Lab 1 - SeizSmart Descriptive Paper

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1. Introduction

Seizures, the silent reaper that sits on the shoulder of millions at this very moment, capable of snuffing out a life with few warnings to those around and even fewer options to those in the midst of an attack. Epilepsy has been on the rise in recent years becoming the fourth most common neurological disease worldwide and is projected to only continue growing well into the future. See Figure 1.

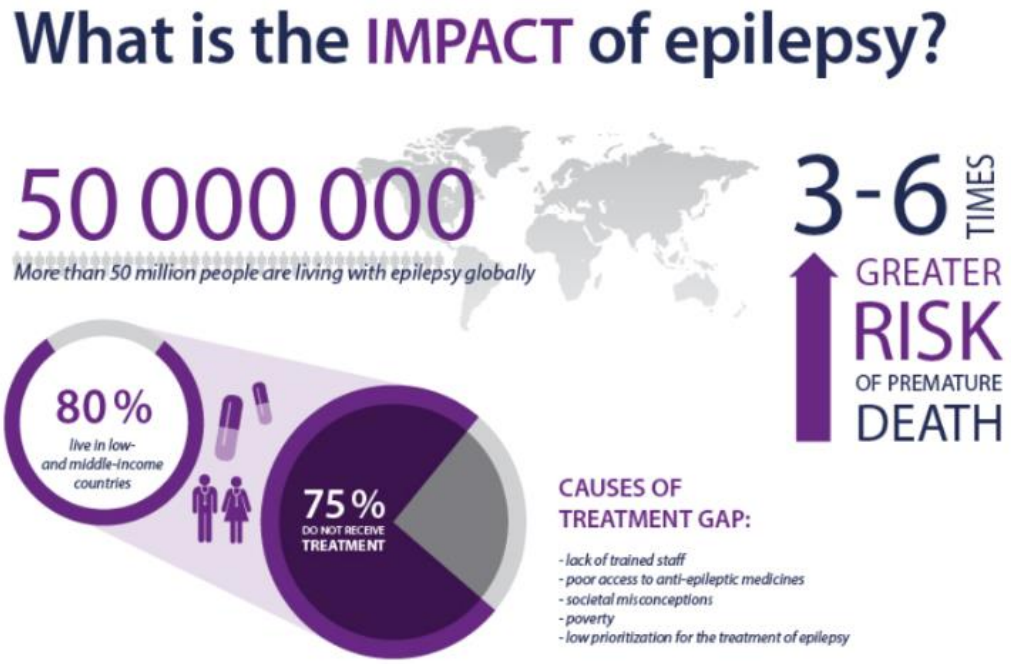

Figure 1: Background of Epilepsy

Despite the growing prevalence there are still many social misconceptions and stigmas about epilepsy, seizures, and how best to treat those suffering. There is a silent battle that those with the condition fight knowing that if they have an attack while alone they could end up losing their life. Even if the stigma is lifted and misconceptions cleared there still remains a larger problem, what to do if a seizure strikes while someone is left alone? Trouble speaking, erratic body convulsions and loss of consciousness make it difficult for one to reach out to others for help which becomes a far bigger issue when the span of time available to save a life is so short. See Figure 2.

