



# SeizSmart

A mobile application for detecting, tracking, and reporting seizures in real-time.

## Formal Design Presentation

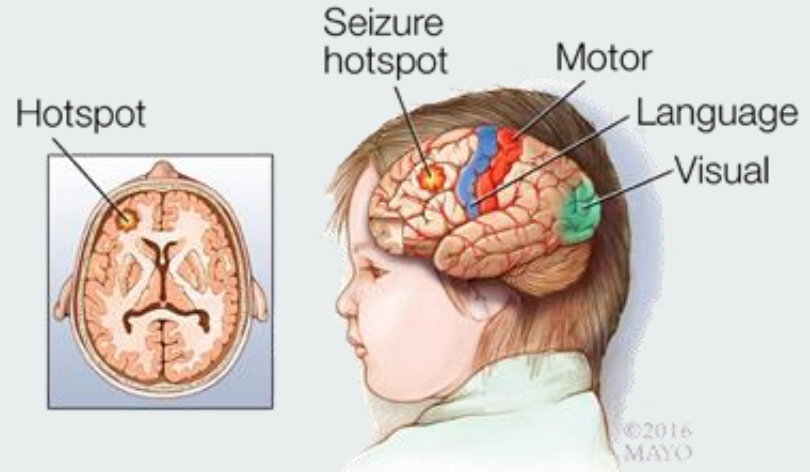
CS 410 Spring 2019

Team Silver

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Alpha Din Gabisi, Jeffrey McAteer

Danielle Luckraft, Peter Scheible





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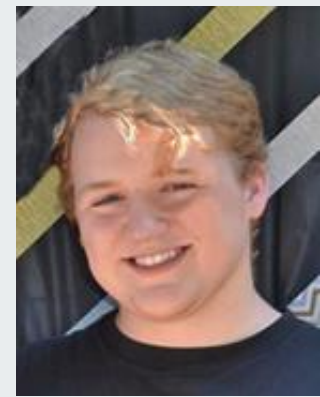
# The Team



**Abel Weldaregay**  
Team Lead / Back-End Developer



**Kevin Sokol**  
UI/UX Developer - Smartphone



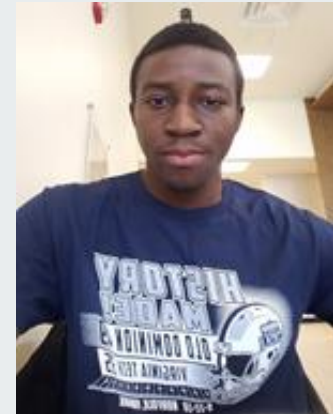
**Peter Scheible**  
UI/UX Developer - Smartwatch



**Danielle Luckraft**  
Webmaster / Developer



**Jeffrey McAteer**  
Infrastructure & ML Engineer



**Alpha Din Gabisi**  
Database Engineer



# Mentors



**Sampath Jayarathna. Ph.D.**



**Jesse Gordon**



# Terminology

- Patient
  - An individual who experiences generalized seizures. May also be referred to as the end user.
- Emergency Contact
  - Anyone who cares for a patient; Usually family members.
- 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.



# Background - Epilepsy

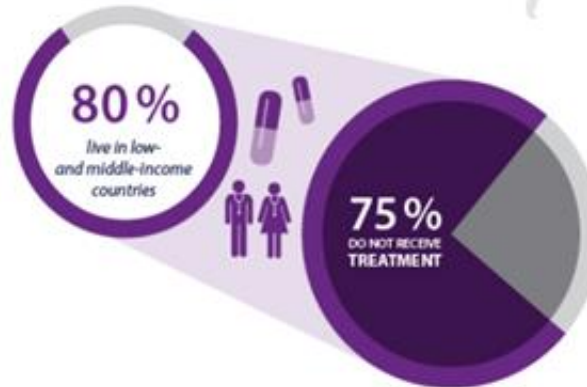
- Epilepsy is the 4th most common neurological disease in the world.
- Cases of epilepsy in the US have increased over the past five years.
- Cases in the US are predicted to increase further by 2020.

## What is the **IMPACT** of epilepsy?

50 000 000

More than 50 million people are living with epilepsy globally

3-6 TIMES  
GREATER  
RISK  
OF PREMATURE  
DEATH



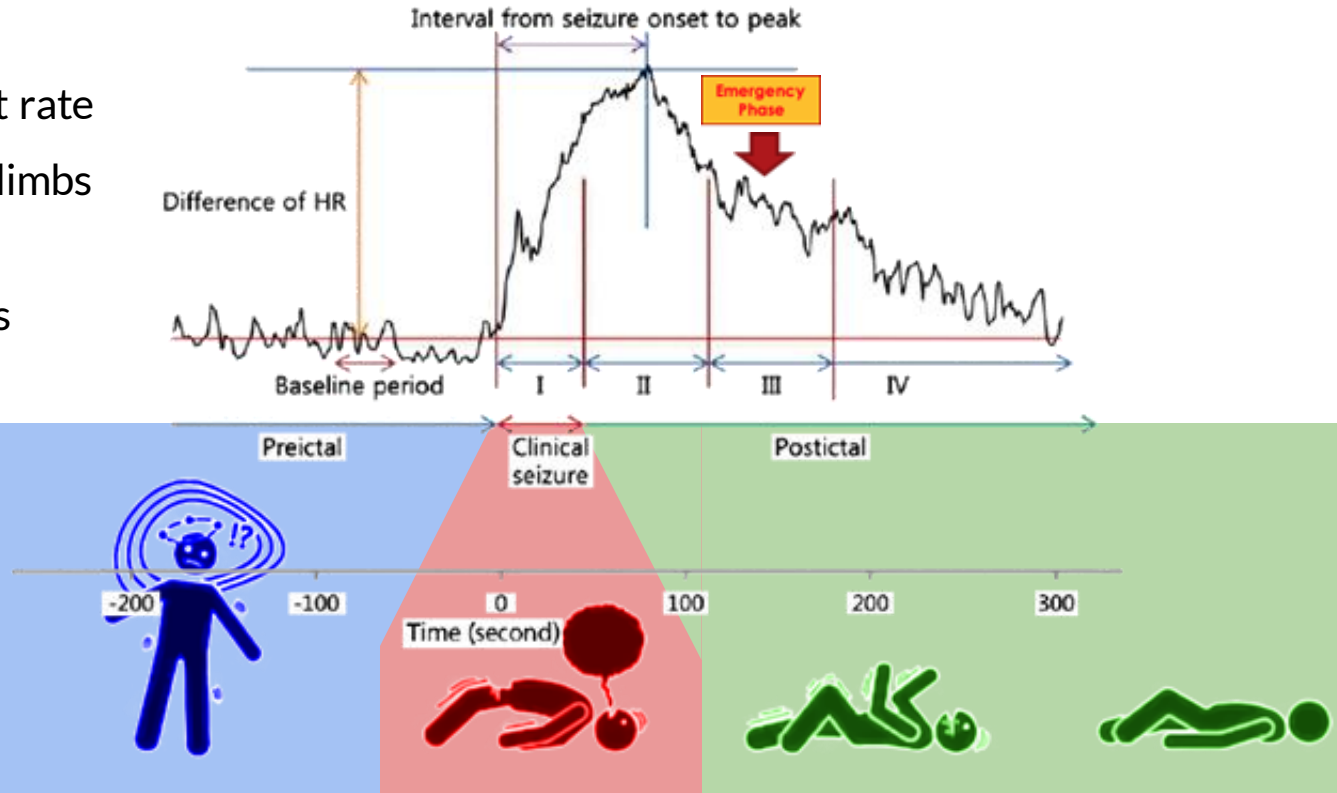
### CAUSES OF TREATMENT GAP:

- lack of trained staff
- poor access to anti-epileptic medicines
- societal misconceptions
- poverty
- low prioritization for the treatment of epilepsy



# Characteristics of Generalized Seizures

- Rapid change in heart rate
- Rapid convulsions in limbs and face
- Loss of consciousness





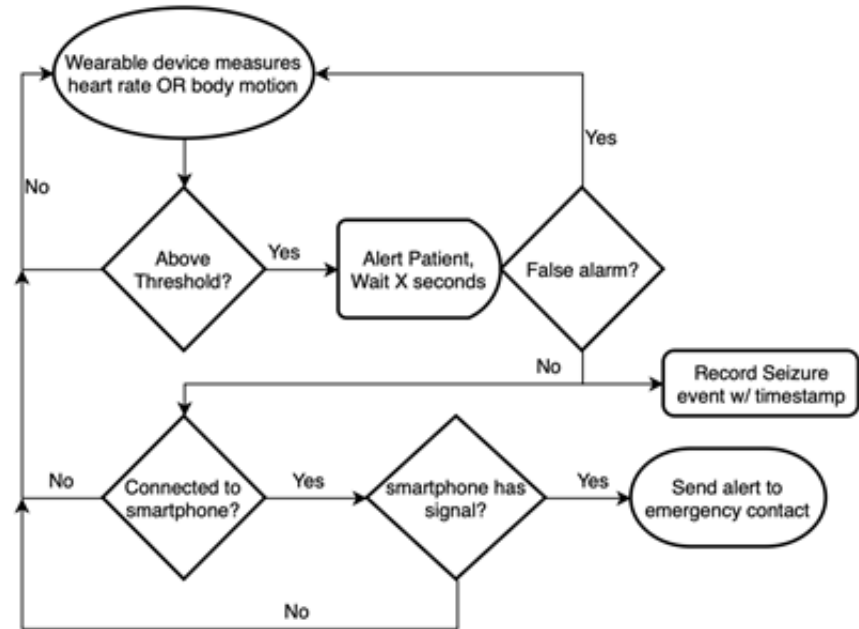
# Problem Statement

- Epileptic seizures are difficult to detect in a timely and accurate fashion and undetected seizures can result in injury or even death.
- Current smartwatch detection technology does not provide the ability to automatically detect the onset of a seizure **based on a combination of heart rate behavior and repetitive body movements.**
- Available devices do not provide capabilities that **tune detection variables to match individual patient seizure characteristics.**
- Existing solutions to detect seizures use smartwatch technology which must be in the **proximity of a smartphone in order to notify emergency contacts.**



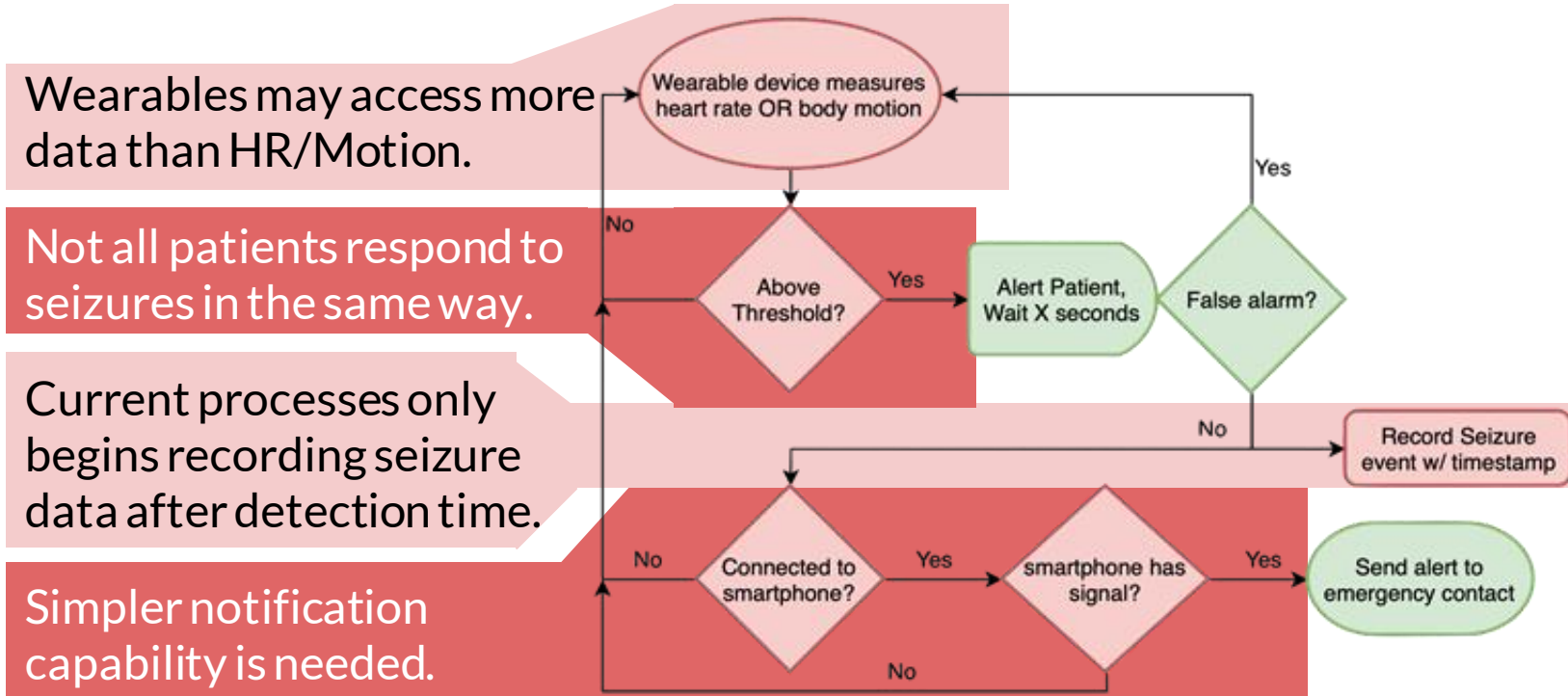
# Current Process Flow

- Most existing solutions detect seizures based on body motion.
- Some detect seizures based on users heart rate.
- The process flow for both are identical.
- No existing system detects based on a combination of both metrics.





