Lab 2 - SeizSmart Product Specification

CS 411W Lab II

SeizSmart Product Specification

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Version 2

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1 Introduction

SeizSmart is a work-in-progress mobile application for detecting, tracking, and reporting seizures in real-time. SeizSmart will implement a wearable seizure detection method using off the shelf smartwatch and smartphone technology, allowing users to notify emergency contacts when a seizure is in progress automatically.

Epilepsy is a neurological condition causing seizures, disruptions of the electrical communication between neurons. Epilepsy is characterized by sudden disturbances of perception or behavior caused by excessive neuroelectric activity. Figure 1 shows the global impact of epilepsy. According to the WHO, with more than fifty million people living with epilepsy globally, epilepsy is the fourth most common neurological disorder in the world after migraines, stroke, and Alzheimer's.

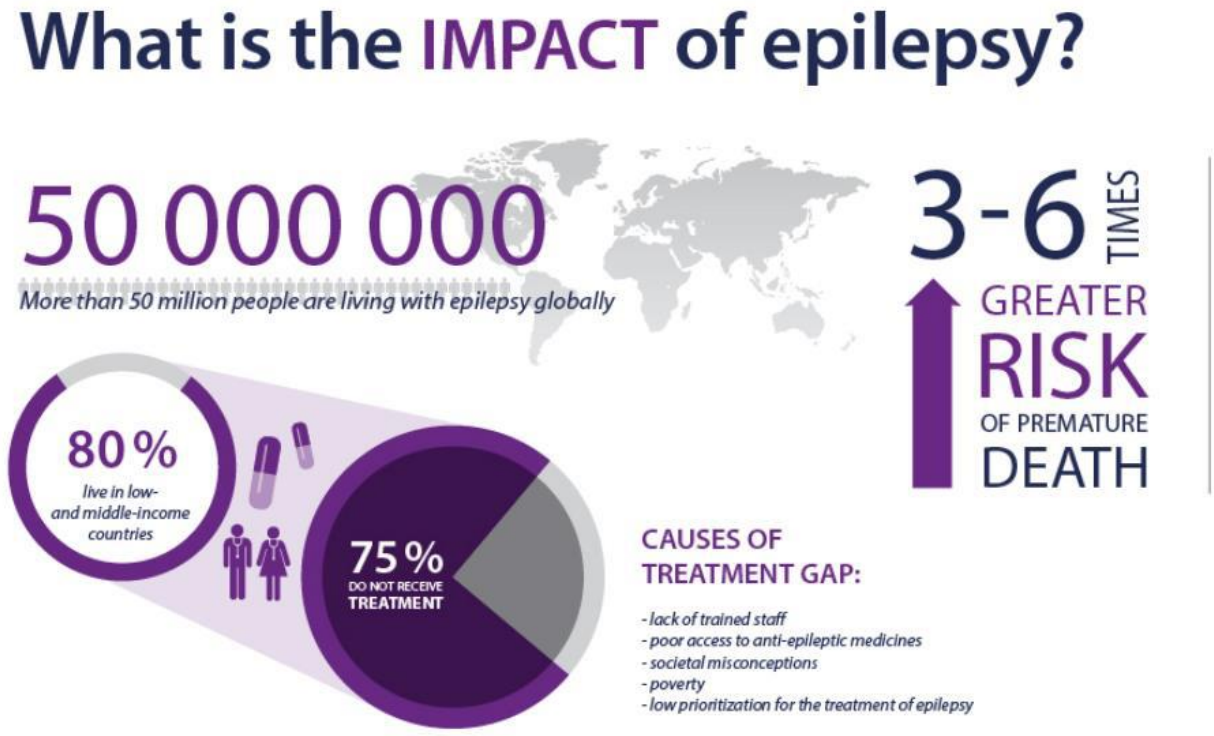

Figure 1: Impact of Epilepsy

A tonic-clonic seizure causes the patient's muscles to contract violently. The tonic-clonic seizure is the most infamous form of seizure and the kind that most attribute to seizures in general. According to the American Epilepsy Society, around 25% of persons with epilepsy experience tonic-clonic seizures in their life. These seizures can be especially dangerous to the patient, causing accidental injuries or even death.

Seizures come in three main phases, the preictal, the ictal, and postictal phases. The preictal phase is the time before the onset of a seizure. This phase significantly varies between patients. Some experience what is known as an aura, a simple partial seizure that can act as a warning sign for the patient. Other patients experience nausea, headaches, or other forms of discomfort for hours to a full day before the seizure with no indication of when the seizure will take place. Not every patient experiences something at this stage; for those patients, the onset of a seizure can come as a complete surprise.

