REVOLUTIONIZING REMOTE HEALTH MONITORING: AUTONOMOUS DETECTION OF PULMONARY AND CARDIAC ABNORMALITIES WITH CUSTOMIZED DIETARY PLANNING

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February 2024

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Project Proposal Report

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DECLARATION

I declare that this is my own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Name	Student ID	Signature
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The above candidate is carrying out research for the undergraduate Dissertation under my supervision.

Signature of Supervisor (Dr. Dilshan De Silva) | Date

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ABSTRACT

This study presents a novel method for ECG testing that focuses on self-assessment by creating an intelligent tablet-based platform. Using dry electrodes, the main goal is to directly obtain 12-lead ECG patterns from the palms, overcoming the shortcomings of traditional ECG techniques. During the signal acquisition phase, the smart tablet is linked to a specialized ambulatory ECG device that is part of a telemedicine kit in the proposed system. The optimal ECG lead signal that was obtained from the apparatus is used to reconstruct the remaining 11 leads using a deep learning model. The result is the combination of the 11 reconstructed leads and the optimal lead. This innovative method provides a self-assessment solution that is easy to use and does away with the hassle that comes with typical ECG methods. The study uses a deliberate fusion of technologies, structures, and algorithms to accurately identify heart rhythms using palm analysis. This work places the integration of dry electrodes, palm-based analysis, and the extraction of 12-lead ECG patterns at the forefront of developments in cardiac monitoring.

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Abbreviation	Description
WHO	World Health Organization
SpO2	Oxygen Saturation
ECG	Electrocardiogram
CNN	Convolutional Neural Network
GPU	Graphics Processing Unit

1. INTRODUCTION

1.1 Background & Literature Survey

A malady is a pathological state that is highly dangerous for a person's general health and can lead to a variety of problems, including pain, psychological discomfort, functional impairment, social difficulties, and even death. Remarkably, diseases comprise a significant fraction of the causes of death worldwide. The World Health Organization (WHO) states that the main causes of mortality rates worldwide are chronic illnesses. Ischemic heart disease alone was responsible for almost 8.89 million deaths in 2019, illustrating this trend. But when all cardiovascular diseases are considered, the annual death toll increases dramatically to over 17.9 million [1]. This emphasizes how important diseases are in determining the state of world health, especially chronic ones.

In order to lessen the effects of cardiac irregularities and improve the preservation of human life, a methodical strategy incorporating ongoing health monitoring must be put into place. This involves patients following a specified course of action that includes routinely visiting specialty cardiology clinics, getting cardiac tests as directed by physicians, and consulting cardiologists as needed. The goal of this all-encompassing approach is to provide a systematic framework for ongoing health surveillance that will guarantee the early identification, treatment, and management of cardiac problems in order to maximize patient outcomes.

In modern times, remote health monitoring systems are used all over the world and play a crucial role as information technology solutions to handle various medical difficulties. Doctor channeling, advice for physical examinations, and real-time monitoring of vital health indicators including blood pressure, pulse rate, blood oxygen saturation (SpO2), and electrocardiogram (ECG) are just a few of the functions that these systems enable. Incorporating these cutting-edge technological solutions has the potential to significantly improve accessibility, optimize healthcare delivery, and encourage proactive health management practices.

The ECG becomes a vital diagnostic method when it comes to cardiovascular illnesses. This diagnostic modality is essential for understanding the complex electrical activity patterns of the heart and for quickly identifying and diagnosing a range of cardiac disorders. ECG testing stands out for being non-invasive, painless, and quick to perform. It is a vital component in the diagnostic methods. The availability of a wide range of ECG tests meets specific needs and increases the diagnostic technique's adaptability and application in cardiovascular healthcare.

According to the literature that is currently available, there are three main forms of ECG testing that are classified: resting ECG, ambulatory ECG, and exercise stress test [2]. In order to minimize the impact of extraneous muscle electrical impulses during the process, the subject must be positioned supine throughout the execution of a resting ECG test. An ECG test performed while at rest usually takes five to ten minutes to complete. On the other hand, an ambulatory ECG uses a portable recorder that is attached for at least a day to allow for free mobility while registering sporadic symptoms that would not show up in a static resting ECG. To determine continued cardiac function, doctors may advise ambulatory ECGs for patients experiencing intermittent symptoms or those recuperating from a heart attack. In order to improve the association between individual experiences and the collected ECG data, patients are asked to record symptoms throughout this time. The third variation, the exercise stress test, examines heart function under physical activity. It is usually conducted through stationary exercise, like riding a bike or walking on a treadmill. This dynamic ECG version, which lasts for about 15 to 30 minutes, can also include pharmaceuticals to see how they affect heart function [2].

