Lab 1- SeizSmart Description

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1. Introduction

SeizSmart is envisioned to be a mobile application for detecting, tracking, and reporting epileptic seizures in real time. SeizSmart will allow users to notify their emergency contacts in cases where they are having a seizure. It will also provide users the ability to view data collected from the smartwatch sensors.

More than fifty million people worldwide suffer from epilepsy, making it one of the most common neurological diseases in the world (Epilepsy Foundation, 2019). As shown in Figure 1, individuals with epilepsy are three to six times greater at risk of premature death and 80% live in low and middle-income countries.

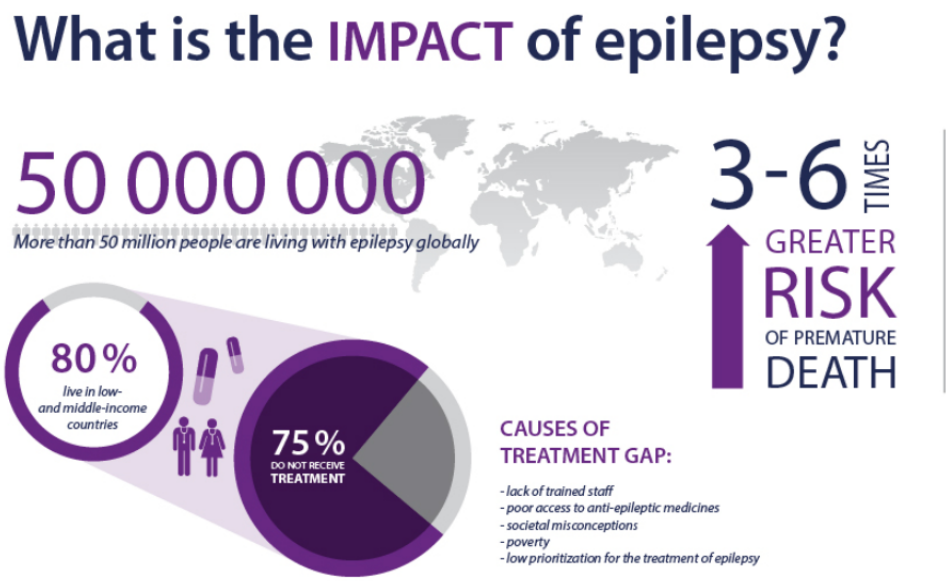

Figure 1: Background of Epilepsy

Epilepsy is a neurological disorder where someone can have a consistent occurrence of seizures. The difference between epilepsy and seizures is that a seizure is a single occurrence while epilepsy occurs consistently throughout the individual's life. The most common type of seizures are generalized seizures. The six types of generalized seizures are tonic-clonic (Grand Mal),

Absence, Myoclonic, Clonic, Tonic, and Atonic. Detection algorithms pick up characteristics of epileptic patterns of generalized seizures in real time. SeizSmart will be able to detect five out of six (5/6) types of generalized seizures. It will not be able to detect Absence seizures because there is not enough observable data at the onset of the seizure to determine if a person is having a seizure.

The three key phases during a generalized seizure are the preictal, ictal, and postictal phases. The preictal is before the seizure, the ictal is during the seizure, and the postictal is after the seizure. As shown in Figure 2, when the patient transitions from the preictal to the ictal phase, there is a rapid increase in heart rate within seconds. As the patient transitions to the postictal phase, the heart rate begins to return to its baseline levels. The ictal phase also includes repetitive body movements and a rapid change in heart rate. As the individual with generalized seizures transitions to the postictal phase, there is a loss of consciousness, which is an emergency. For example, if a person is swimming and has a generalized seizure that results in loss of consciousness and no one is there to help, they can potentially lose their life.

