Lab 1 – SeizSmart Description

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CS 411

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1 Introduction

Reported cases of epilepsy have steadily increased over the last five years from 2014-2019, and this trend is expected to continue to continue into the year 2020. Over 50 million people globally currently live with epilepsy, marking it as the fourth most common neurological disease in the world. Figure 1 displays the impact epilepsy has globally and indicates that those who suffer from the disease are three to six times more at risk of experiencing premature death than someone without seizures. Seizures are difficult to detect in a timely and accurate manner, which can lead to injury, or ultimately, death.

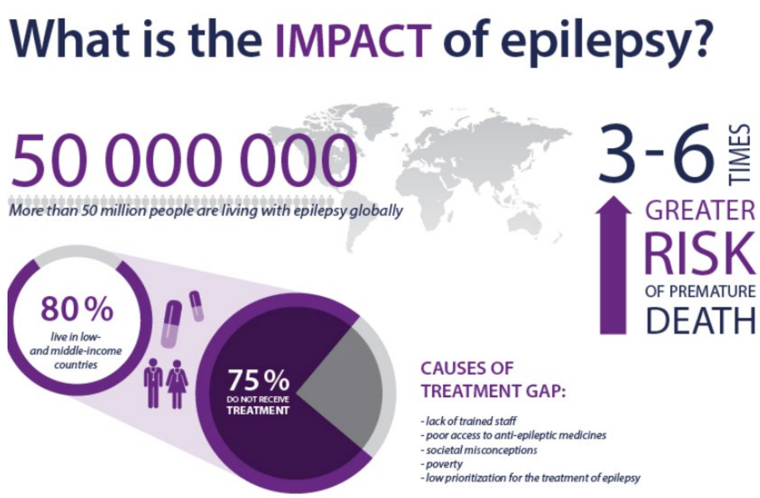

Figure 1: Background of Epilepsy

There are various seizure detection devices available for patients, meant to detect seizures, track seizures, and alert an emergency contact in an emergency situation where the patient is unresponsive. Most of the detection options available use smartwatch technology to monitor either the patient's body movement or their heart rate. The biometric readings taken from the patient are compared to an elected threshold value, and the comparison indicates that that a seizure is happening at a given moment, a detection will be made, and alert will be issued.

Figure 2 shows the current process flow for the existing solutions, which follows the same path regardless of which metric is being used.

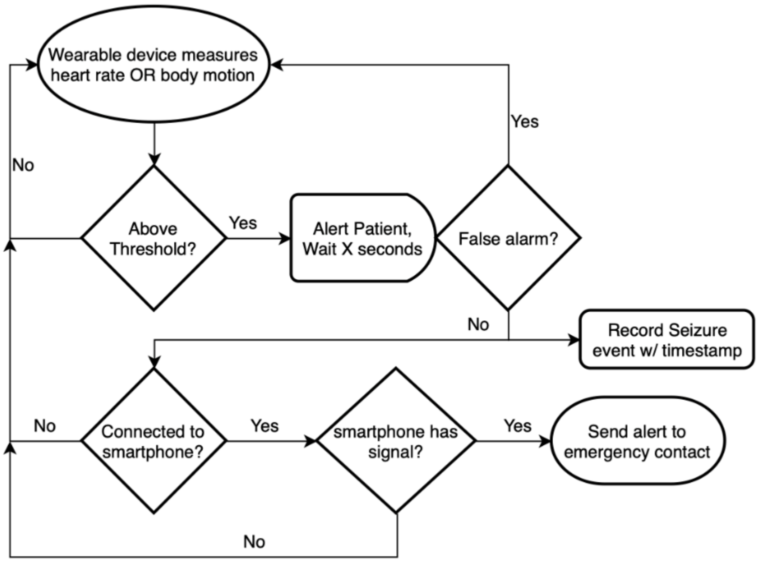

Figure 2: Current Process Flow

Available detection technology has shown inadequate accuracy. There are no products on the market that can evaluate more than one biometric reading concurrently to determine if a seizure is occurring. Furthermore, these solutions are lacking capabilities that can provide personalized detection based on an individual's seizure characteristics. Not all patients have the same symptoms during a seizure, which signifies that is it not appropriate to use a "general case" biometric reading as the threshold value to detect a seizure. For example, in most cases someone who is having a generalized seizure will display an increased heart rate, but this is not always the case. Some individuals can experience a slowed heart rate, or their heart can even stop temporarily during a seizure.