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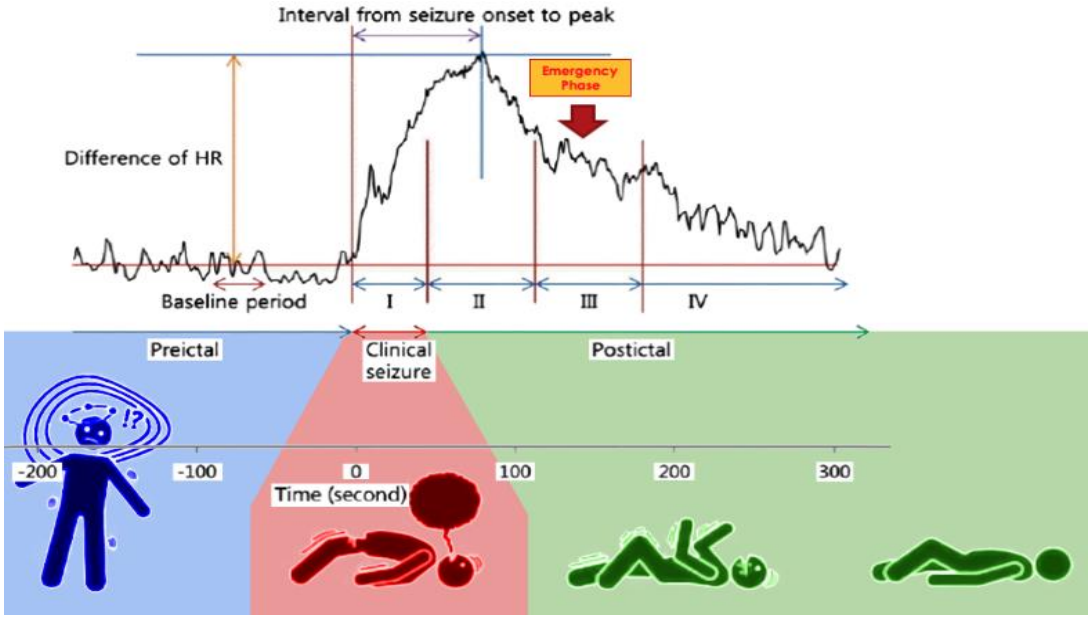

Figure 2: Interval from seizure onset to peak

The most common solution of the modern era has been to create an accessory that monitors a user's heartrate or their body movement for a paid subscription, and if the accessory notices anything that appears off a signal is sent off to a relay that calls help for the patient. [1][2][3][4] But these come at the cost of being tethered to a relay at all times hindering a person's social and/or professional obligations. Not to mention the possibility that the connection to the relay could be severed due to any number of possible reasons. See Figure 3. More so seizures come in many flavors and will not always affect the same person the same way every time, making it difficult for traditional monitors to catch every seizure.

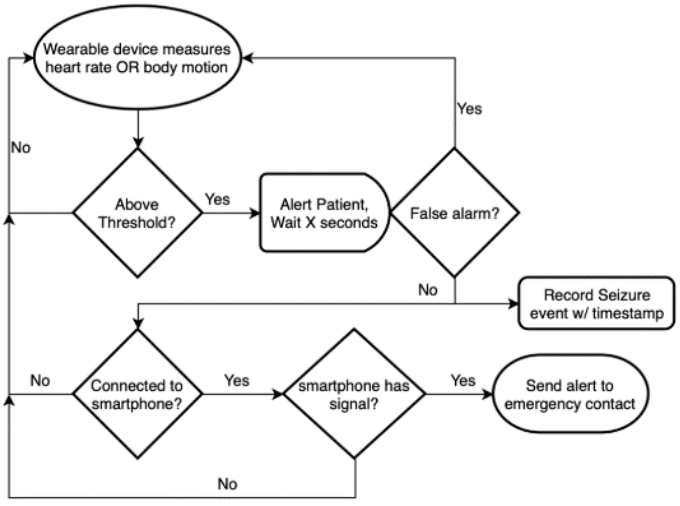

Figure 3: Current Flow of standard Seizure Monitoring Devices

That is where plans for SeizSmart have taken root, intended as an iOS and Android smartwatch app that monitors both the user's heartrate and movements, creates a customized seizure profile for its user for easier detection, uses the watch's in built call functions to issue emergency requests without need for a relay, and is planned to be available free of charge with no prescription required.

2. SeizSmart Description

No one is born to this world exactly the same as any other, humans all have various wishes, goals, issues, and needs that we carry through our lives making flexibility a must in today's chaotic society. SeizSmart aims to be that flexibility for those who need it most by letting patients live their lives the way they want to live, free from being confined to someone else's idea of what their condition "should" be. As a smartwatch application, SeizSmart will have access to the inbuilt accelerometers, gyroscopes, and heart rate monitors to keep track of a patient's heart rate and body movements so as to more accurately detect when an episode may be occurring. Over time the user and their emergency contacts will train the neural network of their personal account to recognize what is a genuine attack for this patient and what is not. More so SeizSmart will allow the patient (or their health care providers) to decide if the reports lean more towards false positives or negatives, decide how best to get in touch with emergency contacts, and even view all collected data and records directly on the smartwatch without the need for a tethering relay.