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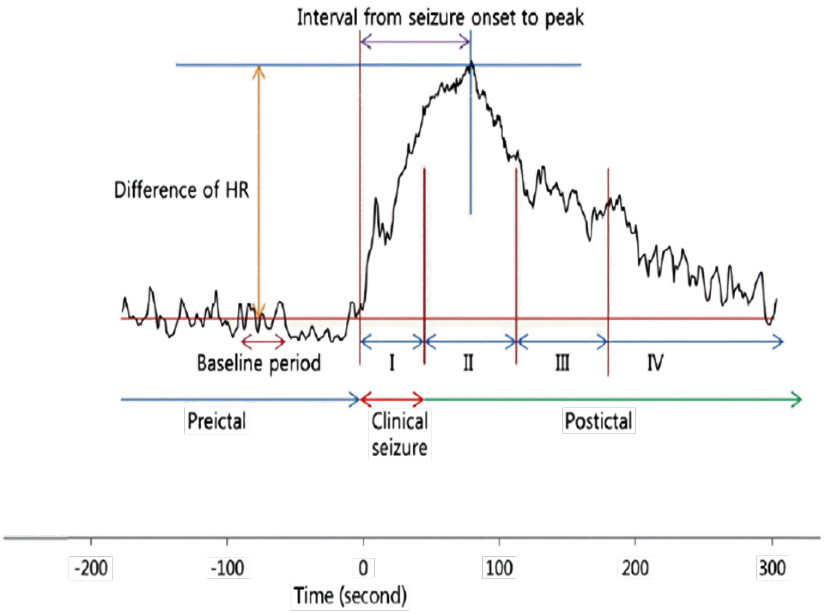

Figure 2: Interval from seizure onset to peak

As depicted in the current process flow in Figure 3, one of the key shortcomings of existing solutions for detecting generalized seizures is that they do not detect based on a combination of heart rate and body movements. Existing solutions only rely on body movements. As a result, it is easy to trigger a false positive by simply jerking your hands around (Velez, 2016). In addition to relying on one metric to detect the onset of a seizure, existing solutions also rely on a relay device in order to notify the patient's emergency contact.

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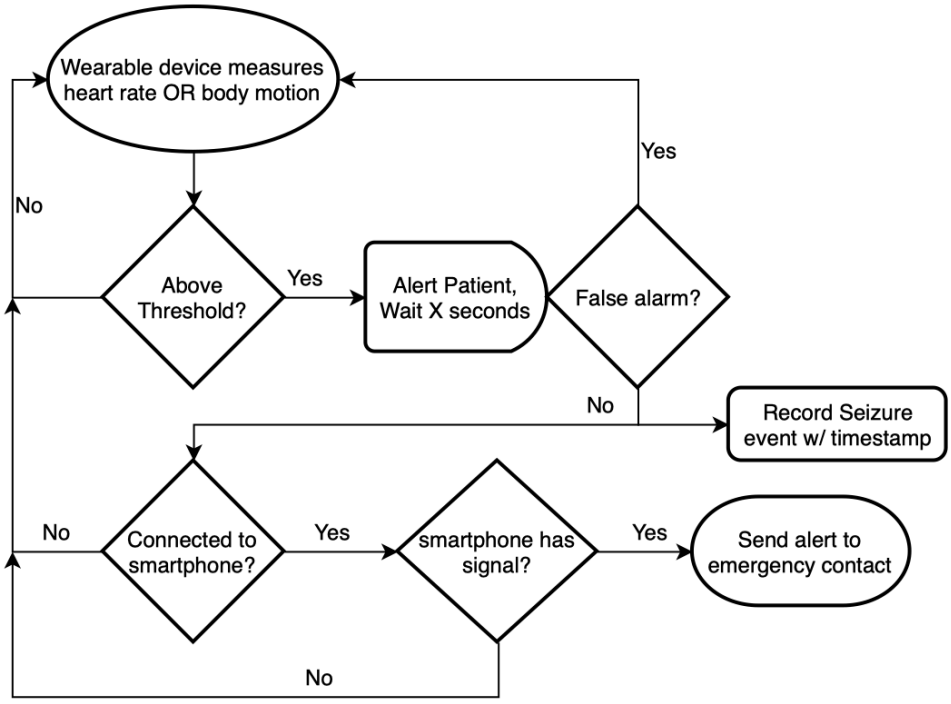

Figure 3 Current Process Flow

2. SeizSmart Description

SeizSmart is designed to be an application that will run both on the smartwatch and the smartphone. The smartwatch application will use the 3-axes of acceleration, gyroscope, and heart rate readings to build a trained neural network that will determine when a user is having a seizure. The smartphone component will be able to build visualizations from the data collected from the smartwatch, display alerts in cases where a seizure is detected, and give users the ability to configure their emergency contacts.