The ictal phase is where the clinical seizure occurs. It is during this phase that the patient's body will start to go through distinguishable physical changes, shown in Figure 2. During this phase, the seizure will affect the patient's heart rate and rhythm. The most common heart rate pattern during a seizure is a steep acceleration at the onset of the seizure, followed by variations during and after the ictal phase. During a study on the cardiac effects of seizures, researchers found that the heart rate patterns during and after this phase were very similar in seizures from the same patient. This is also the phase where the patient experiences muscular convulsions during a grand-mal seizure. These convulsions provide another means for detection through rapid changes in acceleration.

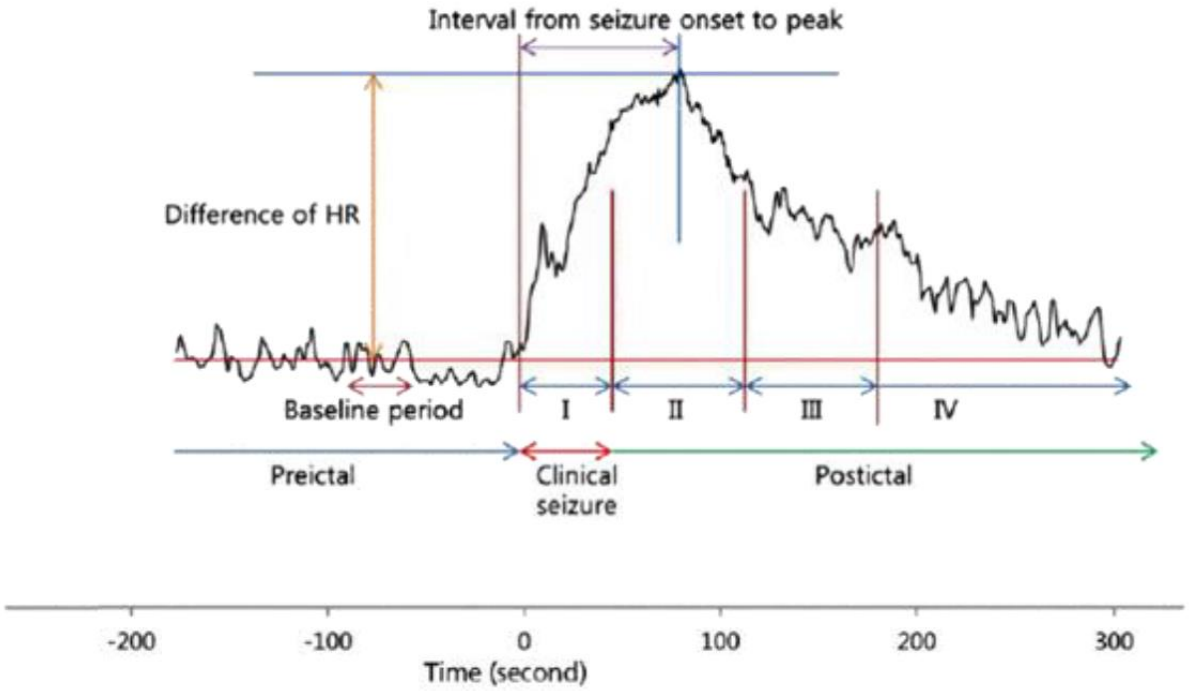

Figure 2: Variations in Heart Rate During The Phases of a Seizure

The postictal phase occurs directly after the seizure subsides, where the patient experiences an altered state of consciousness caused by neuronal exhaustion and hyper-inhibition. It is during this time that the brain recovers from the seizure. Symptoms of the postictal phase can present themselves as changes in behavior, mood, and physical health. At this point, the patient's convulsions have stopped, but the pattern in heart rate

1.1 Purpose

SeizSmart is intended to be an application that uses a trained neural network algorithm to detect generalized seizures in real-time based on a combination of heart and motion data. It will use modern smartwatch technology to monitor the patient's biometrics, detect the onset of a generalized seizure, and directly notify the patient's emergency contacts.

When implemented, SeizSmart will provide peace of mind to patients who suffer from generalized seizures and the patient's caretakers. Patients who are unsupervised when

experiencing a generalized seizure are at a higher risk of injury or death. SeizSmart will notify caretakers of seizures when they happen, reducing the need for constant supervision and allowing patients and their caretakers more freedom to go about their lives.