# Current Process Flow





# Solution Statement

Our proposed solution, SeizSmart, implements an advanced, wearable seizure detection capability using off-the-shelf smartwatch technology that is able to:

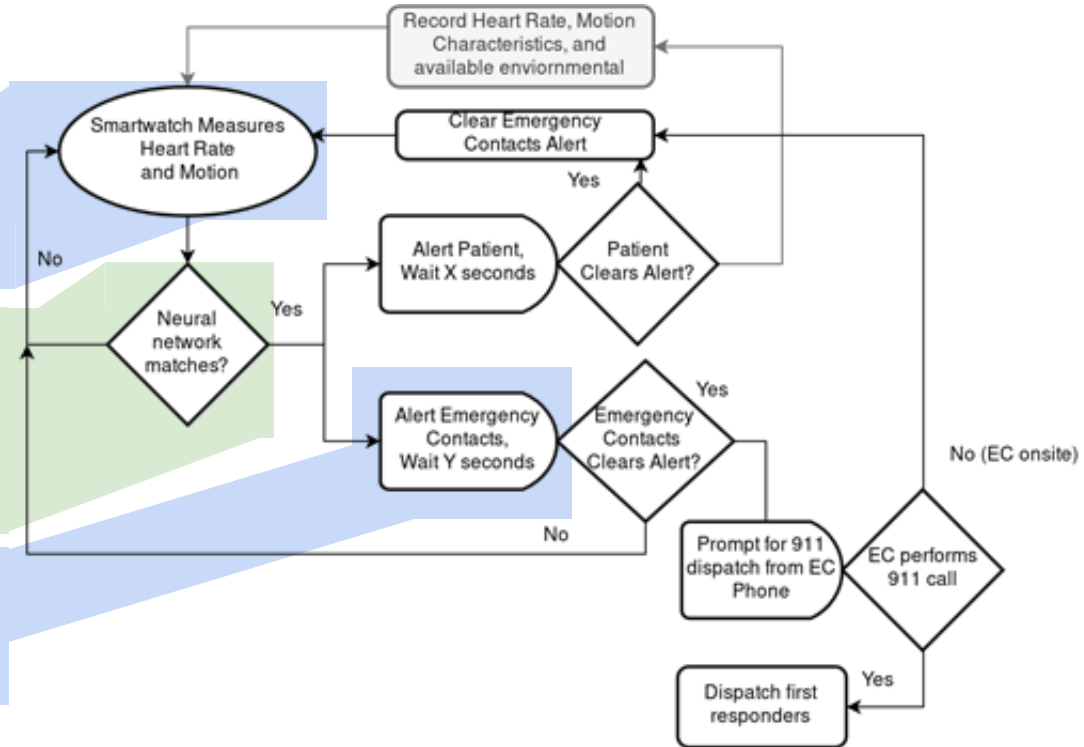
- automatically detect epileptic seizures from combined heart rate **and** motion metrics,
- detect seizures using an algorithm which matches individual patient seizure characteristics,
- track and record all information surrounding seizure events,
- and provide automatic notification to emergency contacts without requiring a relay.

# Solution Process Flow

Detection is based on a combination of heart rate and body motion metrics.

Detection performance is enhanced using a patient-unique machine learning approach.

Emergency notification is issued directly from the user's smartwatch.





# Target Consumers and End Users

## Customers

- Medical providers
- Concerned party of individual with generalized seizures

## End-Users

- Individuals who have the most common types of generalized seizures:
  1. Clonic
  2. Tonic
  3. Tonic-Clonic
  4. Atonic
  5. Myoclonic



# Benefits to Customer/User-base

- Detection Performance and Hardware Flexibility
  - Each user's individual seizure profile provides more accurate and customized seizure detection.
  - The user may configure emergency response notifications as desired.
  - SeizSmart is compatible with both Android and iOS smartwatch technology without the need for specialized hardware.
  - SeizSmart will be available without a subscription and a prescription will not be required.
- Peace of Mind
  - A smartphone does not need to be in close proximity to the smartwatch for detection and notification of emergency contacts.
  - SeizSmart is capable of notifying emergency personnel in extreme situations.



# User Roles



## Emergency Contact

- Concerned party
- Friend/Family of Patient



## Patient

- Individual with generalized seizures



## First Responders

- Last resort emergency contact

# Competition Matrix

|  | Direct           |                     |                           |                                     | Indirect                |                                   |
|--|------------------|---------------------|---------------------------|-------------------------------------|-------------------------|-----------------------------------|
|  | <u>SeizSmart</u> | <u>SmartMonitor</u> | <u>empatica embrace 2</u> | <u>SeizAlarm</u>                    | <u>Epilepsy Journal</u> | <u>Epilepsy Health Storylines</u> |
| 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                                     | ✗                | ✓                   | ✓                         | ✗                                   | ✗                       | ✗                                 |





# Solution Deliverables

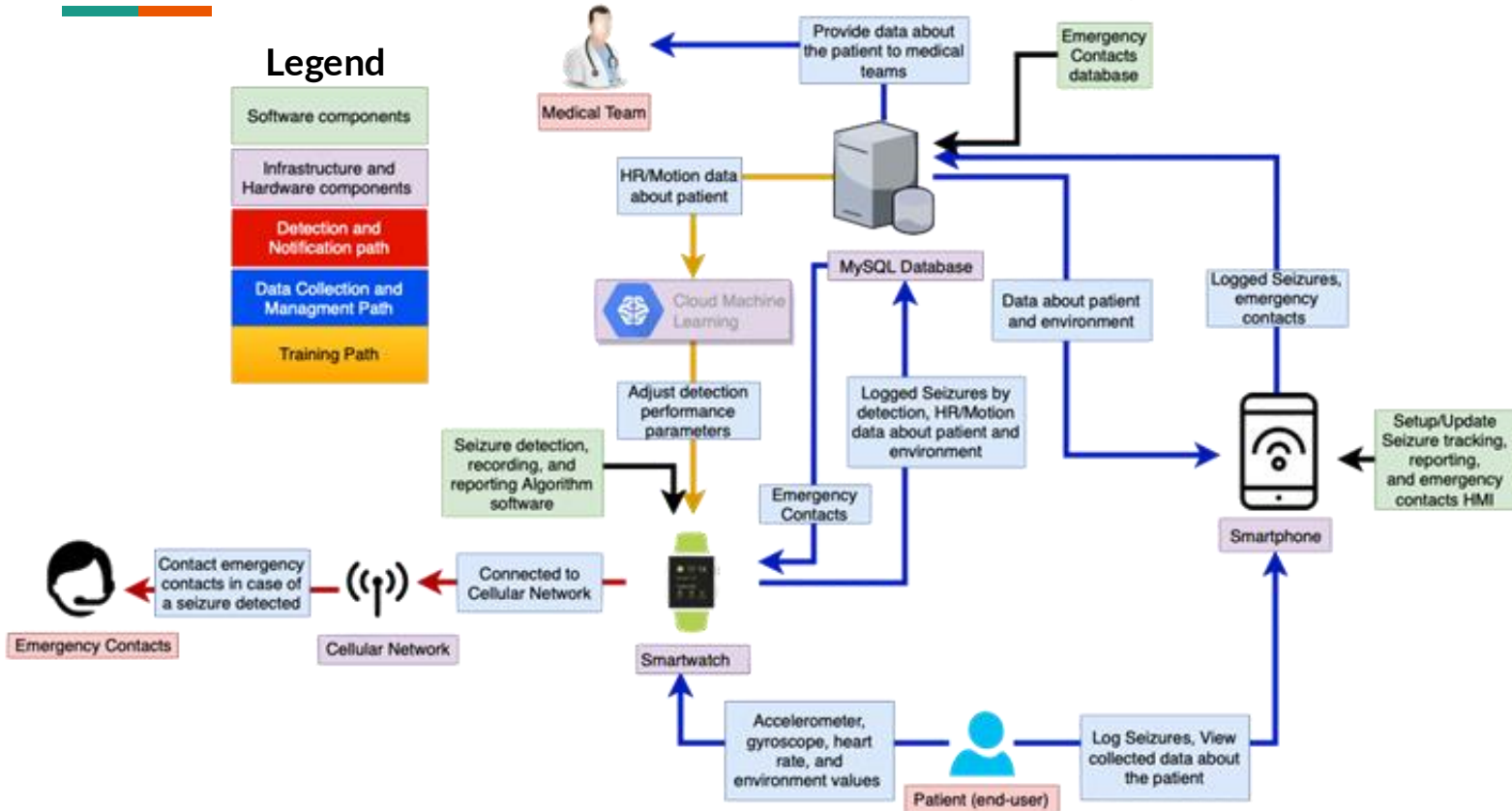
## Android

- **Deliverables:**
  - Android watch app for detecting, Android smartphone app for reporting, recording, and adjusting detection threshold values
- **Server:**
  - HTTP REST API
- **Distribution:**
  - Google Play App Store

## iOS

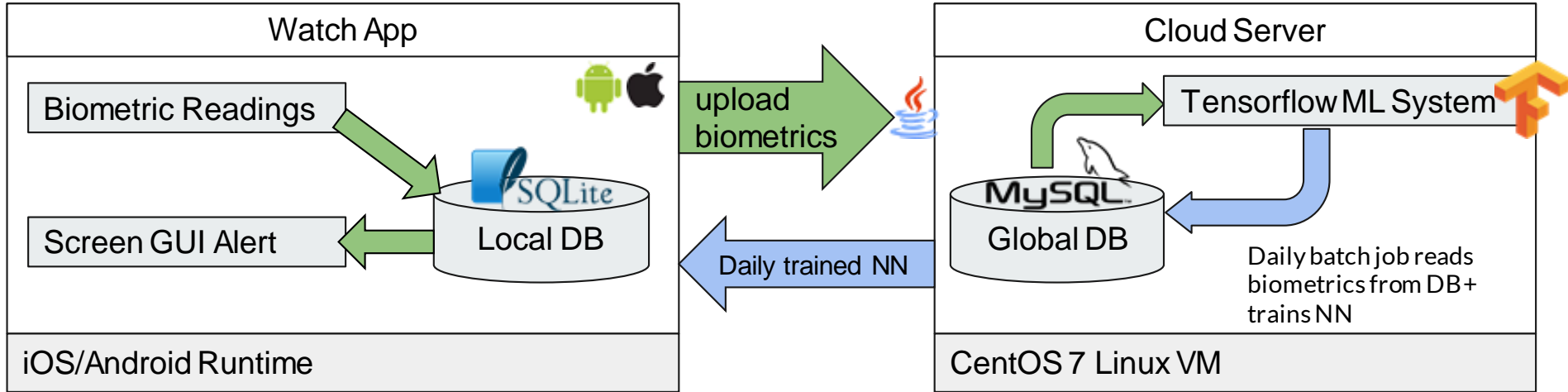
- **Deliverables:**
  - iOS watch app for detecting, iPhone app for reporting, recording, and adjusting detection threshold values
- **Server:**
  - HTTP REST API
- **Distribution:**
  - App Store

