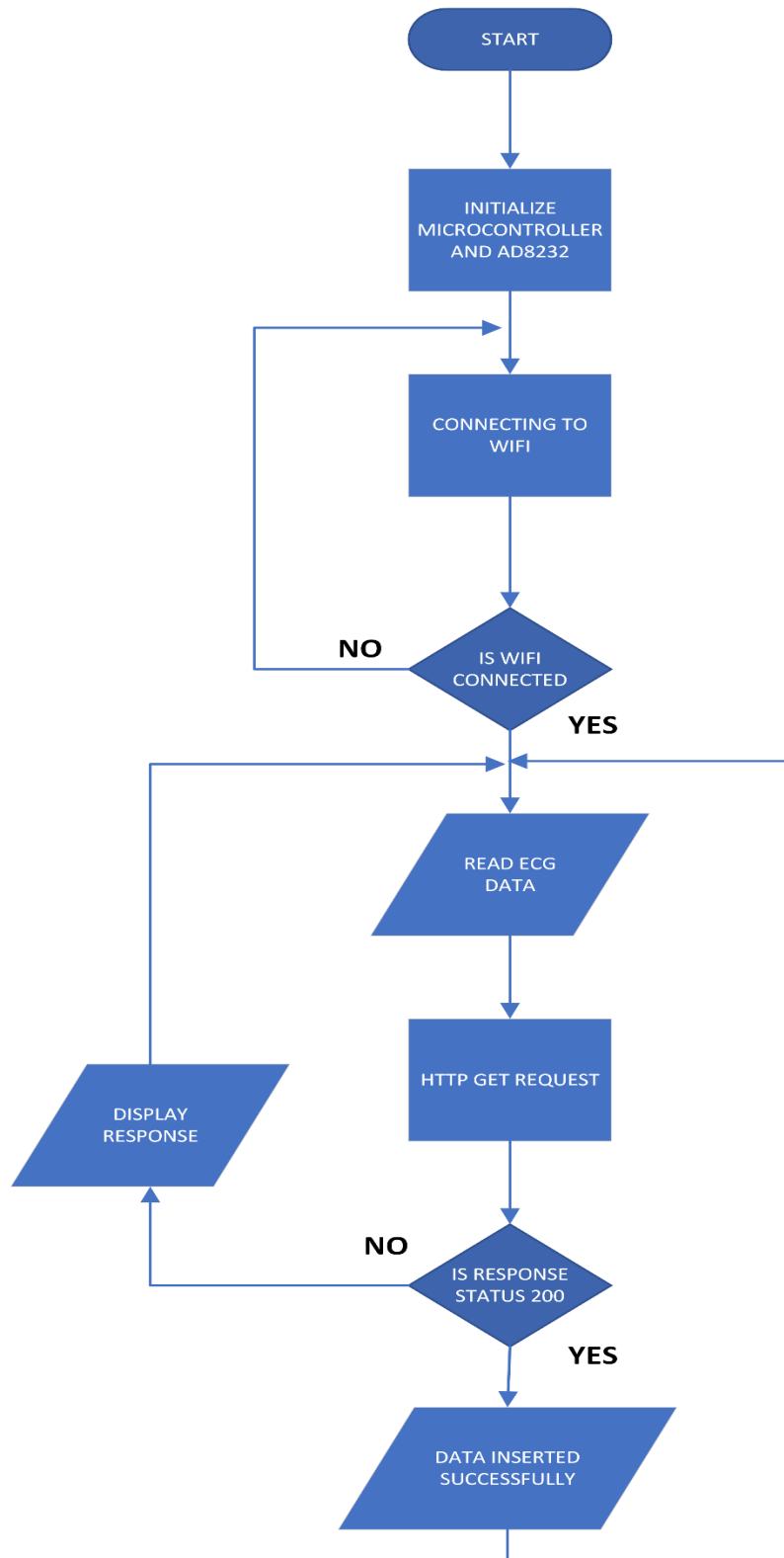


Figure 9:3.7 Flowchart of the system

3.2.6. Physical components

The design of the suggested system is based on the two units in the below-mentioned Figure namely transmitter and receiver unit.

Transmitter unit is composed by An ECG sensor for detecting electrical heart activity, an AD8232 module for extracting, amplifying, and filtering signals, and a NodeMCU ESP 8266 for data processing. Another component of the received unit is a mobile application for receiving an ECG waveform of heart activity. The patient can choose whether or not to grant the doctor access through the mobile application. And web application to gather patient ECG information for a specialist to view.

3.2.6.1. Hardware Design

3.2.6.1.1. Transmitter unit

The components that can be used for this project are listed below in the table. All the components are easily available for purchase from Rwanda market.

Table 3:3.2 Requirement components

S/ N	Components Name	Description
1	NodeMCU	ESP 8266
2	ECG Sensor	AD8232 ECG Sensor Kit
3	USB Adapter	5V Volt USB Adapter
4	Breadboard	-
5	LCD	Display

A. Sensor

Sensor is Measurement device for the body's electric signal. Traditional wet electrodes are used in this system to extract the electric signal [44].And conductive gel is used to lower skin resistance

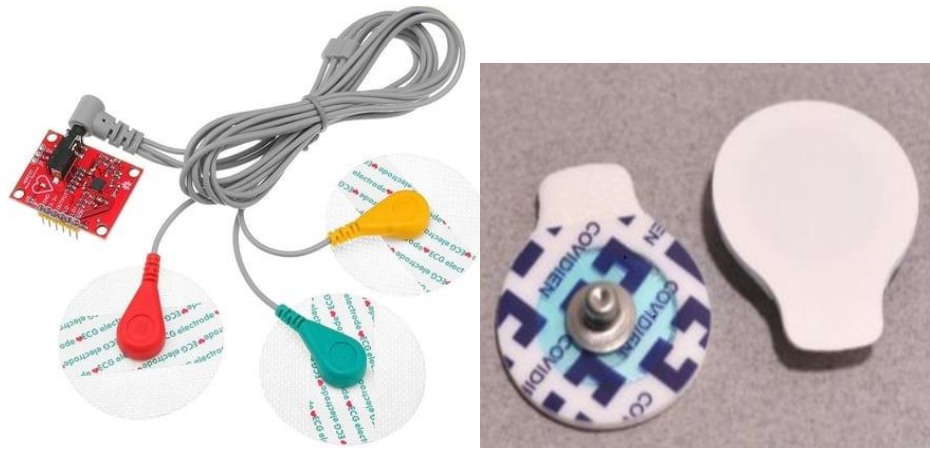


Figure 10:3.8 Sensor and Sensor pads

Typically silver, and a salt metal are used as the electrodes for recording bio-potentials. Along with this, an electrode jelly of some sort is positioned between the electrodes and the skin [45].

B. AD8232 ECG

The sensor panel used to detect the electrical activity of the heart; its price is very low cost. An electrocardiogram (ECG) is used to produce an analog reading. The AD8232 is used as an op-amp to extract, amplify and filter the small signal, this causes to obtain a clear signal from the PR and QT Intervals with ease. ECGs can be very noisy [8] [46].

There are Important pins for this development board used to be connected on NodeMCU pins include SDN, LO+, LO-, OUTPUT, 3.3V, and GND. This board also includes RA (Right Arm) with Red color, LA (Left Arm) with yellow color, and LL (Left Leg) or around Left rib with green color, pins for attaching and utilizing custom sensors [47] [48].

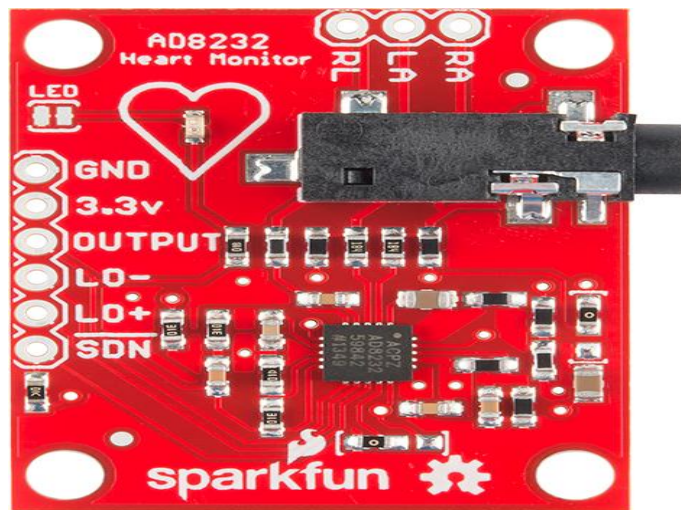


Figure 11:3.9 AD8232 Amplifier board

C. Microcontroller

A microcontroller is a small integrated circuit that controls a single process in an embedded system [22]. Espressif Systems in Shanghai created a microchip WiFi device with IP networking software that uses less power and operates at a respectable speed. Microcontroller is integrated into a system. It performs its task by utilizing its central processor to interpret data that it receives from its I/O peripherals.

This study ESP8266 WiFi module has been used to send the data to Internet of Things device server [49].