Figure 4 shows the currently planned workflow of SeizSmart on a smartwatch device. Starting from the monitoring stage SeizSmart runs a check to see if the patient's vitals and movement match or exceed their neural network profile. If any abnormalities are detected an alert is pushed to the user's watch to clear, if cleared then app will log the environment variables and return to monitoring mode. Should the user fail to clear the response an audio alert is issued from the watch to draw nearby attention, and if there is an available wifi or cell connection an alert is sent to all of the emergency contacts for verification on how to proceed, which can be cleared if it is a false alarm, or acknowledged to begin emergency dispatch procedures. SeizSmart will impliment machine learning algorithms to build the aforementioned neural network and personalized Seizure Profile, while also incorporationg a triple layer of algorithms for detecting, reporting, and recording any issues or findings with the patient. See Figures 5, 6, and 7. These systems should help reduce the number of false positive/negative sezure reports, get all SeizSmart patients the help they need as soon as they need it, and keep a solid record of all incidents that can be used not only by the program itself but also any healthcare professionals involved in the patient's case.

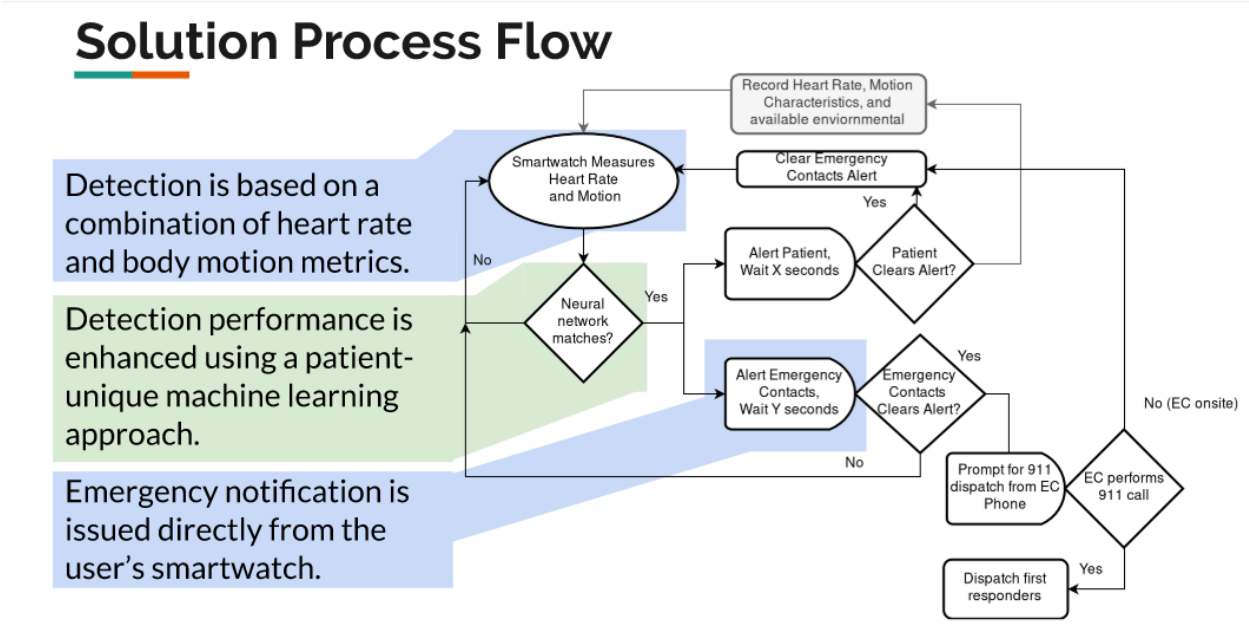

Figure 4: Current flow of SeizSmart monitoring devices

