Lab 1 - Seizsmart Description

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Version 2

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1. Introduction

50 million patients who suffer from clonic seizures have to face unique lifestyle challenges. The most common form, Tonic-Clonic seizures, cause the patient to convulse uncontrollably which puts him/her at risk of death from a multitude of sources. The seizures themselves are not the only cause of death; patients will die from inhaling vomit immediately after a seizure. To prevent deaths, caregivers are required to constantly watch seizure patients. This requires significant effort which may be reduced through modern communication systems, leading to effectively the same amount of care with fewer constraints on the patient's lifestyle.

The patient and caregiver may be freed from these constraints by means of a communication system - patients do not need care before a seizure, only immediately after. Fig. 1 shows the timeline of patient motion associated with clonic seizures. The timeline indicates a detectable change in patient disposition which may be used to trigger an alert to caregivers, who have approximately five minutes to respond during the postictal phase when the patient needs care. Five minutes is enough time to allow a neighbor to be an emergency caregiver, allowing patients to live more ordinary lives without the imposition of a nurse or family member constantly watching them.

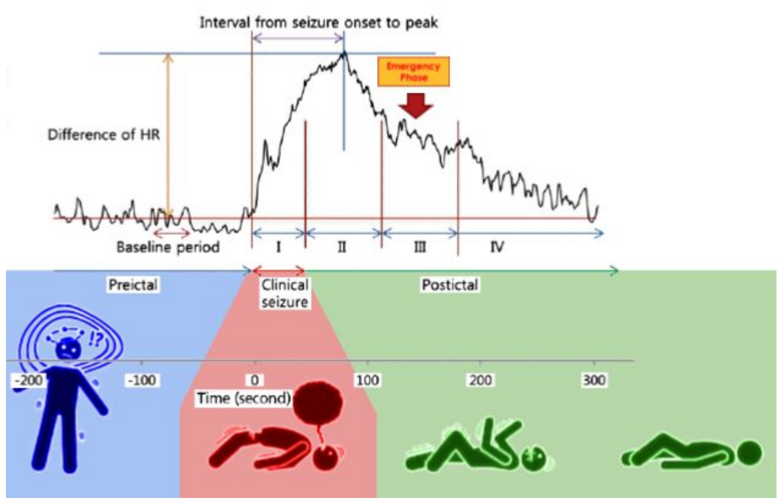

Fig. 1: Timeframe of seizure showing preictal, ictal, and postictal phases

Solutions to this problem already exist, but have reported difficulties because their detection algorithms are generic and cannot track an individual patient's seizure symptoms[17][18]. Instead existing solutions generalize the detection of a seizure across a huge corpus of data which may not represent the patient's actual symptoms. Another problem with existing alert systems is an outdated requirement of a relay device to transmit alerts - the watch transmits to a phone or relay box which in turn transmits to caregivers. Modern smartwatches have LTE and WIFI connections, meaning they can now directly push notifications to caregivers, reducing the number of moving parts and improving the reliability of alerts.

A better solution is currently underway - SeizSmart! SeizSmart will detect seizures using a patient-optimized profile and alert caregivers directly, improving the quality of life for over 50 million patients and their loved ones[15].

2. SeizSmart Description

SeizSmart will be a system which enables wearable electronics (e.g. Android smartwatch) to leverage advances in machine learning for the purpose of detecting seizures within minutes of their onset, if not immediately. After detection several user-configurable alerts and messaging systems may be used to notify caregivers of the emergency, improving the efficiency of care and reducing the number of hours patients need to spend being constantly watched. A second component, the server, will be used to provide the machine learning required to accurately detect seizures.