2.1 Key Product Features and Capabilities

One of the unique features of SeizSmart is that it uses a trained neural network to build a seizure profile that will be unique for each individual user. It detects seizures based on a combination of heart rate and body movement behavior, which are the two key observable characteristics shown in Figure 2. SeizSmart uses the two metrics of heart rate and body motion

as opposed to its competitors that only use one or the other. It will not require a relay device because the smartwatch and smartphone run independently of each other. This increases the mobility of the user by not requiring them to be in close proximity of the smartphone. As shown in Figure 3, SeizSmart begins by measuring the user's heart rate and body motion, then compares those measurements against the users' seizure profile. If it is a match, it alerts the user and the user's emergency contact. If either the user or the emergency contact clear the alert, then the last resort emergency contact will not be notified. Data about the patient will be consistently collected from the smartwatch and will be tagged as seizure or non-seizure data.

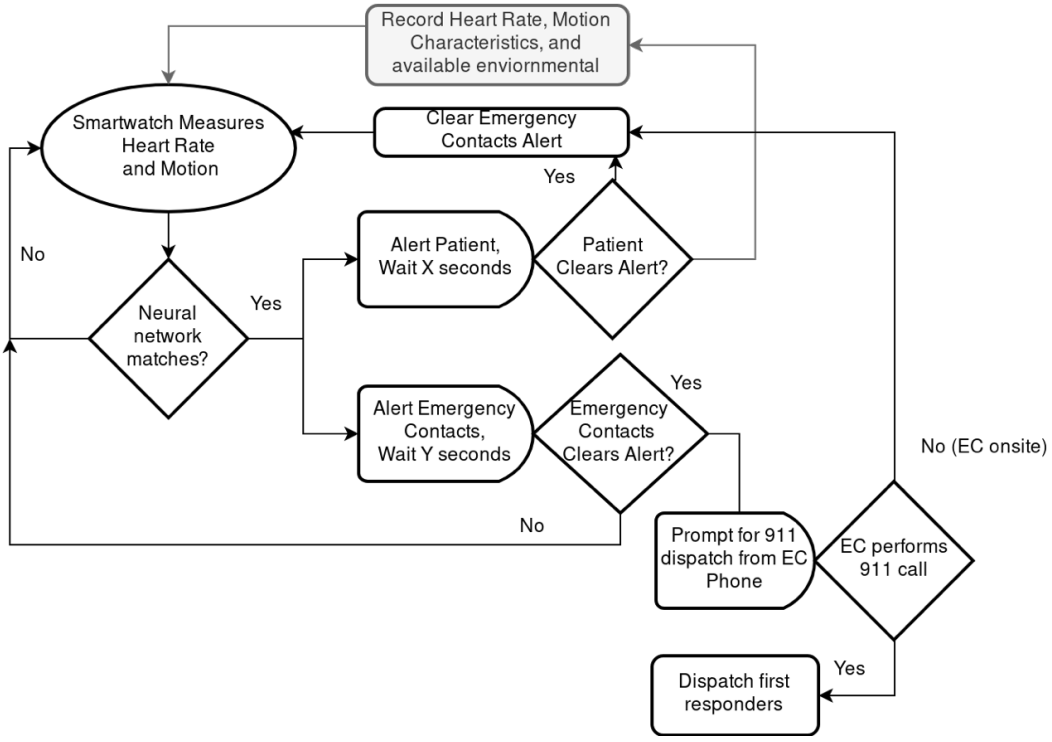

Figure 4: Solution Process Flow

As shown in Figure 4, the detection algorithm will start off by measuring ten seconds of accelerometer, gyroscope, and heart rate data. If the data collected is not based on simulation data, it will be multiplied by 10 and normalized between one and zero to be fed through a trained neural network. If the confidence from the trained neural network is above the predetermined

action threshold, which is a value between 0 and 1, it will proceed to the reporting algorithm, where the patient's emergency contact will be notified.