# Major Functional Component Diagram





# Hardware and Software Components



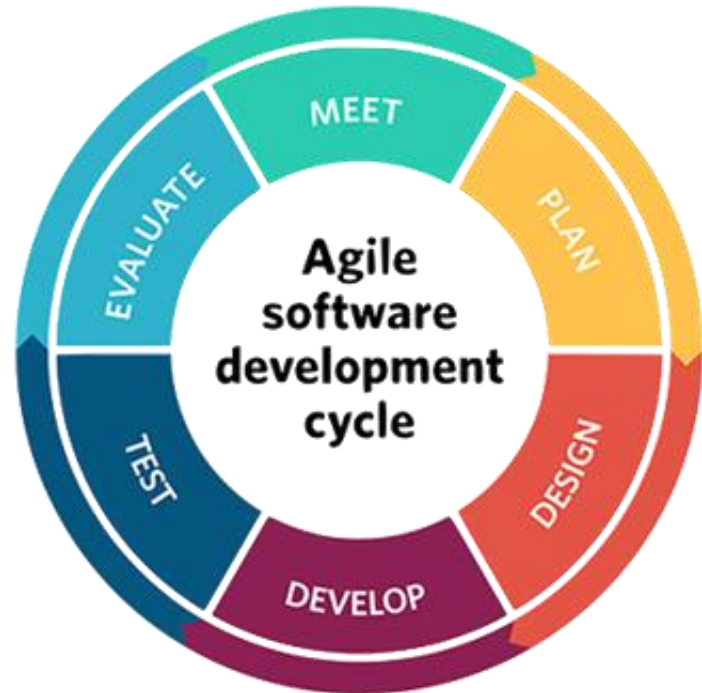
|                              | <b>iOS Smartwatch</b>   | <b>Android Smartwatch</b>   | <b>iOS Phone</b> | <b>Android Phone</b> |
|------------------------------|---|---|------------------|----------------------|
| <b>Min Version</b>           | watchOS 5.2   | Wear OS 2.6   | iOS 8.0.1        | Android 4.3          |
| <b>Hardware Requirements</b> | Wifi, Cellular, Accelerometer, Gyroscope, optical heart-rate sensor | Wifi, Cellular, Accelerometer, Gyroscope, optical heart-rate sensor | Wifi, Cellular   | Wifi, Cellular       |



# Agile Development Model

- Small, diverse team
- Goal is moving target
- Correctness is critical
- Time is limited

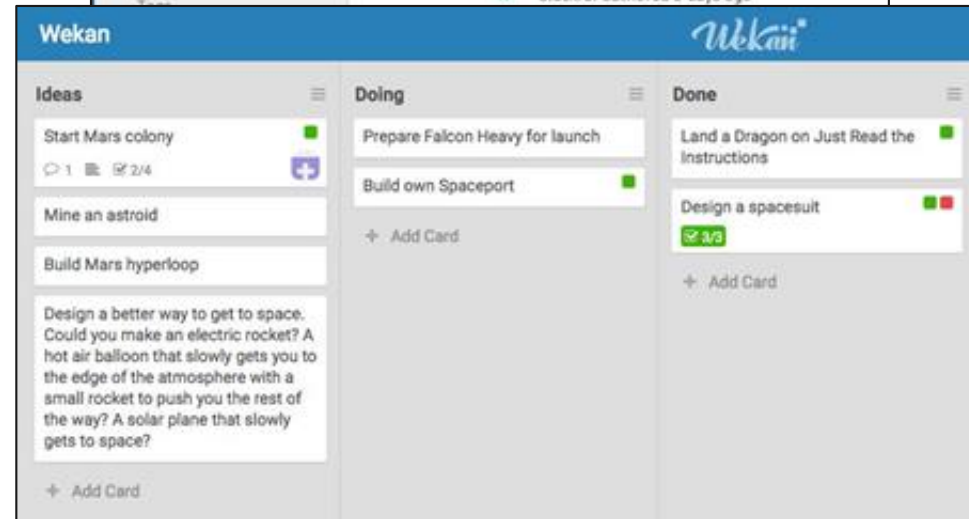
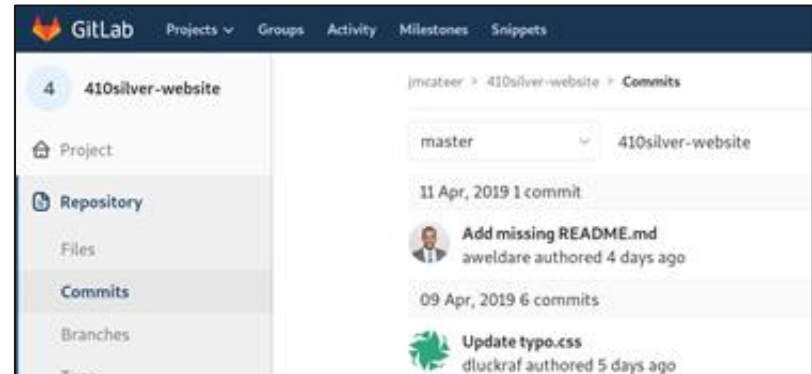
Agile plays to our team's strengths and gives the project a high probability of success





# Coordination Tools

- CS gitlab
  - Shared codebase
  - **Issue tracking**
  - Already in use!
- Wekan kanban instance
  - Run off 411 VM
  - Use cards to **track work in parallel**
- Weekly Sprint Meetings
  - Google Hangouts



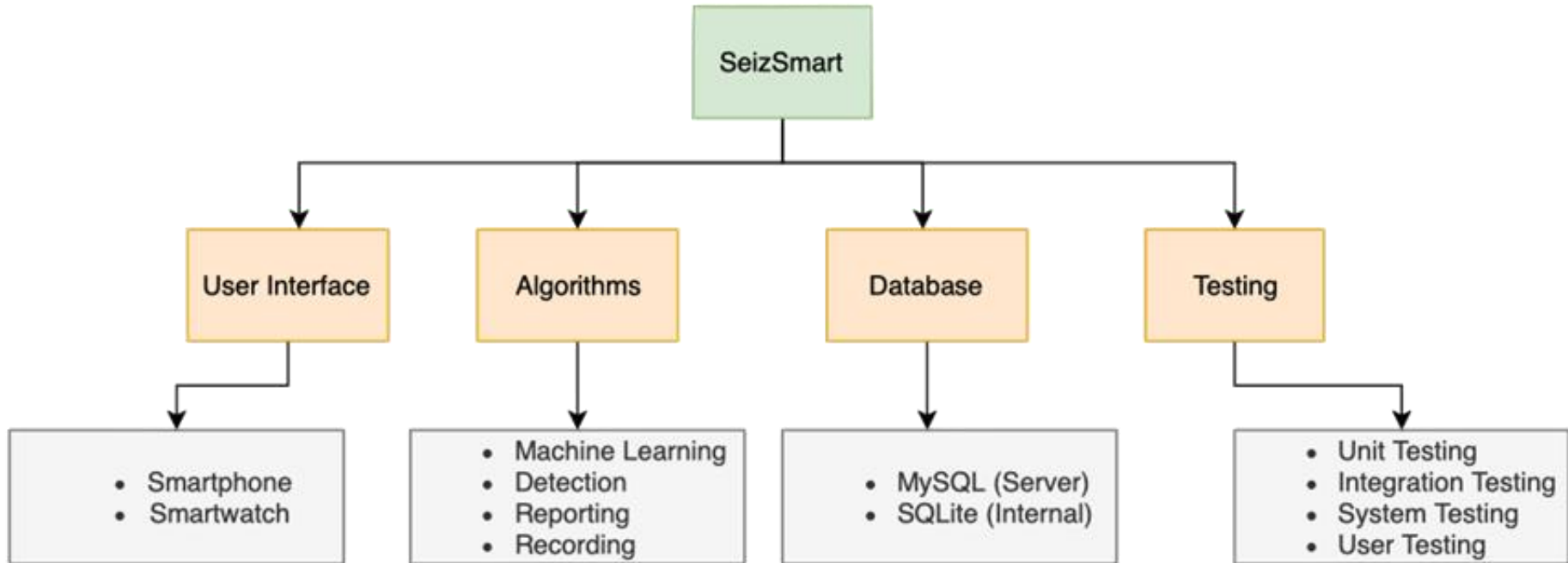


# Development Tools

|                          | <b>Android</b>  | <b>iOS</b>                        | <b>Server</b> |
|--------------------------|-----------------|-----------------------------------|---------------|
| <b>Language</b>          | Java            | Swift                             | Java          |
| <b>IDE</b>               | Android Studios | Xcode                             | Vim           |
| <b>UI/UX</b>             | Android Studios | Xcode                             | HTML5/CSS/JS  |
| <b>Database</b>          | SQLite          | SQLite                            | MySQL         |
| <b>Build Manager</b>     | Gradle          | Swift Package Manager & CocoaPods | Gradle        |
| <b>Version Control</b>   | Git             | Git                               | Git           |
| <b>Issue Tracker</b>     | Gitlab          | Gitlab                            | Gitlab        |
| <b>Testing Framework</b> | JUnit           | XCTest                            | JUnit         |