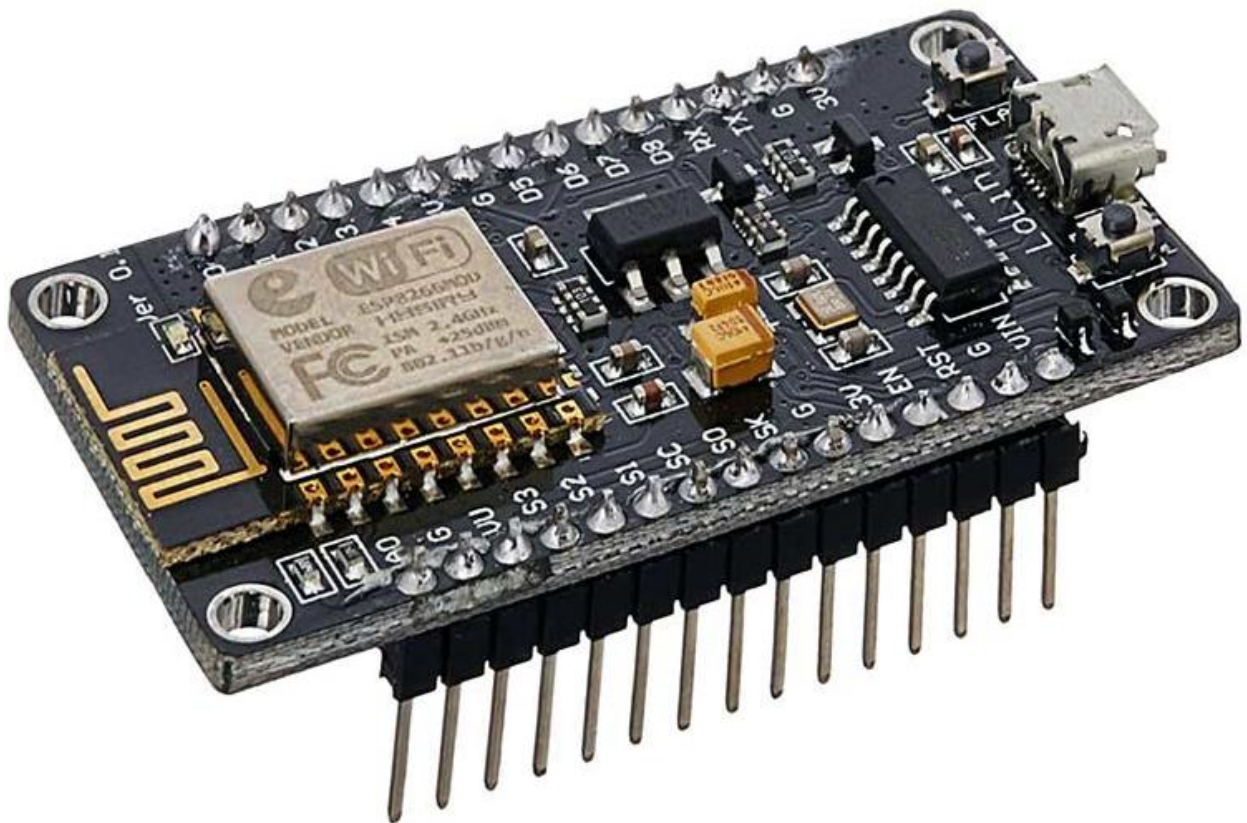


Figure 12:3.10 ESP8266 NodeMCU

Table 4:3.3 Specification of NODEMCU

Specifications	
Microcontroller	32-bit ESP 8266
Operating voltage	3.3V
In put voltage	7-12V
Digital I/O pins	16
Analog In put pins	1
UARTs	1
Memory	4M
PCB antenna	1

D.LCD Display

A type of flat panel display,performs primarily task using liquid crystals. compared to cathode ray tube (CRT) technology, made displays much thinner [51].

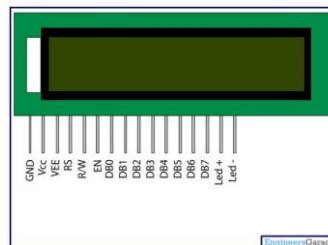


Figure 13:3.11 LCD Display

3.2.6.1.2. Receiver unit

A. Android Phone application

The benefit of this mobile phone system is the ability to receive an ECG waveform of heart activity. Installing the ECG app and having an internet connection on the phone are necessary[52]. Therefore, the patient will use this phone to give the doctor access to his information.

B. Web application

A web application is a website that is dynamic and whose content can be altered. The primary function of this system is to collect patient ECG data so that a specialist can view it.

This web application was created using the Laravel framework and the PHP programming language. We chose Laravel because it is the most well-liked and secure PHP framework. Model-View-Controller Structure (MVC) is used [53].

3.2.6.2. Software unit

Java-based platform independent application known as the Integrated Development Environment (IDE). The IDE for the languages Wiring and Processing served as its foundation. Its codes program uploaded to an Arduino board [5].

This part was chosen to perform all the operations. First of all, first, a Microcontroller program was placed in the transmitter, for processing data and calculation of heart rate. Secondly in receiver side was programed by using JavaScript to receive, and extract the data [43].

3.2.6.2. Codification for the transmitter and Receiver unit

Electrodes are used by the system to find electrical signals produced by the heart. The AD8232 Amplifier amplifies the signal coming from the electrodes, increasing its energy and amplitude. The AD8232 is a front-end integrated circuit for single-lead heart rate monitors [21]. The LO+ and LO- pins of the AD8232 produce a high output if the electrodes are not connected, which is received at GPIOs 14 and 12 on the ESP8266 NodeMCU. The system's primary microcontroller, the ESP8266 NodeMCU, is a low-cost Wi-Fi microcontroller that can be used to control a variety of gadgets, including sensors and actuators. After signal amplification, the amplifier's output is fed to the ESP8266's A0 (analog pin)[40]. The ESP8266 must connect to Wi-Fi upon boot; it is preprogrammed with the SSID and password for this purpose. Once connected, it begins inserting received data on A0 into the MySQL database using an API (Application Programming Interface). On the backend of a web application, the API is constructed. Each piece of information in the database is categorized according to a particular patient, so each piece of information relates to a particular patient. Once a patient has given permission, a doctor can access information[9]. The doctor can see the ECG signal to the web application. Through a React Native-built mobile application, the patient can access his most recent data. The ESP8266 stops inserting data when the electrodes are taken out of the human body [37].

3.2.7. Design and developed of the prototype system

3.2.7.1. Targeting several crucial features of Design are:

- Miniaturization
- user-friendly
- little power usage
- Low cost
- Wireless communication

3.2.7.2. Circuit diagram of the proposed system

The electronic circuit for a non-invasive smart device to check the cardiovascular health of people is shown in the diagram below and we have been designed it by using fritzing software that allows us to create electronic circuits and diagrams[12].

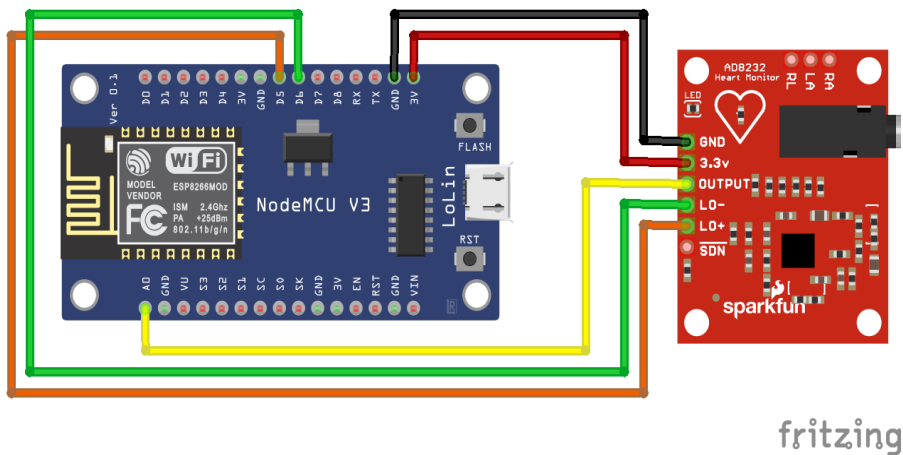


Figure 14:3.12 Circuit diagram

3.2.7.2.1. Circuit connections

A six-pin header on the AD8232 ECG sensor allows it to connect to an ESP 8266 module. These pins are 3.3V supply, GND, Output, LO+, LO-, and SDN. Additionally, the AD8232 ECG has three electrode/sensor breakout connections for the Right Arm (RA), Left Arm (LA), and Left Leg (LL) or around the left ribs

The ESP 8266 board provides power to the AD8232 ECG Module. Connect as follows in order to do so correctly [54]:

1. The 3.3V and GND pins of the AD8232 connect to the 3V3 supply and the ground of the NodeMCU, respectively.
2. Analog signals are output from the AD8232 and connected to the NodeMCU's A0 pin.

3. The pins 10 and 11 of the NodeMCU are connected to the LO+ and LO- of the AD8232 ECG module, respectively [43].

Electrode pads are attached to the subject's body and plugged into the sensor cable to measure the ECG.

3.2.7.2.2. ECG leads positioning

The sensor leads must be positioned properly to ensure an accurate ECG reading. The three leads on the three-lead ECG cable are colored red, green, and yellow.

The electrode red color positioned on the right shoulder of subject [55], on the left shoulder of subject is yellow electrode. Then the green electrode positioned on around the left rib, or left leg of the subject, all electrode must be positioned close to the heart for the best results.

Five of the board's nine pins will be attached to Arduino. GND, 3.3v, OUTPUT, LO-, LO+ and GND, 3.3V, Ao, 11, 10 respectively [56].

3.2.7.2.3: System operations

1. Doctor side

Users must register with a doctor in order to use this system. The patient will provide to the doctor all address such as name, telephone number, province, district, sector, cell and village.

a) The patient will now bring the device to the doctor, who will then provide the device with the code and the password to the patient (email and telephone number for user name and password) [10].

b) Utilizing the person profile, the doctor could view the person's data and notify [56].

2. Patient side

a) Initialize Microcontroller and AD 8232 by using adaptor of 3.3V

b) Connecting WiFi of smart device by sharing the patient's smart phone's network

C) Place electrodes on the chest, do it quietly [57]: close to heart [39].

d) Using the password provided during registration with the doctor (email and phone number for user name and password, respectively), the patient accesses the ECG application that was downloaded to his or her smartphone [7].

e) The patient clicks on his phone's data visibility setting to allow the doctor to view his data.

3.2.7.2.4. Technical specifications of ECG smart device

- Operating voltage:2.5- 3.3V DC
- In put voltage limits:3-7v
- Less power: 170 uA
- Size of design: 9cm-7,7cm
- Operational temperature: from -40°C to +85°C
- Memory:64KB
- Measurement range:40-160bpm

3.3. Limitation

There were other limitations that had an impact on the initial anticipated results of this research; for instance, because we lacked research funding, we were unable to purchase precise equipment. Another incident where the IRB status was not communicated to the hospital in time for it to collect the data.

3.4. Summary

This chapter provide the materials and techniques used to collect and analyze the necessary data to address the research questions posed by this investigation were thoroughly explained in this chapter. Several research techniques were employed, including literature reviews and questionnaires. It also demonstrates where research conducted, the questions asked, and the beneficiaries of this study.

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Introduction

This section describes the system's testing and implementation. The main goal of the testing was to determine whether the system's performance in relation to the study's objectives satisfied user needs and requirements [28].

4.2. Procedure for testing the System

The experiments and tests conducted were used to establish thresholds for the initial system analysis and validate the system. Two experiments were conducted to confirm that the system is working properly [30]:

- Amplification circuit was used to detect and amplify the bio potential signal. In order to obtain a precise heart activity measurement, peak detection was next carried out.
- Calculating the heart rate variability involved using the tuned signal.

4.3. Experimentation outcomes

The subjects were used in two different sets of experiments. In the beginning, electrodes were applied to their bodies, and the amplifier circuit was connected to the electrode output. The subjects' ECG wave forms were then processed and displayed. Second, it was observed that the heart rate variability was measured [26][5].

