Lightweight Machine Learning for Seizure Detection on Wearable Devices

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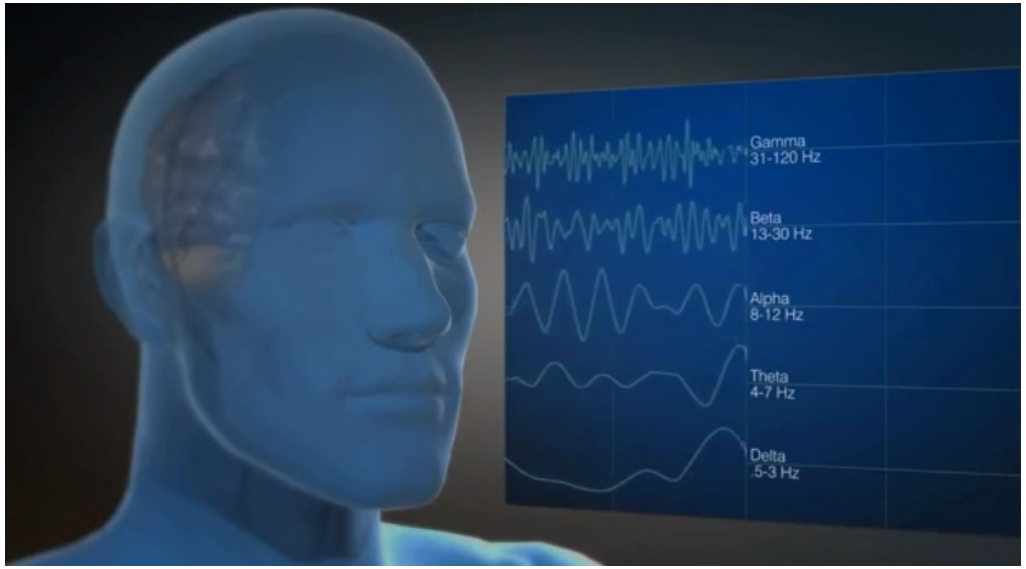
Introduction and Background of Epilepsy

Epilepsy

Epilepsy, as one of the most common neurological disorders, is characterized by **recurrent and unpredictable seizures**. An epileptic seizure is the clinical manifestation of an abnormal and purposeless electrical discharge in the brain cells called neurons.



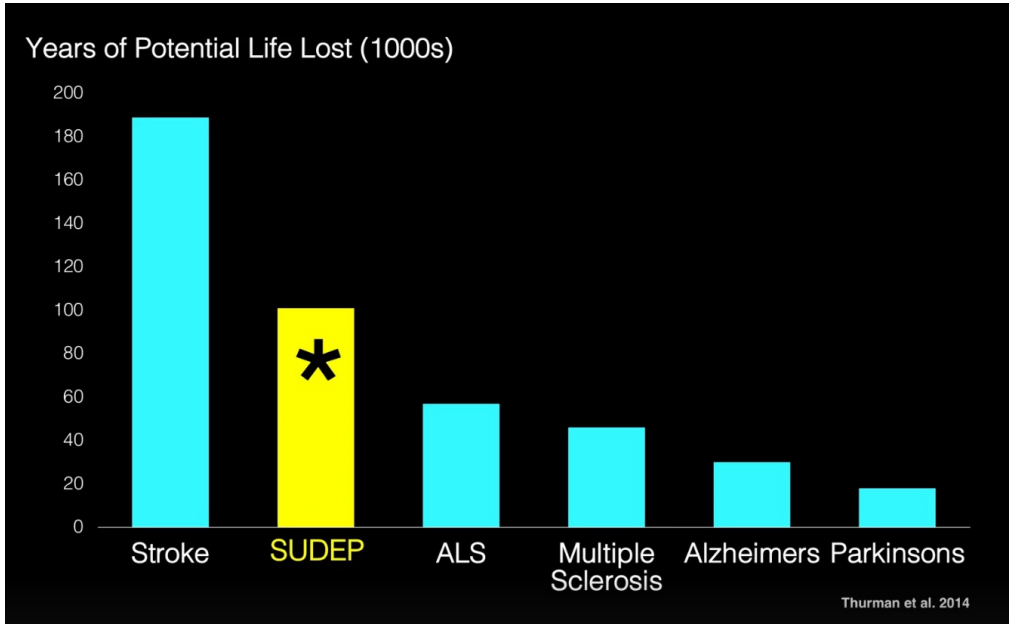
Source: https://gfycat.com/ornatehastykentrosaurus-amyloid-beta-neuroscience-microglia

Epilepsy affects around 65 million people worldwide.