Current seizure detection technology lacks other critical features. Some of the current solutions require costly, specialized hardware instead of being designed to be compatible with popular off the shelf smartwatch technology, such as the Apple or Android Watch. These specialized watches serve no purpose other than to detect seizures, so being required to purchase the expensive hardware is far from ideal. Moreover, solutions that require specialized hardware typically require a prescription to obtain the physical product, and a paid subscription to use the detection capabilities of the product.

For current detection devices to detect seizures and notify emergency contacts, the smartwatch is always required to be in the proximity of a smartphone (a method known as a relay device). Consider what will happen if a patient forgets to bring their smartphone with them when they run out to the grocery store. Ponder the consequence of a patient’s phone running out of battery life or becoming damaged and unusable. In these and other like situations, the patient will be left without seizure detection technology. In addition, the smartwatch device will not have the ability to notify the emergency contact if necessary, putting the patient at a great risk.

SeizSmart is a smartphone application designed to implement an advanced, wearable seizure detection capability based on smartwatch technology. SeizSmart is designed to provide those who suffer from generalized seizures an improved method to detect, track, and report seizure events. SeizSmart will continuously record biometric readings taken by the smartwatch from the individual and will notify the user's emergency contacts for help when an emergency is perceived. The patient will have access to all recorded data regarding their seizures and a peace of mind knowing that a chosen and trusted individual will be contacted to help them if they experience a seizure.

The term “generalized seizure” is indicative of a seizure that occurs throughout the entire brain, in contrast to a “focal seizure” or “partial seizure” which are seen in only one part of the brain. Focal seizures are not detectable by means of smartwatch technology because the symptoms exhibited, such as uncoordinated activity or random or clumsy behavior, are not numerically measurable by smartwatch technology. Due to this, the problem domain for SeizSmart is reduced to only the measurable characteristic symptoms of generalized seizures. Measurable characteristics in this situation include a rapid change in heart rate and rapid convulsions of the limbs and face (as displayed in Figure 3). One type of generalized seizure, the absence seizure, will be the exception as it is characterized only by the loss of consciousness. Because during an absence seizure the individual exhibits no symptoms that can be measured by smartwatch technology, SeizSmart is further limited to detecting all types of generalized seizures excluding absence seizures.

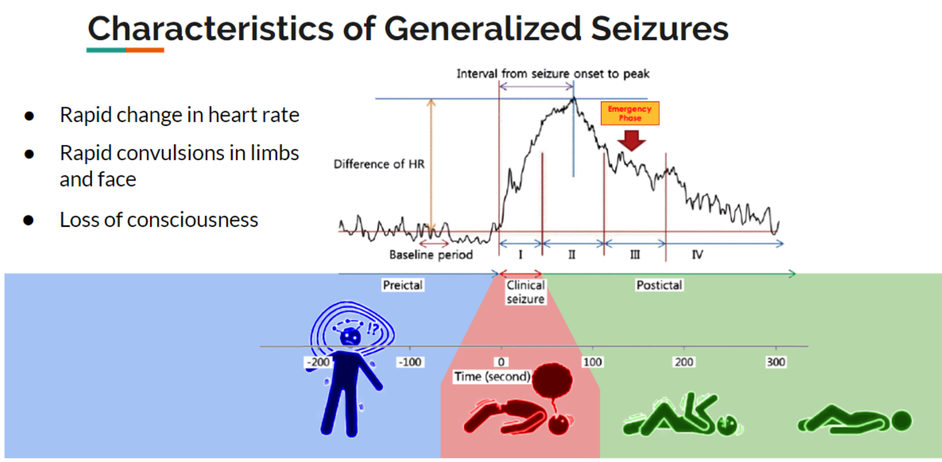

Figure 3: Interval from Seizure Onset to Peak

SeizSmart will continuously monitor the user's heart rate and body movement, simultaneously, to more accurately detect the onset a seizure. To provide optimal precision, SeizSmart will collect the user's current heartrate, body movement biometrics, and other real time environmental variables by means of smartwatch technology. These readings will be passed along with data from the patient's configured seizure profile, through a machine learning algorithm. The outcome will create a seizure profile and a neural network will be trained base these findings. The neural network will develop a precise detection algorithm that will determine if a seizure is occurring at a given moment. The detection algorithm for a specific patient will be tweaked and enhanced as additional biometric readings are recorded, and as seizure events are detected and confirmed and false positives or false negatives (undetected seizures) are recognized.