2.1. Key Product Features and Capabilities

SeizSmart will use historical acceleration, rotation, and seizure tag data to create a trained patient-specific model for detecting seizures. Current acceleration and rotation data from the smartwatch will be fed through the algorithm (also on the smartwatch), and the output will indicate if the user is currently experiencing a seizure. When a seizure is detected, the smartwatch will send an alert in the form of an SMS and/or Direct Message (provided via. the server) directly to emergency contacts. Contacts using the phone app will be prompted to dial 911 on behalf of the patient if they cannot respond to the emergency.

Use of the neural network directly on the smartwatch ensures as little latency as possible between seizure onset and detection, and using the smartwatch's LTE and/or WIFI capabilities ensures alerts are sent with as few failable components as possible. For detection and alerting the server is unnecessary.

The trained patient-specific algorithm will be provided by the server. The smartwatch will record 24 hours worth of local acceleration and rotation data, then upload these every 6 hours to the server. The smartwatch will also include a seizure tag for each section of data which can be modified by the user via the smartwatch. This tag indicates if the section of acceleration/rotation data is related to seizure activity or if it relates to non-seizure activity. Initially the app will use a neural network model trained from public seizure research data. During the first few days of use patients will need to indicate false positives (watch alerts on non-seizure activity like jogging) and false negatives (patient had a seizure at 10am but watch missed it and incorrectly tagged data at that time “not seizure activity”). Every 6 hours the watch will request an updated training algorithm from the server.

2.2. Major Components

SeizSmart will consist of three primary components. The smartwatch will be responsible for collecting biometrics, alerting the user, alerting emergency contacts, and for reporting biometrics to the server. Biometrics include heart rate, motion, and detection status data . The server will be responsible for storing biometric data and training a neural network to detect seizures for use on the smartwatch. A phone app will be used to configure SeizSmart and to receive non-SMS notifications.