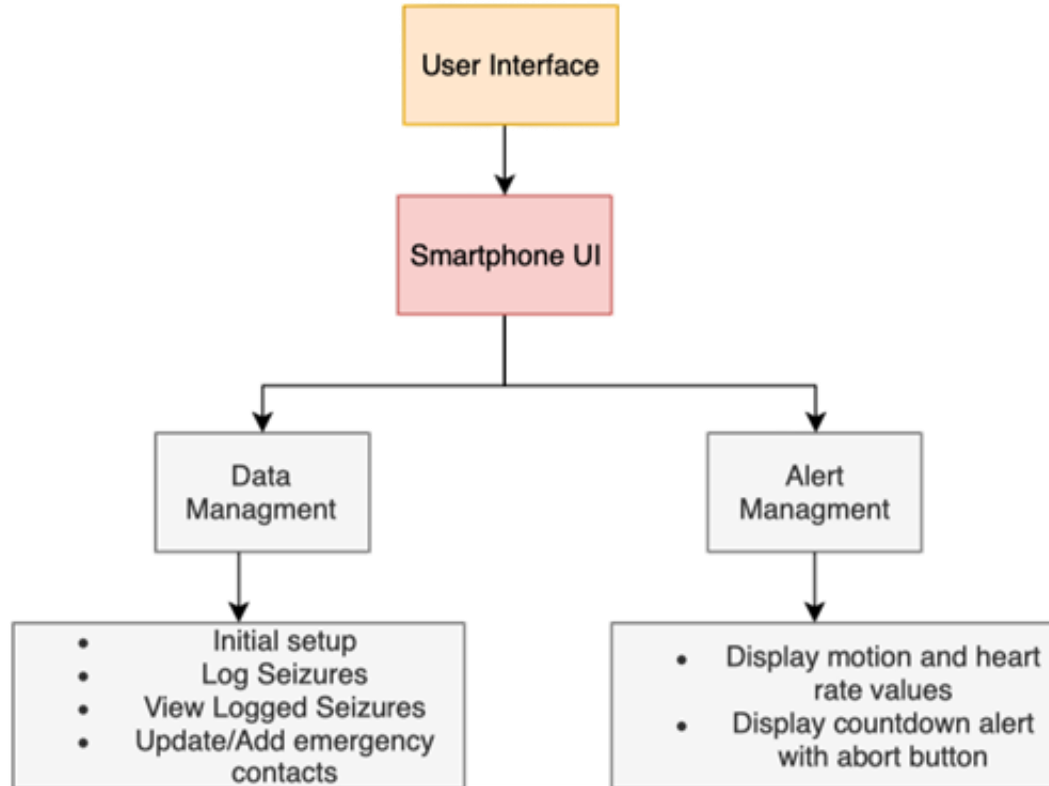


# Work Breakdown Structure (WBS) Overview





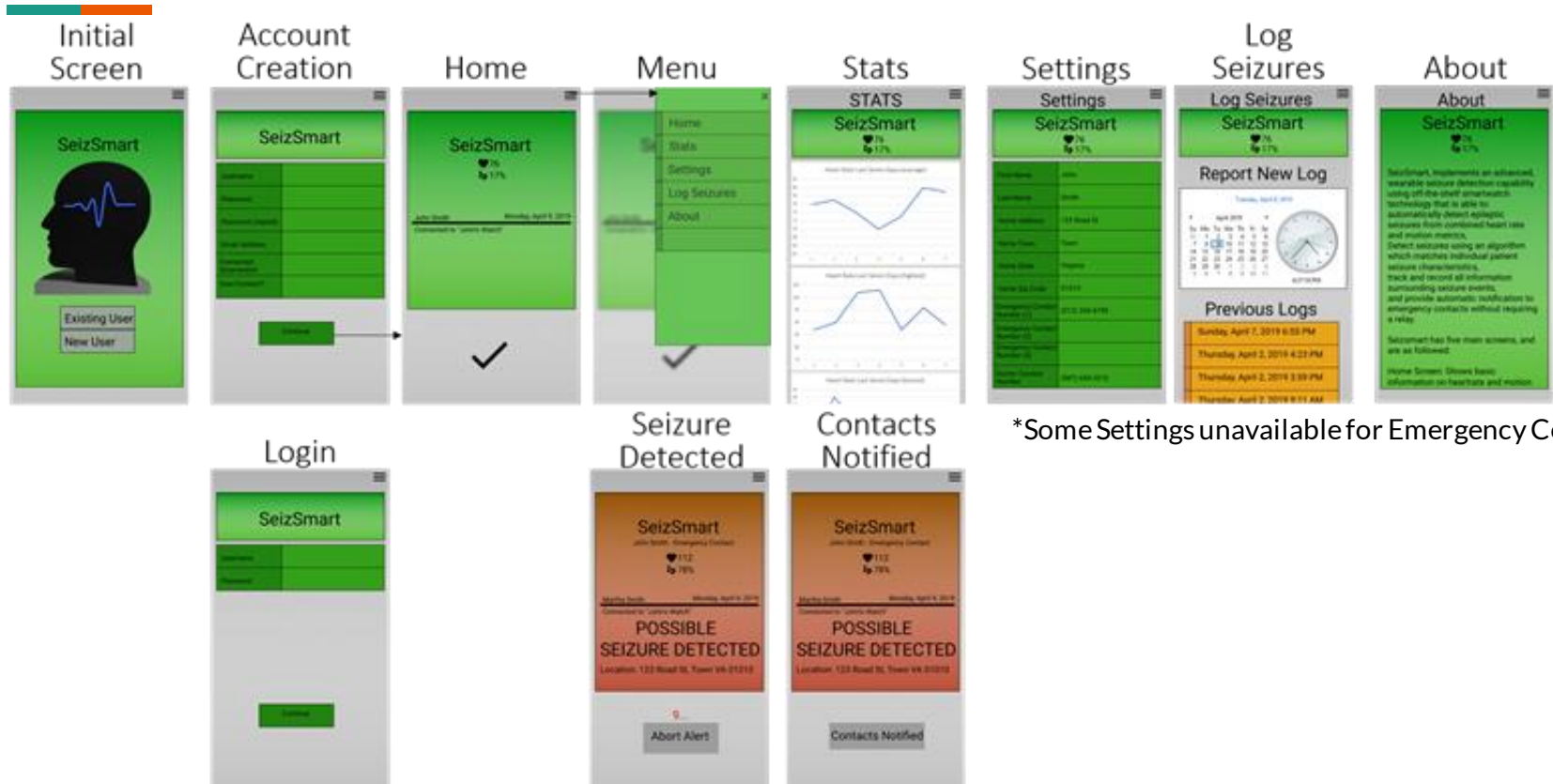
# WBS - User Interface Smartphone







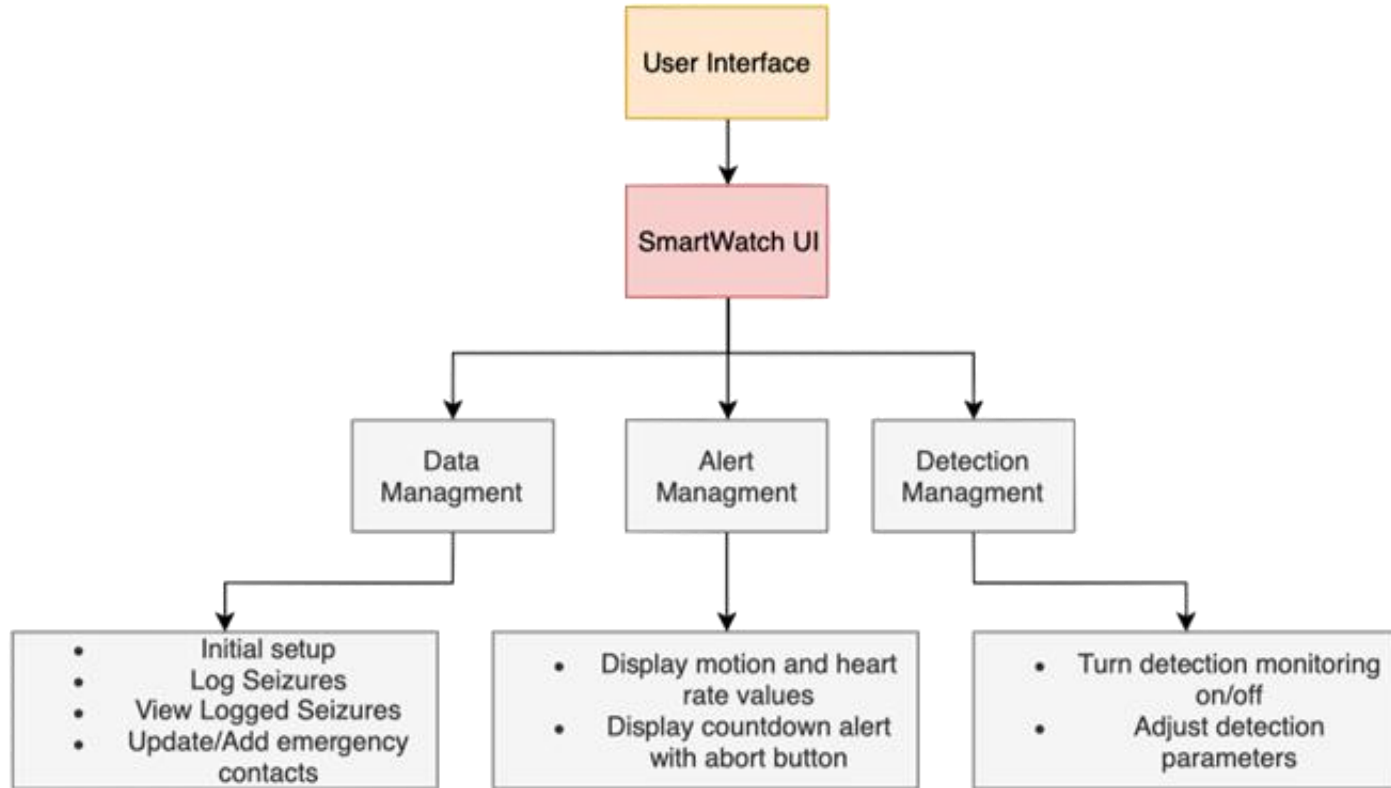
# SmartPhone GUI Mockup - Patient/Emergency Contact



\*Some Settings unavailable for Emergency Contact

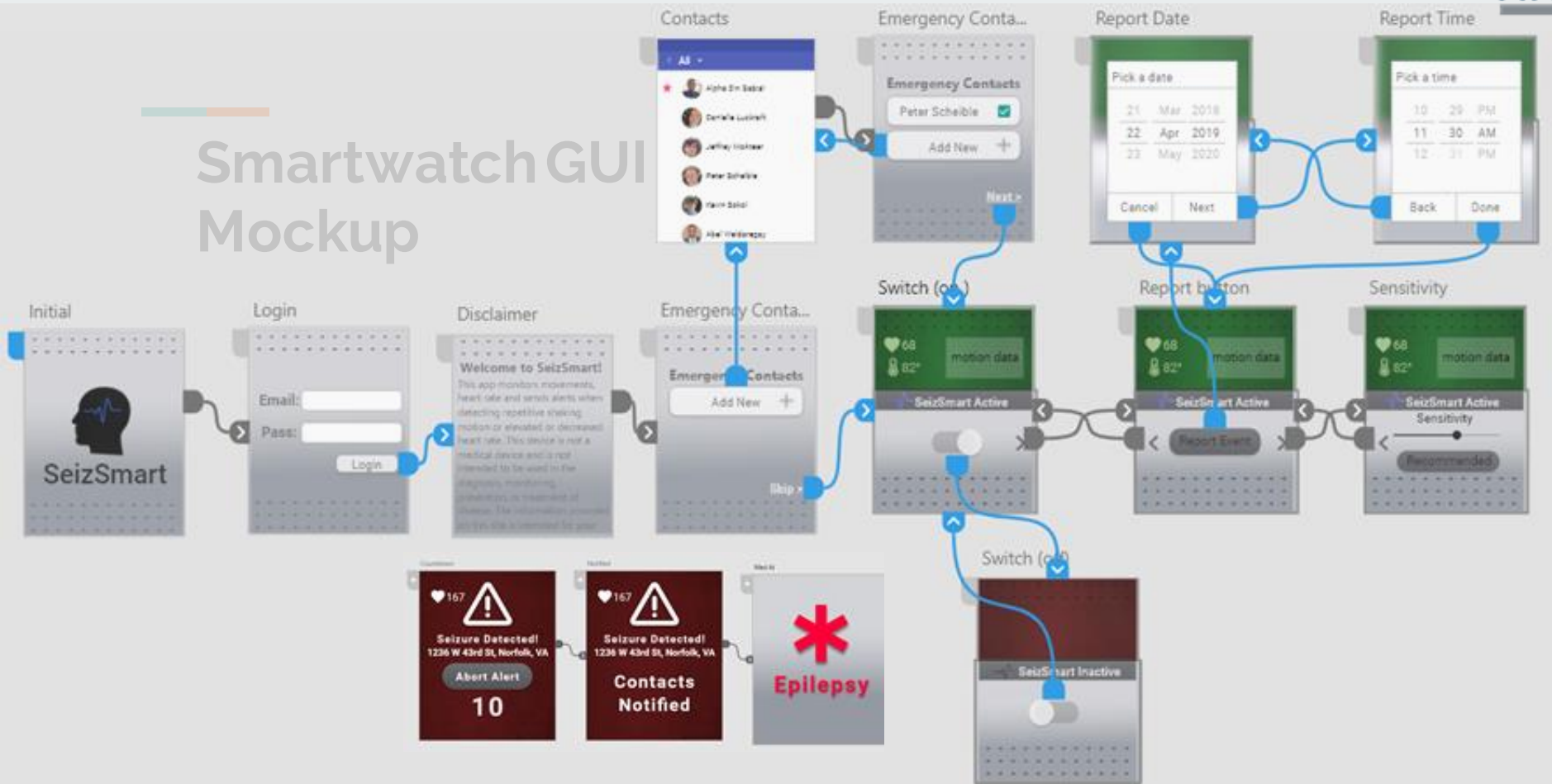


# WBS - User Interface Smartwatch





# Smartwatch GUI Mockup





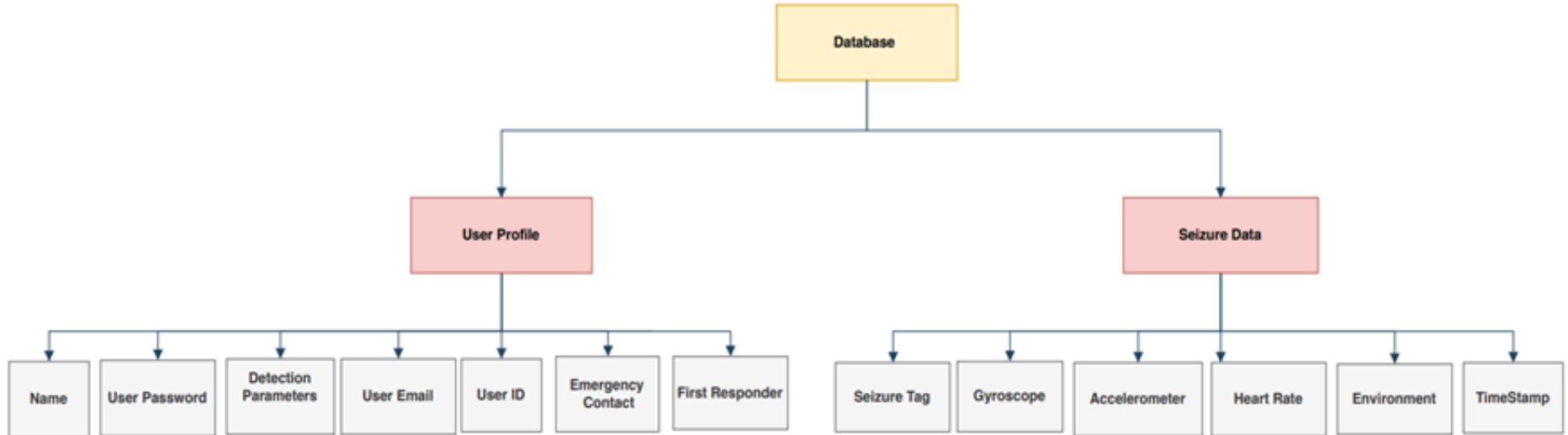
# Database: External Storage MySQL

- MySQL is an open-source relational database management system.
- Stores all data from the watch to be used by machine learning algorithm.
- Data is easily exportable to csv or other formats for research teams.