Heart rate can vary and is only abnormal if it is greater than or less than 100 and 60 beats per minute (bpm) respectively. The subject being tested with a handle ECG Smart device is depicted in the figures below [25].

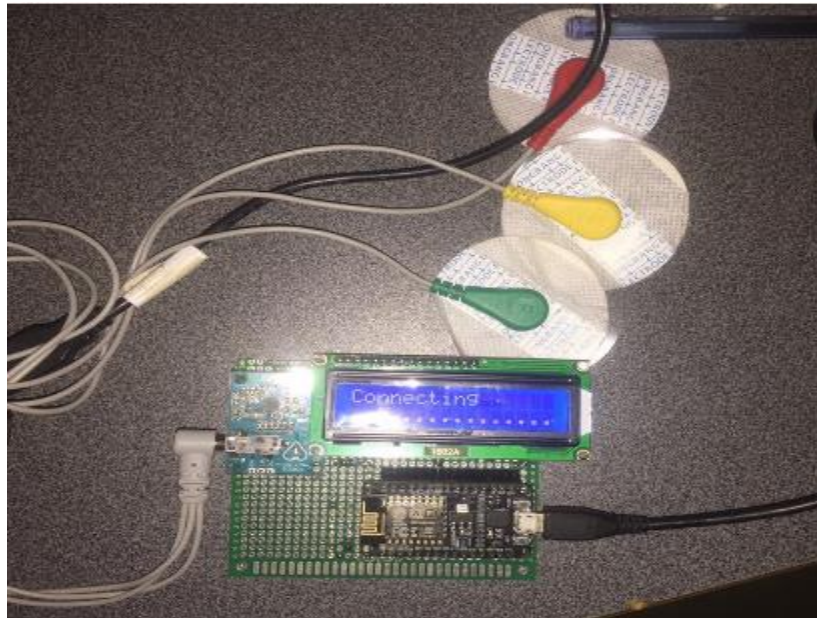
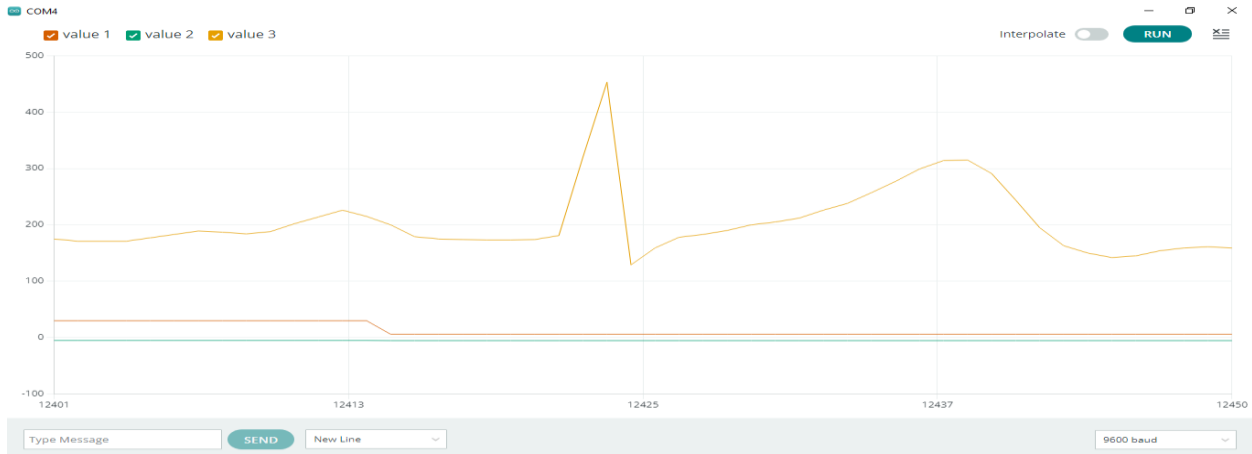


Figure 15:4.1 Experimental set up on sender side



Figure 16:4.2 Waveform on Digital Oscilloscope

In this case on the figure above, three electrodes are positioned as follows: the 1st is on right shoulder, 2nd is on the left shoulder, and the third on the ground of left ribs. The AD8232 output is displayed on Digital Oscilloscope as the figure above.



4.17. ECG waveform from serial plotter

Based on the figure above, the output is analog, the output of AD8232 is connect to the ESP 8266 for processing into digital form. Then the waveform displayed on the serial plotter.

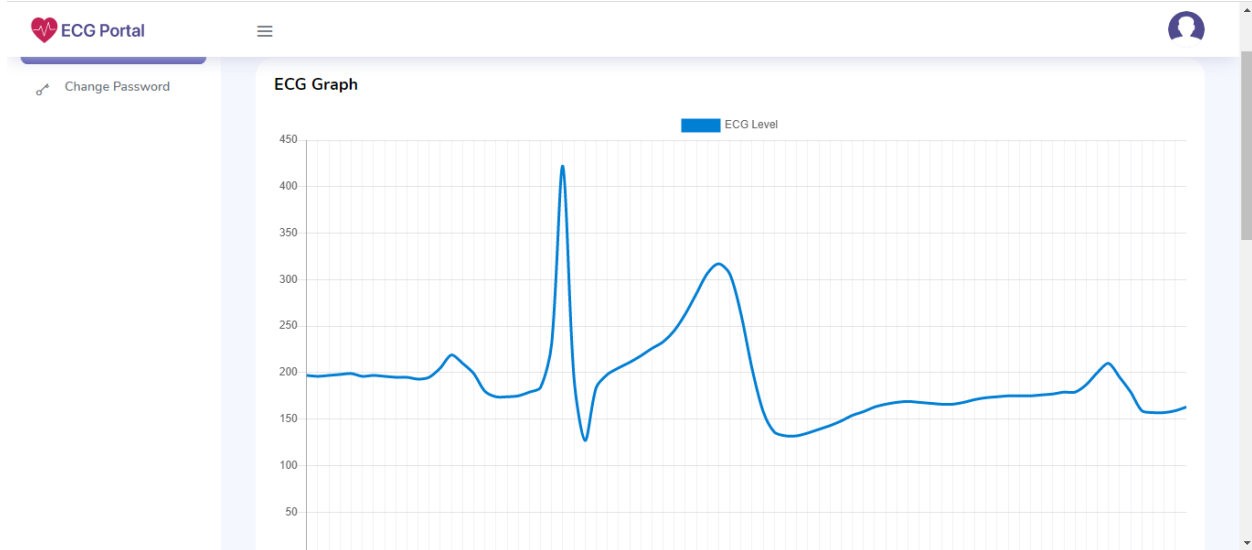


Figure 17:4.3 .ECG Waveform on web application platform

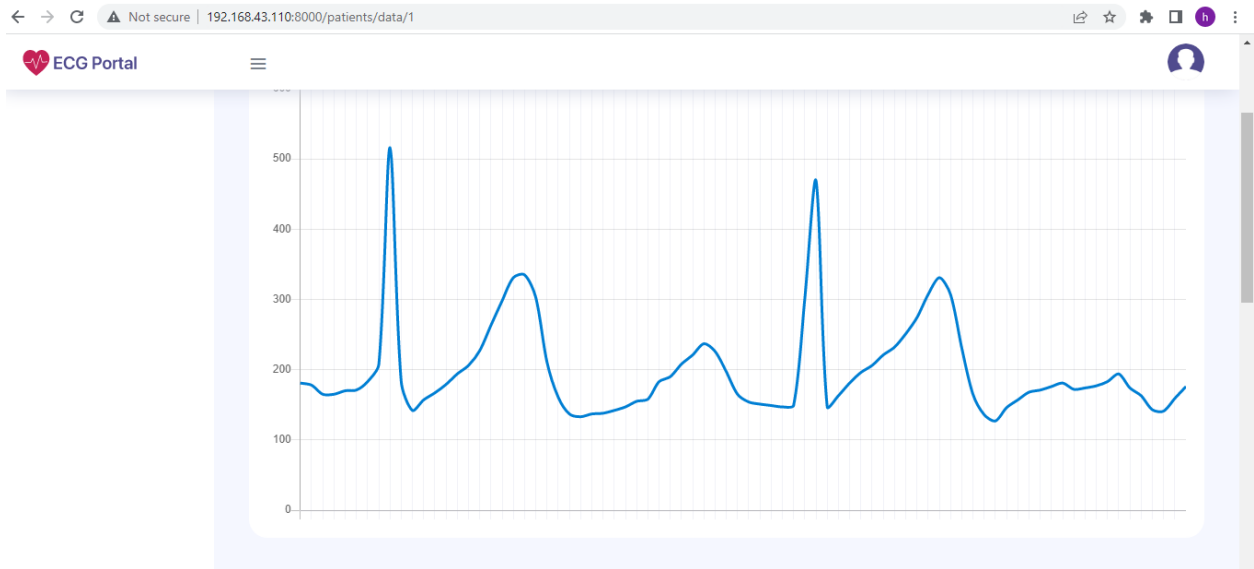


Figure 18:4.4 ECG waveform from Local web server

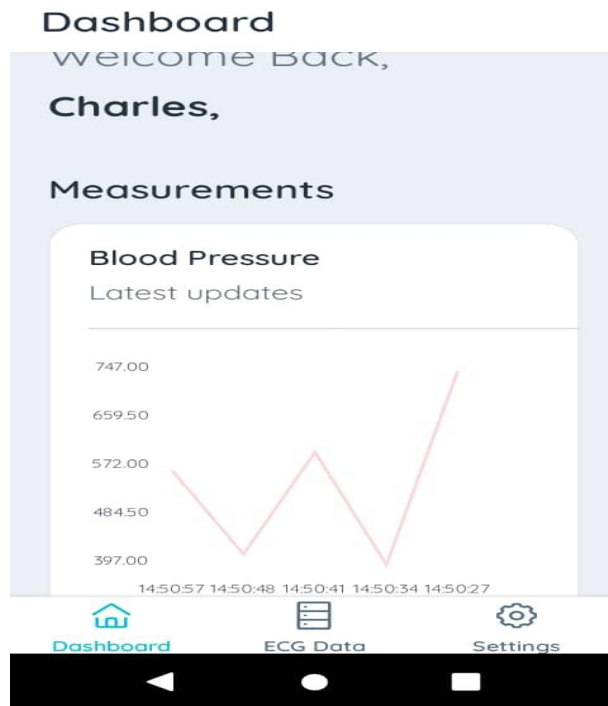


Figure 19:4.5 Android phone application

The screenshot displays the 'Manage Patients' section of the ECG Portal. The interface includes a sidebar with navigation options: 'Dashboard', 'Patients' (which is highlighted), and 'Change Password'. The main content area features a title 'Manage Patients' and a sub-header 'Total Patients: 4'. A '+ Add Patient' button is positioned in the top right corner. Below the header, there is a search bar and a dropdown menu set to 'Show 10 entries'. The central part of the page contains a table with the following data:

#	Names	Email	Phone Number	Location	Actions
1	Honore IMANISHIMWE	imanishimwehono@gmail.com	250780850976	Nyamagabe-Kigali	Action
2	Innocent HIRWA	innocent45@gmail.com	25078000000	Nyamagabe-Kigali	Action
3	Charles HABİYAREMYE	hacharles3@gmail.com	250788699565	Gasabo-Kigali	Action
4	RUSHINGABIGWI Gerard	g.rushingabigwi@gmail.com	25078569187	Nyarugenge-kigali	Action

Figure 20:4.6 ECG platform with patient data.