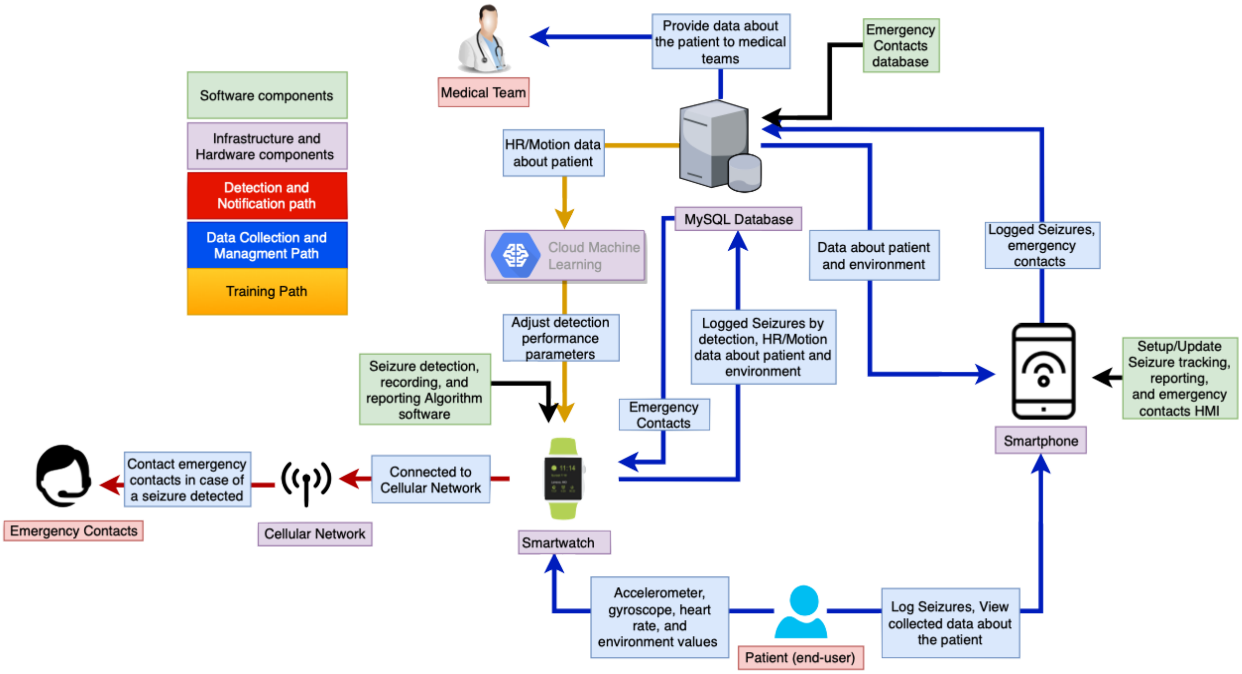

Fig. 2: Major Functional Component Diagram

SeizSmart will require the smartwatch to have accelerometer and rotation sensors, wifi and LTE radios, and approximately 128MB of free space with which to store a day's worth of biometric data. The software written to run on the watch will be responsible for using the neural network to compute a seizure probability tag between 0.0 and 1.0 given the last 30 seconds of biometric data. The watch will have configuration parameters which may be modified by the smartphone app and communicated via the server, one of which is a threshold value between 0.0 and 1.0. Patients may use this to fine-tune the alerting process depending on how error-sensitive they want the final action of the detection algorithm to be.

The server will store biometric data and a trained neural network for each user in a MySQL database, and a tensorflow application will periodically run batch jobs on the data to keep the neural network trained using the most recent biometric information available. Another application will provide a REST API for the smartwatch to push biometric data into and pull neural network data from the database, as well as provide a non-SMS alert API. Fig.3 describes the flow of biometric data between the smartwatch and the server.

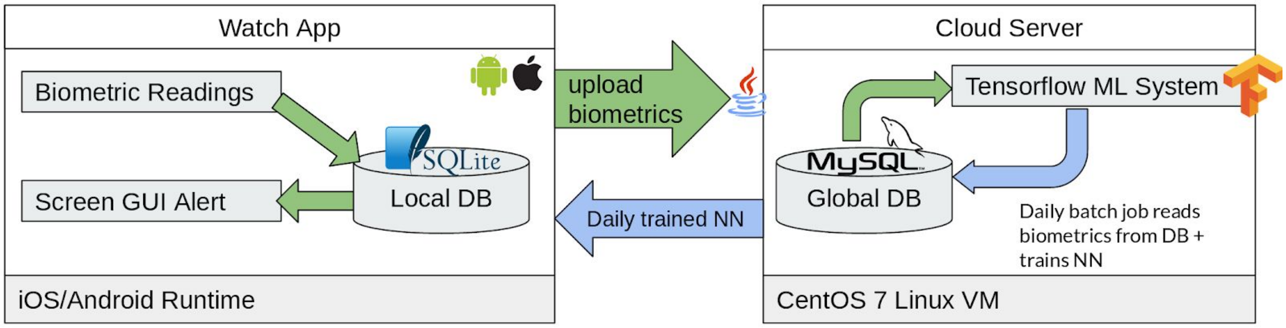

Fig. 3: Hardware and Software Components

2.3. Identification of Case Study

SeizSmart is being developed for patients suffering from epilepsy and their loved ones. Customers will include the patients, their caregivers, and doctors who treat seizure patients. For the case study student volunteers will be used. The study will focus on evaluating how well the algorithm is able to learn a “profile” of biometric data as well as how quickly and reliably alerts may be sent out. The lack of actual seizure patients does not invalidate the study because the learning algorithm will track to any biometric feedback loop, including the non-seizure surrogate biometrics that will be used in the case study.

3. SeizSmart Prototype Description

The SeizSmart prototype will implement every component discussed in Section 2.1, but only for Android smartwatches and Android smartphones. Seizure biometric data will be simulated both by providing the training system with wildly unrealistic data and by providing it with seizure-like data from the case study volunteers. The unrealistic data will be used to test edge cases and prove generalization over a large domain of inputs, while the seizure-like data will consist of hand-shaking motions to show learning may adapt to identify any kind of motion as either seizure or non-seizure. Alerting will only be tested via non-SMS to limit expenses during the prototyping phase.