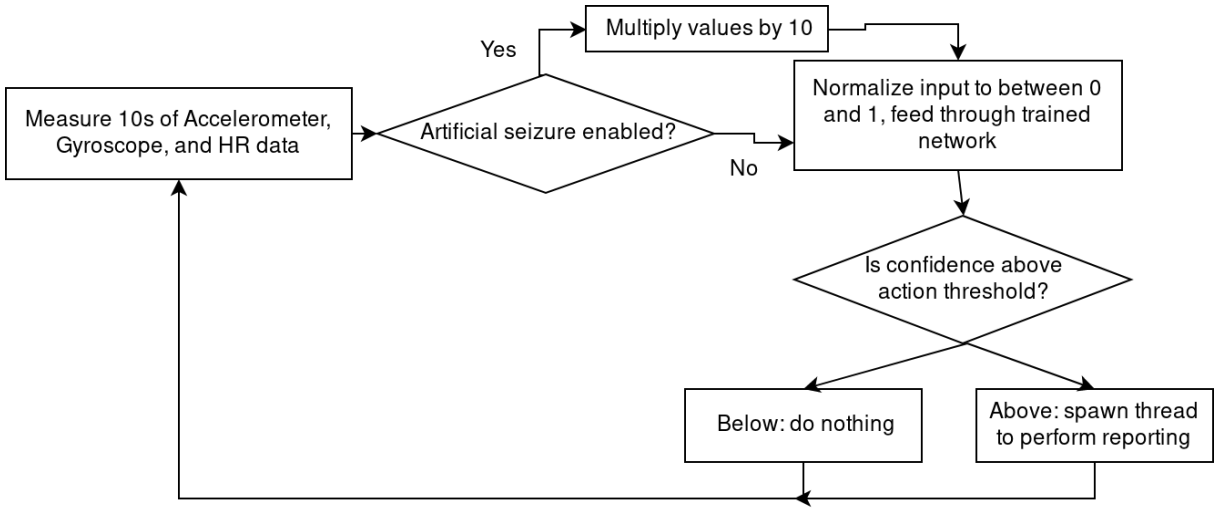

Figure 4 Detection Algorithm Logic Flow

The reporting algorithm will be invoked as soon as a seizure is detected. One of the unique features of SeizSmart is that it announces a public first aid audio alert from the watch, which can potentially get the attention of someone to help the patient. It will also push notifications to all emergency contacts directly from the smartwatch after verifying cellular or WiFi connection. The emergency contacts will be contacted via text message. This will be done by using an SMS gateway that will send an email as an SMS text message. If the emergency contact confirms the seizure, they will be prompted to call 911. The reporting algorithm logic flow is depicted in Figure 5.

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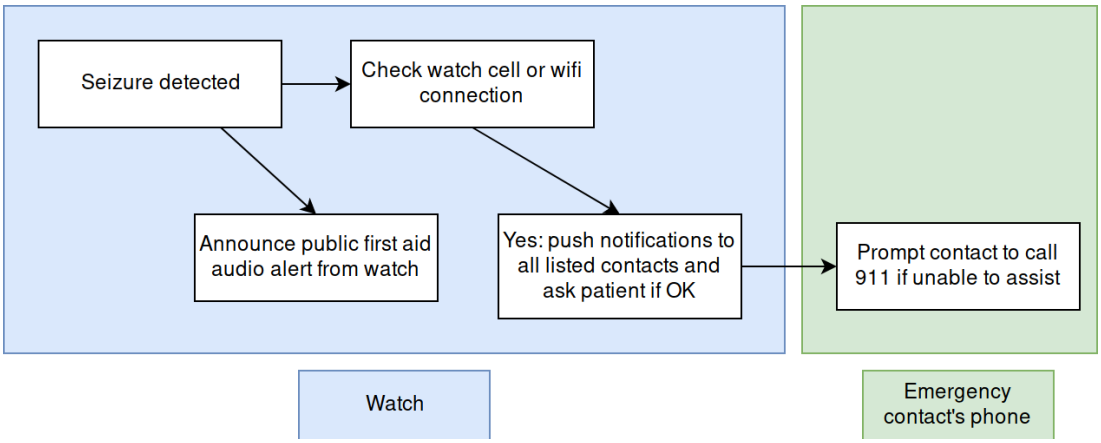