SeizSmart will keep track of the patient's seizures in a log available to and manageable by the patient and their caretaker. This feature will provide a semi-automatic way to track their seizure history. The log will contain the date and time the seizure took place, and the available sensor data for that period. This information could help narrow down possible seizure triggers for the patients. The information may also bring attention to changes in how frequently the seizures occur and the duration of the seizures, better informing the patient's physician of what action to take in the treatment.

SeizSmart will not be able to predict seizures before the onset of known symptoms. It will only be able to detect an in-progress generalized seizure. It will not be able to detect absence seizures because this kind of seizure is very brief and does not present biomarkers detectable by a smartwatch. SeizSmart is not a medical application and is not intended to be used in the diagnosis, monitoring, prevention, or treatment of epileptic seizures.

1.2 Scope

SeizSmart will consist of an Android watch app for seizure detection, an Android phone app for reporting, recording, and adjusting detection thresholds. It will have a TensorFlow neural network to generate the detection algorithm. For the prototype, there will be a seizure data simulator that will generate data similar to what might be expected from patients using the watch using weighted random number generation.

SeizSmart will have the ability to learn from simulated experimental data and send an alert to emergency contacts. The detection algorithm should be able to detect seizure events in simulated data that were not used in training. As more data is used to train the model, the accuracy of the detection algorithm should increase. The prototype should also have an option to trigger the behavior corresponding to a seizure event manually. When triggered, the watch will issue an alert and start a countdown with an option to abort followed by sending an SMS alert to the patient's emergency contacts and tagging the corresponding data as a seizure.

1.3 Definitions, Acronyms, and Abbreviations

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 who cares for a patient; usually family members.

Epilepsy: A neurological disorder characterized by multiple unpredictable seizures.

Generalized Seizure: Seizures that affect both cerebral hemispheres from the onset of the seizure.

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

MySQL: My Structured Query Language, an open-source relational database management system. Named after co-founder Monty Widenius's daughter, My.

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.

SMS: Short Message Service, A text messaging service used by most mobile devices.

SQLite: Structured Query Language Lite, A database management system that is designed to be embedded into the end program, rather than accessed externally.

TensorFlow: An open-source machine learning library for research and production.

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.

Neural Network: A set of algorithms designed to learn and recognize patterns in raw data.

Weighted Random Number Generation: A process to generate a number where different values have set probabilities that are not necessarily uniform.

WHO: World Health Organization, a global organization that works to combat diseases.

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1.5 Overview

This product specification provides an outline of the SeizSmart prototype, specifically the hardware and software that will be utilized by the application, the capabilities and features it will demonstrate, and the requirements necessary to meet the objectives discussed in Section 1.1. Section 2 of this document will provide a summary of the prototype's architecture, a discussion of its functionality, and an explanation of the external interfaces required.

2 General Description

The Seizsmart Prototype will work as a proof-of-concept for using machine learning to detecting and reporting reporting seizures from a smartwatch.

2.1 Prototype Architecture Description

SeizSmart is comprised of the following major components shown in Figure 3:

2.1.1 Hardware

- Smartwatch: The primary frontend device for the end-user. It will monitor the patient’s heart rate and motion metrics using the watches accelerometer, gyroscope, optical heart-rate sensors. The watch will temporarily store these recordings locally using an SQLite database. It will analyze the data as it records, searching for patterns indicative of a generalized seizure.

- Smartphone: The smartphone application will be used to configure account settings for the end-user. The application will also allow users to view a log of their past seizures with corresponding sensor data. From the seizure log, the user will have the capability to add seizures that were undetected by SeizSmart and remove falsely detected seizures.

- Cloud Server: Will host a MySQL database and the TensorFlow neural network training algorithm. must be on a network accessible by the smartwatch and the patient's smartphone.

2.1.2 Software

- Recording Algorithm: Will gather seizure-related data to be used in training. The algorithm will read the sensor values on the smartwatch and record them to a local SQLite Database. The local data will be pushed to the cloud server's MySQL Database on a daily basis.

- Reporting Algorithm: Used to notify the patient's emergency contact in the event of a seizure. the smartwatch will act as a medical alert bracelet, indicating the patient is epileptic and sounding an alarm. The watch will then send a notification to the patient's emergency contacts, alerting them of the patient's status and GPS location, if available.

- Detection Algorithm: Used to distinguish when a patient is having a generalized seizure in real-time using a trained neural network. When it detects a seizure, it will trigger the Reporting Algorithm.

