ECE-492

Proposal Document

E-Band

Team Members:

Albin Alex, Andrew Gambino, Eric Holsworth, Bradley Jean, and Padmini Yerramasu

Faculty Supervisor:

Nathalia Peixoto

Executive Summary

When a seizure takes place, one or more of these areas are most affected: decreased heart rate as a result of little to no breathing, increased and rapid muscle contraction, and sporadic movement; whether it be from falling or convulsions [9]. Seizures may occur in hazardous environments which poses an additional risk to the patients. These individuals need to have proper safety protocols in place for these events. The *E-Band* provides those safety protocols through extensive physiological monitoring, such as heart rate, muscle contraction, and rapid movement. This *E-Band* will be suited with a force-sensitive sensor (FSR), electrocardiography (ECG) sensor, and an accelerometer which will measure muscle contraction, heart rate, and rapid movement respectively. When the *E-Band* sensors detect an anomaly in any of those areas, an alert is sent to the user requesting the individual to respond if they are not having a seizure. If the user fails to respond in time or confirms a medical emergency, another alert is sent to their caretaker/emergency contact that they may be having a seizure. This device has the potential to save lives and provide real-time monitoring of physiological traits with an easy-to-use user interface.

Problem Statement

Motivation

Epilepsy is a neurological disorder caused by excessive and abnormal neuronal activity which results in seizures [3]. If these seizures occur while the individual is unsupervised, they can hurt themselves while convulsing. Furthermore, certain types of seizures can last for prolonged periods, which can be life-threatening [3]. An early notification system can help to mitigate the length of the seizure and the time that the individual receives medical attention. This device, *E-Band*, will be monitoring three factors: heart rate, muscle tension, and falling. Studies have proven there are certain early indicators or warnings of seizures such as increased heart rate and sweating.

This project provides an opportunity to design products that assist those within the epileptic community. Many engineering products that do physiological monitoring are catered towards athletes in an attempt to improve their physical abilities. None of these devices are engineered and catered to specifically monitor those with epilepsy in both an accurate and discrete manner.

The epileptic community was specifically targeted because of the substantial amount of patients. Roughly, 1.2% of the United States' population has epilepsy which means there are about 3 million adults and 500 thousand children who suffer from seizures [4]. Furthermore, 70% of children experience silent seizures, often with no convulsions, preventing caretakers and observers from using standard seizure detection methods [2].

In essence, epileptics lack a solid device that can accurately track their physiological symptoms, detect seizures, and notify proper caretakers. At the moment, no notable engineering company offers these services within a compact product catered towards these individuals, even though one is desperately needed.

Identification of Need and Market Review

The objective is to develop a device and technique for measuring epilepsy parameters with high precision and accuracy. There have been other stand-alone experiments that have created precision devices measuring similar and different parameters for epilepsy. One such experiment measured temperature, sound, and motion [7]. On the market, there is one stand-alone device called Pulse Guard that measures heartbeat with precision and accuracy for individuals with epilepsy. Limitations for devices such as Pulse Guard are the price and effectiveness. The downside of accurate and effective devices is the size and comfort.

The device will measure three parameters for epilepsy. These parameters will include heart rate, muscle contraction, and motion. The wearable device will not restrict the user's daily movement. Additionally, the *E-Band* will be low-cost and have low power consumption.