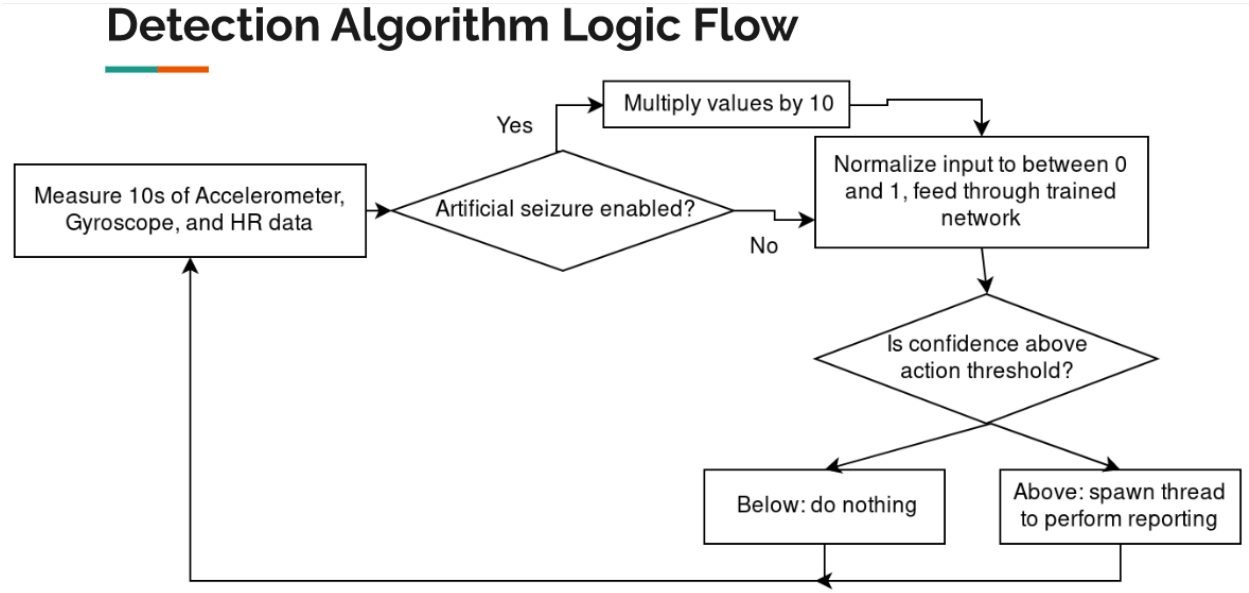

Figure 5: Detection Algorithm Flow

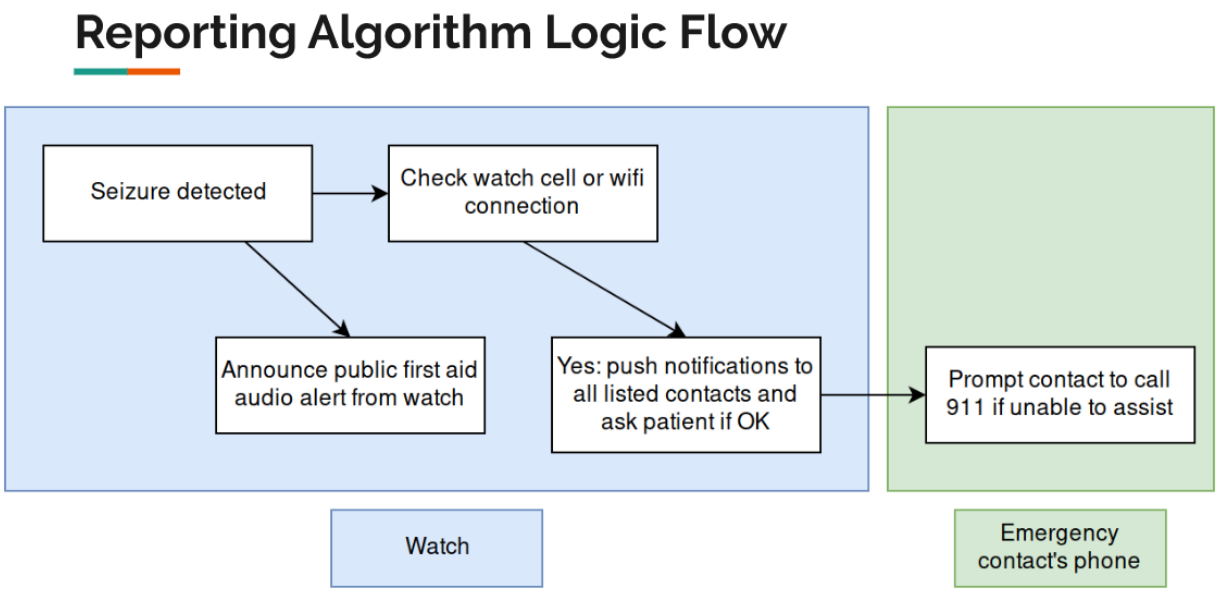

Figure 6: Reporting Algorithm Flow

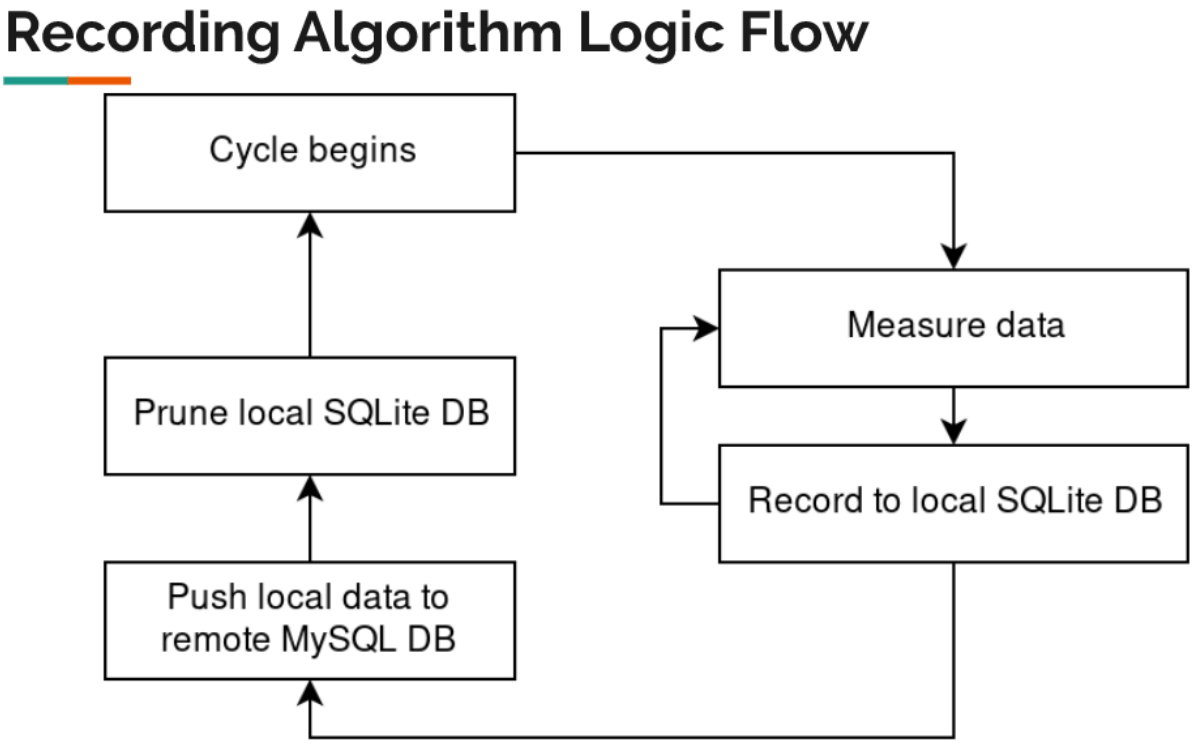

Figure 7: Recording Algorithm Flow

2.2. Major Components

There are four main components to this software solution in total being a smartphone application that will act as the main hub for the user profile, settings, and gathering emergency contacts, the smartwatch application and database which will monitor the user for any abnormalities from their profile, the four algorithms that work together to monitor for seizure activity in real time, and the cloud server which further helps with data logging. See Figure 8.

