Lab 2 – SeizSmart Product Specification

Danielle Luckraft

CS 411

Professor Thomas J. Kennedy

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Version 2

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1 Introduction

SeizSmart is designed to detect, track, and record seizures in real time. A smartphone, a smartwatch, an SQL database and machine learning technologies are meticulously combined to offer these capabilities. SeizSmart will demonstrate the power of machine learning by implementing efficient methods that are presumed to detect seizures more accurately than competing products. The prototype will closely mimic the real-world product, with only minor differences. The SeizSmart prototype will partially consist of off the shelf technology, including a smartphone and smartwatch. The smartwatch is designed to collect and store various biometric readings from the patient, detect seizures, and send notifications once a detection is made. The smartwatch and the smartphone independently provide a user interface for the patient and alert the patient of a seizure. The prototype for SeizSmart will be almost identical to the real-world product.

1.1 Purpose

SeizSmart will enable a collaboration of smartwatch and smartphone technology to record and report an individual's biometric readings and seizure data. The final product will detect seizures experienced by a patient based on a combination of their heart rate and exhibited body movements and will notify their emergency contact(s) if they appear to be in danger. The SeizSmart prototype smartwatch application will use the 3-axis acceleration, gyroscope, and heart rate sensors of the smartwatch to gather heart rate and body motion readings from the patient. A machine learning method called a neural network will be implemented within a detection algorithm to determine in real time if a patient is having a seizure. A recording method will be used to store biometric data for training the neural network. The smartphone application will be used by the patient to receive notifications if a seizure is detected. A reporting algorithm will be responsible for notifying the patient's emergency contact(s) with a text message when the patient does not abort their alert within a timely manner. The smartphone user interface will be used for configuration and will provide visualizations of seizure data for the patient to view. At this time, SeizSmart is intended to be strictly limited to detecting and tracking seizures and will not be a tool capable of predicting seizures. Out of the six types of generalized seizures, SeizSmart will be able to detect five of them. The term "generalized seizure" is indicative of a seizure that occurs throughout the entire brain. SeizSmart will not be capable of detecting an absence seizure, because a patient experiencing this type of seizure displays no measurable symptoms.

1.2 Scope

The prototype for SeizSmart will implement all components of the anticipated real-world product, for only Android smartwatches and smartphones. Collecting real-time seizure data from patients for testing purposes is not realistic, so seizure data including motion biometrics and heart rate will be simulated for prototype development. The prototype will demonstrate the data is appropriately recorded into the local smartwatch database and moved daily to the external server indicating the recording algorithm is successful. The prototype will demonstrate proficient learning and alerting capabilities. It will verify the machine learning approach using a neural network can be successfully utilized by the detecting algorithm. The prototype will also be used to confirm that appropriate notifications are issued to alert the user and emergency contact, implying success of the reporting algorithm.

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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. Due to the lack of measurable symptoms, this type of seizure is the only one out of six types of generalized seizures that SeizSmart is unable to detect.

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: A seizure that occurs throughout the entire brain. Nerve cells on both sides of the brain misfire, causing muscle spasms, black outs, or falls. This contrasts with a "focal seizure" or "partial seizure" which are seen in only one part of the brain. There are six types of generalized seizures: tonic-clonic, tonic, clonic, atonic, myoclonic, and absence.

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

Neural Network: A computer system that is designed to behave similarly to the human brain and nervous system.

Patient: An individual who experiences generalized seizures. May 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 characteristics of tonic and clonic seizures. Formally known as a grand mal seizure.

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1.5 **Overview**

This product specification summarizes the SeizSmart prototype hardware and software configuration, external interfaces, capabilities and features. The sections that follow include information regarding a thorough description of the hardware, software, and external interface architecture of the SeizSmart prototype. The significant features of the prototype will be revealed; the performance characteristics of each key feature will be described in terms of outputs, displays, and user interaction; and the parameters to control, manage, or establish that feature will also be specified. The algorithms for detecting, reporting, and recording seizures are key functionalities of SeizSmart.