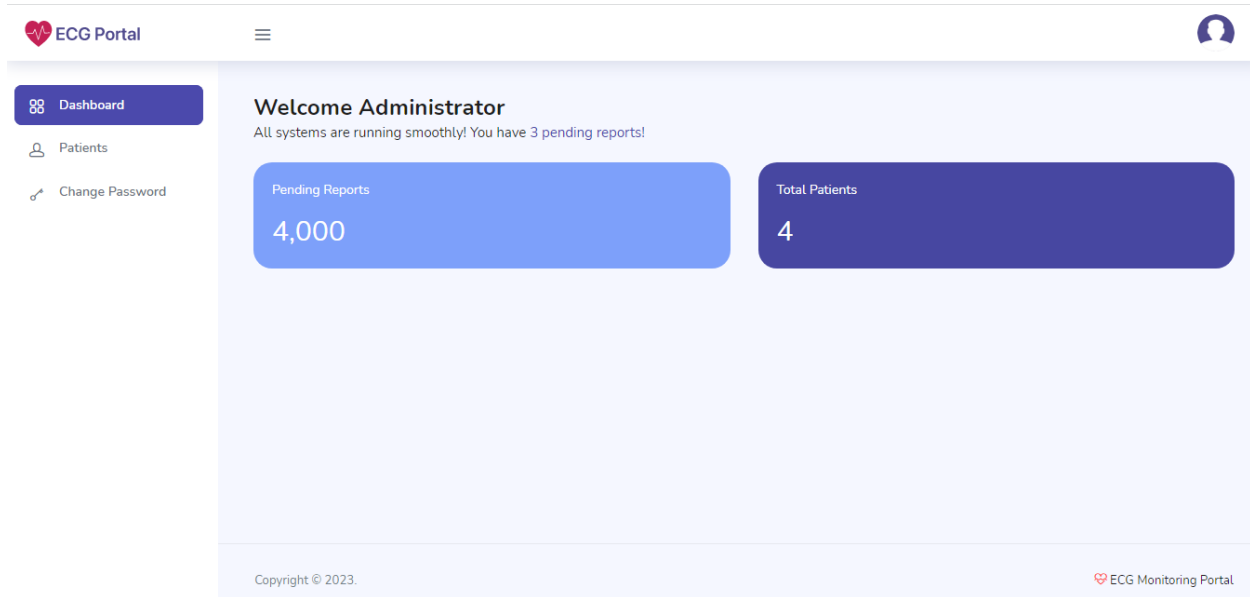


Figure 21:4.7 ECG Platform

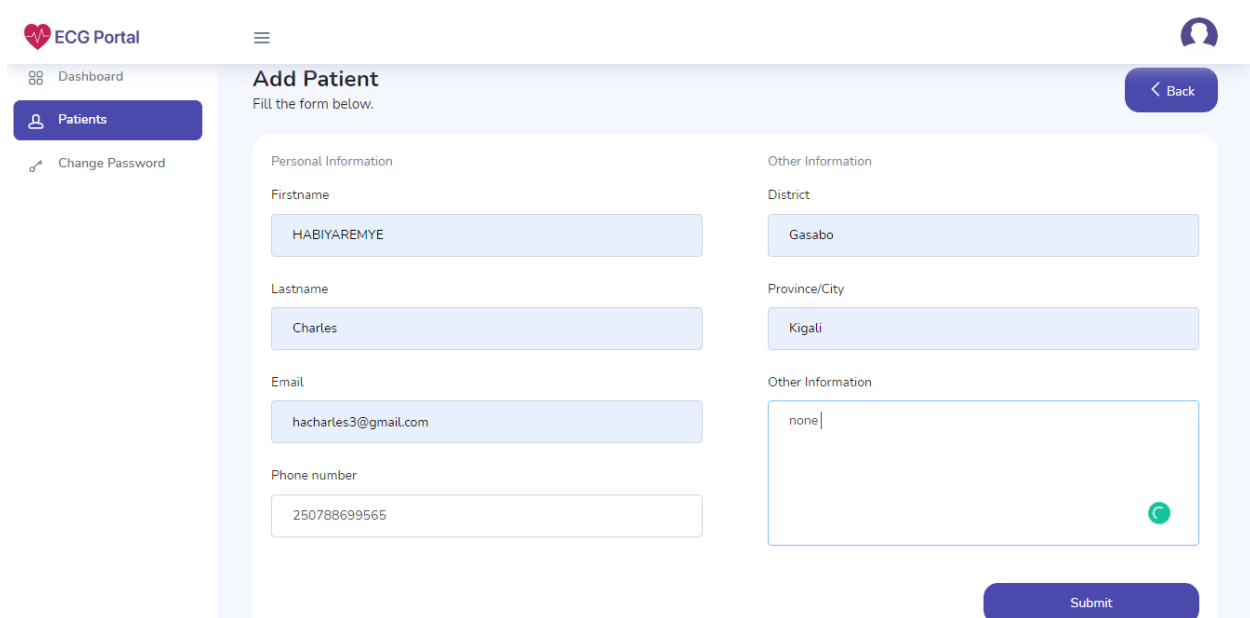


Figure 22:4.8. Patient registration platform

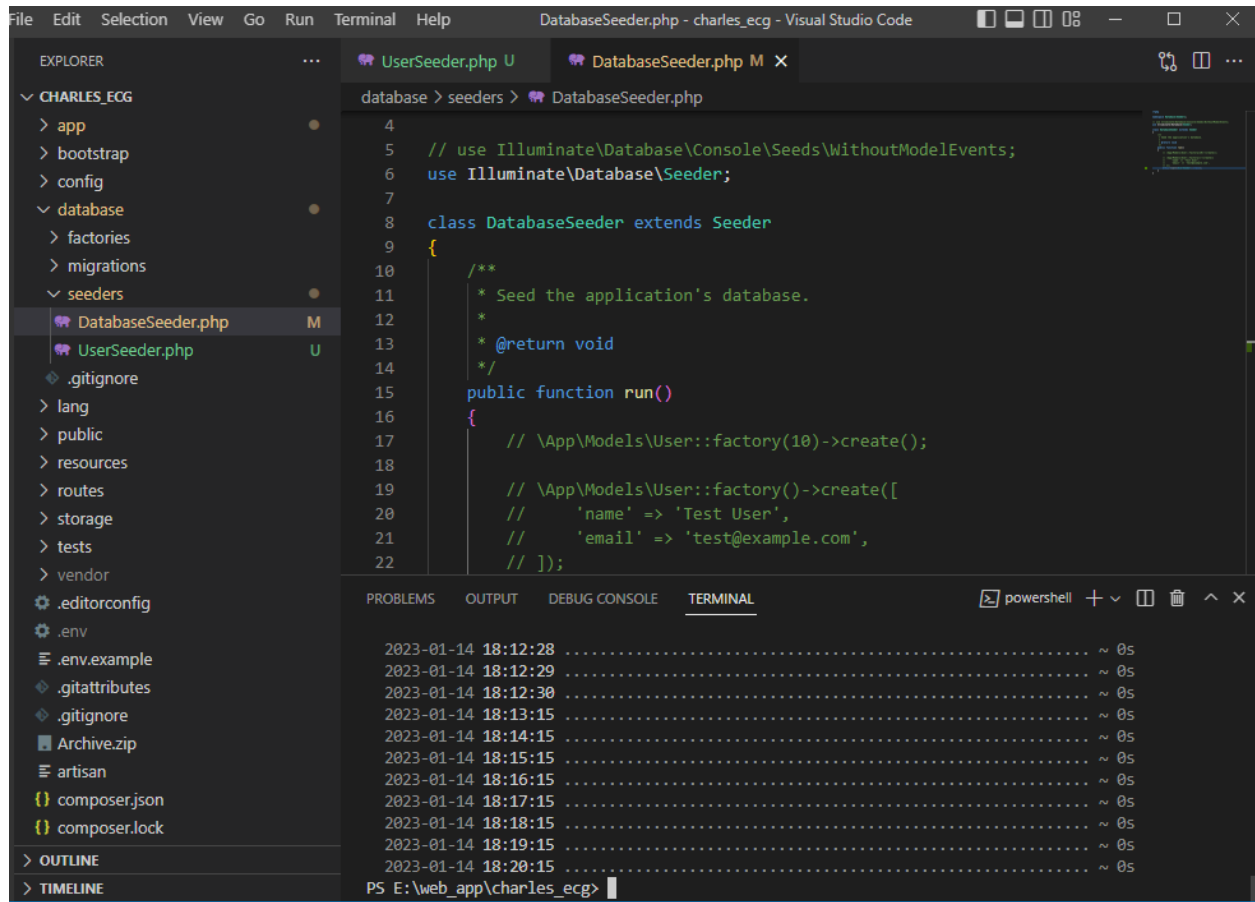


Figure 23:4.9. Code of ECG Platform

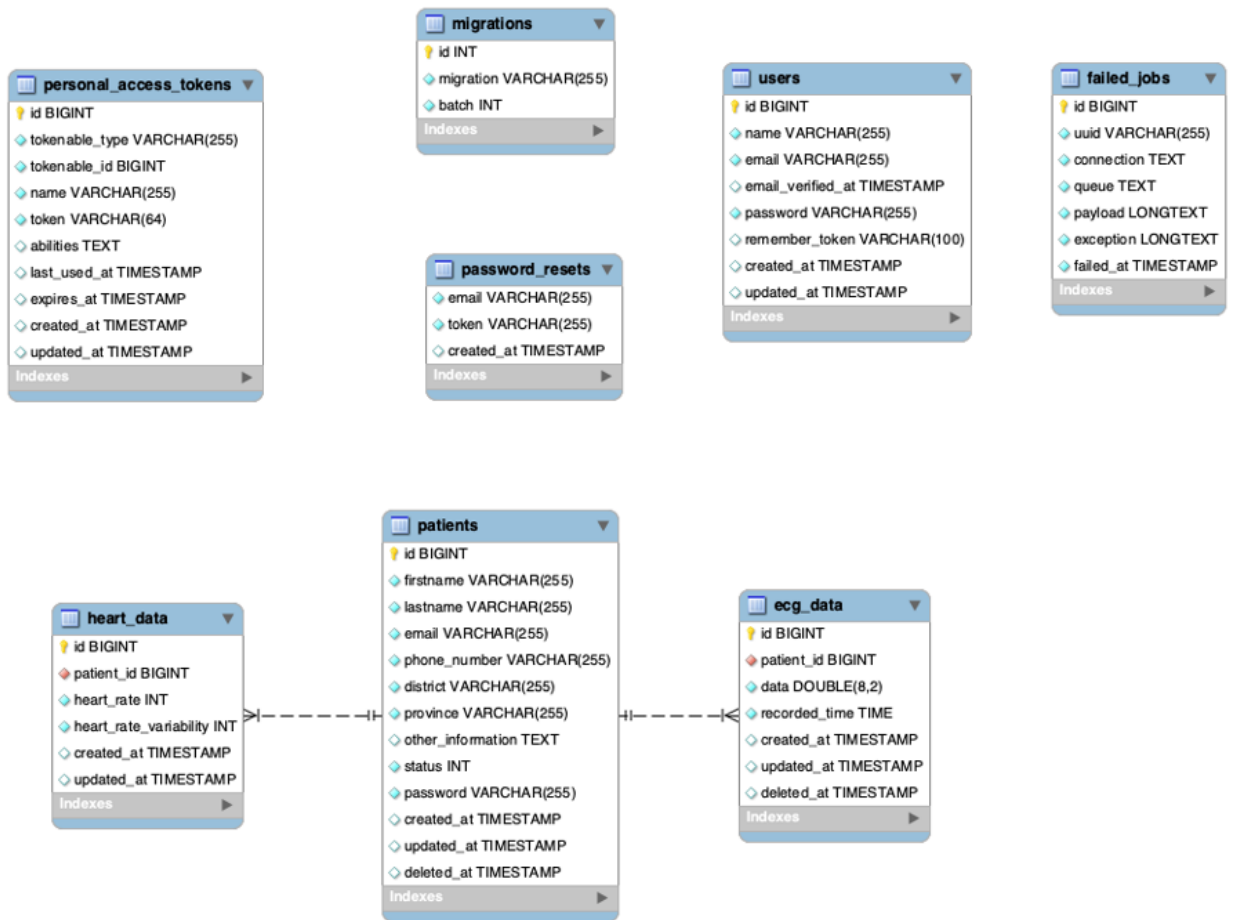


Figure 24:4.10 Relationship between Tables in database

4.3.1. Performance analysis of the proposed system

Based on the research findings, were attained by putting the proposed system's prototyping scenarios into practice, we say that the system is better than the situation as it is.

4.3.1.1. The existing system and the proposed system comparison

Table 5:4.1 Comparison between existing system and the proposed system

S/N	Existing situation on market	Proposed system
1	High cost	Low cost
2	Higher impedances and more unstable signals	Low impedance to reduce the noise produced while recording signals
3	The hand movements present a challenge on signal	Hand movement, highly effective signal
4	Uncomfortable to the wearer.	Well attached to the skin
5	More prone to mains interference and movement artifacts than sticker electrodes	Superior to dry electrode in terms of resistance to mains interference and movement artifacts

4.3.1.2. The proposed system generates a waveform comparison.

We tried to display the waveform on different platforms to see the quality of signal.

Table 6:4.2 Displayed waveform

S/N	Platform	Comments
1	Oscilloscope	Before being processed and sent to the cloud database, the signal was strong and had little noise in the waveform that was displayed.
2	Local web server	Due to the network problem some data is lost the microcontroller is not able to send, that's why we don't have a good waveform, and here computer is considered as server.
3	Serial plotter	This is done by using USB cable to transfer data to the laptop and we lost some data, that is why we don't have a good waveform as we see on the figure above due to the internet issue
4	Remote web server	Since this system is online, a lot of data is lost due to network issues, which causes the waveform to be poor, so it needs high-speed internet.

4.3.1.3. Waveform Generated by the proposed system

In the proposed ECG system, several waves are displayed, the study made attention to the space between the waves in the analysis we conducted. The interval we found are PR interval, QRS interval and QT interval, these intervals are expressed in time second.

