EEG Signal Filtering and Spectral Analysis for Seizure Detection

Butterworth and Kolmogorov–Zurbenko Filtering of CHB-MIT Scalp EEG Recordings

Akif Khan[1] and Antonios E. Marsellos[2]

[1]Sanford H. Calhoun High School, 1786 State St, Merrick, NY 11566

[2]Dept. Geology, Environment and Sustainability, Hofstra University, Hempstead, NY, USA

ABSTRACT

Electroencephalography records brain activity noninvasively, but seizures are hard to detect: the signals are noisy and often overlap with normal rhythms. EEG from seizure and non-seizure recordings was analyzed in R using Butterworth and Kolmogorov–Zurbenko filtering, then Fast Fourier Transform and periodogram estimation. Seizure segments consistently showed higher delta power and suppressed alpha activity, and a systematic channel ranking confirmed those shifts.

DELTA POWER · 0.5–4 Hz

δ ↑

Low-frequency power rises consistently during seizure segments, across multiple channels.

ALPHA POWER · 8–13 Hz

α ↓

Alpha activity is suppressed during seizures, the mirror image of the delta shift.

BANDS RANKED

5

Delta, theta, alpha, beta and gamma, extracted per channel and ranked by seizure difference.

Background

No warning. Epileptic seizures often occur without warning, creating real risk for patients.

Buried signal. EEG measures brainwave activity, but seizure patterns are subtle and buried in noise.

Why filtering. Signal detection and filtering are critical to reveal useful features.

Where to look. Previous studies suggest the canonical frequency bands, delta through gamma, hold important clues to seizure onset.

Seizure signatures hide inside ordinary noise.

Method and Materials

Data. EEG from a seizure record (chb01_03) and a non-seizure record (chb01_04) in the CHB-MIT Scalp EEG Database.

Preprocessing. Butterworth and Kolmogorov–Zurbenko (KZ) filters for noise removal; FP1–F7 and other shared channels extracted.

Spectral analysis. Fast Fourier Transform to capture frequency content, plus periodogram power spectral density estimation for seizure versus non-seizure comparison.

Band power. Relative power in delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz) and gamma (30–50 Hz), normalized and ranked by channel.

Software. RStudio (v4.2.1) with the kza, TSA and imputeTS packages and base spectral functions.

Filter first, then let the spectrum talk.

Results

Time domain. Raw seizure EEG showed noisy fluctuations and sudden amplitude spikes; filtering reduced the noise and clarified the underlying rhythms (Figs. 1 and 2).

FFT. Seizure signals showed distinct peaks at lower frequencies, while non-seizure activity had more distributed power (Fig. 3).

Periodogram. Overlay plots revealed increased low-frequency power during seizures, along with altered complexity measured by entropy (Fig. 4).

Band power. Delta power consistently increased during seizures across multiple channels while alpha power decreased; theta and gamma showed moderate but noticeable differences (Fig. 5).

Delta up, alpha down, across many channels.

Discussion and Conclusion

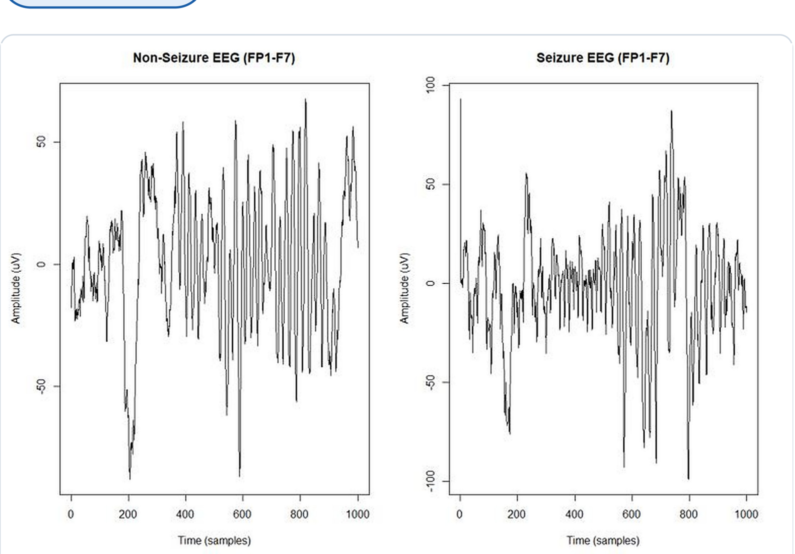
Reliable workflow. Filtering combined with spectral and band power analysis provides a reliable workflow for highlighting seizure-related EEG features.