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2 General Description

As displayed by the Major Functional Components Diagram in Figure 1, SeizSmart will be composed of three main components including an Android smartwatch, an Android smartphone, and an external server. The prototype will architecturally be very similar to the real-world product. The main components are the smartphone, smartwatch (and the peripheral sensor hardware), and the cloud server that hosts the Machine Learning Model used to detect seizures. Figure 1 displays the overall architecture of SeizSmart.

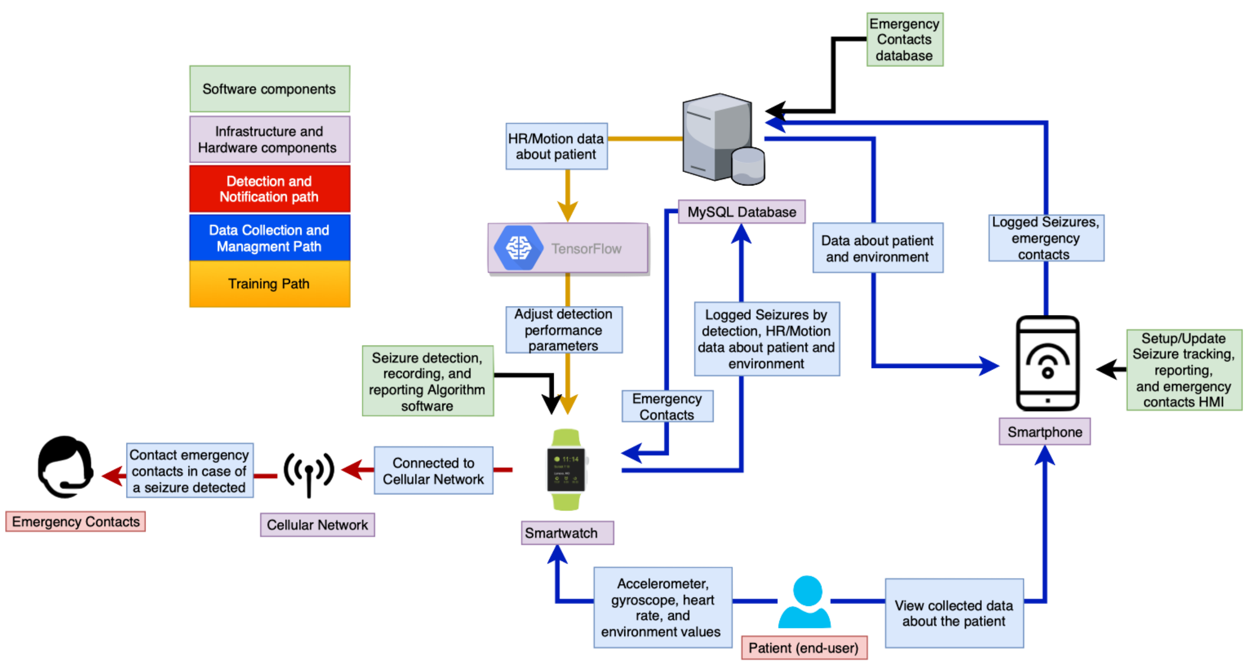

Figure 1: MFCD

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2.1 Prototype Architecture Description

Both the smartphone and watch interface will allow an existing user to log in to the SeizSmart application. The prototype will only provide the option for an existing user to log in; it will not implement the capability to create a new user like the real-world component will. Once the user gains entry, they will continue past a disclaimer. They will view a home screen displaying the patient's current biometric data. A menu option will take the user to other screens that allow the user to interact with the application. The smartphone will provide an interface for the patient to view statistics, configure the settings, and log seizures. The smartwatch will provide an external interface for the user to configure the sensitivity of seizure detection, report missed seizures, and add emergency contacts. Both the smartwatch and smartphone will populate an alert to the display when a seizure is detected and provide the option for the patient to abort the alert. For the prototype, the emergency contacts will be notified of the seizure directly from the patient's smartwatch. The notification will be sent as a text message over Wi-Fi, therefore the emergency contacts will not use the smartwatch app or smartphone app.