In the medical field, there are two basic methods used to acquire ECGs. Table 1 provides a detailed description of these two different approaches, including the electrode arrangement used and the resulting output ECG leads.

TABLE 1: Comparative analysis of main ECG mechanisms

ECG Mechanism	Number of Electrodes	Output ECG Leads
Standard 12-Lead ECG	10	I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, V6
3-Lead ECG	3	I, II, III

Four limb electrodes and six chest electrodes must be carefully positioned in order to obtain a 12-lead ECG [3], [4]. Figure 1 shows the standard 12-lead ECG placement. In the three-dimensional realm of cardiac activation, each of these 12 ECG leads represents a unique vector [5]. This arrangement allows for a more detailed analysis of the heart, defining its anterior, lateral, and inferior sections. Interestingly, changes seen in certain ECG leads for each anatomical region offer important information about the localized issues related to cardiac activity [6].

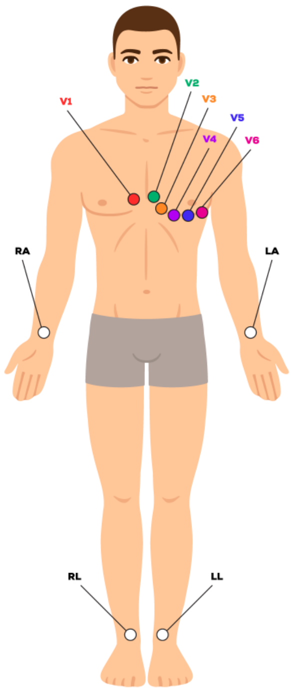

Figure 1: 12 lead ECG placement

Source: [13]

1.2 Research Gap

Four important studies in the field of ECG are examined in the thorough literature evaluation of earlier research projects. A noteworthy study that examined "A Palm Pilot based pocket ECG recorder" was led by Yongning Zou et al. [7]. An ambulatory ECG acquisition device made especially to run on the Palm operating system was used as part of the research technique to collect ECG data. The study's findings showed that lead I and lead II could be directly obtained from the device, while lead III had to be obtained using a calculated method [7]. This work represents an important advancement in the field of ECG research. When examining the state of the field, the study "ECG in Your Hands: A Multi-Vendor ECG Viewer for Personal Digital Assistants" by F. Chiarugi et al. [8] is noteworthy. The ambulatory ECG device used in this investigation was equipped with disposable electrodes to facilitate the collecting of ECG signals. The device produced 12-lead ECG patterns with remarkable success, demonstrating its effectiveness in complete cardiac monitoring. Moreover, the device had an integrated ECG viewer that made it possible to view the recorded ECG signals on the device itself, which advanced the development of portable and customized ECG diagnostics [8].

Looking at the state of research now, another notable study is that of Klaus-Peter Hoffmann et al., which investigated "Flexible dry surface-electrodes for ECG long-term monitoring" [9]. Research efforts resulted in the creation of a novel measurement tool that is characterized by the addition of textile-integrated Ag/Cl dry electrodes that are intended especially for the recording of complete 12-lead ECG patterns. By providing a flexible and wearable solution with dry surface electrodes, this innovative method has great promise for improving ECG long-term monitoring and furthering the continuous advancement of cardiac monitoring technology [9]. André Lourenço et al. conducted an important study that is described in the research paper "Palm-based ECG biometrics" [10] in the field of modern research. Using a creative method, the researchers used Ag/Cl dry electrodes with the virtual ground concept, which were purposefully made to do away with the requirement for the traditional ground lead. This technology opened up a new and promising direction in the field of ECG biometrics by making it easier to collect ECG signals straight from the palms. The research findings, especially when considering palm-based biometric applications, provide important new insights into the creation of effective and alternative approaches for ECG signal capture [10].

Based on the previously indicated corpus of research, three key features have surfaced as centers of interest for the investigation of novel ECG techniques. These include, notably, the effective recording of full 12-lead ECG patterns, the use of dry electrodes, and the emphasis on hands or palms as integral measurement areas. A thorough comparative study, as presented in Table 2, compares these unique characteristics over the range of the cited research works and the suggested solution, offering a nuanced comprehension of the contributions and developments in the field. The purpose of this comparison framework is to make it easier to assess the suggested solution in light of important characteristics found in earlier studies.