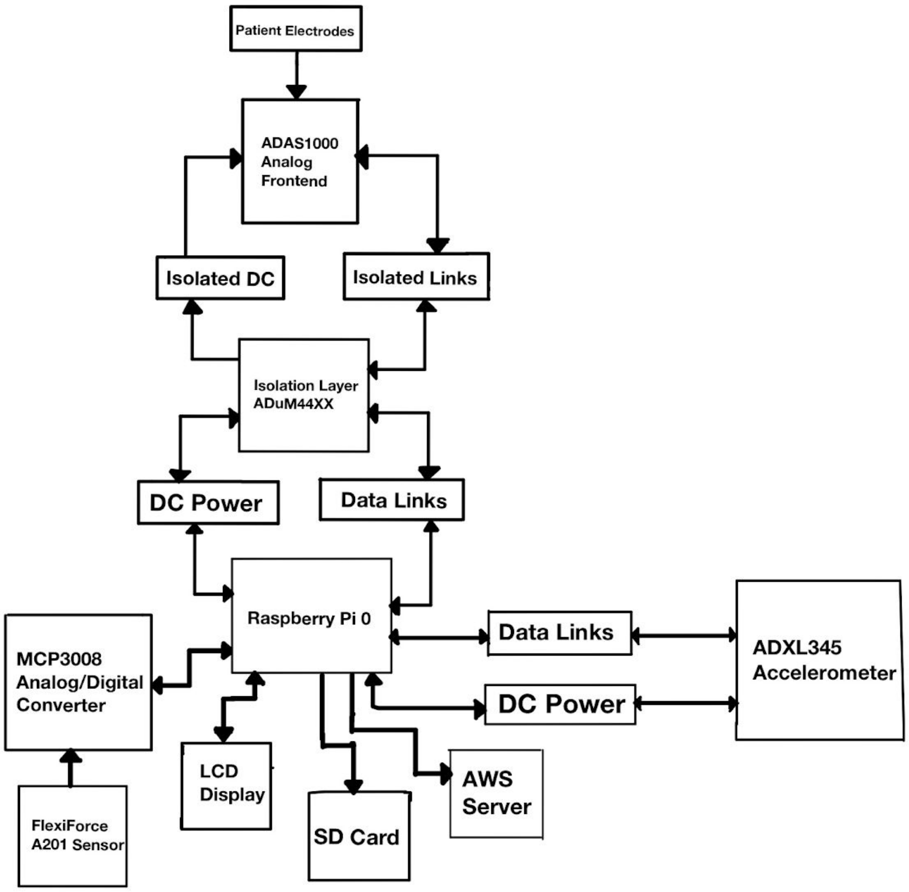
The developed technology will help in the monitoring of epileptic individuals remotely in a residential or public environment. *E-Band* will allow for quicker response time to the individual when a seizure occurs. The device could be modified for other disabilities and/or disorders in their respective communities that need continuous monitoring. A potential issue that would occur is a fluctuation in project funding since the measured data will continuously be transferred and stored in AWS server and server storage cost would change based on usage. False flags and alerts can cause trust and reliability issues with emergency contacts.

Approach

Problem analysis with external design

Many engineering products that perform physiological monitoring are catered towards athletes in an attempt to improve their physical abilities. None of these devices are engineered and catered to specifically monitor those with epilepsy in both an accurate and discrete manner.

In essence, epileptics lack a solid device that can accurately track their physiological symptoms, detect seizures, and notify proper caretakers. At the moment, no notable engineering company offers these services within a compact product catered towards these individuals, even though one is desperately needed. We need to create a device that can monitor physiological symptoms present in epileptic patients undergoing seizures, and efficiently send an alert to caretakers or emergency services so that further action could be taken if need be.



Introduction to background knowledge supporting the project

Epilepsy is a central nervous system disorder in which brain activity becomes abnormal. This can lead to seizures or other unusual behavior [3]. During a seizure, there are bursts of electrical activity in your brain. This activity causes different symptoms depending on the type of seizure and what part of the brain is involved. Seizures can take on many different forms and affect different people in different ways. These behaviors can cause significant damage to the individual if they do not receive emergency care in time. These symptoms include temporary confusion, staring spells, uncontrollable jerking movements of the arms and legs, loss of consciousness or awareness, increased heart rate, perspiration, and breathing.

Seizures that appear to involve all areas of the brain are called generalized seizures. Six types of generalized seizures exist. Absence seizures often occur in children and are characterized by staring into space or subtle body movements such as eye blinking or lip-smacking. These seizures may occur in clusters and cause a brief loss of awareness. Tonic seizures cause stiffening of your muscles. These seizures usually affect muscles in your back, arms, and legs and may cause you to fall to the ground. Atonic seizures, also known as drop seizures, cause a loss of muscle control, which may cause you to suddenly collapse or fall. Clonic seizures are associated with repeated or rhythmic, jerking muscle movements. These seizures usually affect the neck, face, and arms. Myoclonic seizures usually appear as sudden brief jerks or twitches of your arms and legs. Tonic-clonic seizures are the most dramatic type of epileptic seizure and can cause an abrupt loss of consciousness, body stiffening and shaking, and sometimes loss of bladder control or biting your “tongue”. [9]