The smartwatch used by the patient must come with hardware sensors. The type of sensors included will vary depending on the patient's specific Wear OS compatible smartwatch. The minimal sensors required include the gyroscope, accelerometer, and heart rate sensor. The sensors will be utilized to continuously collect the patient's biometric readings and other environmental variables including temperature, illuminance, air pressure, and humidity. The collected data will be stored locally on the smartwatch SQLite database for up to 24 hours.

The cloud server, hosted by an ODU virtual machine, will contain a TensorFlow Machine Learning Model for a Neural Network and a MySQL database that will hold all recorded biometric data, environmental data, and user profile data. Data stored locally on the smartwatch will be consistently transferred to the server. The TensorFlow Machine Learning Model will be fed the new biometric data daily and will be responsible for training the neural network with the data provided. The newly trained neural network will be transferred to the and will be used to in detecting seizures. The server will also comprise a MySQL database that will hold all recorded biometric data, environmental data, and user profile data for the emergency contact(s). All communication between the server and smartwatch is done via an HTTP REST API provided by the server. Table 1 summarizes the differences between the anticipated product and the SeizSmart prototype.

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Feature	**Final Product**	**Prototype**
Smartwatch		
Biometric Recording	3-dimensional acceleration and rotation will be recorded with millisecond timestamps	3-dimensional acceleration and rotation will be recorded with millisecond timestamps
Seizure Detection	A trained neural network will continuously evaluate 30 second chunks of biometric data and begin alerting on detection of a seizure	A trained neural network will continuously evaluate 30 second chunks of biometric data and begin alerting on detection of a seizure
Alert Process	An API call will be made to tell the server to alert non-SMS contacts, simultaneously an SMS message will be texted to every contact on the emergency contact list.	An API call will be made to tell the server to alert non-SMS contacts
Smartphone		
Alert Reception	Smartphone will listen to a websocket for non-SMS alerts from the server	Smartphone will listen to a websocket for non-SMS alerts from the server
Alert display	Caregiver smartphone will display alert and prompt for 911 call or to clear the alert.	Caregiver smartphone will display alert and prompt for 911 call or to clear the alert.
Patient Configuration UI	Smartphone will have UI for patients to report false positives, tag false negatives, and set confidence thresholds before alerts are triggered.	Smartphone will have UI for patients to report false positives, tag false negatives, and set confidence thresholds before alerts are triggered.
Data Ingest	Server will receive and store timestamped biometric data with seizure tags	Server will receive and store timestamped biometric data with seizure tags
Training	Server will periodically train and store a neural network using past biometric data	Server will periodically train and store a neural network using past biometric data
Alert Propagation	Server will handle websockets to provide real time non-SMS alerts to caregiver smartphones	Server will handle websockets to provide real time non-SMS alerts to caregiver smartphones
REST API	Server will provide a REST API for watches and phones to store and request user settings and trained neural networks	Server will provide a REST API for watches and phones to store and request user settings and trained neural networks

Table 1: Prototype Features

2.2 Prototype Functional Description

Multiple critical functional components are vital to the success of SeizSmart. An extensive machine learning algorithm is required to accomplish the core objective of detecting seizures. The key element of the detection algorithm is a trained neural network, based on the patient's biometric data recorded during a seizure event. SeizSmart encompasses other functional components that are responsible for issuing alerts when a seizure is detected as well as storing the biometric data used in machine learning. The SeizSmart process flow is documented in Figure 2, illustrating relationships among distinctive components of SeizSmart.