Table 7:4.3 Normal range of wave intervals

S/N	Interval	The normal Range of Time
1	PR	(120-200) ms
2	QRS	(80-100) ms
3	QT	(460-475) ms (360-460) ms for adult men (370-470) ms for adult women

1. PR interval

PR interval may be a sign of some particular heart disease:

Longer PR interval is associated with the Heart failure and coronary artery diseases, this due to the slowing of heart conduction between atria and ventricles. This indicates a first-degree block of heart muscles. While Shortened PR interval indicates quickly heart conduction between atria and ventricles, which would cause shortness of breath.

2. QRS interval

The prolonged QRS interval is Due to delayed ventricular electrical activation, this is associated with increment of coronary disease. The small QRS interval is associated to the obesity, which can cause High blood pressure and stroke.

3. QT interval

The ventricles' depolarization and subsequent repolarization showed by the time duration of QT interval. Age and gender have an impact on QT intervals. Long QT interval causes hypertension. Short QT interval causes risk of atrial and ventricular arrhythmias. Heart may beat too slowly or too quickly. The portable ECG's output is a graph with various waves on it, each representing a different electrical or mechanical event in the heart. To find issues with the various heart activity phases, changes in these waves are used to identify heart problems.

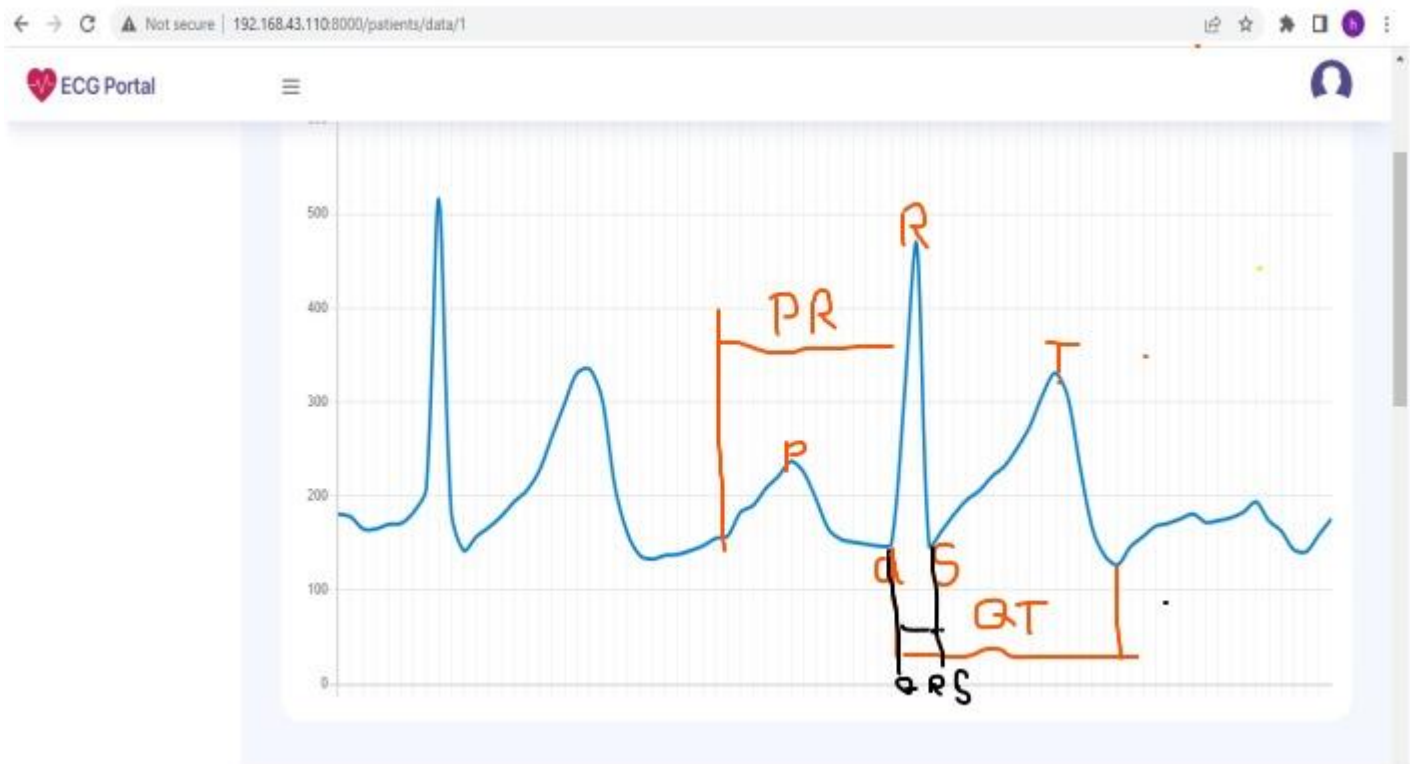


Figure 25:4.11 Waves and intervals

4.3.1.4. Sample of heart rate

The table below displays the three consecutive days average heart rates of ten patients as well as their monitored heart beat conditions.

Table 8:4.4 Sample heart rate of 10 patients.

Patient ID	Age	Heart rate				Status (60-100)
		DAY1	DAY2	DAY3	Average	
P1	28	86	72	99	85.7	healthy
P2	26	70	88	110	89.3	healthy
P3	44	68	78	60	68.7	Healthy
P4	32	71	92	80	81.0	Healthy
P5	30	90	72	84	82.0	Healthy
P6	42	68	72	75	71.7	Healthy
P7	46	95	90	92	92.3	Healthy
P8	48	120	100	110	110.0	consult doctor
P9	40	100	105	90	98.3	Healthy
P10	30	72	76	68	72.0	Healthy

4.3.1.5. Heart rate taken by using Blood pressure standard machine

This is measured using a device that has been approved by the global FDA, and then the results are compared to the performance of the sample that was created.