Clinical case. These methods strengthen the case for developing automated detection systems that could support neurologists and improve patient safety.

Future work. Multi-channel comparisons, entropy-based classifiers, and integration with machine learning approaches.

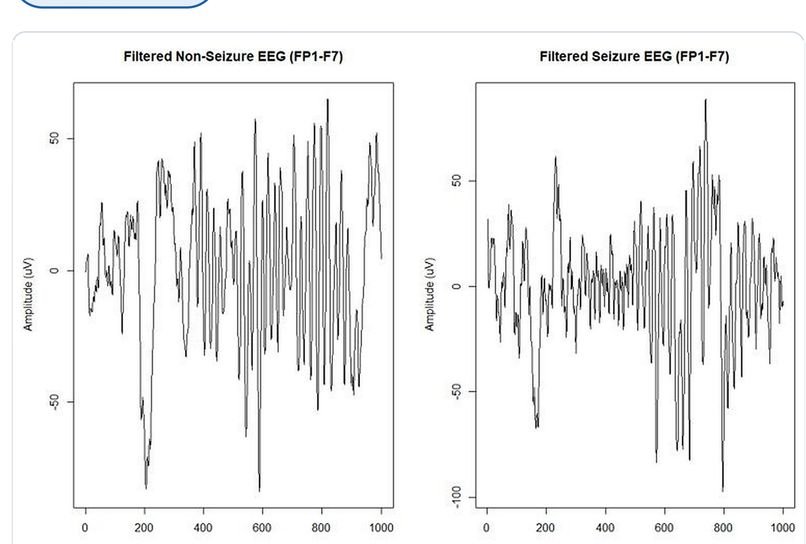
A reproducible workflow, not a one-off.

FIG. 1



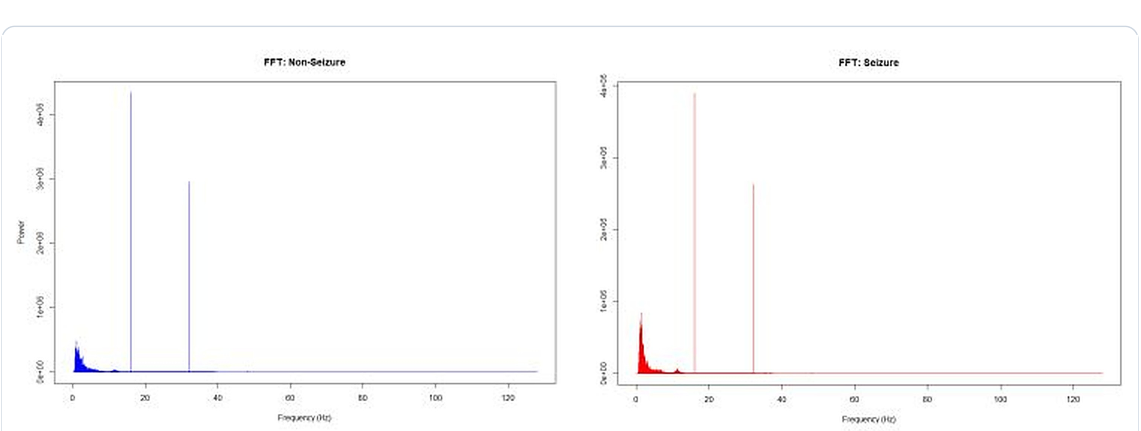
Raw EEG signals for non-seizure (left) and seizure (right), FP1–F7 channel. The seizure trace carries sudden amplitude spikes on top of ordinary-looking noise.

