ECG SHIRT
ECE 445 PROJECT PROPOSAL

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1. Introduction

1.1 Problem

Cardiovascular disease is currently the leading cause of death in the world, with myocardial infarctions being one of the most common types of this disease. Myocardial infarctions are often treatable when diagnosed quickly; however, symptoms of a myocardial infarction are not always detectable and thus, treatment may be delayed. Around 15 million people around the world die from heart attacks each year and over 1/3 of those who experience a heart attack do not experience the most common warning signs. The first test done to diagnose any past or present myocardial infarctions is an Electrocardiogram, or ECG. The ECG can often detect a heart attack earlier than blood tests for heart damage, which can take 4+ hours to indicate damage to the heart. The increased accessibility of ECGs to the public can increase the detection of heart attacks and decrease the fatality of these events.

1.2 Solution

Our proposed solution to increase public accessibility to ECGs is to design a low-cost portable ECG that contains 4 leads in the ECG and transmits data to a health-app which can warn the user of an abnormal cardiovascular behavior that might result in a myocardial infarction. This portable ECG can be worn at any time and will be developed in such a way that it can be attached to t-shirts and will be particularly useful to populations at risk for myocardial infarction. Other ECG wearables, such as the Apple Watch, only measure 1 lead and are therefore unable to reliably detect heart attacks. An additional challenge that long-term ECG wearables continue to face is motion artifacts. We hope to design a low cost 4 lead ECG portable device which can be attached onto a variety of t-shirts or other wearables and is, thus, accessible to everyone and can be used in everyday activities.

1.3 Visual Aid
1.4 High Level Requirements

- The 4 leads will pick up data and transmit it to the application at a rate of 500 Hz in a readable signal wave format that can be analyzed digitally. These leads will be the ones placed on the: bipolar, unipolar, chest, and augmented. These 4 electrodes should be able to pick up P, QRS, and T waves from the heart rhythm. We will use textile electrodes rather than gel for more suited augmentation to the user.

- The readings picked up from the 4 lead electrodes will be transmitted into a signal waveform that can be read digitally and analyzed using ML models and programming. The readable format for our model would be P, QRS, and T waves represented as data points that can be viewed in a 2D graph-like format w x-axis as time and y-axis as amplitude of the wave in mm which can also be inferred in mV. The primary purpose of the analyzer will be to detect change in ST in comparison to a normal heartbeat.

- Since the readings will be less accurate than an industrial standard 12 lead ECG, we will look for a change in elevation in the ST in the inputted wave signal from the electrodes as an indication of a potential heart attack. This will act as a preemptive warning that something could be wrong, and the user might potentially be at a risk of a heart attack. This warning alert will be raised by the application which will have the same refresh rate as ECG readings (500 Hz) and will be based on the inputted readings.

2. Design

2.1 Block Diagram
2.2 Block Descriptions

2.2.1 Power

This is the subsystem that will supply power for our data subsystem, which will be our on-board circuit. It is composed of two lithium polymer batteries 3.7 V which will go through a buck boost converter (DC-DC converter) to supply our microcontroller with power. The voltage from our buck boost converter will also pass through two linear regulators (positive and negative) to supply our analogue to digital converter with positive and negative voltage to operate. The power subsystem is important to our design since our data acquisition process through the ECG leads is dependent upon constant and correct power supply to the circuit.

*Requirement:* Power subsystem must supply at least 1400mAh at 3.3V to the microcontroller and at +/− 2.5V to ADC’s continuously while the electrodes measure the wave and send the wave over to our data subsystem.

2.2.2 Data

The data subsystem acts as our electrode reading acquisition subsystem. It is composed of 4 leads which will make contact with the user’s skin and pick up heartbeat rhythms. Those rhythms will then be passed through the analogue to digital converter to convert the analogue heartbeat signals to a digital signal. These digital signals will be communicated to the microcontroller through SPI. The microcontroller will take these signals and write them to our provided memory, an SD card or on-board memory through Wi-Fi or Bluetooth for further analysis. The data subsystem is important since this will act as the backbone system of our design which will include the electrical circuit we will be working with and provide the data for our application to analyze and present.