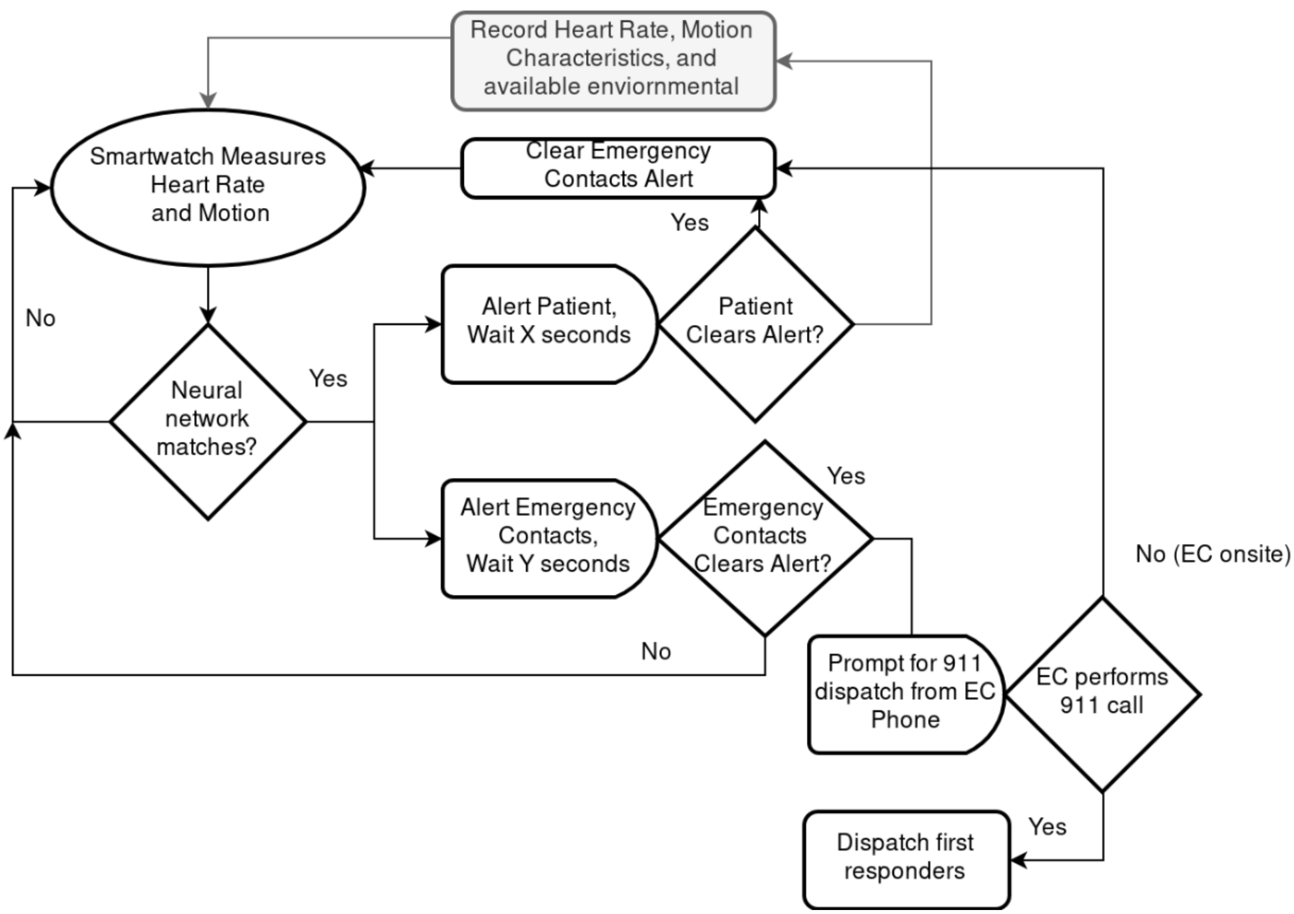

Figure 2: Solution Process Flow

TensorFlow software is utilized to build a unique seizure profile, based on a trained neural network, for each individual patient. The required parameters that need to be fed to the neural network are the accelerometer values, the gyroscope values, the patient's heart rate, and the seizure tag assigned to the seizure data. The seizure tag indicates if the seizure data was recorded during a seizure or not. When the app is initially set up to be used for the first time, taking place on the server, machine learning will be applied to the patient's seizure data history (or general seizure data) to calculate a preliminary neural network. This model will be used to detect seizures based on the values of the patient's current heart rate, body movement, and user-configured sensitivity fed to it. The neural network will be trained daily; detection performance parameters are adjusted every 24 hours based on new seizure data. The new trained weights that form the neural network, will be provided to the smartwatch to be pushed onto the smartwatch to detect seizures.

The detection algorithm implements a machine learning model, known as a neural network, to detect seizures. The patient's real-time biometric data (heart rate and body movement) is continuously monitored via the smartwatch sensors and fed to the neural network. The neural network determines if a seizure is occurring in real time, and the seizure data is marked with a seizure tag to indicate the result. Random training data will be used in training the neural network for the prototype. For purposes of demonstrating and testing the prototype, real time seizure data will be simulated.