Table 9:4.5 Measurement of BP machine

Patient ID	Age	Heart rate				Status(60-100)
		DAY1	DAY2	DAY3	Average	
P1	28	71	60	77	69.3	healthy
P2	26	58	64	61	61.0	healthy
P3	44	66	70	54	63.3	healthy
P4	32	64	72	68	68.0	healthy
P5	30	70	63	68	67.0	healthy
P6	42	65	60	62	62.3	healthy
P7	46	82	72	77	77.0	healthy
P8	48	101	93	90	94.7	healthy
P9	40	80	90	92	87.3	healthy
P10	30	65	68	65	66.0	healthy

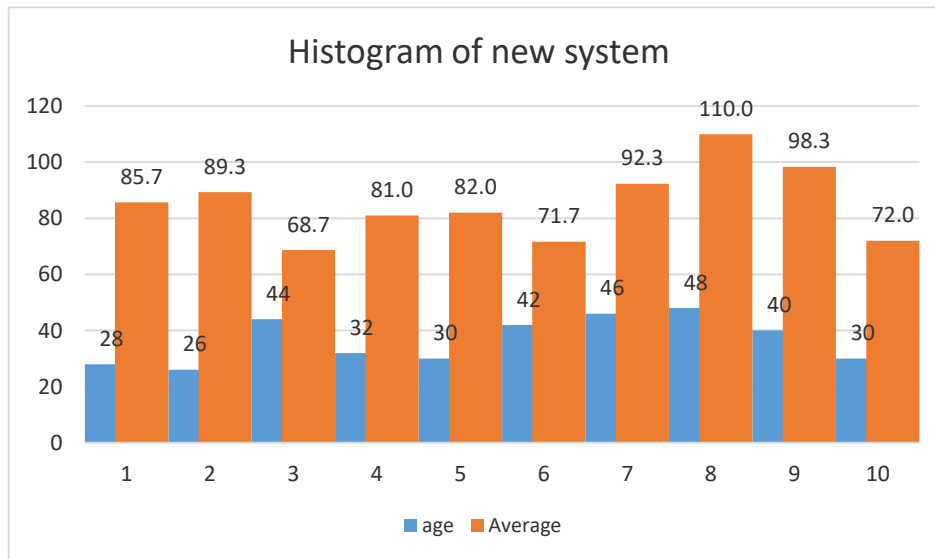


Figure 26: 4.12 Histogram of New system:

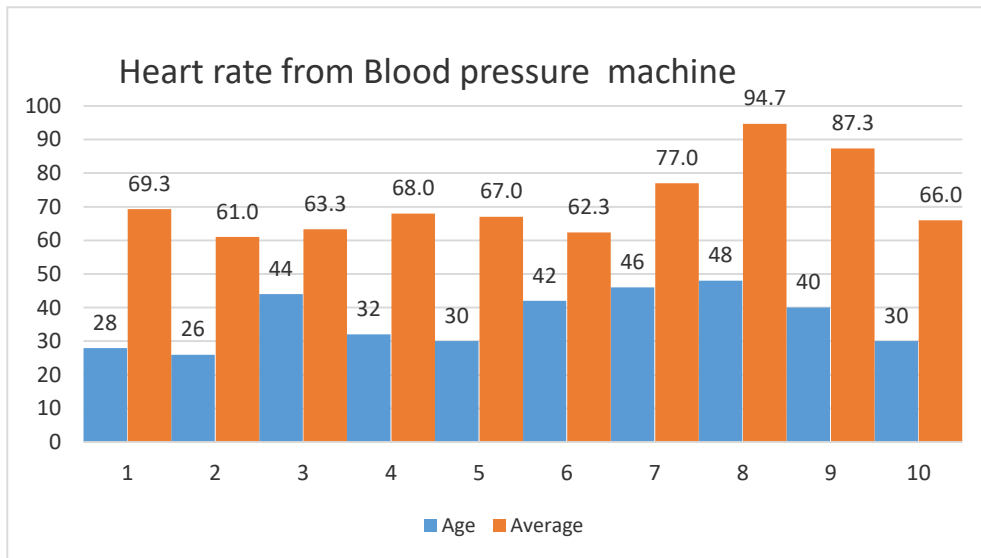


Figure 27:4.13 Histogram of BPMachine

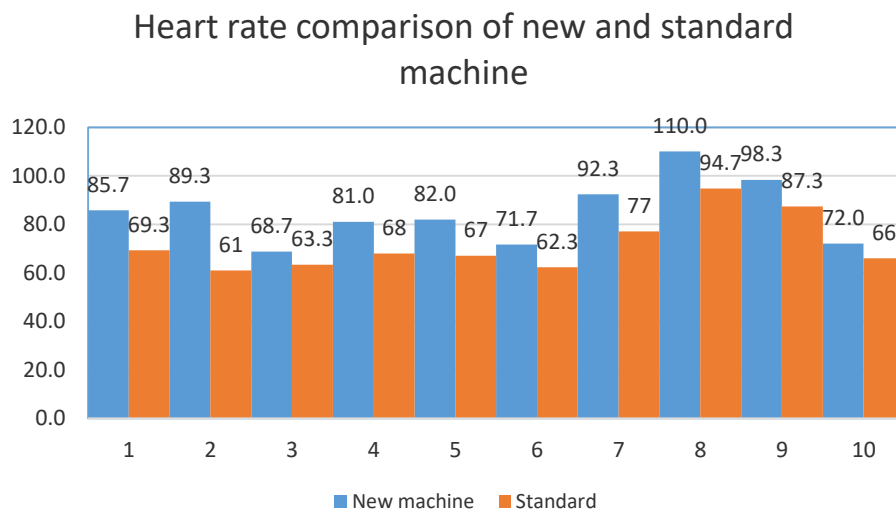


Figure 28:4.14 Histogram comparison of new system and BP Machine

stripchart for comparision

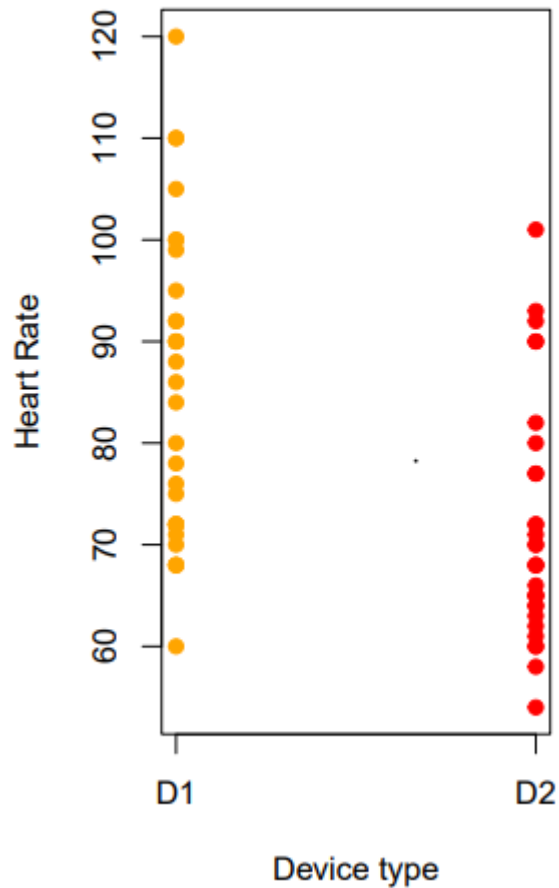


Figure 29:4.15 Stripchart comparison

Analysis of variance Table

Table 10.4.6 Analysis of Variance.

	Factor device
DF(Degree of freedom)	1
Sum Sq (sum square)	2733.8
Mean Square	2733.75
F Value	14.866
Pr(probability/P value)	0.0002917***

Using different graphic visualization statistical test we confirm that the measures obtained using our new device are not significantly different from those obtained using the standard existing one. The new system has strongest accuracy.

By taking our pulse, we can determine our heart rate as well as evaluate the strength, regularity, and nature of our pulse. Any irregularities may be signs of a heart condition and need to be looked the waves. The normal range of heart rate for adult is 60-100bpm, for newborn is 100-160bpm for 1year old is 80-130bpm and 70-110 bpm for 6years old.

We choose this parameter, because, it is the first indicator of cardiovascular status.

4.4. DISCUSSION

This project's main goal was to design and prototype a non-invasive smart device for assessing a person's cardiovascular health. Before using this system, you should keep in your mind that there could be delays from the system to the cloud database for the data to be displayed on the graph because this is being done over the internet. Another one when the electrode is place on body but in bad position, there would be misinterpretation of ECG waveform .to avoid this you could place it in standard position. This section deals with the discussion of research questions in relation to the results as follow:

1. How non-invasive smart device will be developed for real-time human cardiovascular status?

Due to lifestyle and climate change, the heart diseases are also increasing therefore researchers continue to research if they can fight heart disease, so in 2004 a researcher invented a wearable ECG smart watch where the patient could take measurements at home and send them to the clinic. But this system showed weakness were body motion causes degradation of signal quality. To solve this problem new proposed system with sticker electrodes where motion does not change the quality of the signal. The patient could be equipped by the ECG sensor, NodeMCU and Mobile application.

2. How architectural concept will be implemented as a proof-of-concept prototype?

I came up with the concept for the device after observing people who were suffering from heart disease. The device would allow them to measure themselves, send the results to their doctor, who would then inform them of their condition. Sticker electrodes were used to sense the heart signal in the prototype, followed by an AD 8232 for amplification and filtering, and a NodeMCU ESP8266 for data processing. Where NodeMCU sends data to a cloud database using a Wi-Fi network communication.

3. Will the developed system able to record, store and send data captured to the doctor for diagnostic analysis?

Prototype was tested on ten people, and the data recorded, stored and sent to the database for used to review by a doctor, then doctor sent to the patient a notification, the effectiveness of this

system can be determined by comparing the data obtained by the new system and the data obtained from blood pressure device that was approved by the FDA, using this system, the study examined the heart rates of ten individuals. In addition, we checked these people by using the blood pressure machine their heart rate and recorded. Checkup was done in three days consecutive. The performance of this system according to this measurement is 95%.

4.5 Summary

To track the state of the cardiovascular system, a non-invasive smart device was designed. The system tested to determine the heart activities especially heart rate to confirm that the system is in good working order. An electrode, an amplifier, a microcontroller, and a wireless transmitter module are included in this system. Thus, the ECG data is recorded in a cloud database for the doctor to review. If a critical condition exists, the doctor will notify the patient via mobile phone

CHAPTER 5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The wearable ECG smart watch technique for detection of heart diseases have been introduced so far, but the hand motion causes the degradation of signal quality and also is very expensive[58]. The proposed system, may be a relatively cheap, small size tool that is widely available that could be used to identify heart disease in people who are not in a clinical setting and the body motion does not cause any degradation of signal quality. This system was tested and the result showed that the system could be a good way to address the problems of the current system. This system could help to decrease the death rate due to heart attack. The performance of this system is 95% compared to the Blood pressure machine during measurement of heart rate. Both patients and healthcare professionals can benefit from the flexibility and cost-saving options provided by this type of health monitoring system. However, the prototype further researcher can enhance performance and adjust to the fashion of the time.