Figure 5 Reporting Algorithm Logic Flow

The purpose of the recording algorithm is to record seizure related data that will be used in the detection algorithm. The cycle begins by the smartwatch collecting data and storing it in the internal smartwatch database called SQLite. At a specific time interval, the data collected will be pushed to the MySQL database for permanent storage. After receiving a successful response from the server on the watch, the uploaded data will be removed from the smartwatch to free up space and the cycle will restart.

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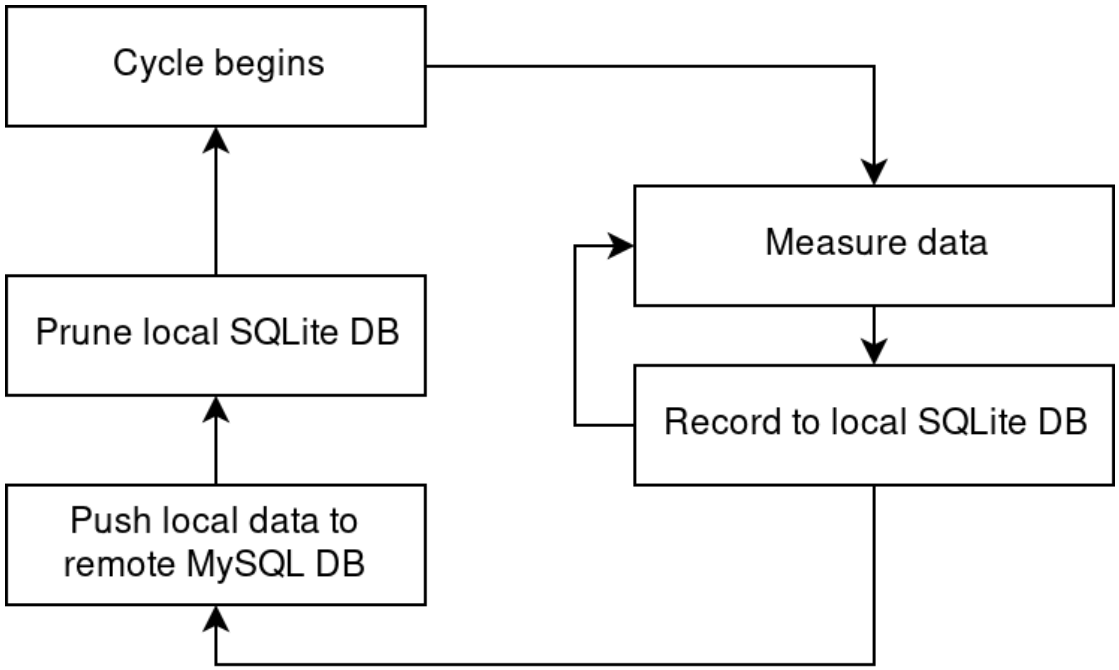

Figure 6 Recording Algorithm Logic Flow

2.2 Major Components (Hardware/Software)

SeizSmart consists of three main components. The smartwatch application will be responsible for detecting seizures and sending an alert to the user and the user's emergency contact(s) when a seizure is detected. The smartphone application gives users the ability to view data collected from the smartwatch, report false positives, and configure their account. The server will be responsible for hosting the database that consists of two main tables: the User Profile and Seizure Data. The User Profile will contain basic user information such as their account credentials and emergency contacts. Seizure Data will contain data collected from the sensors on the watch with a Boolean value to indicate if a seizure occurred. There will also be an internal database that will be running on the smartwatch. It will hold temporary data that will be sent to the external database hosted on the server.