TABLE 2: Comparison of former researches

Application Reference	**Using dry electrodes**	**Using hands (palms)**	**Obtaining 12-Lead ECG**
A Palm Pilot based pocket ECG recorder [7]	X	X	X
ECG in Your Hands: A Multi-Vendor ECG Viewer for Personal Digital Assistants [8]	X	X	✓
Flexible dry surface-electrodes for ECG long-term monitoring [9]	✓	X	✓
Palm-based ECG biometrics [10]	✓	✓	X
Proposed System (CardioRespFit AI)	✓	✓	✓

Given the dearth of prior studies that tackle the combination of the three critical characteristics that we have found, our study suggests developing an entirely novel smart tablet platform. Using dry electrodes, this novel technology seeks to capture 12-

lead ECG signals from the palms of the hands. We envision a practical and approachable way to detect cardiac abnormalities by utilizing this strategy. This innovative concept offers a holistic solution that combines state-of-the-art technology with useful clinical applications, marking a substantial advancement in the sector.

1.3 Research Problem

As was previously explained, there are two primary methods used in the present capture of ECG. The standard 12-lead ECG method requires exact electrode positioning on the body, which is thoroughly illustrated in Figure 1. Simultaneously, as Figure 2 shows, the 3-lead ECG method requires precise electrode placement on the body. Interestingly, disposable electrodes (gel conductive electrodes) are mostly used in both approaches, indicating how commonplace they are in modern ECG procedures. These standardized techniques for electrode placement and type are essential parts of the widely used ECG acquisition systems.

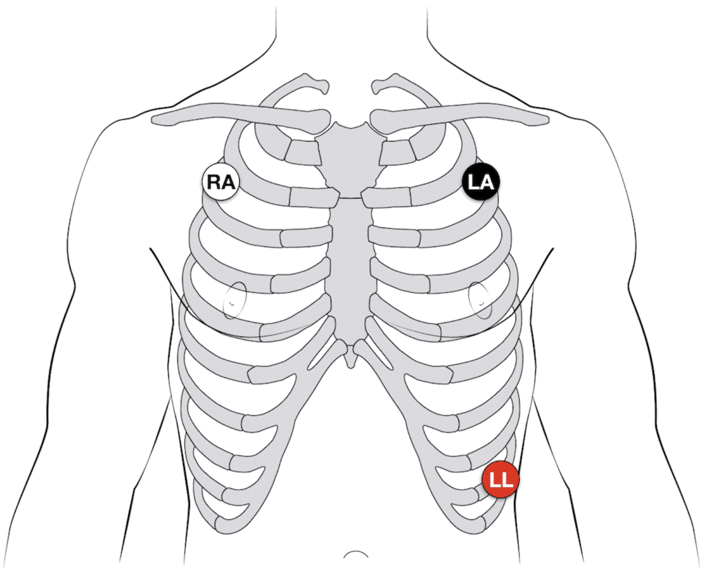

Figure 2: 3 lead ECG placement

Source: [14]

As such, current ECG acquisition technologies are not ideal for people who want to self-evaluate their heart health. Given this, we have developed the research problem to investigate the following question: "What are the most effective procedures for applying dry electrodes to the hands or palms in order to extract 12-lead ECG information?" By offering dry electrodes as a workable and practical substitute, the research's primary goal of innovating and advancing ECG acquisition methodologies, particularly in the setting of self-assessment is emphasized in this problem description.

2. OBJECTIVES

2.1 Main Objectives

The primary objective of this work is to provide an advanced smart tablet platform that will make self-assessment ECG tests easier. The ultimate objective of the research is to take a whole 12-lead ECG pattern straight out of a person's palms. This research goal emphasizes a dedication to developing and reinventing ECG testing techniques, especially when it comes to self-evaluation. The platform that is being imagined is expected to provide a revolutionary and approachable way to gather vital cardiac data.

2.2 Specific Objectives

There are four specific objectives should be reached in order to achieve the main objective mentioned above.

- Determine the optimal ECG lead for obtaining accurate readings from the palms.
    - Gathering the signal of optimal ECG lead which contains more cardiac data is the objective of this phase. To acquire ECG signal, a customized ambulatory ECG device is to be used.

- Reading the relevant ECG lead through dry electrodes.
    - Reading the optimal ECG lead which is identified from the previous objective is the objective of this phase. Dry electrodes are integrated with the customized ambulatory ECG device to read the ECG signal.