# WBS - Server Database (External Storage)





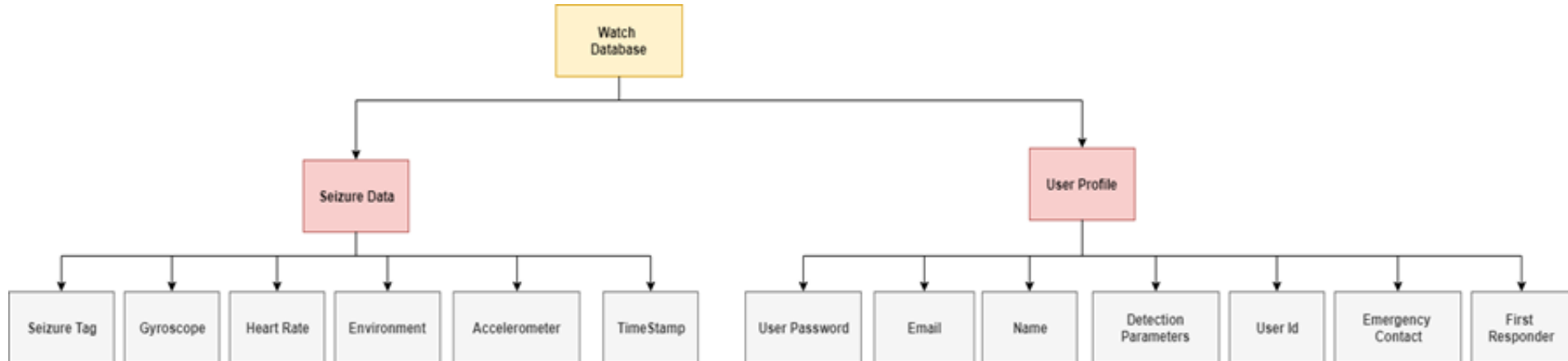
# Database: Local Storage SQLite (Smart Watch)

- Used for local storage on the smartwatch.
- Will hold data before being sent to the main database on the server