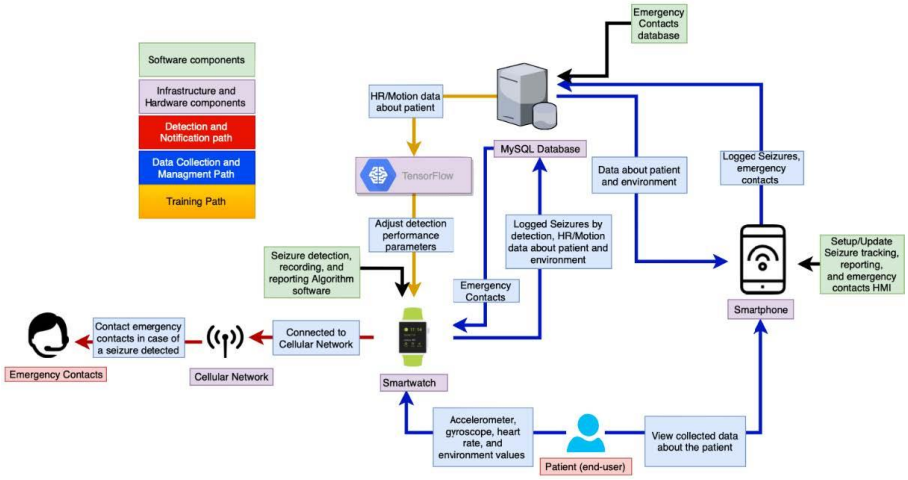

Figure 3: Major Functional Component Diagram (MFCD)

2.2 Prototype Functional Description

The major functions of the SeizSmart prototype include the following:

- Threshold Manager: This function will allow the end-user to define the sensitivity of their detection algorithm. If the end-user would rather make sure that every generalized seizure is detected, but some non-seizure activity is falsely detected, they can decrease their detection threshold. Alternatively, if the end-user is receiving too many false seizure reports, they can increase the detection threshold to reduce this.

- Data Offloading: Data stored on the watches SQLite Database is sent to the MySQL database, and the SQLite Database is pruned to save space on the watch.

- Emergency Contact Manager: This function will allow the end-user to add and remove contacts on their emergency contacts list. It will also allow them to disable and reenable emergency contacts on their list without fully removing them. A conceptual design for this functionality is shown in Figure 4.

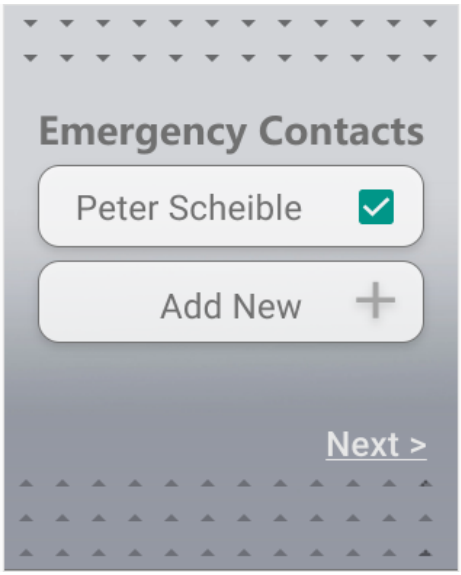

Figure 4: Emergency Contact Manager Concept

- Manual Event Input: This function will allow the end-user to report a generalized seizure that was not originally detected by the detection algorithm, adding to their seizure log and helping to train their personal seizure profile.
- Manual Event Removal: This function will allow the end-user to remove a seizure from their log and from their training dataset.
- Alert Termination: Allows the patient to abort an alert if they are not having a seizure when the detection algorithm indicates they are.

2.3 External Interfaces

This section identifies the physical and logical interfaces used within and by the prototype. The characteristics of each type of interface used and the type of information transferred are described.

2.3.1 Hardware Interfaces

- The smartphone and smartwatch will be interfaced with a Bluetooth connection.
- The smartphone will communicate with the patient's emergency contacts through a cellular network.
- The smartwatch and smartphone will communicate with the Cloud Server over a wi-fi or cellular network internet connection.

2.3.2 Software Interfaces

- The smartwatch app will interface with an SQLite database for data storage.
- The cloud server will interface with TensorFlow to train the detection algorithm.

- The cloud server will store its data on a MySQL database.
- The smartphone and smartwatch will connect over a Wear OS interface.

2.3.3 User Interfaces

The user will interact with SeizSmart with the touchscreens on their smartphone and smartwatch.

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