World Health Organization. Epilepsy: a public health imperative[M]. World Health Organization, 2019.

Epilepsy

People with epilepsy (PWE) have a 2-3 times **higher mortality rate** compared to the corresponding healthy population, mainly because of **seizure-caused accidents** and Sudden Unexpected Death in Epilepsy (**SUDEP**).



Source: https://www.ted.com/talks/rosalind_picard_an_ai_smartwatch_that_detects_seizures

Epilepsy is the second neurological cause of years of potential life lost mainly due to seizure-caused accidents and SUDEP.

Thurman et al.. Sudden unexpected death in epilepsy: assessing the public health burden[J]. Epilepsia, 2014, 55(10): 1479-1485.

Gold Standard

Video-EEG recording is the gold standard of epilepsy monitoring but has several limitations for monitoring outside the hospital environment.

Source: https://mnepilepsy.org/

Wearable Techniques

Smart wearable techniques such as SensorDot (SD) of Byteflies can detect the onset of seizures in **real time** and **alert** family members and caregivers for rescue to **reduce mortality rate** caused by SUDEP.

Source: https://tpe-sealing.de/2020/05/05/deutsch-belgische-koproduktion-zwischen-byteflies-und-tpe-sealing-2/

Wearable techniques for epilepsy monitoring can bring higher quality of life, better healthcare system without social stigma.

https://biomedepi.github.io/seizure_detection_challenge/

Wearable Techniques

Automated EEG-based seizure detection on wearable devices provides the possibility of **real-time patient monitoring** in ambulatory settings. However, wearable devices have stringent **resource constraints**, including limited memory storage, computing power, and battery lifetime.

Source: https://byteflies.com/

Lightweight machine-learning models tailored to wearable devices are indispensable for the realization of real-time epilepsy monitoring.

Sopic D, Aminifar A, Atienza D. e-glass: A wearable system for real-time detection of epileptic seizures[C]//2018 IEEE International Symposium on Circuits and Systems (ISCAS). IEEE, 2018: 1-5.