- Training the model to re-construct the remaining 11 ECG leads.

    - A deep learning model is to be built with the Attention U-Net Framework [11] which takes the acquired ECG signal from the previous objective as the input and re-constructs the remaining 11-leads by analyzing the cardiac data contained in the input.

- Design and implement a smart tablet-based platform for ECG viewing, facilitating user-friendly access and interpretation of cardiac data.
    - The outcome of this phase is a smart tablet-based platform which contains user-friendly interfaces and an ECG viewer that is easy to view 12-ead ECG patterns. Also, this platform gives a full guidance for the users during the ECG assessment.

3. METHODOLOGY

The proposed system demonstrates the capability to identify cardiac rhythms by thoroughly analyzing data obtained from the palms. The complexities of this analysis procedure are explained in Figure 3, which offers a graphic depiction of the methodical and complex approach used by this specific system component. The system's ability to identify cardiac rhythms via palm-based analysis is demonstrated by this graphical representation, which also helps to clarify the analytical details.

3.1 Component Diagram

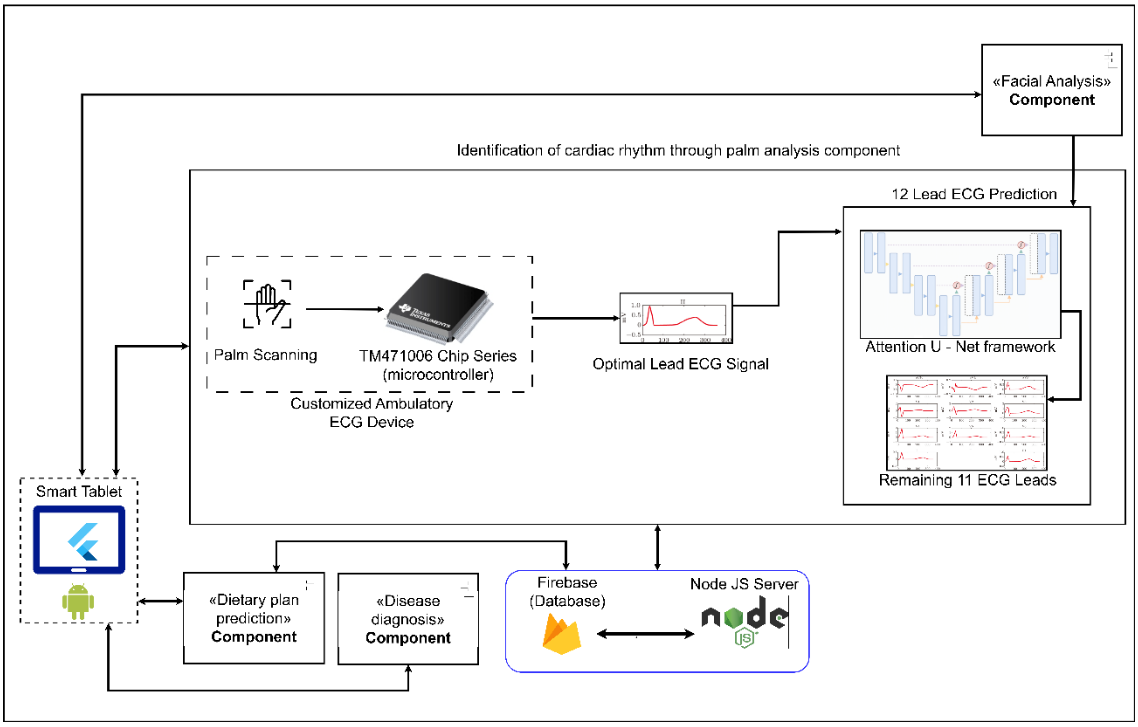

Figure 3: Identification of cardiac rhythm through analysis of palms component diagram

As part of the suggested remedy, a customized ambulatory ECG device is identified as a component part of the telemedicine kit. The device is essential to the acquisition of ECG signals since it integrates with the smart tablet in a fluid manner. An exhaustive list of information and specifications for this portable ECG machine is thoroughly displayed in Table 3.