Approach (based on conceptual design)

The approach is to use a pressure sensor, ECG sensor, and accelerometer connected to a raspberry pi to monitor the epileptic individual’s physiological symptoms and detect when a seizure could be imminent or happening currently. When these symptoms are picked up by the *E-band*, it will notify the user on an LED screen. This will then prompt the user with an option to press a button on the device to disable the pending notification to a caretaker. If not pushed it will send the notification to the caretaker so that they may take further action if need be. This is done to prevent false flags on the user’s end if they decide to engage in strenuous physical activity that could otherwise cause muscle tension, raise heart rate, or any other physiological signs that could represent an impending or undergoing seizure. The *E-band* will consistently update and send notifications through the cloud to save space on physical storage as well as give the caretakers the ability to have a consistent view of the patient's physiological signs.

Alternative approach

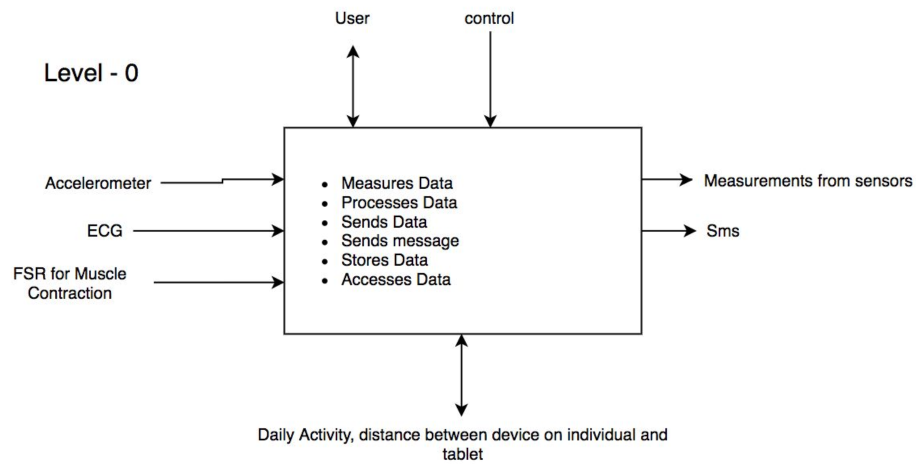
An alternative approach that could be utilized would be to use a custom-built microcontroller to control one sensor, that being an ECG sensor, and attach it to a user's wrist to monitor heart rate. This proposed solution would cut down on size and battery usage, while still monitoring one of the most important physiological signs from the user.