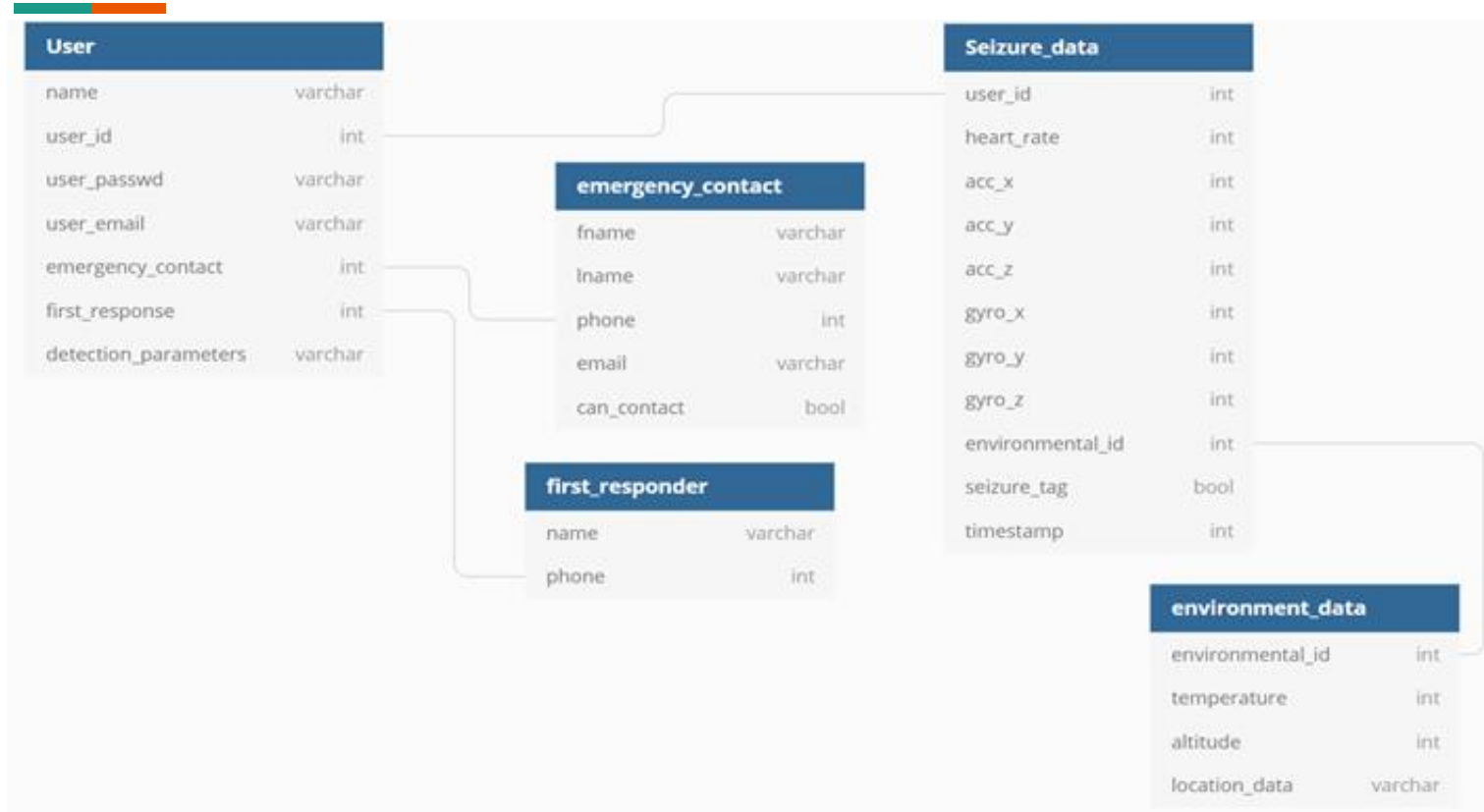


# WBS - Smartwatch Database





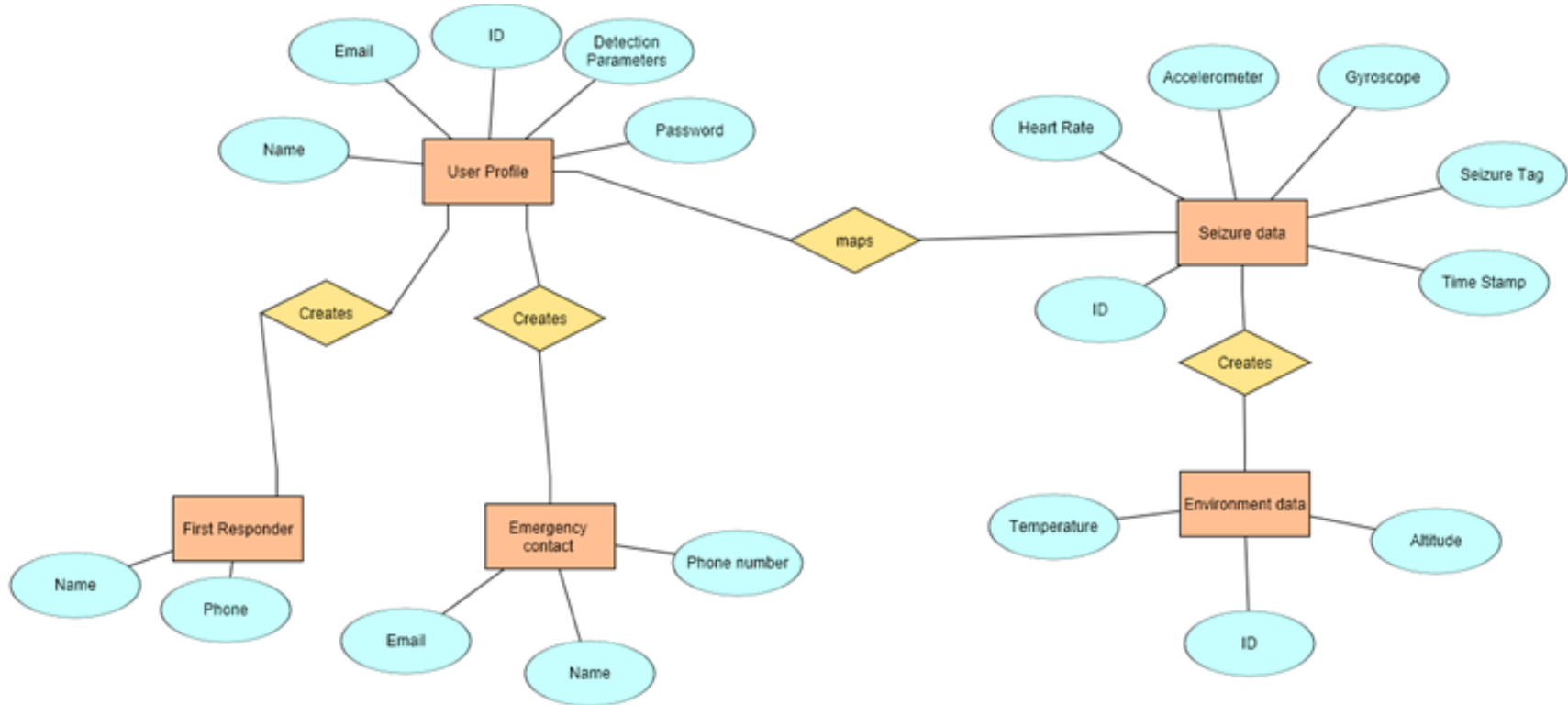
# Database Schema





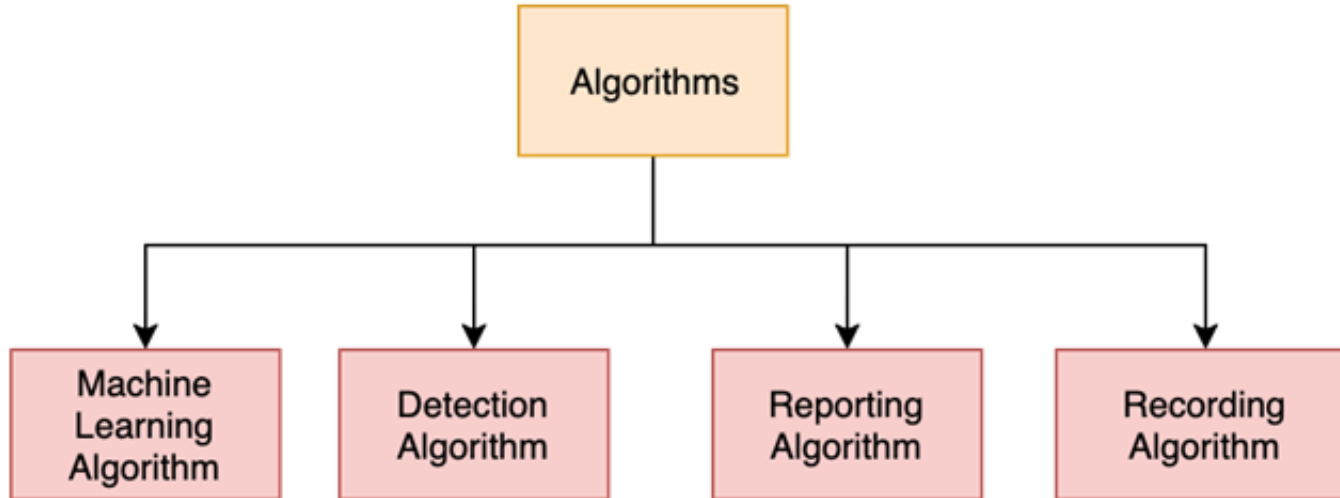


# Entity Relationship Diagram (ERD)




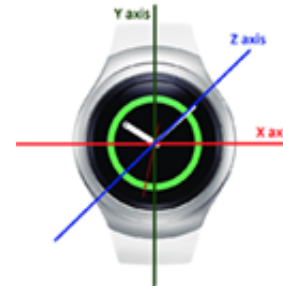


# WBS - Algorithms



# Machine Learning Algorithm

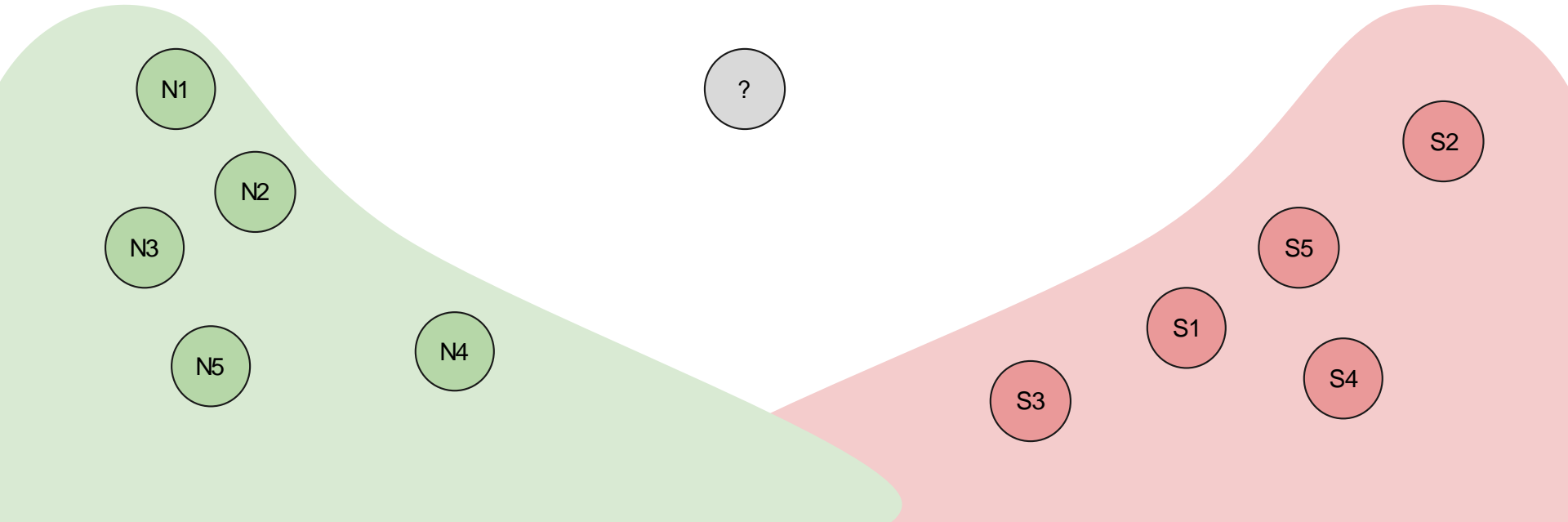
- **Purpose**
  - Build a unique seizure profile for each individual patient
- **Tools**
  - TensorFlow 
- **Parameters**
  - Motion data collected about patient
    - Accelerometer values
    - Gyroscope values
  - Patient's heart rate
  - Seizure tag





# Machine Learning Algorithm: Objective

Answers the question: given two sets containing N-dimensional element and a new N-dimensional element, which set does the new element belong to?





# Machine Learning Algorithm: Preprocessing

Each training session will use:

Min, Average, and Max X,Y,Z acceleration over last 5 mins, 1 min, and 10 sec

Must remove gravity; sdk has helper functions

Then clamp value in  $m/s^2$  between -1 and 1, add 1 and divide by 2 to get value between 0 and 1

Min, Average, and Max X,Y,Z gyroscope rotations over last 5 mins, 1 min, and 10 sec

Add 360 to given degrees then divide by 720 to get value between 0 and 1

Min, Average, and Max 10-second heart rate measured over last 5 mins, 1 min, and 10 sec

Clamp between 30 and 250 beats per minute; subtract 30 and divide by 220 to get value between 0 and 1

Total of  $3*(3*3*3) + 3*(3*3*3) + 3 = 165$  input nodes

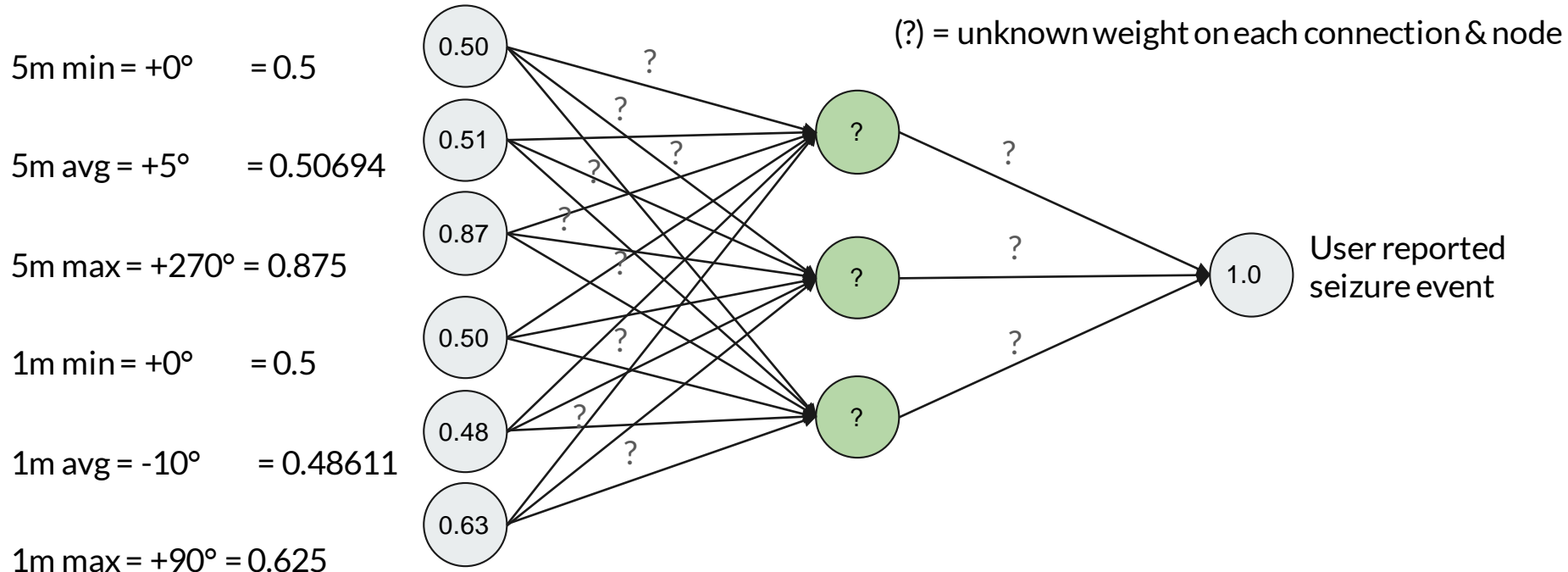
Single output node is 0 if no seizure during time period, 1 if seizure during time period.



# Machine Learning Algorithm: Training

Small portion of total network: x-axis rotation data & it's small role in detecting a seizure.

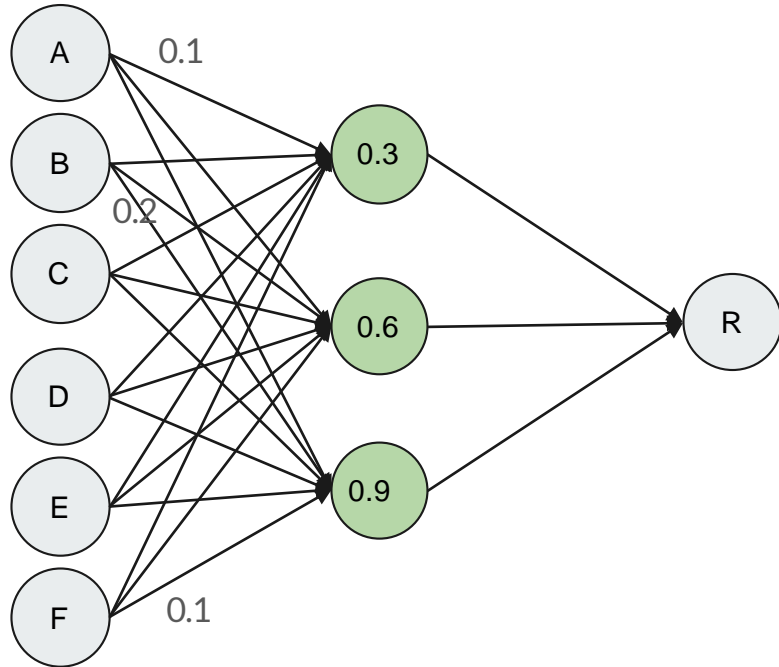
Training is computationally intensive, occurs on the server, and uses the Gradient Descent training algorithm





# Machine Learning Algorithm: Evaluation

Evaluation is computationally trivial (adding/multiplying ~200 numbers) and occurs on watch in real-time as 10-second batches of data are read from sensors



To compute R using trained weight values:

$$R = \sum(A*0.1 + B*0.2 \dots F*0.1) * 0.3 + \sum(A*0.1 + B*0.2 \dots F*0.1) * 0.6 + \sum(A*0.1 + B*0.2 \dots F*0.1) * 0.9$$

Finally compare R against the user's preferred sensitivity coefficient. If set to 0.5, this means when  $R > 0.5$  we act on a seizure event