*Requirement:* The microcontroller in the data subsystem must collect the data from the electrodes and supply it to the SD card at a rate of at least 500 Hz.

2.2.3 Application

The application subsystem is the subsystem that our users will be able to interact with. It is composed of a storage system, which will store the data coming in from the data subsystem. That data will then be forwarded to our machine model algorithm, which will analyze the data, by looking for an ST elevation in the signal and classify it as “safe” or “warn” according to whether the user is at a risk or a heart attack depending on their heartbeat rhythm input. This algorithm will be implemented using the python language. The last component of this subsystem is the UI frontend that will be the display for our design. Whenever a “warn” signal is indicated by the ML model, the frontend will display a warning sign indicating to the user that their body is at risk of a heart attack. The frontend will be developed using React Native. The application subsystem is important to our design since this will be the main form of interaction that our product will have with the user and display the results of our subsystems working together.
Requirement: The data acquired from the subsystem should be updated on the display at a rate of 500 Hz + running time of the machine learning algorithm.

2.3 Tolerance and Semantics Analysis

Our initial design involved 12 ECG leads but we are attempting to execute the task with 4 ECG leads. Devices with a varying number of leads exist in health-tech today. Although we know that the pulses can still be picked up and useful data can be collected, we are unaware of the consequences to their entirety. Based on some research, the 4-lead ECG consists of 3 electrodes placed on the: right arm, left arm, left leg and 1 electrode connected to ground which can be the right leg.

The diagram below is a representation of two ECG waves, the one on the left is a regular ECG of a healthy person and the one on the right is of a person experiencing a heart attack. You can see the main difference is the ST segment. The elevation in the ST segment is the most common sign of a heart attack. To begin with, this elevation is what we will be looking for when detecting a heart attack. An ST elevation or depression that is 1mm or greater is considered a sign of a potential heart attack; 1mm represents the amplitude of the wave. The ECG wave data will be provided by Dr. Erickson and our machine learning model will be trained according to the data we are provided. When our ECG shirt picks up the signals it will be able to detect ST elevation to the extent that our model allows. Of course, the waves we will be getting from 4 leads will be less accurate but that is why the position of right arm, left arm, left leg, and right leg were chosen. These placements are the key in measuring the QRS and T segments which is what we need to look for a heart attack.

![ECG Diagram](image)

Citation: semanticscholar.org

3. Ethics and Safety

We think that the technology that could come to creation from further iterations of what we are attempting to build could change the lives of people suffering from heart diseases and many other diseases whose symptoms are reflected on the ECG. (ACM 1.1)
Medical data obtained for testing and validation was obtained in a legal manner from Dr. Hanna Erickson, who initially pitched the concept. Any medical data used or obtained will be kept private and will strictly be used for research proposals. (ACM 1.6, ACM 1.7)

Our team of computer engineers is working with a Dr. Hanna Erickson and her team of researchers, and we are making sure that we have a deep understanding of the physiological aspect as we move ahead in the project. Our goal would be to create a prototype which can be further iterated to a market ready product which can be made available to the public through a healthcare program. (ACM 2.1, ACM 2.6, ACM 3.5)

To claim that our tech can detect any diseases, we would require an FDA approval. Until then we will be in a testing/validation phase and this tech cannot be used to monitor actual heart patients in need to ensure the safety of our users. (ACM 1.3, ACM 3.2)

We are trying to change the approach taken to wearable ECG monitors by using textile electrodes for ECG leads. Health-tech is filled with innovation and there are a lot of other ECG monitors which are mobile; ours has an end goal of being portable or being incorporated into a T-shirt and we believe the approach is innovative. (ACM 1.5)
References