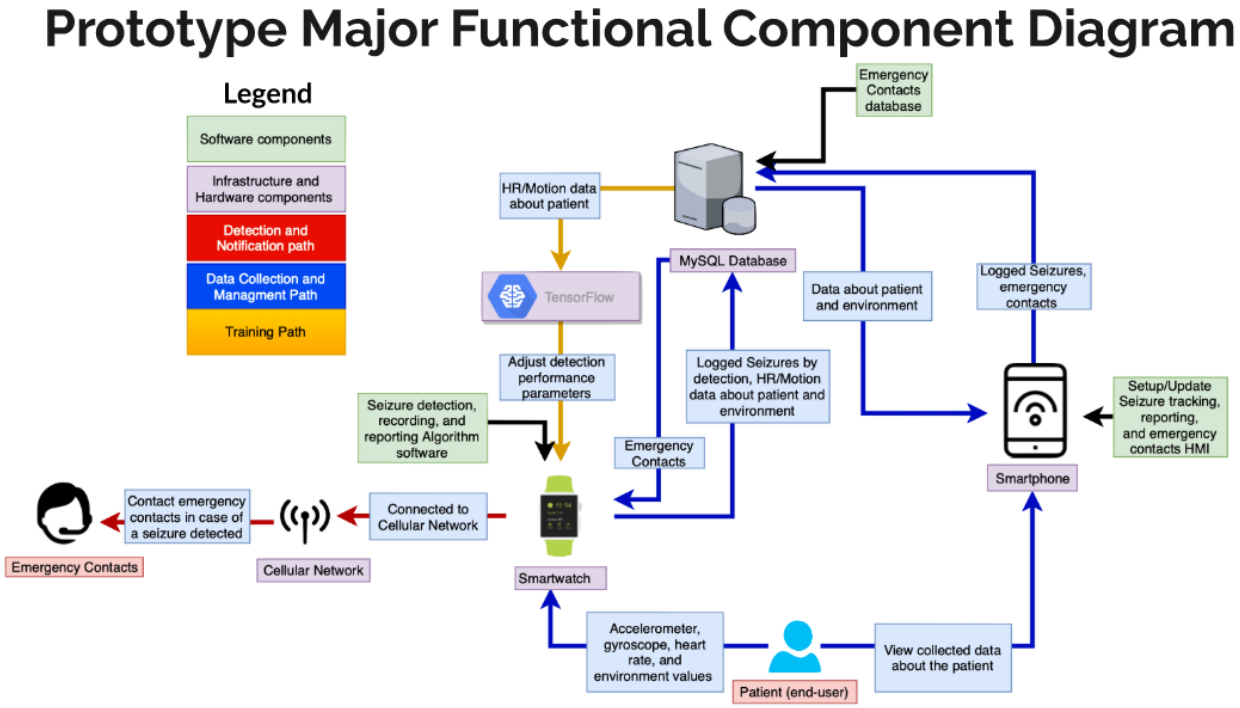

Figure 8: Prototype MFCD

SeizSmart is currently being designed for patients who suffer from any type of generalized seizures (clonic, tonic, tonic-clonic, atonic, myoclonic), their loved ones, and their healthcare providers. SeizSmart seeks to give peace of mind to all those whose lives are affected by the persistent condition of this terrifying condition. Furthermore if should SeizSmart's technology prove successful then there is a possibility that it could be further worked on and expanded to provide similar aid to patients of other life altering conditions.

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3. SeizSmart Prototype Description

The SeizSmart Prototype currently in development is planned to have all of the needed algorithms fully functional such that it could be rolled out for proper testing, however due to the dangerous and sporadic nature of seizures and epilepsy, all functions and data that would be pulled from during a real world incident, including the growth of the machine learning systems, will need to be artificially implemented so as to not endanger anyone. See Figure 9.

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

Figure 9: Real World VS Prototype

The core goal of the prototype testing is to confirm that SeizSmart is able to recognize conditions outside of the intended threshold, respond to the timed prompts accordingly, perform the necessary connections and contacts, correctly build a neural network, and watch's collected data interacts as expected with the application with a minimal margin of error.

Figure 10 shows the intended flow of data between the servers and the application, illustrating how the biometrics are read, recorded, transferred to the cloud for neural network training, and the new neural network data update is then returned to the user's application. The host application of the watch will include a built-in alert system for the user, as well as communication with emergency contacts and healthcare providers who can opt into smart phone alerts and displays.