5.2. Recommendations

After realizing that numerous people die from heart disease in the world, we recommend the people to prevent it early. They could purchase a portable smart device to track heart disease at home. And everyone should have a cardiologist to monitor the heart condition, in addition, this system needs to be put in place as soon as possible by the Rwandan government that could therefore pay cardiologists, they keep track of patients who are receiving care at home. Another one, people work hard at their sports and incorporate them into their daily lives.

5.3. Future Study

In the future, the researchers could measure the wave intervals, could add GPS, whenever the patient sends heart measurements from home, and doctor found that patient has serious case of cardiac emergency immediately GPS would be used to locate where patient lives and send an ambulance right away. They could also add a video call, which would enable the caregiver and caretaker to communicate while the patient is at home and also, they could power regulator. Moreover, the majority of chargers operate at voltages greater than 3volts and this system uses 3V-5V. Finally, they could use on this system 5G (Network Generation) in order to assist in making data transmission network improvements.

REFERENCES

- [1] S. Kaplan Berkaya, A. K. Uysal, E. Sora Gunal, S. Ergin, S. Gunal, and M. B. Gulmezoglu, 'A survey on ECG analysis', *Biomedical Signal Processing and Control*, vol. 43, pp. 216–235, 2018, doi: 10.1016/j.bspc.2018.03.003.
- [2] A. Mbewu and J. Mbanya, 'Cardiovascular Disease Cardiovascular Disease', *Disease and Mortality in Sub-Saharan Africa*, vol. 349, no. DC, pp. 1–22, 2006, doi: 10.1161/CIR.0000000000000757.American.
- [3] G. A. Mensah and D. W. Brown, 'An overview of cardiovascular disease burden in the United States', *Health Affairs*, vol. 26, no. 1, pp. 38–48, 2007, doi: 10.1377/hlthaff.26.1.38.
- [4] A. A. Mohamed, A. A. Arifi, and A. Omran, 'The basics of echocardiography', *Journal of the Saudi Heart Association*, vol. 22, no. 2, pp. 71–76, 2010, doi: 10.1016/j.jsha.2010.02.011.
- [5] N. Shanmugasundaram, R. Bharathkumar, T. Gowthamraj, V. Kaliyugathuayyan, and A. Manojkumar, 'ECG_Monitoring_System_using_Arduino_and', pp. 2–5.
- [6] M. E. H. Chowdhury *et al.*, 'Wearable real-time heart attack detection and warning system to reduce road accidents', *Sensors (Switzerland)*, vol. 19, no. 12, 2019, doi: 10.3390/s19122780.
- [7] M. Twagirumukiza, O. Sebatunzi, E. Amendezo, and A. Kagame, 'Inhospital cardiovascular morbidity and mortality in the department of internal medicine at CHU Kigali (Rwanda)', *Annals of Tropical Medicine and Public Health*, vol. 1, no. 1, p. 9, 2008, doi: 10.4103/1755-6783.43071.
- [8] A. F. Otoom, E. E. Abdallah, Y. Kilani, A. Kefaye, and M. Ashour, 'Effective diagnosis and monitoring of heart disease', *International Journal of Software Engineering and its Applications*, vol. 9, no. 1, pp. 143–156, 2015, doi: 10.14257/ijseia.2015.9.1.12.
- [9] S. Thool, 'Implementation of ARM7 Based Handheld ECG Unit Prototype for Remote Areas as Premedical Checkup at Home', vol. 2, no. 7, pp. 201–206, 2013.
- [10] E. J. da S. Luz, W. R. Schwartz, G. Cámara-Chávez, and D. Menotti, 'ECG-based heartbeat classification for arrhythmia detection: A survey', *Computer Methods and Programs in Biomedicine*, vol. 127, pp. 144–164, 2016, doi: 10.1016/j.cmpb.2015.12.008.
- [11] M. A. Silverio and F. B. Eng, 'Implementation of Smart Devices in the Construction Industry', 2019.
- [12] Corey Benson and Robert Girardin, 'A Guide to Understanding Web Application Development', pp. 1–17.
- [13] J. T. Oduor, 'A Model for home-based remote monitoring of asthmatic patients', 2017.

- [14] V. Wahane and P. V. Ingole, 'An Android based wireless ECG monitoring system for cardiac arrhythmia', *2016 IEEE Healthcare Innovation Point-of-Care Technologies Conference, HI-POCT 2016*, pp. 183–187, 2016, doi: 10.1109/HIC.2016.7797727.
- [15] P. A. Iaizzo, 'Chapter 5 Anatomy of the Human Heart', *Handbook of Cardiac Anatomy, Physiology, and Devices: Second Edition*, pp. 1–659, 2005.
- [16] Bartlett, 'the Cardiovascular System', 2017.
- [17] A. Merrikhi, H. R. Asadabadi, A. A. Beigi, S. M. Marashi, H. Ghaheri, and Z. N. Zarch, 'Comparison of percutaneous versus open surgical techniques for placement of peritoneal dialysis catheter in children: A randomized clinical trial', *Medical Journal of the Islamic Republic of Iran*, vol. 28, no. 1, 2014.
- [18] F. O. F. Science, 'MASTER ' S THESIS University of Stavanger Department of Electrical Engineering and Biometric Authentication from ECG Signals on Wearable Devices', no. June, 2019.
- [19] S. Tanvir Alam, Md. Moin Hossain, Md. Kafiul Islam, and M. Dehan Rahman, 'Towards Development of a Low Cost and Portable ECG Monitoring System for Rural/Remote Areas of Bangladesh', *International Journal of Image, Graphics and Signal Processing*, vol. 10, no. 5, pp. 24–32, 2018, doi: 10.5815/ijigsp.2018.05.03.
- [20] M. Hasan, 'Analysis of beat-to-beat ventricular repolarization duration variability from Electrocardiogram signal', *Research Gate*, vol. 4, no. 3, pp. 23–30, 2015.
- [21] B. V. P. Prasad and V. Parthasarathy, 'Detection and classification of cardiovascular abnormalities using FFT based multi-objective genetic algorithm', *Biotechnology and Biotechnological Equipment*, vol. 32, no. 1, pp. 183–193, 2018, doi: 10.1080/13102818.2017.1389303.
- [22] J. Kanade, S. Bansode, P. Gawande, P. M. P. Potdar, and P. K. J. Kulkarni, 'Patient Health Monitoring System', pp. 2180–2182, 2018.
- [23] J. L. Lohr and S. Sivanandam, 'Introduction to echocardiography', *Handbook of Cardiac Anatomy, Physiology, and Devices, Third Edition*, pp. 385–397, 2015, doi: 10.1007/978-3-319-19464-6_22.
- [24] A. A. Mohamed, A. A. Arifi, and A. Omran, 'The basics of echocardiography', *Journal of the Saudi Heart Association*, vol. 22, no. 2, pp. 71–76, 2010, doi: 10.1016/j.jsha.2010.02.011.
- [25] D. Ghimire, 'Basic Echocardiography', *Medical intern*, no. Southwestern University School of Medicine, pp. 1–71, 2015.
- [26] R. Nowotny, *Chapter 5: X-Ray Production*. 2014.

- [27] Palmer E.S.P., G. P. Hanson, and J. Honeyman-buck, ‘Diagnostic Imaging in the Community’, p. 4.7, 2011.
- [28] Z. T. Al-Sharify, T. A. Al-Sharify, N. T. Al-Sharify, and H. Y. Naser, ‘A critical review on medical imaging techniques (CT and PET scans) in the medical field’, *IOP Conference Series: Materials Science and Engineering*, vol. 870, no. 1, 2020, doi: 10.1088/1757-899X/870/1/012043.
- [29] S. Edyvean and J. Gelijns, *Chapter 11: Computed Tomography*, vol. 44, no. 2. 2013.
- [30] A. Block, I. Rahamathullah, D. Saplacan, and E. Chen, ‘Bachelors Thesis’, 2015.
- [31] A. Dupre, S. Vieau, and P. A. Iaizzo, ‘Basic ECG theory, 12-lead recordings and their interpretation’, *Handbook of Cardiac Anatomy, Physiology, and Devices: Second Edition*, pp. 257–269, 2005, doi: 10.1007/978-1-60327-372-5_17.
- [32] Q. Zhu, X. Tian, C. W. Wong, and M. Wu, ‘Learning Your Heart Actions from Pulse: ECG Waveform Reconstruction from PPG’, *IEEE Internet of Things Journal*, vol. 8, no. 23, pp. 16734–16748, 2021, doi: 10.1109/JIOT.2021.3097946.
- [33] S. T. Prasad and S. Varadarajan, ‘ECG Signal Analysis: Different Approaches’, *International Journal of Engineering Trends and Technology*, vol. 7, no. 5, pp. 212–216, 2014, doi: 10.14445/22315381/ijett-v7p275.
- [34] M. Shanthi, P. Pekka, and N. Bo, ‘Global atlas on cardiovascular disease prevention and control’, *World Health Organization*, pp. 3–18, 2011.
- [35] S. Warach, C. S. Kidwell, and A. E. Baird, ‘Magnetic Resonance Imaging’, *Stroke: Pathophysiology, Diagnosis, and Management*, pp. 461–479, 2004, doi: 10.1016/B0-44-306600-0/50024-9.
- [36] F. Luis and G. Moncayo, *No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title.*
- [37] R. J. Hall, *150 Practice ECGs: Interpretation and Board Review*, vol. 24, no. 2. 1997.
- [38] A. ALMAZROA and S. ABDULRAHMAN, ‘Algorithms design for improving homecare using Electrocardiogram (ECG) signals and Internet of Things (IoT)’, 2021.
- [39] S. Currie, N. Hoggard, I. J. Craven, M. Hadjivassiliou, and I. D. Wilkinson, ‘Understanding MRI: Basic MR physics for physicians’, *Postgraduate Medical Journal*, vol. 89, no. 1050, pp. 209–223, 2013, doi: 10.1136/postgradmedj-2012-131342.
- [40] S. S. Sarade, N. A. Jadhav, and M. D. Bhambure, ‘PATIENT MONITORING AND ALERTING SYSTEM BY USING GSM’, pp. 1036–1038, 2015.
- [41] N. Esp, ‘Introduction to’, no. July, pp. 0–3, 2017.