FIG. 2



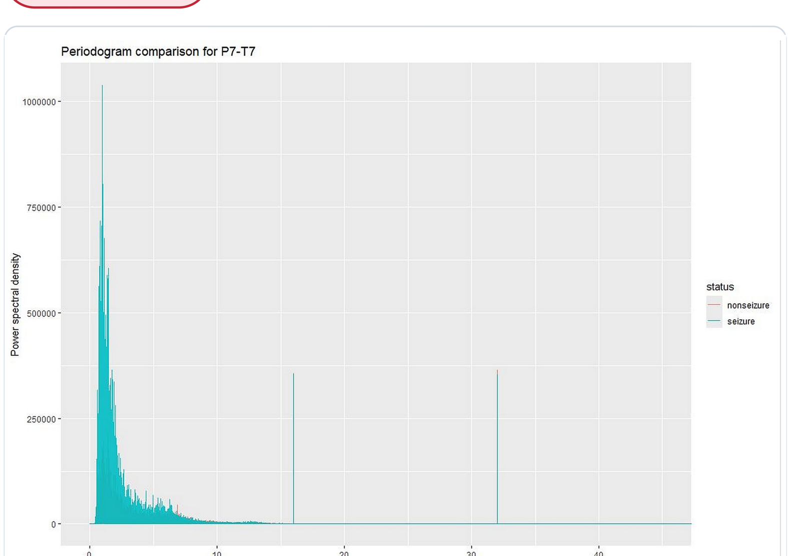
The same two channels after Butterworth and KZ filtering. Noise is reduced and the underlying rhythms become far easier to compare.

FIG. 3



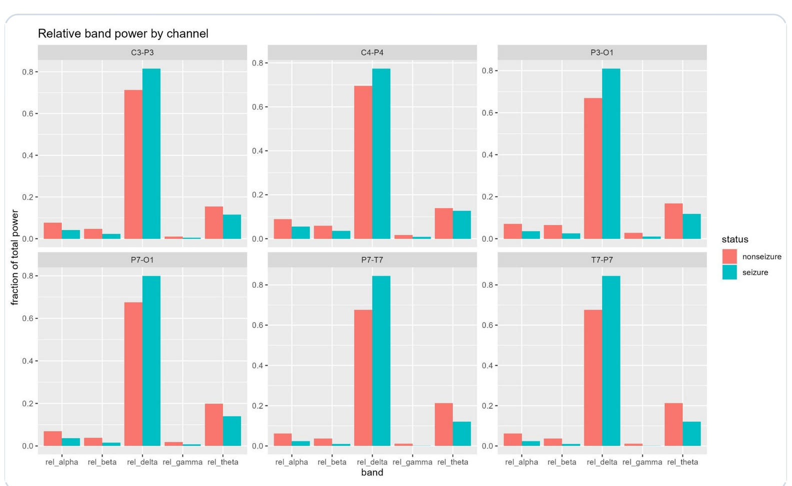
FFT plots for non-seizure (left, blue) and seizure (right, red), showing the difference in spectral peaks. Seizure power concentrates at lower frequencies.

FIG. 4



Periodogram comparison for the P7–T7 channel, highlighting the seizure-related increase in low-frequency power.

FIG. 5



Relative band power across EEG channels, showing increased delta and altered alpha during seizures. The pattern repeats channel to channel.

REFERENCES

1. Chan K, Ripley B (2022). TSA: Time Series Analysis. R package version 1.3.1.
2. Close B, Zurbenko I, Sun M (2020). kza: Kolmogorov–Zurbenko Adaptive Filters. R package version 4.1.0.1.
3. Moritz S, Bartz-Beielstein T (2017). imputeTS: Time Series Missing Value Imputation in R. The R Journal, 9(1), 207–218.
4. Glannon W (2022). Neuroethics and deep brain stimulation research. Journal of Neural Engineering.
5. Shoeb A (2009). EEG Database for Seizure Detection (CHB-MIT Scalp EEG Database). PhysioNet.
6. Tzallas AT, Tsipouras MG, Fotiadis DI (2009). Epileptic seizure detection in EEGs using time–frequency analysis. IEEE Trans. Info. Tech. in Biomedicine, 13(5), 703–710.

ACKNOWLEDGEMENTS

Thank you to Dr. Antonios E. Marsellos and the Department of Geology, Environment and Sustainability at Hofstra University for providing the tools to conduct this research.