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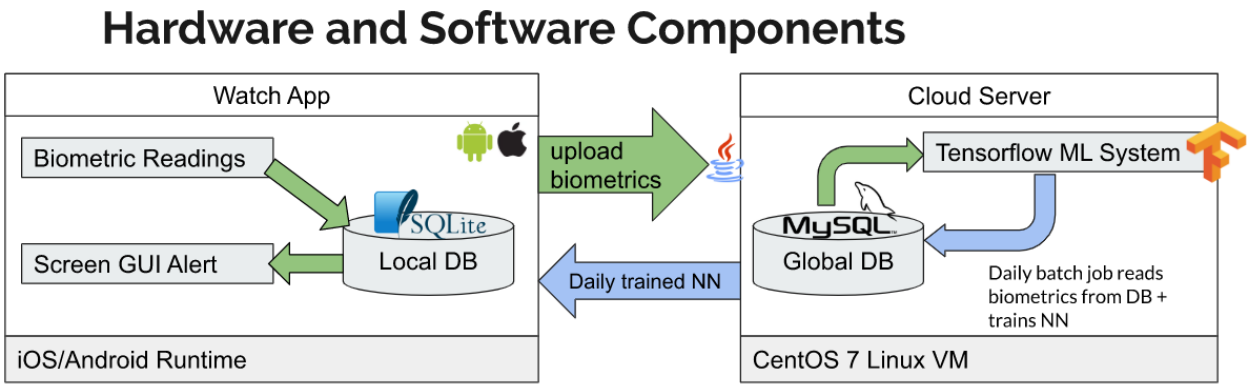

	Android Smartwatch	Android Phone
Min Version	Wear OS 2.6	Android 4.3
Hardware Requirements	Wifi, Cellular, Accelerometer, Gyroscope, optical heart-rate sensor	Wifi, Cellular

Figure 10: Hardware and Software Components

The prototype will be considered a success once the application and watch are able to work together to accurately detect the patient's heartrate and motion, compare this data to currently known thresholds, alert the patient in the case that the threshold is broken, and should the patient prove unresponsive have the alert pushed to the emergency contacts without the aid of a tethered phone or relay device. See Figure 11.

Competition Matrix	SeizSmart	Direct: SmartMonitor	Direct: empatica embrace 2	Direct: SeizAlarm	Indirect: Epilepsy Journal	Indirect: Epilepsy Health Storylines
Detect, record and track generalized seizures in real time	✓	✓	✓	✗	✗	✗
Monitor repetitive shaking motion	✓	✓	✓	✓	✗	✗
Continuously monitor the user's heart rate	✓	✗	✗	Only checks for elevated heart rate	✗	✗
Alert emergency contact when the user does not respond	✓	✓	✓	✓	✗	✗
Report data about the environment at the onset of a seizure being detected	✓	✗	✗	✗	✗	✗
Function fully without dependence on a smartphone or external device	✓	✗	✗	✗	✗	✗
Use machine learning to detect generalized seizures	✓	✗	✓*	✗	✗	✗
Require a subscription or prescription	✗	✓	✓	✗	✗	✗

Figure 11: Competition matrix

To make this dream a reality however it will be required to use and learn multiple different APIs and programming languages. It is incredibly difficult to quantify the amount of time a team will need to familiarize themselves with such matters. Even more pressing however is that at the moment the sensitivity and precision of the watch hardware is a complete unknown which will make the initial testing phases much more difficult as that information is vital in setting up the necessary thresholds.

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4. Glossary

Alphabetical list of terms and abbreviations.

Accelerometer: *Tool used for measuring the acceleration of an object*

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

Gyroscope: *Tool for measuring the orientation of an object*

Heart-rate Monitor: *Tool for measuring the heart rate of an individual*

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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5. References

[1] "Website." [Online]. Available: Tzallas, A. T., Tsipouras, M. G., Tsalikakis, D. G., Karvounis, E. C., Astrakas, L., Konitsiotis, S., & Tzaphlidou, M. (2012, February 29). Automated Epileptic Seizure Detection Methods: A Review Study. Retrieved from https://www.intechopen.com/books/epilepsy-histological-electroencephalographic-and-psychological-aspects/automated-epileptic-seizure-detection-methods-a-review-study. [Accessed: 11-Sep-2019].