- [42] Analog Devices, ‘AD8232 Single-Lead ECG’, *Data Sheet*, pp. 1–28, 2013.
- [43] T. Aho *et al.*, ‘Designing IDE as a Service’, *Communications of Cloud Software*, vol. 1, no. 1, pp. 1–10, 2011.
- [44] P. Lalanda, J. Bourcier, J. Bardin, and S. Chollet, ‘Smart Home Systems’, *Smart Home Systems*, 2010, doi: 10.5772/8415.
- [45] M. Bravo-Zanoguera, D. Cuevas-González, M. A. Reyna, J. P. García-Vázquez, and R. L. Avitia, ‘Fabricating a portable ECG device using AD823X analog front-end microchips and open-source development validation’, *Sensors (Switzerland)*, vol. 20, no. 20, pp. 1–30, 2020, doi: 10.3390/s20205962.
- [46] P. Pierleoni, L. Pernini, A. Belli, and L. Palma, ‘An android-based heart monitoring system for the elderly and for patients with heart disease’, *International Journal of Telemedicine and Applications*, vol. 2014, 2014, doi: 10.1155/2014/625156.
- [47] T. D. Joshi and S. K. Parchandekar, ‘Real Time Multi-Patient Heart Rate and ECG Monitoring System Using Wireless Sensor Network’, pp. 3363–3367, 2017.
- [48] M. C. T. Manullang, J. Simanjuntak, and A. L. Ramdani, ‘Implementation of AD8232 ECG Signal Classification Using Peak Detection Method For Determining RST Point’, *Indonesian Journal of Artificial Intelligence and Data Mining*, vol. 2, no. 2, p. 61, 2019, doi: 10.24014/ijaidm.v2i2.7593.
- [49] R. Bannatyne and G. Viot, ‘Introduction to microcontrollers’, *Wescon Conference Record*, pp. 564–574, 1997, doi: 10.1201/9781420077681.ch1.
- [50] E. Datasheet, ‘ESP8266 Serial Esp-01 WIFI Wireless’, *ESP8266 Serial Esp-01 WIFI Wireless*, p. 12, 2004.
- [51] J. Ylä-mella and M. S. Eng, ‘Liquid Crystal Displays : Material Content and Recycling Practices University of Oulu University of Oulu University of Oulu’, no. August, 2014.
- [52] A. Harris and M. Cooper, ‘Mobile phones: Impacts, challenges, and predictions’, *Human Behavior and Emerging Technologies*, vol. 1, no. 1, pp. 15–17, 2019, doi: 10.1002/hbe2.112.
- [53] J. Link, ‘Web Applications’, *Unit Testing in Java*, no. November, pp. 241–262, 2003, doi: 10.1016/b978-155860868-9/50014-6.
- [54] M. Bravo-Zanoguera, D. Cuevas-González, J. P. García-Vázquez, R. L. Avitia, and M. A. Reyna, ‘Portable ECG System Design Using the AD8232 Microchip and Open-Source Platform’, no. May 2020, p. 49, 2020, doi: 10.3390/ecs-a-6-06584.
- [55] B. Campbell, D. Richley, C. Ross, and C. Eggett, ‘Clinical Guidelines by Consensus Recording a Standard 12-Lead Electrocardiogram Clinical Guidelines by Consensus

Recording a standard 12-lead electrocardiogram', *Society for Cardiological Science & Technology (SCST)*, vol. 1, no. 1, pp. 1–25, 2017.

[56] Mindray, 'Panorama ® ECG Lead Placement Procedure', 2014.

[57] M. Hasan, 'Analysis of beat-to-beat ventricular repolarization duration variability from Electrocardiogram signal', *Research Gate*, vol. 4, no. 3, pp. 23–30, 2015.

[58] N. Ahmed and Y. Zhu, 'Early Detection of Atrial Fibrillation Based on ECG Signals', pp. 1–17, 2020.

APPENDICES

Appendix 1: Mode of Data Collection (Example the Questionnaire)

1. Do you work in a cardiology service? *

Yes

No

2. You've been employed here for over two years. *

Yes

No

3. Are you utilizing an ECG device?

Yes

No

4. Are the ECG readings able to be saved in your system? *

Yes

No

5. Do you have a system a doctor can use to examine heart parameters without the patient present? *

Yes

No

6. Can't a patient take their own heart measurements and send them to the doctor? *

Yes

No

7.If the patient have a portable ECG machine ,and measure her/his heart parameters at the home can you help in daily work? *

Yes

No

8.Can anyone design to you a system to receive patient data would help you? *

Yes

No

9.Without visiting the doctor, is there a way to inform the patient of his/her results? *

yes

No

Appendix 2: The Utilized Codes

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
#include <ESP8266HTTPClient.h>
#include<LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);

const char *ssid = "ecg"; // wifi name
const char *password = "123456789"; // wifi password
String url = "https://ecg.imanishimwe.com/ecg_data/3/";
String url1 = "https://ecg.imanishimwe.com/heart_data/3/";
String Link, Link1;
long instance1=0, timer;

double hrv =0, hr = 72, interval = 0;

int value = 0, count = 0, data[500];

bool flag = 0;

#define shutdown_pin 10

#define threshold 300 // to identify R peak

#define timer_value 10000 // 10 seconds timer to calculate hr

void setup() {

    Serial.begin(9600);
    lcd.init();
    lcd.backlight();
    pinMode(14, INPUT); // Setup for leads off detection LO +
    pinMode(12, INPUT); // Setup for leads off detection LO -

    WiFi.begin(ssid, password); // connecting to wifi using provided ssid and
password
    Serial.println("");

    Serial.print("Connecting"); // display connecting status on serial monitor
    lcd.setCursor(0,0);
    lcd.print("Connecting");
    int i = 0;
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print("."); // while nodeMCU is connecting display dot
        lcd.setCursor(i,1);
```

```

    lcd.print(".");
    if(i < 16){
        i++;
    } else {
        i = 0;
    }
}
lcd.clear();

lcd.setCursor(2,0);
lcd.print("Connected");
lcd.setCursor(0,1);
lcd.print(WiFi.localIP());
Serial.println("");
Serial.print("Connected to ");
Serial.println(ssid); // display wifi name once nodeMCU gets connected to wifi
Serial.print("IP address: ");
Serial.println(WiFi.localIP()); // display nodeMCU ip address
delay(2000);
lcd.clear();
}

void loop() {
    WiFiClientSecure client;
    HTTPClient http;
    lcd.setCursor(0,0);
    lcd.print("Ready to correct data");
    client.setInsecure();
    if((digitalRead(14) == 1)|| (digitalRead(12) == 1)){
        lcd.setCursor(0,0);
        lcd.print("leads off!");
        Serial.println("leads off!");

        digitalWrite(shutdown_pin, LOW); //standby mode

        instance1 = micros();

        timer = millis();
        lcd.clear();
    }

    else {
        lcd.clear();
        lcd.setCursor(2,0);
        lcd.print("Collecting Data");
    }
}

```

```

for(int i=0; i<=500; i++){
    digitalWrite(shutdown_pin, HIGH); //normal mode

value = analogRead(A0);

value = map(value, 250, 400, 0, 100); //to flatten the ecg values a bit

if((value > threshold) && (!flag)) {

    count++;

    Serial.println("in");

    flag = 1;

    interval = micros() - instance1; //RR interval

    instance1 = micros();

}

else if((value < threshold)) {

    flag = 0;

}

if ((millis() - timer) > 10000) {

    hr = count*6;

    timer = millis();

    count = 0;

}

hrv = hr/60 - interval/1000000;

Serial.print(hr);

Serial.print(",");

Serial.print(hrv);

Serial.print(",");

Serial.println(value);

```

```

data[i] = value;

delay(1);
}
Link1 = url1+String(hr)+"/"+String(hrv);
http.begin(client, Link);

int httpCode1 = http.GET();
if(httpCode1 > 0)
{
    if(httpCode1 == HTTP_CODE_OK){
        String payload1 = http.getString();
        Serial.println(payload1);
    }else
    {
        Serial.printf("[HTTP] GET... failed, error: %s\n",
http.errorToString(httpCode1).c_str());
    }
}else{
    Serial.printf("[HTTP] GET... failed, error: %s\n",
http.errorToString(httpCode1).c_str());//Print request response payload
}
for(int i=0; i<=500; i++){
    Link = url1+String(data[i]);
    http.begin(client, Link);

    int httpCode1 = http.GET();
    if(httpCode1 > 0)
    {
        if(httpCode1 == HTTP_CODE_OK){
            String payload1 = http.getString();
            Serial.println(payload1);
        }else
        {
            Serial.printf("[HTTP] GET... failed, error: %s\n",
http.errorToString(httpCode1).c_str());
        }
    }else{
        Serial.printf("[HTTP] GET... failed, error: %s\n",
http.errorToString(httpCode1).c_str());//Print request response payload
    }
}
http.end(); //Close connection
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Data Collected");
lcd.setCursor(0,1);
lcd.print("Successfully");

```

```

    Serial.println("data collected successfully");
  }
}

```

Codes from R studio

The screenshot shows the RStudio interface with the following components:

- Source Editor:** Contains R code for data analysis:


```

1 Charles_RESULTS
2 stripchart(Heart_rate~as.factor(Device),vertical=T,pch=19,data = Charles_RESULTS,
3           xlab = "Device type", ylab = "Heart Rate",col=c("orange","red"))
4 Analysis<-lm(Heart_rate~as.factor(Device),data = Charles_RESULTS)
5
6 anova(Analysis)
7 plot(Analysis,which = 1)
8 qqplot(Analysis)
9 hist(Analysis)
10 sresids<-rstandard(Analysis)
11 hist(sresids)
12 TukeyHSD(aov(Analysis))
13 dev.off()
14

```
- Environment:** Shows loaded objects:

Object	Class	Size
Analysis	List of 13	
Charles_RESULTS	60 obs. of 2 variables	
df1	30 obs. of 5 variables	
- Console:** Shows the output of the ANOVA test:


```

R 4.1.1 · C:/Users/Ruganzu/Desktop/geopandas/
null device
1
> anova(Analysis)
Analysis of Variance Table

Response: Heart_rate
          Df Sum Sq Mean Sq F value    Pr(>F)
as.factor(Device) 1  2733.8  2733.75  14.866 0.0002917 ***
Residuals       58 10665.9   183.89
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
>

```