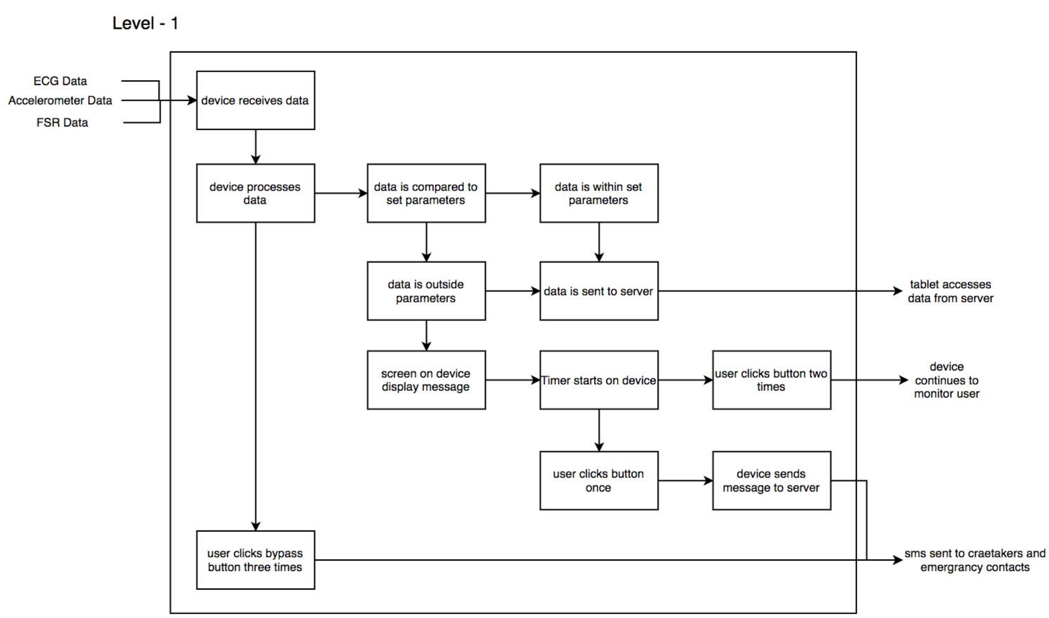
Project Requirements Specification

The *E-band* will need to implement a Raspberry Pi 0 w, with connected devices being an ECG sensor, pressure sensor, accelerometer, and LED screen with buttons. The Raspberry Pi 0 w will be powered by a connected battery and supply power to all the connected devices. An AWS server will also be required to upload data into the cloud and send notifications through AWS's various services. A tablet will be available on the side that can access the data present within AWS real-time, as well as receive notifications from the caretakers. Lastly, an armband with adjustable straps will be worn by the patient and house all the electrical components.