[2] "Website." [Online]. Available: Giannakakis, G., Sakkalis, V., Pediaditis, M., & Tsiknakis, M. (1970, January 01). Methods for Seizure Detection and Prediction: An Overview. Retrieved from https://link.springer.com/protocol/10.1007/7657_2014_68. [Accessed: 11-Sep-2019].

[3] "Website." [Online]. Available: Devices & Technology. (n.d.). Retrieved from https://www.dannydid.org/epilepsy-sudep/devices-technology/. [Accessed: 11-Sep-2019].

[4] "About SmartWatch Inspyre™ by Smart Monitor – smart-monitor." [Online]. Available: https://smart-monitor.com/about-smartwatch-inspyre-by-smart-monitor/. [Accessed: 11-Sep-2019].

[5] "Website." [Online]. Available: Velez, Mariel, et al. "Tracking Generalized Tonic-Clonic Seizures with a Wrist Accelerometer Linked to an Online Database." Seizure, U.S. National Library of Medicine, July 2016, www.ncbi.nlm.nih.gov/pubmed/27205871. [Accessed: 11-Sep-2019].

[6] "Website." [Online]. Available: Borujeny, Golshan Taheri, et al. "Detection of Epileptic Seizure Using Wireless Sensor Networks." Journal of Medical Signals and Sensors, Medknow Publications & Media Pvt Ltd, 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3788195/. [Accessed: 11-Sep-2019].

[7] February;25(2):28-29, N. R., Publish date: December 6, 2., & Publish date: December 18, 2. (2019, January 07). Mobile Devices May Provide Accurate Seizure Detection and Help Prevent SUDEP. Retrieved from https://www.mdedge.com/neurology/epilepsyresourcecenter/article/130162/epilepsy-seizures/mobile-devices-may-provide

[8] van Elmpt, Wouter J C, et al. "A Model of Heart Rate Changes to Detect Seizures in Severe Epilepsy." Seizure, U.S. National Library of Medicine, Sept. 2006, www.ncbi.nlm.nih.gov/pubmed/16828317.

[9] Borujeny, Golshan Taheri, et al. "Detection of Epileptic Seizure Using Wireless Sensor Networks." Medical Signals and Sensors, Medknow Publications & Media Pvt Ltd, 2013, www.ncbi.nlm.nih.gov/pmc/articles/PMC3788195/.

[10] Velez, Mariel, et al. "Tracking Generalized Tonic-Clonic Seizures with a Wrist Accelerometer Linked to an Online Database." Seizure, U.S. National Library of Medicine, July 2016, www.ncbi.nlm.nih.gov/pubmed/27205871.

[11] Kołodziej, M., Majkowski, A., Rak, R. J., Świderski, B., & Rysz, A. (2017, September). System for automatic heart rate calculation in epileptic seizures. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28523469

[12] Nei, M. (2019). Cardiac Effects of Seizures. American Epilepsy Society.

[13] Zijlmans, Maeike, et al. "Heart Rate Changes and ECG Abnormalities during Epileptic Seizures: Prevalence and Definition of an Objective Clinical Sign." www.ncbi.nlm.nih.gov/pubmed/12181003.

[14] "Demystifying Epilepsy and Increasing Awareness." and Research, Mayo Clinic, Mayo Foundation for Medical Education https://newsnetwork.mayoclinic.org/discussion/epilepsy-demystify-disease-and-increase-awareness/.

[15] "Epilepsy Foundation." Epilepsy Foundation, 13 Mar. 2019, www.epilepsy.com/.

[16] "About SmartWatch Inspyre™ by Smart Monitor – Smart-Monitor." Smart, smart-monitor.com/about-smartwatch-inspyre-by-smart-monitor/.

[17] "Embrace2 Seizure Monitoring | Smarter Epilepsy Management | Embrace Watch." www.empatica.com/embrace2/.

[18] "SeizAlarm Epilepsy Seizure Detection." SeizAlarm Epilepsy Seizure Detection, seizalarm.com/.

[19] "Epilepsy Journal App | OllyTree Applications." Epilepsy Journal, www.epilepsy-journal.com/.

[20] "Health Storylines™." Health Storylines™, www.healthstorylines.com/.