SeizSmart software will be compatible with relatively affordable and multipurpose off the shelf smartwatch technology and will not require any specialized hardware. Additionally, the intention is that there will be no required subscription or prescription to acquire access to the product and services making the product readily available and affordable to most individuals.

2 SeizSmart Description

SeizSmart will detect, record, and report the individual's biometric readings and seizure data. SeizSmart will detect seizures based on a combination of heart rate and motion metrics, along with other available environmental statistics such as the time of day and weather outside. Smartwatch technology will provide an accelerometer, gyroscope, and special sensors to establish biometric readings describing the patient's heart rate and body movement. The combined data will be sent through a machine learning algorithm to develop an individualized seizure profile that characterized a patient's seizures. A neural network will be consistently trained to allow for notable accurate seizure detection. For as long as no seizure is detected, this cycle will start over, repeating indefinitely.

Upon the detection of a seizure, an alert will be sent to the patient in attempt to collect a response from them, indicating they are safe. If the patient is not actually experiencing a seizure, they will have the capability to clear the alert and enter feedback regarding the false positive directly into the watch. If the alert is not cleared within a certain amount of time, the assumption is that the individual is at risk, and the next step is notifying the user's chosen emergency contact. Because a relay device is not required, the notification to the emergency contact will be deployed directly from the smartwatch. They will have the ability to clear the alert if they are onsite with the patient or can confirm the patient is safe. If unable to reach the patient and confirm their safety, the emergency contact, when prompted, will have the option to contact emergency services which will initiate a notification to first responders to be dispatched.

2.1 Key Product Features and Capabilities

SeizSmart is designed to detect seizures in real time, and record and report data regarding detected seizure events. SeizSmart is unique in its method to detect seizures, providing an individualized and customized detection experience. Detection is individualized by the seizure profile created for each individual along with their ability to customize the sensitivity of the detection algorithm. Using both the patient’s heart rate and body movement measurements to detect seizures further increases the accuracy of detection that SeizSmart can provide. This accomplishes optimal seizure detection accuracy which other solutions are lacking. The detected seizures are recorded and can later be reported as desired. Three algorithms are implemented by SeizSmart to complete these three tasks.

A detection algorithm is intended, in real time, to determine if a patient is experiencing a generalized seizure. The smartwatch technology tools included with an Android watch, along with a trained neural network are responsible for defining the detection algorithm. Values for acceleration, gyroscope rotation, and heart rate are taken at five minutes, one minute, and ten seconds, appropriate calculations are made, and as displayed in Figure 4 an appropriate detection algorithm is obtained.

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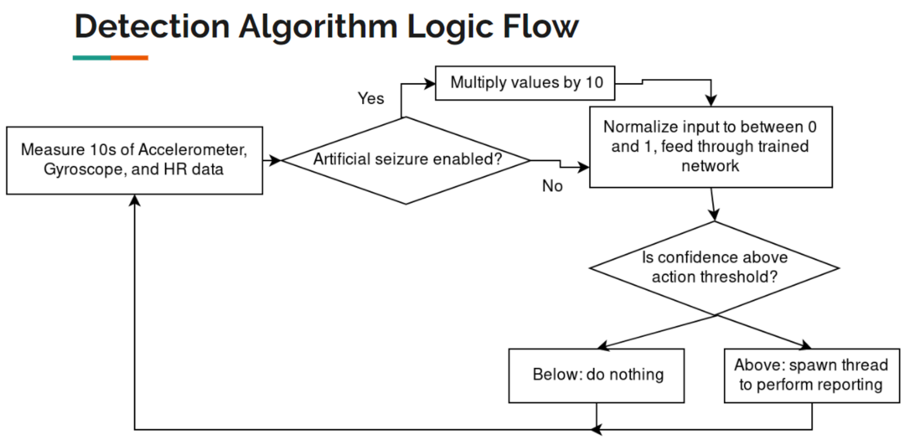