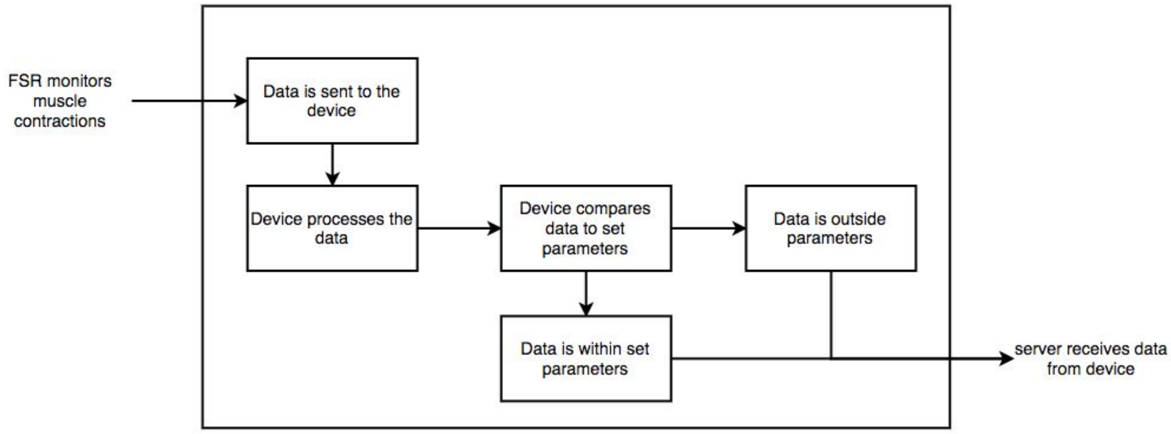
System Design

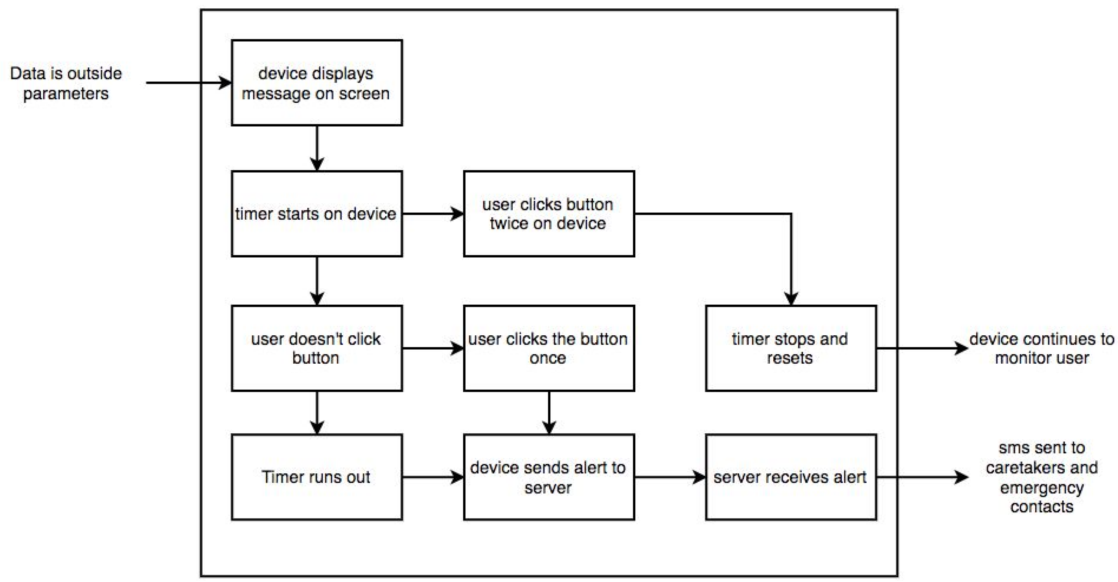
Functional Decomposition



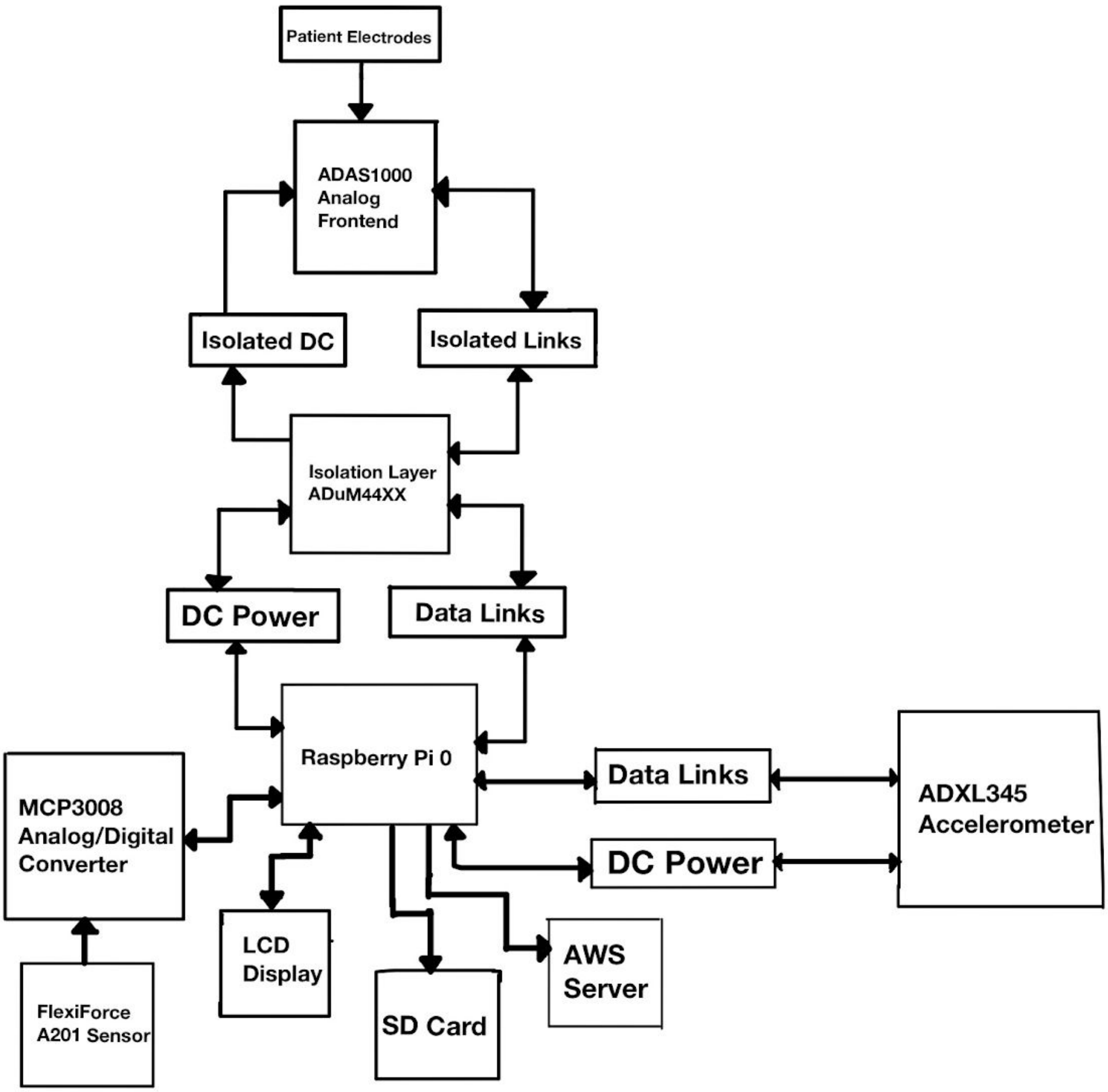


Level - 2


FSR monitors muscle contractions
Data is sent to the device
Device processes the data
Device compares data to set parameters
Data is outside parameters
Data is within set parameters
server receives data from device