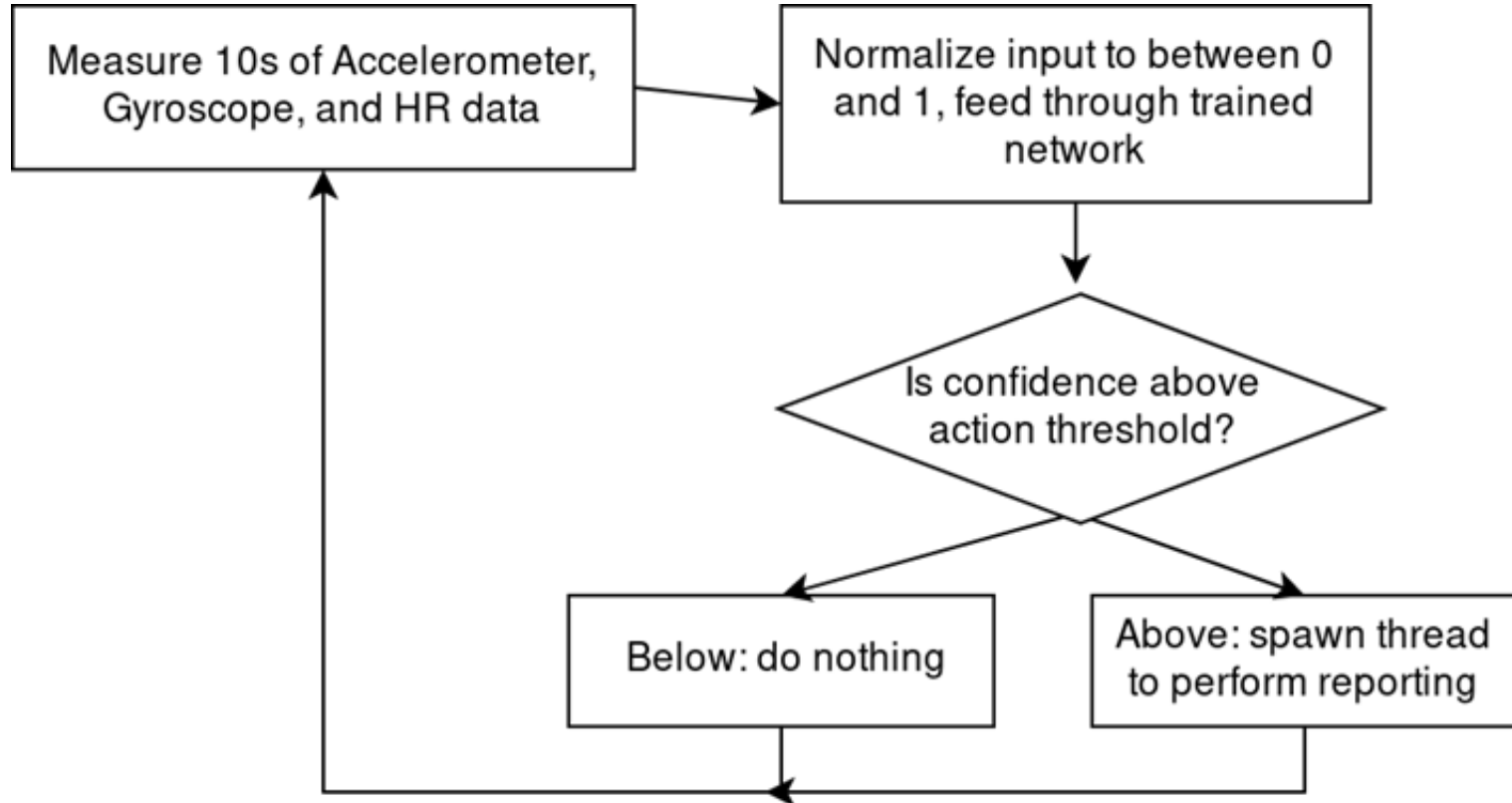
# Detection Algorithm

- **Purpose**
  - Determine if a patient is having a generalized seizure in real time
- **Tools**
  - Smartwatch sensors
  - Trained Neural Network
- **Parameters**
  - Acceleration 5m, 1m, 10s / avg, min, max / x, y, z
  - Gyroscope rotation values 5m, 1m, 10s / avg, min, max / x, y, z
  - Heart rate 5m, 1m, 10s / avg, min, max





# Detection Algorithm Logic Flow



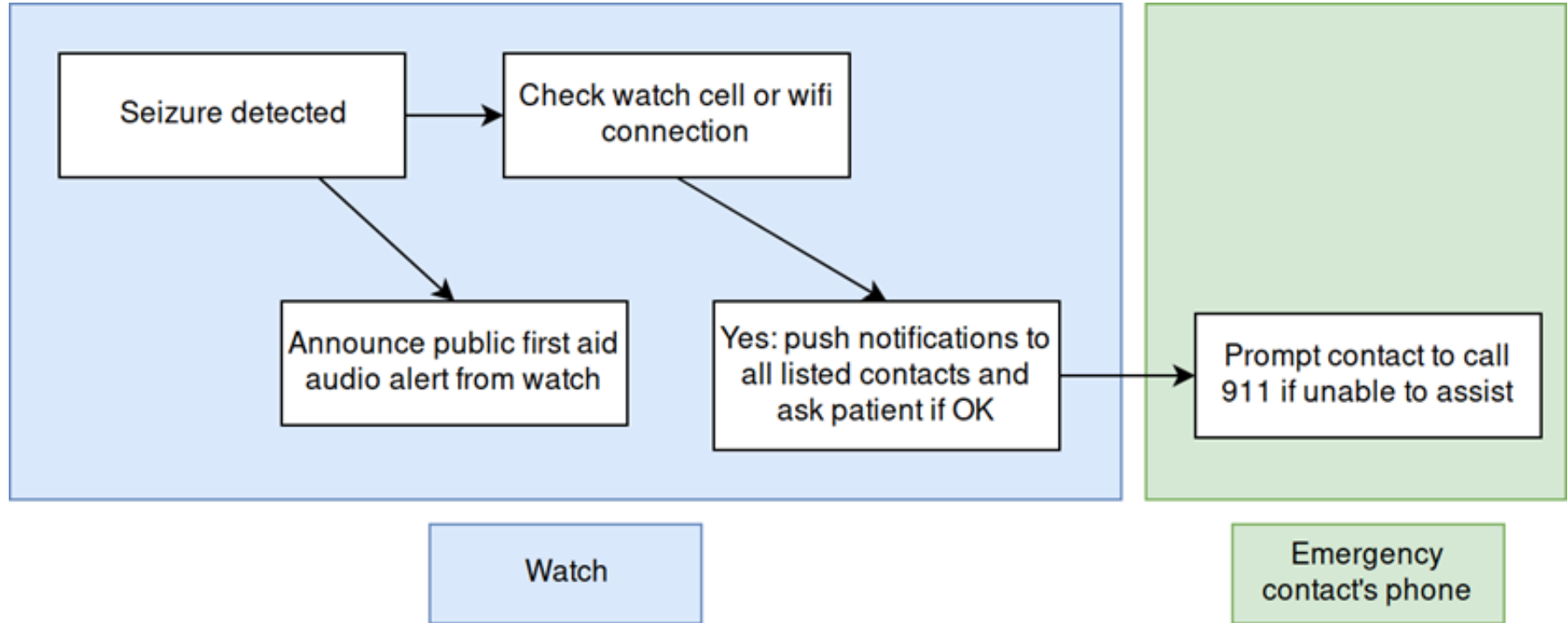


# Reporting Algorithm

- **Purpose**
  - To notify the patient's emergency contact and in some cases the patient's last resort emergency contact
- **Tools**
  - Smartwatch with cellular or wifi network
- **Parameters**
  - Data about the patient
    - Patient's emergency contacts list
    - Patient's last resort emergency contact
    - Patient's location coordinates
    - Patient's heart rate and body motion data



# Reporting Algorithm Logic Flow



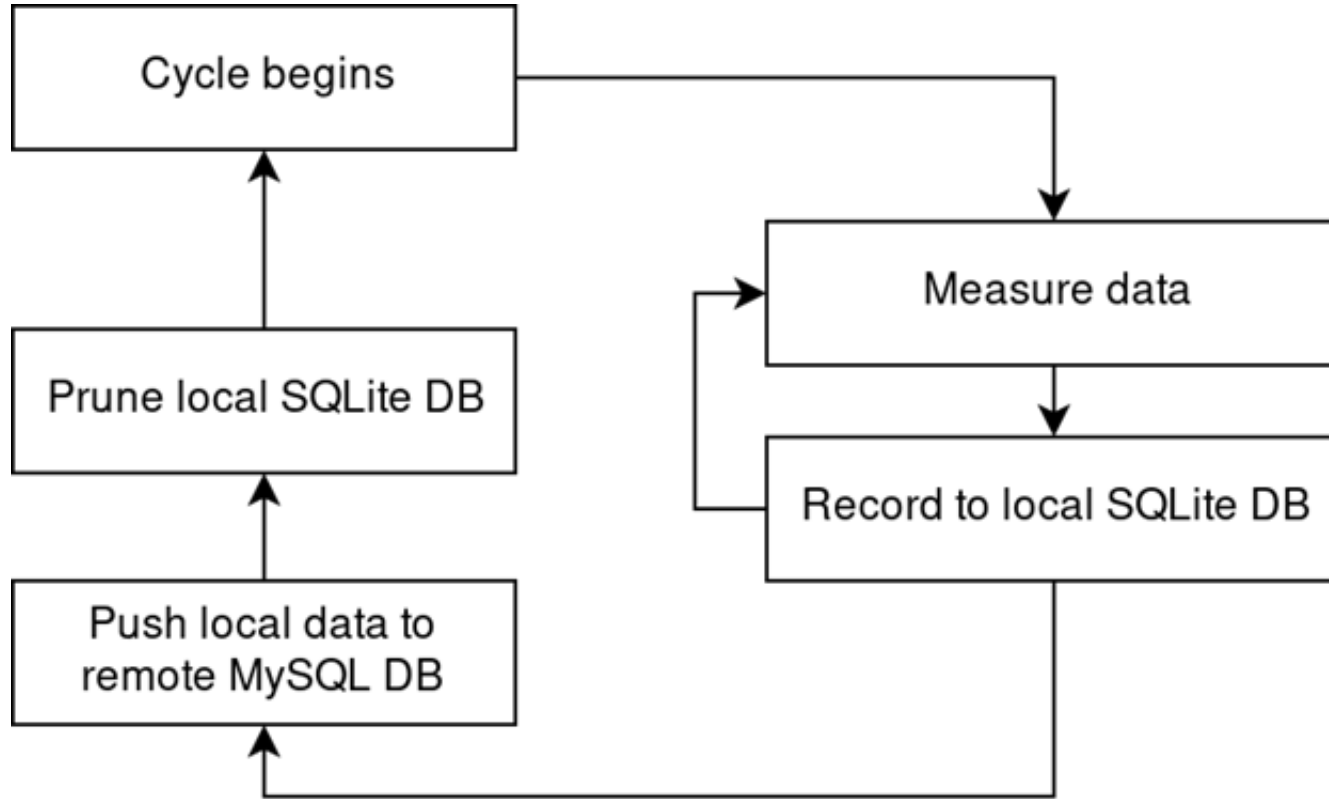


# Recording Algorithm

- **Purpose**
  - Record seizure-related data used in training.
- **Tools**
  - SQLite
  - MySQL
- **Parameters**
  - Heart rate
  - Accelerometer readings
  - Gyroscope readings
  - Seizure tag