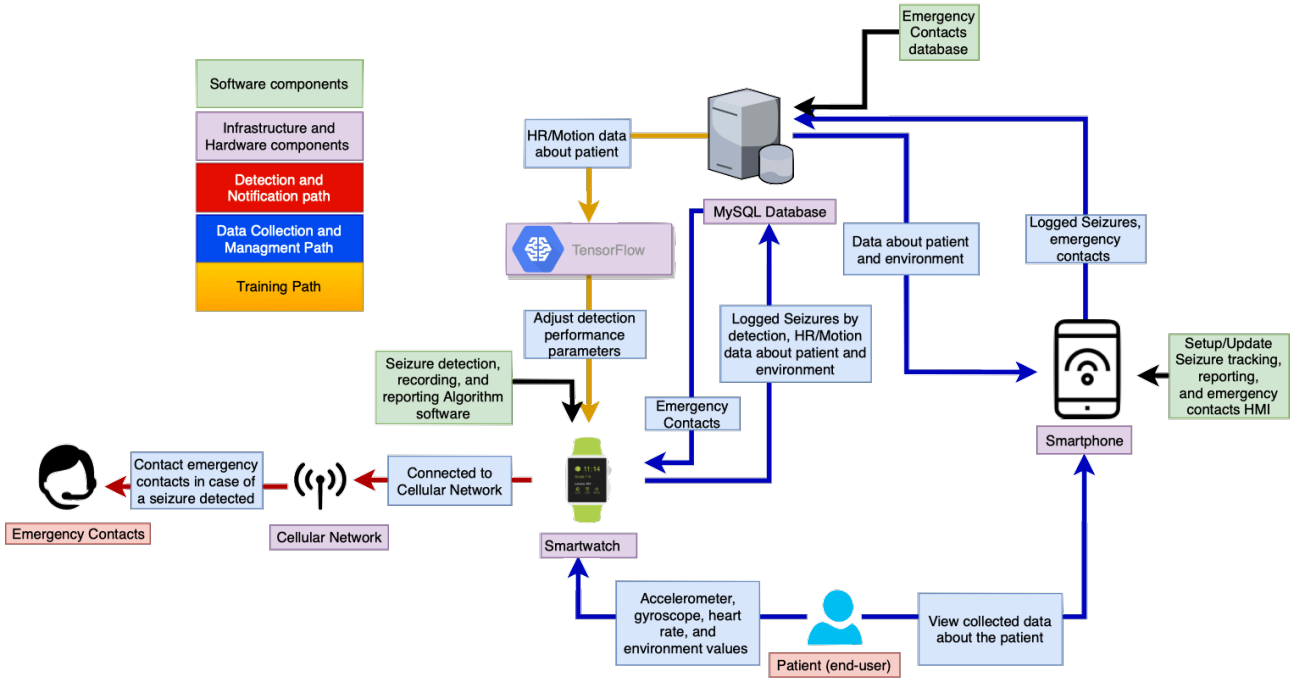

Figure 7: Major Functional Component Diagram

SeizSmart will utilize the hardware specified in Figure 7. The smartwatch application will utilize cellular network to contact emergency contacts when a seizure is detected. The smartphone will be responsible for configuring and updating seizure tracking as well as editing emergency contacts. The smartwatch will be collecting accelerometer, gyroscope, and heart rate data from the end-user as well as environmental data that can act as a potential trigger to a seizure. The algorithm that will be used to detect seizures will run on Google's TensorFlow library and will receive heart rate and motion data from the external database running on the server. The output of the detection algorithm will be used to tune the detection performance parameters on the smartwatch.

2.3 Identification of Case Study

The target customer base will be the concerned party of individuals with epilepsy. This can be a friend or family member of the epileptic individual. The target customer will also include medical providers; the data collected about the individual with epilepsy can be valuable to doctors in better understanding the patient's seizures. The end user will be anyone with epilepsy who has generalized seizures.

Existing solutions do not detect generalized seizures based on a combination of heart rate and body motion. They also require a relay device, and some require special hardware. SeizSmart leverages off-the-shelf smartwatches, which the end user may already have, to detect generalized seizures based on a combination of heart rate and body motion, without requiring a relay device.