3.1 Prototype Functional Goals and Objectives

The SeizSmart prototype is expected to demonstrate learning and alerting capabilities. The correctness of the learning will be evaluated by having a volunteer tag one type of motion data (e.g., moving arm in a circle) as “seizure” and tag all other motion while wearing the watch “non-seizure”. After 24 hours of training, the volunteer will again perform the type of motion they tagged as “seizure” and the system should perform alerting as described above. False positives are expected at the beginning of training and a reduction will be expected as training goes on. A lack of reduction in false positives after training constitutes a failure of the prototype.

The smartphone component will be evaluated based on its ability to store user settings and receive alerts when the smartwatch detects seizure activity.

The server will not be directly tested, but will be integral to the proper functions observed in the smartwatch and smartphone. If the other two systems operate as expected, it is safe to say that the server is performing notification and training duties successfully.

3.2. Prototype Architecture (Hardware/Software)

The prototype architecture consists of a virtual server, one smartwatch, and at least two smartphones. One smartphone will be set up to simulate the patient’s phone (for managing seizure data and settings), the other will be the caregiver (for receiving alerts). The virtual server must be reachable over a network from both the smartphone and the smartwatch. The database does not fall into architectural considerations because it will be an implementation detail of the server, and the smartwatch and smartphone will only use the server’s API to access data.

The smartwatch prototype will read 3-axis acceleration and rotation (hereafter “biometric”) data and record this to a SQLite table along with millisecond-precision timestamps. The watch will periodically pull the most recent 30 seconds of biometric data and feed it through the neural network. An adjustment will be made to the timestamps such that the most recent timestamp is exactly 0 and the furthest is around negative 30,000 milliseconds; this aids in learning generalization because relative timestamps are the only ones required for detection purposes. After detection of a seizure, the smartwatch will use the REST API to tell the server to send an alert to everyone on the patient's emergency contact list.

The server prototype will routinely receive biometric data pushed via the smartwatch from the smartwatch's SQLite table and store this in the MySQL database. The server will also store and serve user settings data to facilitate phone-watch communication. The server will implement a WebSocket component used in the smartphone. Smartphones will open the websocket channel and use it to listen for non-SMS alerts sent from the smartwatch to the server. The server will also run offline jobs to train user neural networks using past biometric data.

The smartphone app in caretaker mode will listen to a WebSocket for alerts, and upon receiving an alert will sound an audible tone and display a visible alert telling the caretaker who is having a seizure, what their most recent known location was, and will prompt them to call 911 if they are unavailable or clear the alert if it is a false positive.

3.3. Prototype Features and Capabilities

Prototype features will be identical to the real world features with the exception of SMS alerts and the only implementation difference is the prototype is limited to Android smartwatches and smartphones. A complete list of features is available in Table 1.

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

Feature	Final Product	Prototype
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.
Server		
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

3.4. Prototype Development Challenges

During the prototype phase refinements will be done on the training algorithm until a useful performance and accuracy are achieved. It is currently unknown what training methodologies are ideal for the prototype and only real-world data and experimentation can reveal the ideal methodology. Several methodologies have been researched and will be tested. Training using Gradient Descent promises good precision at the cost of high training times. Training using Newton's method will reduce the number of steps to get a precise answer, but computing the inverse of matrices required is computationally expensive.

One risk during the prototype phase is the inability of users to operate the smartwatch and smartphone applications. To mitigate this, developers will use uncomplicated designs and conform to modern design norms (e.g. material design, “hamburger menus”) to reduce the amount of unexpected user interface elements exposed to the user. The prototype phase will also require that volunteers have the necessary educational requirements to operate smartphones; an education level above Kindergarten will be required to participate in the prototype phase.

4. Glossary

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

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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