Transforming Epilepsy from a chronic condition towards an acute one.

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March 20, 2019,
Sunnyvale, California
We enable lean development of wearable health

We are building the most comprehensive data set of vital signs outside the hospital.

We allow clinical studies of more than 10000 patients, no matter where they are.

We translate data into objective, 24-7 clinical insights
Any signal, any time

- Heart activity
- Muscle activity
- Respiration
- Skin conductance
- Motion
- Blood pulse
- Brain activity
- Eye motion
EPILEPSY

$15B
Yearly cost in US

1/26
People affected

100k
Yearly deaths

20%
Wrongly diagnosed

33%
No treatment available

$1B/Yr
No improvement!
DIFFICULT TO DIAGNOSE IN THE HOSPITAL

Video EEG monitoring
24h to 5 days hospitalization
$$$
No seizure = no data

Self-reported outcome
Less than 50% accuracy
Time consuming
Low patient adherence
SEIZE IT
Your wearable epilepsy solution

82 patients
390 seizures
9800 hours data

Optimized Sensor selection
Seizure detection with 90% sensitivity
Scalable demonstrator
OLD VERSUS NEW
NEXT STEPS

Multi-centered validation

Largest Epilepsy dataset outside the hospital

Online seizure detection

Clinical application
MACHINE LEARNING FOR HEALTHCARE: A MODULAR APPROACH

More training data
More interpretation
Lower complexity
Easier to validate
FEATURE EXTRACTION EXAMPLE: GENERAL PURPOSE PEAK DETECTOR

Sensor Dot will record your vital signals

Google Cloud Platform analysis your data

Filtering

Convolution

Peak find

Annotated data allows doctors to make better diagnosis

Measure your health 24/7
GENERAL PURPOSE PEAK DETECTOR

Approach 1: 1D convolutional NN
simple CNN (2 conv layers), 1 pooling layer, and 1 fully connected output layer with per sample prediction.

Approach 2: 2D convolutional NN
simple CNN (4 conv layers), 1 pooling layer, and 2 fully connected output layers with predictions per sub epoch (window of size QRS).

TESTED ON 50.000 HR OF SENSOR DOT DATA!!
MODULAR LAYER EXAMPLE: MOTION TRACKING

Approach: Principal component analysis
## HARDWARE SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>ECG Dot</th>
<th>Motion Dot</th>
<th>Epilepsy wearable</th>
<th>Docking station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery power</td>
<td>65mAh</td>
<td>65mAh</td>
<td>100mAh</td>
<td>/</td>
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<tr>
<td>Wireless Connectivity</td>
<td>BLE &amp; Proprietary</td>
<td>BLE &amp; Proprietary</td>
<td>BLE &amp; Proprietary</td>
<td>BLE, WiFi, LTE, GSM</td>
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<tr>
<td>CPU</td>
<td>ARM M4 @ 64MHz</td>
<td>ARM M4 @ 64MHz</td>
<td>ARM M4 @ 64MHz</td>
<td>ARM A53 (Quad-Core)</td>
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<tr>
<td>Sensors</td>
<td>1 lead ECG @ 1ksp</td>
<td>3 DOF ACM @ 200sp</td>
<td>3 lead EEG @ 250sp</td>
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<tr>
<td></td>
<td>3 DOF ACM @ 50sp</td>
<td>3 DOF ROT @ 200sp</td>
<td>3 channels PPG @ 250sp</td>
<td>3 DOF ACM @ 250 sps</td>
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<td>Memory</td>
<td>256MB (31 hours)</td>
<td>256MB (30 hours)</td>
<td>512MB (32 hours)</td>
<td>64GB</td>
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<td>Power consumption</td>
<td>Target: 2000uA</td>
<td>Target: 2000uA</td>
<td>Target: 3125uA</td>
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<tr>
<td>Sensors</td>
<td>300uA</td>
<td>250uA</td>
<td>1500uA</td>
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<tr>
<td>Acquisition (RF + Logging)</td>
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<td>1000uA</td>
<td>1000uA</td>
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<tr>
<td>Tiny ML</td>
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<td>750uA</td>
<td>625uA</td>
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</tbody>
</table>
**EMBEDDED SEIZURE DETECTION BASED ON EEG**

**Requirements:**
Low memory usage + low computational complexity

**Assumptions:**
Seizure spatio (+ temporal) signature is stationary
Seizure spatio (+ temporal) signature is unique with regards to noise

**Approach:**
max-SNR filter

\[
\max_w \frac{E\{(w^T s(t))^2\}}{E\{(w^T n(t))^2\}} = \max_w \frac{w^T R_{ss} w}{w^T R_{nn} w}
\]

= generalized eigenvalue problem
EMBEDDED SEIZURE DETECTION BASED ON EEG

Step 1: Algorithm design
Threshold on RMS amplitude, calculated over 3 seconds (= minimal length of seizure)
Training: find minimum RMS amplitude to detect all Seizure epochs

Step 2: Define noise epochs
Find epochs with RMS amplitude higher than RMS of seizure epochs.
These epochs are referred to as noise.

Step 3: Calculate filter coefficients
Characterize Seizure and Noise covariance matrices
Solve generalized eigenvalue problem
EMBEDDED SEIZURE DETECTION BASED ON EEG

Filter Results
EMBEDDED SEIZURE DETECTION BASED ON EEG

Algorithm Results

**Memory**: 3 seconds of RMS values (int16) + N filter coefficients (float) + N samples (int16)

**Complexity**: N additions + N multiplications + 1 square operation (apply filter) + 1 addition + 1 subtraction (update RMS) + 1 threshold operation
Epilepsy = a condition Defined by unpredictability

Unprovoked, Recurrent seizures
Lack of control
Societal stigma

33%
No treatment available

Educational problems
Limited employability
No driver license

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