3 SeizSmart Prototype Description

The SeizSmart prototype will implement all algorithms required for the final product. The seizure data will be generated by simulating the characteristics of generalized seizures, which are a rapid change in heart rate and repetitive body motion. The distribution of the smartphone and smartwatch application will be limited to an internal development team. The key benefits of implementing the prototype are that it will validate all algorithms, and highlight flaws in design and implementation.

3.1 Prototype Functional Goals and Objectives

The objective of the prototype is to demonstrate that generalized seizures can be accurately detected based on a combination of heart rate and body movements, while running in off the shelf technology. It will validate SeizSmart detection algorithm running on the server and reporting algorithm that will be running on the watch and smartphone. Seizure data will be

simulated based on publicly available data. The prototype will detect based on a trained neural network, which will demonstrate that the detection process will be unique for each individual patient.

3.2 Prototype Architecture (Hardware/Software)

The prototype architecture will consist of a cloud server as well as a smartphone and smartwatch. A daily batch job will read biometrics from the MySQL database running on a cloud server and will train the neural network using the Tensorflow machine learning library. The output of the machine learning algorithm will be recorded to the database. The biometric readings from the daily trained neural network will then be stored in the smartwatch internal database to tune the detection parameters, which will make the detection process unique for each individual patient.

The prototype server infostructure will be composed of one cloud server responsible for hosting the Tensorflow machine learning library and the MySQL database. It will also be responsible for running any needed server side software during development.

3.3 Prototype Features and Capabilities

The prototype will have minor differences compared to the final product. The prototype will be limited to smart devices running Android and some features will be eliminated from the prototype due to the shortage of development time. A complete comparison of features that will be implemented for the prototype can be found in Table 1.

The prototype will perform the detection algorithm on simulated data. The data will be generated based on publicly available data to determine a baseline set of data, as well as, data that represents the onset of a seizure. The prototype will be able to record and track generalized seizures in real time, which will be implemented through the simulation of a seizure event. The

prototype will also be able to alert emergency contacts directly from the smartwatch by having the smartwatch application run independently of the smartphone.

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

3.4 Prototype Development Challenges

The development of the prototype will require the mitigations of correlating data between motion sensors and heart rate readings, battery drainage due to high use of sensors, and running out of development time. The same sampling rate will be given to both motion sensors and heart

rate readings to correlate the data. Only sensors that are being used will be turned on to minimize battery drainage.

4. Glossary

Absence Seizure: A generalized onset seizure that lasts only a few seconds causing the patient to suffer lapses in awareness. Formerly known as a petit mal seizure.

Atonic Seizure: Also known as drop attacks. In this kind of seizure, some or all of the patient's muscles suddenly become limp.

Complex Partial Seizure: A brief seizure that starts in one side of the brain, also referred to as a focal (onset) impaired awareness seizure. During this kind of seizure, the patient loses awareness of their surroundings.

Clonic Seizure: A seizure characterized by sustained, rhythmic jerking of the patient's body.

Emergency Contact: Anyone the patient lists to contact during an emergency; usually family members.

Epilepsy: A neurological disorder characterized by multiple unpredictable seizures.

Myoclonic seizure: A seizure characterized by brief jerking or twitching of muscles.

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

Seizure: A disturbance in the brain caused by a sudden surge in neuroelectric activity.

Seizure Profile: Personalized for each patient, describes information regarding the individual's typical seizure, such as physical indicators, or their average 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.

Simple Partial Seizure: A brief seizure that starts in one side of the brain, also referred to as a focal onset aware seizure. During this kind of seizure, the patient does not lose awareness of their surroundings.

Tonic Seizure: A seizure in which the patient's body, arms, or legs suddenly stiffen.

Tonic-Clonic Seizure: What most people think of when they hear the word "Seizure." It combines the characteristics of tonic and clonic seizures; a type of generalized seizure that involves a loss of consciousness and violent muscle contractions.

Last resort emergency contact: the last person that will be notified in cases where emergency contacts do not respond.

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