Figure 4: Detection algorithm flow

Patients and caretakers will have the ability to configure their account to adjust the sensitivity of the detection algorithm. The sensitivity should be adjusted depending on the caretaker or patient's desire to lean more towards having false positives or false negatives. Some individuals may prefer to be overcautious and will not mind possibly having an abundance of false positives if it means there is less of a chance that a seizure goes undetected. Alternatively, some patients and caretakers may feel comfortable enough to lower the detection sensitivity to avoid an overwhelming number of false positive alerts coming to their smartwatch.

A reporting algorithm has been designed that will notify a patient's emergency contact when appropriate, and in extreme cases the patient's last resort emergency contact which could be emergency services. The required smartwatch, having cellular or Wi-Fi network connection, will independently deploy these notifications to the appropriate party, meaning that a relay device (typically, a smartphone connected to a network) is not required to detect seizures and send out notifications to individuals. Parameters for the reporting algorithm include the patient's emergency contact list and last resort point of contact. Additionally, the patient's location coordinates, and their current heart rate and body motion data will be provided to the emergency contact when an alert is deployed to them. This information that will assist the emergency contact in locating the patient in addition to understanding the severity of their current situation. The process flow for the reporting algorithm can be seen in Figure 5. Once a seizure is detected, if Wi-Fi or cellular connection is available, a notification will be pushed to the individual's watch asking if they are okay. Notifications will also be directed to the emergency contacts' phones. If the user is unresponsive and the emergency contact is unable to assist, when prompted, the emergency contact can choose to call 911 and emergency services will be dispatched to the patient's current location. At the same time the Wi-Fi connection will be being confirmed, a public first aid audio alert will sound from the watch, explaining to citizens standing by what is happening to the patient and informing them with how they should help.

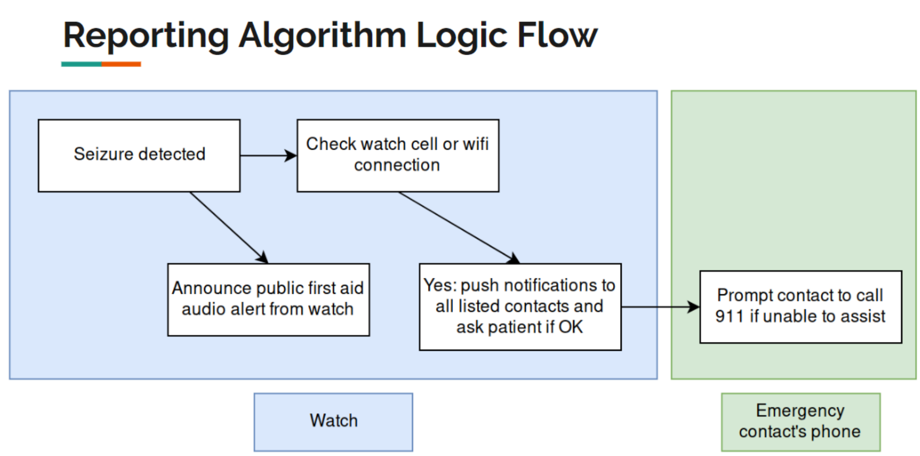

Figure 5: Reporting algorithm flow

The recording algorithm takes the seizure-related data recently obtained from the patient and is stored locally on the watch. The data will be used in training the neural network on the cloud server and needs to be relocated from the local database to the remote database so that testing can be conducted. As shown in Figure 6, the logic flow is simple; The data is measured and recorded locally in the SQLite database on the watch. Data on the smartwatch is pushed to the global database on the remote cloud server daily. Once the data is recorded to the global database, the local SQLite database is pruned, and the cycle starts over again.