When a seizure is detected, the reporting algorithm will issue a cycle of notifications directly from the user's smartwatch. The notifications will first be issued to the user's smartwatch, then vocally to bystanders, and finally to the elected emergency contact's phone as a text message.

The recording algorithm will record seizure-related data used in training. The patient's biometric data will be read by Smartwatch sensors and initially stored on the watch via an SQLite database. Daily, the data is transferred to a MySQL server where stored indefinitely.

2.3 External Interfaces

SeizSmart is comprised of various hardware, software, and user interfaces joined by 3 specific endpoints. The various interfaces offer a flexible user experience for patients that allows them to configure the application and view seizure data from either their smartwatch or smartphone. SeizSmart is specifically designed to ensure seizure patients will be protected by the detecting and alerting capabilities even when the smartwatch is not in the proximity of the smartphone. In other words, SeizSmart will continue to collect data and detect seizures even if the smartwatch is not connected to the smartphone.

2.3.1 Hardware Interfaces

The key hardware interfaces that make up the SeizSmart prototype are the smartphone and smartwatch. Both devices allow the user to communicate with the SeizSmart application. This includes the volume button, the power button, the display surface, and other hardware buttons. The smartwatch also has built in peripheral devices, called sensors, which will differ among smartwatches. The sensors required to use the SeizSmart application are the gyroscope, accelerometer, and heart rate sensor. These are required as they are the essential parameters for detecting seizures. Additionally, depending on their availability, SeizSmart will utilize other sensors to collect environmental variables. For SeizSmart to access the biometric and environmental readings from the sensors, the Wear OS Sensor APIs will be used to provide a framework of classes and interfaces to perform essential sensor-related tasks.

2.3.2 Software Interfaces

SeizSmart will permanently store a history of the patient's seizure data, where it will be used for training the neural network and for future reference. The large amount of data that will be accumulated will not suitable to store on the smartwatch. For the prototype, the data will be put into an external MySQL database hosted on a virtual machine. Biometrics collected and initially stored locally on the smartphone will be moved into the external database via a SQL query each day. The server will provide an HTTP REST API for this purpose.

2.3.3 User Interfaces

The SeizSmart prototype will be compatible with any Wear OS watch running OS 2.6 or higher, and any Android phone, OS 4.3 or higher will be compatible with SeizSmart. The watch and smartphone must be compatible as well since the SeizSmart application requires the two devices to interact. The watch can be any shape or size available. The user interfaces for smartwatch and smartwatch are maneuvered via touchscreen color displays. Other display specs such as the dimensions, shape, or resolution will vary depending on the model of the smartwatch or smartphone that the patient uses.

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2.3.4 Communications Protocols and Interfaces

To transfer data to from the local smartwatch to the external database, an HTTP REST API is implemented. REST, or Representational State Transfer, is an architectural style used to develop a means of communication between a client and a sever. In the SeizSmart protype, the client will be the smartwatch while the server will be the external cloud server hosted on the ODU virtual machine. HTTP is a set of guidelines that must be followed when transferring files via the Web. This protocol was chosen because it can easily get messages through on a patient's home network, as it is typically unfiltered by network firewalls.

The SeizSmart prototype server is currently listed at 'http://411silverf19-mgmt.cs.odu.edu/'. The server has three specific endpoints that are vital to the communication between the local SeizSmart components and the external server. One of the endpoints will be responsible for uploading a JSON payload of biometric logs to the server. Specifically, biometric and environmental data collected by the smartwatch sensors, initially stored on the watch, will be transferred to the server via this endpoint. A different endpoint will return a JSON payload of trained weights for use in detection. In other words, each day, the smartwatch will retrieve the trained neural network from the server via this endpoint. The final endpoint is a significant component involved with notifying emergency contacts. When a seizure is detected, this endpoint will post a list of the patient's emergency contact(s) who must be notified of the detected seizure. The notification to the emergency contact will be issued directly from the smartwatch over a Wi-Fi connection.