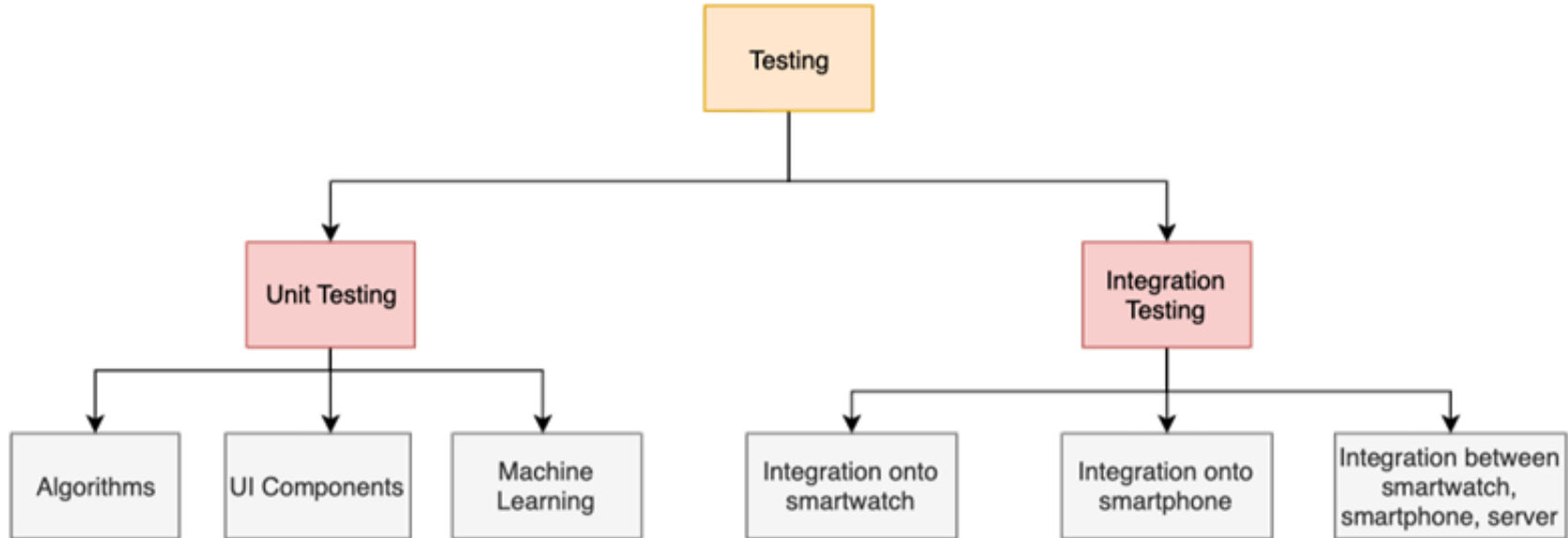


# Recording Algorithm Logic Flow



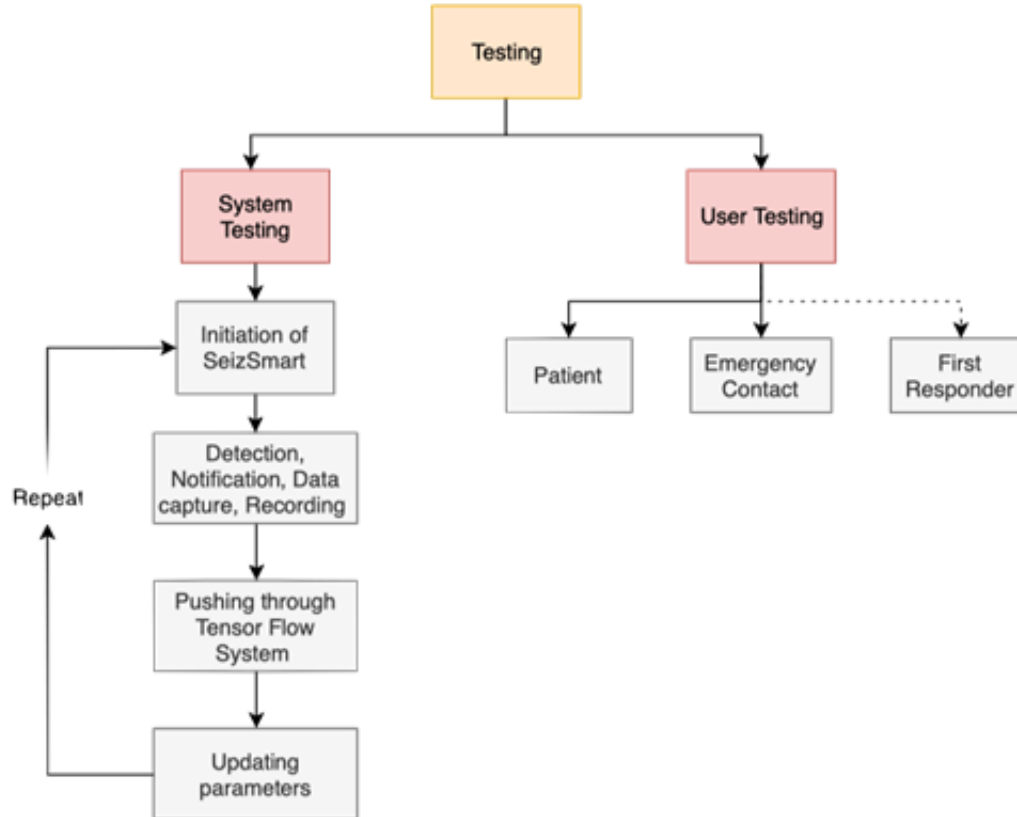


# WBS - Testing





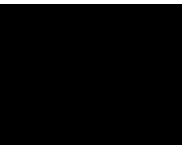
# WBS - Testing Continued





# Risk Matrix

|        |           | Probability   |     |              |           |           |
|--------|-----------|---------------|-----|--------------|-----------|-----------|
|        |           | Very Low      | Low | Moderate     | High      | Very High |
| Impact | Very High | <b>C3, T1</b> |     |              | <b>T5</b> |           |
|        | High      |               |     | <b>C4,C5</b> | <b>T3</b> |           |
|        | Moderate  |               |     | <b>T4</b>    |           | <b>C1</b> |
|        | Low       | <b>C2</b>     |     |              |           |           |
|        | Very Low  |               |     |              | <b>T2</b> |           |







# Customer Risks-C1

# Mitigation

- The detection process will go through a “learning” phase which may increase the number of false positives

- Let the patient know ahead of time that there will be a learning phase for the application

Impact

## Probability

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C3, T1   |     |          | T5   |           |
| High      |          |     | C4,C5    | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |





# Customer Risks-C2

# Mitigation

- May require a certain level of end user technical competency and commitment/dedication

- Provide detailed instructions of how to properly use the application

**Probability**

|           | Very Low      | Low | Moderate     | High      | Very High |
|-----------|---------------|-----|--------------|-----------|-----------|
| Very High | <b>C3, T1</b> |     |              | <b>T5</b> |           |
| High      |               |     | <b>C4,C5</b> | <b>T3</b> |           |
| Moderate  |               |     | <b>T4</b>    |           | <b>C1</b> |
| Low       | <b>C2</b>     |     |              |           |           |
| Very Low  |               |     |              | <b>T2</b> |           |

**Impact**





# Customer Risks-C3

# Mitigation

- Patient data could be leaked in the event of a potential data breach

- Encrypt all collected data about the patient

**Probability**

|           | Very Low      | Low | Moderate     | High      | Very High |
|-----------|---------------|-----|--------------|-----------|-----------|
| Very High | <b>C3, T1</b> |     |              | <b>T5</b> |           |
| High      |               |     | <b>C4,C5</b> | <b>T3</b> |           |
| Moderate  |               |     | <b>T4</b>    |           | <b>C1</b> |
| Low       | <b>C2</b>     |     |              |           |           |
| Very Low  |               |     |              | <b>T2</b> |           |

**Impact**





# Customer Risks-C4

# Mitigation

- If no network is available, important data can be lost

- We will preserve the most important data, which is seizure data, in the Smartwatch itself.

## Probability

Impact

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C3, T1   |     |          | T5   |           |
| High      |          |     | C4, T5   | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |





# Customer Risks-C5

# Mitigation

- If no network is available, emergency contacts can not be notified.

- An audio alert will sound and instructions will display on watch so anyone nearby can aid effectively.

## Probability

Impact

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C3, T1   |     |          | T5   |           |
| High      |          |     | C4, C5   | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |





# Technical Risks-T1

# Mitigation

- Security breach

- Encrypt all data in transit and at rest

**Probability**

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C, T1    |     |          | T5   |           |
| High      |          |     | C4,C5    | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |

**Impact**





# Technical Risks-T2

# Mitigation

- Battery drainage due to the high use of sensors in smartwatch

- Only activate sensors that will be used and turn off all sensor listeners when not being used

**Probability**

|           | Very Low      | Low | Moderate     | High      | Very High |
|-----------|---------------|-----|--------------|-----------|-----------|
| Very High | <b>C3, T1</b> |     |              | <b>T5</b> |           |
| High      |               |     | <b>C4,C5</b> | <b>T3</b> |           |
| Moderate  |               |     | <b>T4</b>    |           | <b>C1</b> |
| Low       | <b>C2</b>     |     |              |           |           |
| Very Low  |               |     |              | <b>T2</b> |           |

**Impact**





# Technical Risks-T3

- Ability to determine an appropriate amount of data needed to validate our initial model, and to then capture enough example data to effectively train the personalized algorithm

# Mitigation

- Speak with experienced neurologists who may be able to suggest or guide us to the frequency of certain paths of the AI decision tree. Initialize trained network using public research data biometric readings

## Probability

Impact

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C3, T1   |     |          | T5   |           |
| High      |          |     | C4,C5    | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |







# Technical Risks-T4

# Mitigation

- Correlating data between sensors to detect a seizure

- Set the same sampling rate of all sensor updates

Impact

## Probability

|           | Very Low | Low | Moderate  | High | Very High |
|-----------|----------|-----|-----------|------|-----------|
| Very High | C3, T1   |     |           | T5   |           |
| High      |          |     | C4,C5     | T3   |           |
| Moderate  |          |     | <b>T4</b> |      | C1        |
| Low       | C2       |     |           |      |           |
| Very Low  |          |     |           | T2   |           |





# Technical Risks-T4

# Mitigation

- Correlating data between sensors to detect a seizure

- Set the same sampling rate of all sensor updates

Impact

## Probability

|           | Very Low | Low | Moderate | High | Very High |
|-----------|----------|-----|----------|------|-----------|
| Very High | C3, T1   |     |          | T5   |           |
| High      |          |     | C4,C5    | T3   |           |
| Moderate  |          |     | T4       |      | C1        |
| Low       | C2       |     |          |      |           |
| Very Low  |          |     |          | T2   |           |





# Technical Risks-T5

# Mitigation

- Machine learning might degrade performance

- There will be an option to revert threshold values back in time, or completely reset threshold values back to initial values

## Probability

Impact

|           | Very Low | Low | Moderate | High      | Very High |
|-----------|----------|-----|----------|-----------|-----------|
| Very High | C3, T1   |     |          | <b>T5</b> |           |
| High      |          |     | C4,C5    | T3        |           |
| Moderate  |          |     | T4       |           | C1        |
| Low       | C2       |     |          |           |           |
| Very Low  |          |     |          | T2        |           |





# Technical Risks-T5

# Mitigation

- Machine learning might degrade performance

- There will be an option to revert threshold values back in time, or completely reset threshold values back to initial values

## Probability

Impact

|           | Very Low | Low | Moderate | High      | Very High |
|-----------|----------|-----|----------|-----------|-----------|
| Very High | C3, T1   |     |          | <b>T5</b> |           |
| High      |          |     | C4,C5    | T3        |           |
| Moderate  |          |     | T4       |           | C1        |
| Low       | C2       |     |          |           |           |
| Very Low  |          |     |          | T2        |           |





# What SeizSmart Will Not Do

- It will not predict seizures in advance of known symptoms
- It detects all types of generalized seizures except for absence seizures
- It is not a medical application and is not intended to be used in the diagnosis, monitoring, prevention, or treatment of epileptic seizures.



# Key Points Summary

- SeizSmart is a mobile application based on smartwatch technology that is designed to improve the detection, tracking, and reporting of generalized seizures.
- The Problem
  - Current applications only check for an increase in heart rate or rapid body movements.
  - Current applications require a prescription or subscription plan in order to detect and track seizures.
  - Current applications require the smartwatch to be in close proximity to the relay device to transmit alerts and notifications.
- The Solution
  - Continuously monitor the end-user's heart rate and body movements.
  - Apply machine learning to the collected data about the end-user's seizures to build a unique, personalized, more accurate seizure profile.
  - Execute within the smartwatch itself to enable independent operation without requiring proximity to a relay device.



# Interactive Prototypes

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- App:
  - <https://xd.adobe.com/view/17e93316-724a-4f5a-6827-3e06b38ce038-61d8/>
- Alert:
  - <https://xd.adobe.com/view/1c7d93db-b2ca-40c6-71e2-d50d1892ada8-6a4c/>
- Phone:
  - <https://www.figma.com/proto/NXfp6jJo21H7FiibaDyuyVVS/SeizSmart-Phone-UI-Test?node-id=0%3A1&scaling=scale-down>







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# Appendix A1 - User Stories (Patient)

- a. As a patient, I need to receive an alert when a seizure has been detected
- b. As a patient, I need to be given x amount of seconds to respond to the given alert before my emergency contact is notified
- c. As a patient, I need to be able to cancel an alert
- d. As a patient, I need to have the ability to turn detection mode on and off
- e. As a patient, I would like to log seizures
- f. As a patient, I would like to view all my recorded seizures
- g. As a patient, I would like to pick which emergency contact receives a notification during the onset of a seizure.
- h. As a patient, I need to add emergency contacts who will receive a notification during the onset of a seizure. (Need)
- i. As a patient, I need to be able to switch on emergency notifications (Need)
- j. As a patient, I need to be able to store and change emergency contacts as required (Need)
- k. As a patient I would like to be able to tweak detection parameters as needed.
- l. As a patient I would like the smartwatch to vibrate or emit an audio alarm when a seizure is detected.
- m. As a patient, when I don't respond to my initial alert, I would like the smartwatch to emit an alarm or verbal notification to alert bystanders what is happening



# Appendix A1 - User Stories (Patient) Continued

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- a. As a patient, when I don't respond to my initial alert, I would like the smartwatch to emit verbal instructions telling bystanders how to help me
- b. As a patient, if I fall, I would like the watch to include that in the notification to my emergency contact/first responders





# Appendix A2 - User Stories (Emergency Contact)

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- a. As an emergency contact, I need to receive an alert when a patient is having a seizure. (Need)
- b. As an emergency contact, I need to have the ability to cancel an alert from being sent to first responders if I am available to assist the patient. (Need)
- c. As an emergency, I need to know patient location and patient phone number during a seizure.
- d. As an emergency contact, I need to know patient heart rate in the alert to confirm if this is an actual seizure or just a false positive.