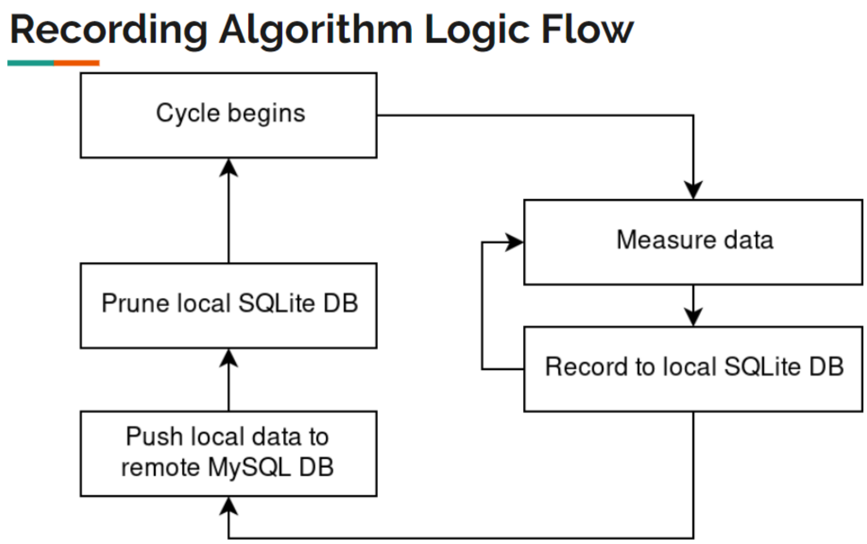

Figure 6: Recording algorithm flow

2.2 Major Components

2.2.1. Smartphone Application.

An Android smartphone, version 4.3 or higher with Wi-Fi and cellular capabilities is required to run SeizSmart. An Android smartphone application is needed for purposes of reporting and recording seizures, as well as for adjusting detection threshold values. The smartphone application will be provided via an HTPP REST API Server and distributed from the Google Play App Store. The smartphone user interface for SeizSmart's mobile application will allow for data management and alert management by the end user directly via the smartphone. From the smartphone UI, the end user will be able to complete the initial setup for SeizSmart, log seizures and view a history of their logged seizures, on top of adding emergency contacts.

Alerts will also be managed via the mobile application. The end user will be able to view motion and heart rate values that have been read and recorded on the mobile app. Additionally, the countdown alert that is displayed when a seizure is detected will appear on the mobile application with an abort button presented.

2.2.2. Smartwatch Application and Smartwatch Database

An Android watch application will be provided for detecting seizures. Furthermore, to run SeizSmart software, the user will need to have access to an Android smartwatch, OS version 2.6 or higher, with Wi-Fi and cellular capabilities. The smartwatch must provide specific technology, including an accelerometer, a gyroscope, and an optical heart-rate sensor. These features are essential to obtain readings for heart rate, motion, and environmental variables that are required to detect a seizure.

Biometric readings will be taken, and the data will be temporarily stored on an SQLite database, locally on the watch. If the data entered into the watch database indicates that a seizure is occurring based on the current seizure profile, a GUI alert will be initiated to alert the user, giving them the chance to abort the alert. The smartwatch must be able to connect to a cellular network, allowing it to be operated independently from a smartphone. This gives the watch the ability to alert emergency contacts in the patient is unresponsive to the initial alert sent to them.

2.2.3. Cloud Server and Server-Side Database

Daily, biometric readings that are recorded locally on the smartwatch will be uploaded to a cloud server onto a more robust MySQL global database. Using a CentOS 7 Linux virtual machine, running a TensorFlow machine learning system, the biometrics are read from the database and the neural network is trained based on the data. The updated neural network is pushed to the watch daily, continuously optimizing detection capabilities as biometric data and seizure information accumulates.

2.2.4. Machine Learning Algorithm

A seizure profile describes a specific individual's typical seizure such as physical indicators, or their typical threshold for certain biometrics readings during a seizure. Technically speaking, it is a matrix of weights that are computed from training data. Once initiated, the seizure profile can be used to classify new biometric inputs as seizure or non-seizure related. The purpose of the seizure profile is to provide more accurate seizure detection. The goal of SeizSmart's machine learning algorithm is to create the unique seizure profile for each individual end user. TensorFlow will be the tool used to create the machine learning module for SeizSmart. The parameters that will be provided to the machine learning algorithm are the motion data collected about the patient, including the accelerometer and gyroscope values, in addition to the patient's heart rate and their seizure tag (the user's identification number in SeizSmart's database). The machine learning method used will be a neural network that in combination with the user's preferred sensitivity coefficient will be used to determine if a seizure is occurring.