TABLE 3: Ambulatory ECG device information

Product name	PMB (Panacea's Medi Belt)
Manufacturer	PulzSolutions (Pvt) Ltd.
Current market availability	Hemas Cardiac ICU
Current market price	Not for sale (used only by the Hemas Hospital Chain)
Number of electrodes connected	4

The optimal ECG lead signal obtained from the specified device is effortlessly transferred to the smart tablet application. The optimal ECG signal is then subjected to a second step in the application framework, where it is processed using a deep learning model that is intended to reconstruct the remaining ECG leads. Based on the Attention U-Net Framework, which evolved from Convolutional Neural Network (CNN) principles, the deep learning model's architecture is built [11]. The computational power of an NVIDIA Tesla P100 graphics processing unit (GPU) is utilized to increase the effectiveness of the training process for this deep learning model. This significantly accelerates the computational effort and speeds up the training stage.

During the final phase of the procedure, the 11 leads that were reconstructed using the deep learning model are combined with the optimal ECG lead that was obtained from the ambulatory ECG device. This combined ECG data set is then sent to the Node backend server so that it can be stored in the Firebase database. This final phase makes sure that the enriched ECG data is properly compiled and stored, which makes it easier to retrieve and analyze the data later on inside the larger telemedicine framework.

Table 4 provides a detailed overview of the technologies, architectures, and algorithms used in the palm analysis component of cardiac rhythm detection.

TABLE 4: Technologies, architectures and algorithms used.

Technologies	Flutter, Python, TensorFlow, Keras, Node
Architectures	Attention U-Net
Algorithms	CNN

4. PROJECT REQUIREMENTS

4.1 Functional Requirements

1. The optimal ECG lead obtained from the palms should be displayed in real-time.
2. The optimal ECG lead should be recorded for 10 seconds.
3. The remaining 11 leads should be acquired with high accuracy and displayed.

4.2 Non-functional Requirements

1. Interfaces should be User-friendly.
2. The application should be reliable.
3. Results should be more efficient.

4.3 Data Requirements

1. PTB-XL large publicly available electrocardiography dataset [12]

4.4 System Requirements

Software requirements are meant to specify the software resources that have to be implemented on a system in order for the proposed system to operate as intended. The following are the requirements for the software specs of this proposed component.

1. Flutter to build the cross-platform mobile application.
2. Firebase as the real-time database

3. TensorFlow libraries to manipulate signal data and signal processing.
4. Keras to build the deep learning model.
5. Node as the backend server to keep the connection between the database and mobile application.

4.5 User Requirements

1. Users need to be guided throughout the ECG assessment.
2. Users should be able to view their 12-lead ECG clearly.

4.6 Use Cases

1. Create a user account
2. Login to the application
3. Perform ECG Test
4. View past ECG Test records

4.7 Test Cases

TABLE 5: Test Cases

Test Case ID	Test Case Name	Scenario	Expected Output
1	Ambulatory ECG device connection test with the smart tablet	Ambulatory ECG device is not connected with the smart tablet	An error message displays on the tablet screen and give the necessary instructions to connect the ambulatory ECG device with the smart tablet.
2	Palm placement test	Palms are not placed correctly on the dry electrodes.	An error message displays on the tablet screen and give a guidance to the user to place the palms correctly on dry electrodes.
3	Process interruption test	User takes out palms while the ECG acquisition process (10 seconds time duration)	An error message displays on the tablet screen, discards the previously recorded signal and restarts the signal acquisition process.
4	Final results test	User keeps the palms correctly while the ECG acquisition process (10 seconds time duration)	Gives the final results with the 12-lead ECG patterns.