Data is outside parameters
device displays message on screen
timer starts on device
user clicks button twice on device
user doesn't click button
user clicks the button once
timer stops and resets
device continues to monitor user
Timer runs out
device sends alert to server
server receives alert
sms sent to caretakers and emergency contacts

System Architecture



Preliminary Project Plan (492 & 493)

Main Tasks for ECE 492

- Create Amazon Web Services (AWS) Account and install a web server. Used to store the data and contact the EMS.

Main Tasks for ECE 493

- Conduct a practical test on Dr. Peixoto's contact who has seizures.
- Solder the ECG and muscle contraction sensors, as well as the accelerometer to the circuit board. Attach the Raspberry Pi to the circuit board with a connector.
- Observe the different sensors' measurements when the *E-Band* is used on patients with epilepsy. For the muscle contraction sensor, the force applied to the sensor is measured. For the ECG sensor, the electrical signals are measured according to the patients' heart rate.
- Data will be processed instantly for the patient to know whether they had experienced a seizure.

Allocation of Responsibilities:

Albin & Eric:

Create an algorithm for the accelerometer and implement it on Raspberry Pi 0. Analyze accelerometer data to determine the threshold to classify what is a fall.

Padmini & Bradley:

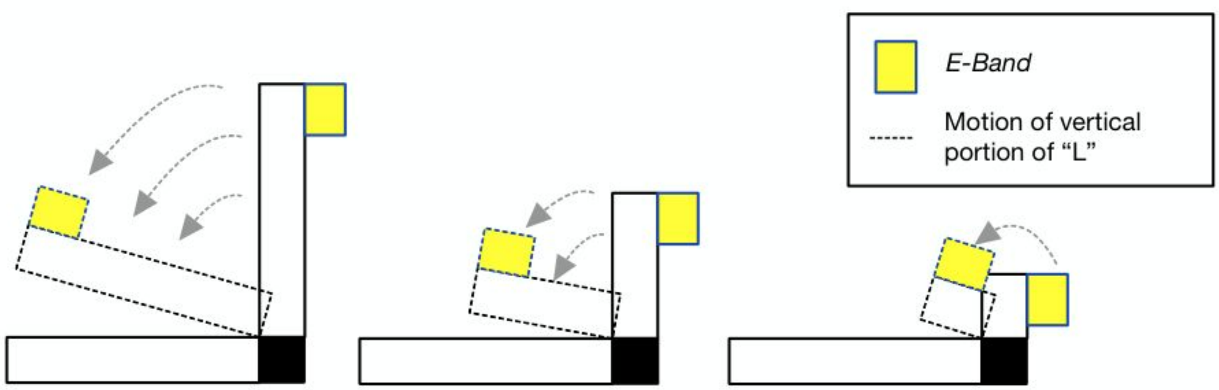
Create an algorithm for the ECG sensor and implement it on Raspberry Pi 0. Analyze the ECG sensor data.

Andrew:

Create an algorithm for muscle contraction sensor and implement it on Raspberry Pi 0. Analyze the muscle contraction data to determine the threshold.

Preliminary Experimental Plan

Since there are three different sensors, there will be an experiment for each sensor and a practical test. The first experiment will test the accelerometer by a fall test. The *E-Band* will be attached to an "L" shaped rod falling from varying vertical heights as shown in the figure below [5].



The analysis of data from the first experiment will determine the threshold for what classifies as a fall. This threshold will be used as one of the factors for notifying emergency contacts and medical professionals. Once this threshold is set, the *E-Band* will be attached to test subjects where they will purposely fall to confirm the reliability of the threshold.

The second experiment will test the ECG sensor. The *E-Band* will be attached to an individual along with a pulse oximeter on their finger. A pulse oximeter will provide the heart rate of the individual. The heart rate information from the pulse oximeter will be compared to the heart rate information from the ECG sensor. Both of the measured values should be equal to each other.