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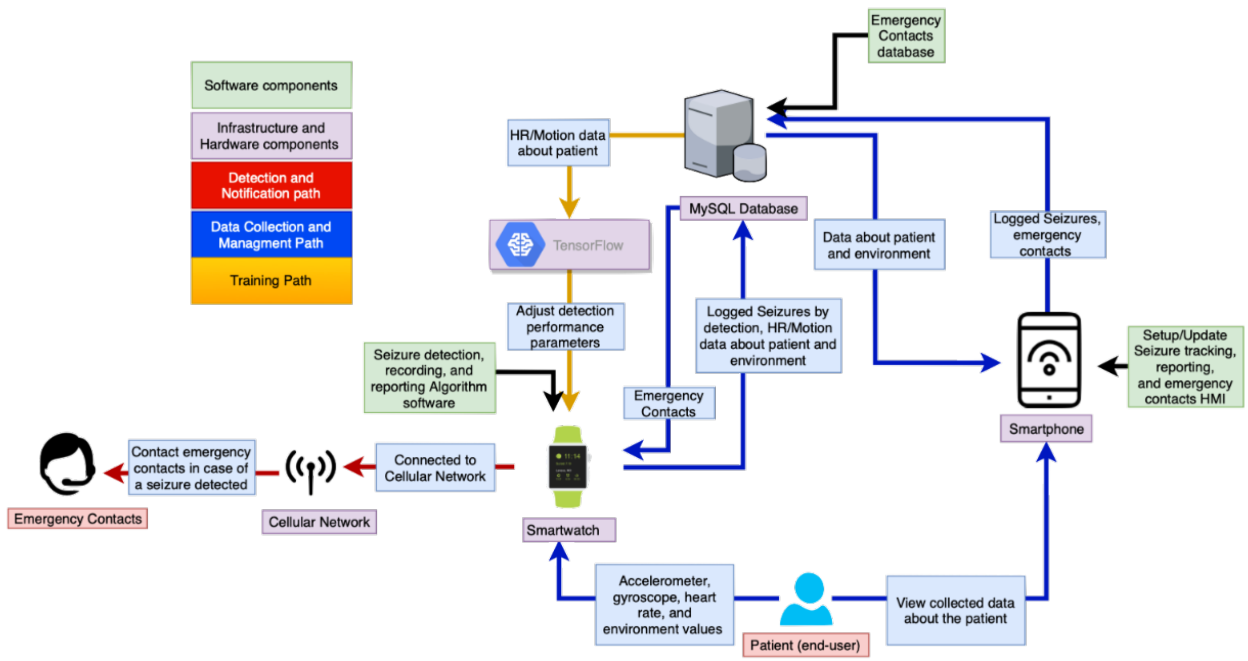

Figure 7: MFCD

2.3 Identification of Case Study

SeizSmart is being developed for individuals who experience epileptic seizures themselves, and for the caretakers of patients who suffer from seizures. This product will offer a peace of mind to both the end user and family and friends of the patient. The end user's anxiety will be eased as they feel a sense of safety and security knowing that their chosen emergency contact will always be notified if they become unresponsive while undergoing a seizure. Family and friends who are close to the patient typically worry about the wellbeing of their loved one who suffers from epileptic seizures. The hope is that these individuals will also find a peace of mind knowing that SeizSmart will always be there with their loved ones, even when they cannot be. In the future, I can anticipate SeizSmart being used to predict seizures in some situations, if specific patterns of biometric readings can be detected after a history of seizure data is accumulated and the seizure profile and machine learning algorithm for the individual is enhanced. If this occurs, I expect that doctors and researchers will be interested in studying this data and findings and attempt to use the information to aid new methods to prevent, (or at least, to anticipate and be prepared for), seizures.

3. SeizSmart Prototype Description

3.1 Prototype Functional Goals and Objectives

The prototype for SeizSmart will simulate real world data. Research will be conducted to obtain relevant data already collected from other researchers in similar trials. A weighted random number generator will be designed to generate random values with the same distribution from those findings. A seizure will be detected based off threshold values determined ultimately by the detection algorithm. A neural network is a machine learning method that is defined as a linear combination of monomial terms, where the constants are changed until the function matches the desired output. This is the method chosen by the development team to detect seizures. Developers will demonstrate that the prototype can accommodate to any simulation of data, meaning that if good input data is provided, the neural network approach to analyzing the data will always apply. Null hypothesis testing will also be done by swapping out trained watched and expecting the detection performance of the watch to be less accurate for foreign test data than for test data from the individual that the watch was trained on.