4.8 Wireframes

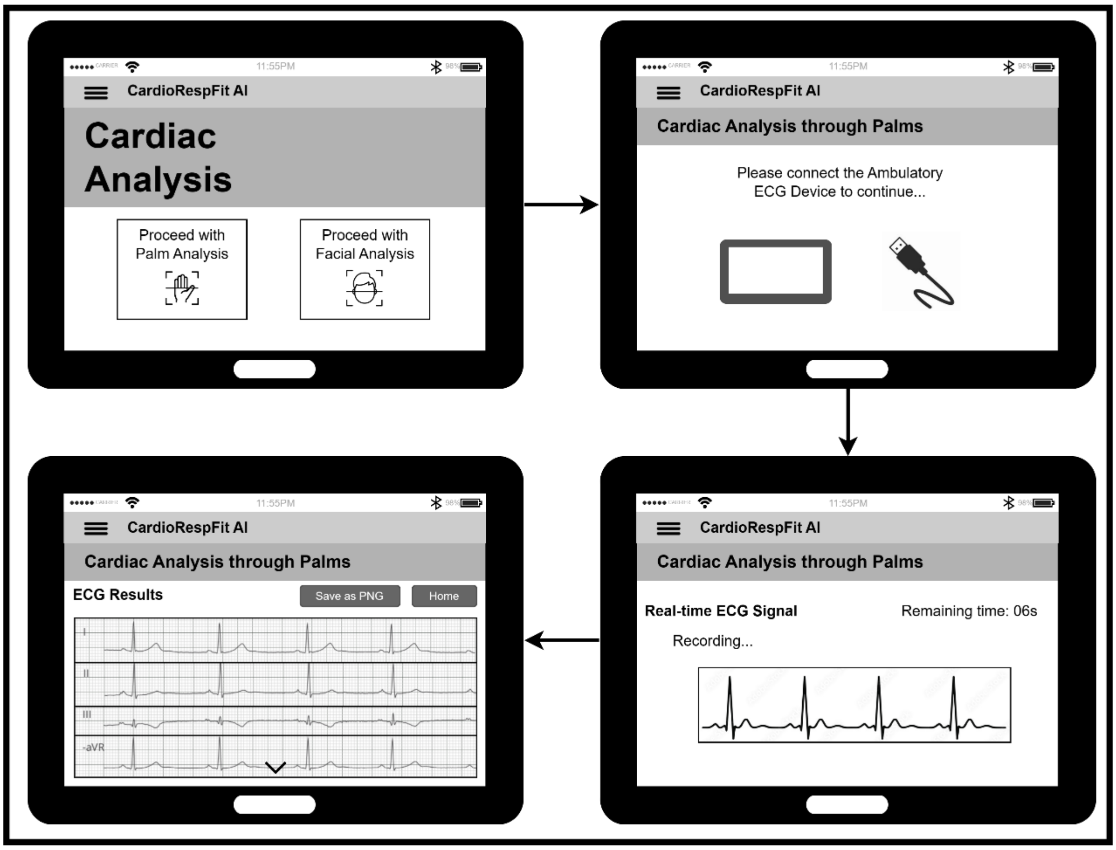

Figure 4: Wireframes of cardiac rhythm analysis through palms process

5. WORK BREAKDOWN STRUCTURE (WBS)

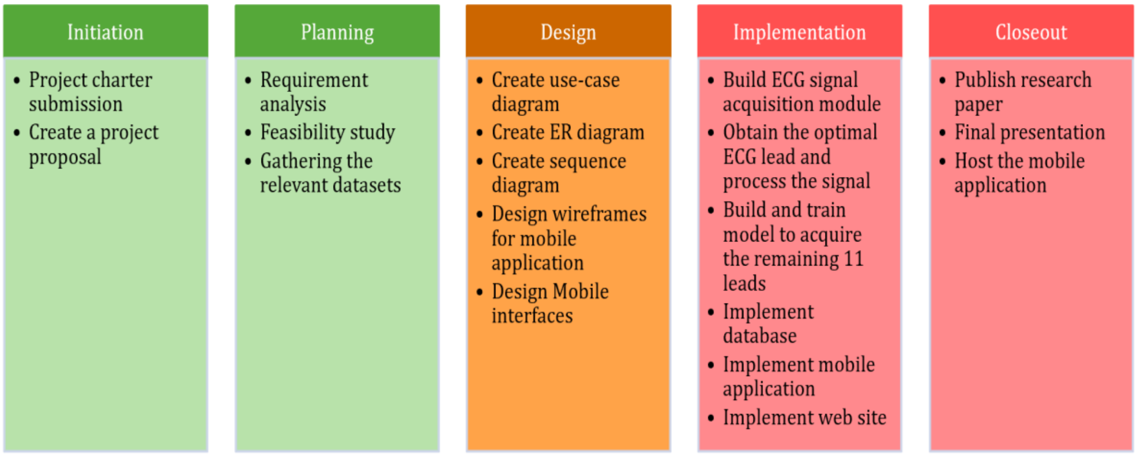

Figure 5: Work breakdown chart of the component

6. BUDGET AND BUDGET JUSTIFICATION

Table 6 shows the overall budget for the entire proposed system roughly.

TABLE 6: Expenses for the proposed system

Expenses	
Requirement	**Cost**
Telemedicine kit	500 USD
Subscription fee	29 USD / month
Doctor consultation fee	49 USD / month
Research & development	150,000 LKR per annum
Cloud hosting	25,000 LKR per annum
Other costs	30,000 LKR per annum

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APPENDICES

Appendix A: Plagiarism report