Our Lightweight Machine-Learning Framework

Lightweight Seizure Detection

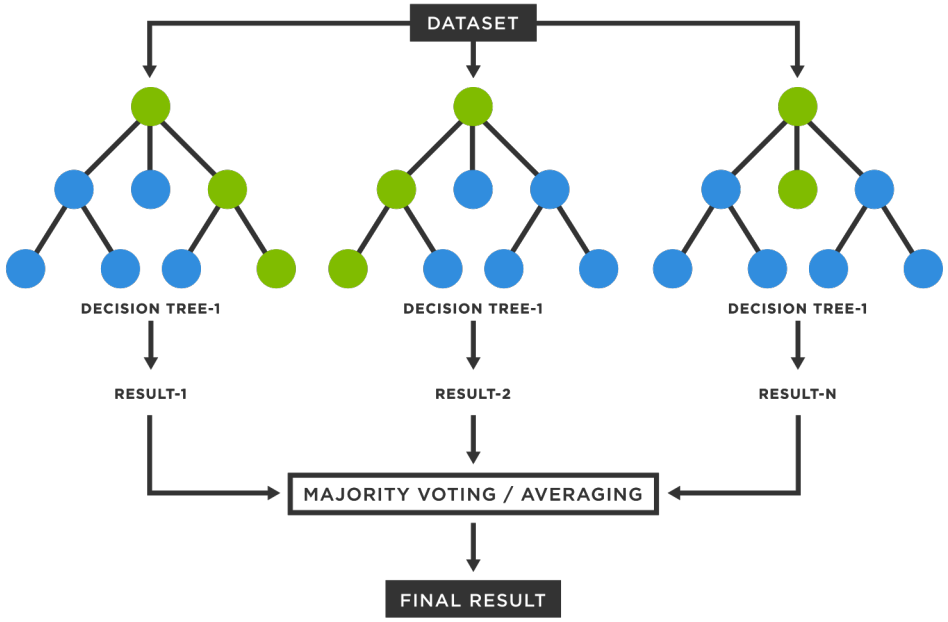
[0.0-0.1] Hz [8.0-12.0] Hz

[0.1-0.5] Hz [12.0-13.0] Hz

[0.5-4.0] Hz [13.0-30.0] Hz

[4.0-8.0] Hz [30.0-45.0] Hz

+

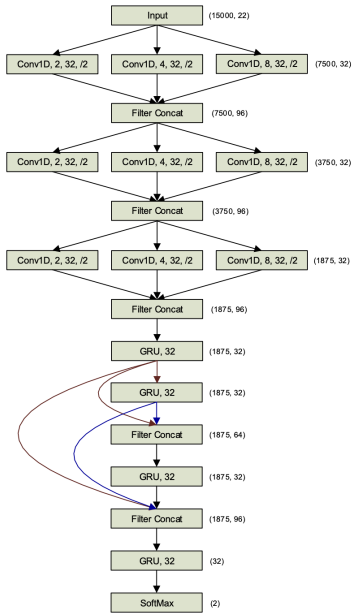


Power Features

Random Forest

Surrel, G., Aminifar, A., Rincón, F., Murali, S., & Atienza, D. (2018). Online obstructive sleep apnea detection on medical wearable sensors. *IEEE transactions on biomedical circuits and systems*, *12*(4), 762-773.

Data-Centric Seizure Detection



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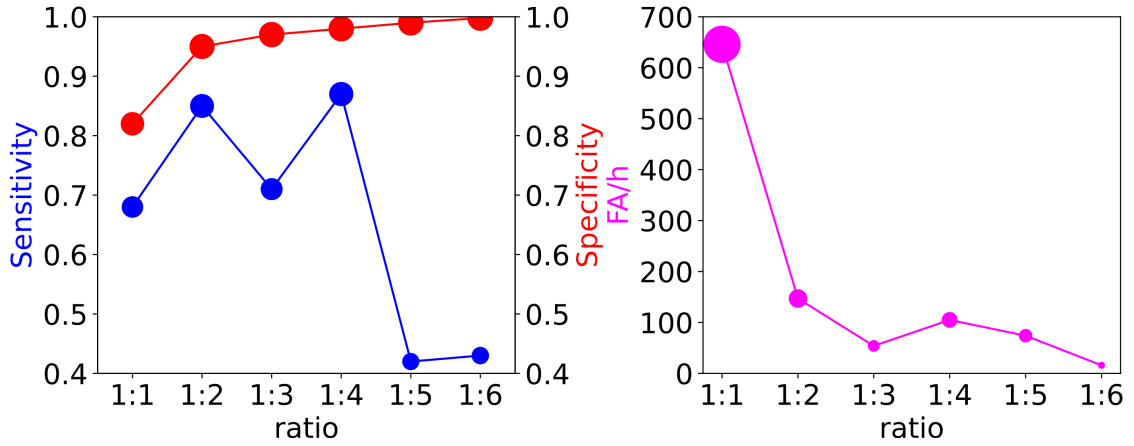

ChronoNet **Data Manipulation Techniques**

FA/h shows a rapid decline and the value of ratio should be carefully selected to make an optimal trade-off between FA/h and Sensitivity.

Roy S, Kiral-Kornek I, Harrer S. ChronoNet: a deep recurrent neural network for abnormal EEG identification[C]//Artificial Intelligence in Medicine: 17th Conference on Artificial Intelligence in Medicine, AIME 2019, Proceedings 17. Springer International Publishing, 2019: 47-56.

Performance on SeizeIT2

Random Forest

Leave-one-patient-out Cross-validation

Evaluation	Sensitivity	Specificity
Validation Data	73.6%	96.7%

ChronoNet

Trained on SeizeIT1 data

Evaluation	Sensitivity	Specificity
Validation Data	15.2%	99.8%

In the context of the ICASSP 2023 Epilepsy Detection Challenge, we were among Top 5

Questions?

Thank you!