3.2 Prototype Architecture (Hardware/Software)

Table 1 displays the list of features and elements originally designed during the design stage of SeizSmart. Alongside the products that are intended to be fully functional when the real-world product is released, is a column indicating the actual level functionality that will be exhibited in the prototype. The prototype will physical have all Android hardware and software described thus far. The original design intended to provide a solution for both Android and iOS, but due to time restraints it was determined to focus solely on a solution compatible with Android products for the time being. Additionally, emergency services will likely be unable to be notified at this time as the regulations and possibilities surrounding the option to involve emergency services is not completely clear. It would be unsafe and undesirable to initiate seizures in epileptic patients. Additionally, it seems completely unreasonable to take the time to locate enough epileptic patients willing to be testers for the product. Additional time would inevitably accrue while waiting for them to experience enough seizures to generate adequate testing data for the product. To expedite testing for the product, and to ensure that an appropriate amount of testing is completed, multiple aspects of the prototype will be implemented through the simulation of a seizure event.

Real World Product vs Prototype

Functional elements	Real World Product	Prototype
Detect generalized seizures in real time	Fully Functional	Implemented through simulation of seizure event
Record generalized seizures in real time	Fully Functional	Implemented through simulation of seizure event
Track generalized seizures in real time	Fully Functional	Implemented through simulation of seizure event
Monitor repetitive shaking motion	Fully Functional	Fully Functional
Continuously monitor the user's heart rate	Fully Functional	Fully Functional
Alert emergency contact when the user does not respond	Fully Functional	Fully Functional
Collect data about the environment at the onset of a seizure being detected	Fully Functional	Fully Functional
Use machine learning to detect generalized seizures	Fully Functional	Implemented through simulation of seizure event
Fully functional without dependence on a smartphone or external device	Fully Functional	Fully Completed

Table 1: Prototype Features

3.3 Prototype Features and Capabilities

The prototype will take recorded heart rate and body movement data from patients who underwent similar clinical trials, using the information to train a neural network for testing purposes. The trained watch will be fed random test data that is similar to the data obtained from the outside trials and will be able to indicate whether or not based off of the trained seizure profile and detection algorithm that the individual is experiencing a seizure. The accuracy of the results will be analyzed, and accuracy of the detection will indicate that the software is able to take body movement and heart rate behavior simultaneously, along with other environmental variables and the user's seizure profile, and correctly detect if the patient is having a seizure. Configurations will be adjusted and monitored for appropriate changes in results as the sensitivity of the detection algorithm is increased and decreased.

3.4 Prototype Development Challenges

A potentially major challenge that may come from developing our prototype is the time needed to become adequately knowledgeable of the multiple API's we will be accessing. Learning the smartwatch, smartphone, and TensorFlow API's may have a hefty learning curve for those who have not worked with these APIs previously.

Another challenge is that we are using off the shelf smartwatch technology manufactured by Android rather than the smartwatch used being specialized and developed and manufactured by SeizSmart. This means that the manufacturers statements regarding their hardware must be trusted. Although these features are suspected to be good enough for detecting seizures, the sensitivity and precision of the watch hardware, such as the accelerometer rotation, is otherwise unknown. This creates a possibility that slight tremors which may be comparable to a person shivering from the cold, are difficult to detect.

The server being developed is behind a firewall. This means that order to test the server in a realistic environment, the development team will need to setup a VPN client or SSH-tunneled access allowing the server to be used efficiently.

4 Glossary

Emergency Contact: Anyone who cares for a patient; usually family members.

Patient: An individual who experiences generalized seizures. May also be referred to as the end-user.

Seizure Profile: Personalized for each patient, describes information regarding the individual's typical seizure, such as physical indicators, or their typical threshold for specific biometrics during a seizure. The seizure profile is used to provide more accurate seizure detection. Technically; a matrix of weights computed from training data used to classify new inputs as seizure or non-seizure related.

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