The final experiment will test the muscle contraction sensor. The *E-Band* will be attached to an individual along with a transcutaneous electrical nerve stimulation (TENS) unit. A TENS unit supplies electrical impulses through electrodes attached to an individual's skin [6]. As the TENS unit sends electrical impulses to the skins, the muscle surrounding the electrodes will contract mimicking seizure muscle contractions [6]. The *E-Band* will measure the force of these contractions. Through testing will lead to a threshold for contractions that can indicate a seizure.

The practical test will determine the feasibility, reliability, and practicality of the *E-Band*. The *E-Band* will be worn by Dr. Nathalia Peixoto's contact who has seizures. The contact will provide feedback on battery life, comfort, reliability, heat output, user interface, and performance of the device. This feedback will be used to alter and modify the *E-Band*.

Potential Problems

With this device, there is new knowledge and skills that will be required to undergo manufacturing and testing. The first skill required is the ability to program a user interface between the *E-Band* and the AWS. This will require knowledge in using the AWS Cloud services to create, maintain, and manage a server to interface with our hardware collecting data from the physiological test points. Interfacing between the raspberry pi and the screen display will be another skill required. This will require the knowledge of programming the raspberry pi to display a message on the display screen. Another skill required with this device is how to effectively measure and collect physiological data. Determining the precise locations for the sensors to monitor these physiological traits as well as being able to understand how to analyze the data collected will be a new challenge to our group.

In addition to all the new knowledge and skills required to make this design come to fruition, there are also some potential risks associated with the *E-Band.* One of these risks is the potential for this design to ultimately fail. This would be due to the sensors being unable to effectively measure and monitor the physiological traits. Other risks relate to the fragility of the device. The components used, although do not require high operating voltages, may have the potential to shock the user if the armband is damaged extensively. The final risk is the potential for the AWS server to crash. If the server runs into an issue where it is unable to process the data and crashes, it could put the user in danger if they end up having a seizure.

Overall, the majority of new knowledge and skills required to complete this design revolve around the user interface capabilities using an AWS server to send and receive messages as well as collecting and analyzing data from the sensors to monitor the users. With these challenges in mind, some risks that develop are the risks of ultimate failure due to ineffective monitoring, as well as the potential fragility of the armband where, if damaged excessively, could shock the user. In addition to this, the risk of the AWS server crashing poses a problem that the user could be put in a monitorless situation.

References

[1] D. Esposito *et al.*, "A Piezoresistive Sensor to Measure Muscle Contraction and Mechanomyography," *Sensors (Basel)*, vol. 18, no. 8, Aug. 2018, doi: 10.3390/s18082553.

[2] "About us," *PulseGuard*. https://pulseguard.org/about-us/ (accessed Oct. 01, 2020).

[3] "Articles," *Cedars-Sinai*. https://www.cedars-sinai.org/health-library/articles.html (accessed Oct. 02, 2020).

[4] "Epilepsy Fast Facts | CDC," Sep. 30, 2020. https://www.cdc.gov/epilepsy/about/fast-facts.htm (accessed Oct. 02, 2020).

[5] D. Aphairaj, M. Kitsonti, and T. Thanapornsawan, "Fall detection system with 3-axis accelerometer," *J. Phys.: Conf. Ser.*, vol. 1380, p. 012060, Nov. 2019, doi: 10.1088/1742-6596/1380/1/012060.

[6] "How to Compare TENS Units – A Review of 5 Signal Types," *RS Medical*. https://www.rsmedical.com/blog/compare-tens-units-by-signal-type (accessed Oct. 02, 2020).

[7] P. T. Jagtap and N. P. Bhosale, "IOT Based Epilepsy Monitoring using Accelerometer sensor," 2018 International Conference on Information , Communication, Engineering and Technology (ICICET), Pune, 2018, pp. 1-3, doi: 10.1109/ICICET.2018.8533869.

[8] "Types of Seizures | Epilepsy | CDC," Sep. 30, 2020. https://www.cdc.gov/epilepsy/about/types-of-seizures.htm (accessed Oct. 02, 2020).

[9] "What Happens During A Seizure?," *Epilepsy Foundation*. https://www.epilepsy.com/start-here/about-epilepsy-basics/what-happens-during-seizure (accessed Oct. 02, 2020).