

BrainSurf: An Open-Source Python Library for EEG Signal Analysis in Meditation Research

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Abstract—BrainSurf is an open-source Python library designed for preprocessing, feature extraction, and visualisation of EEG (Electroencephalography) data, with a focus on cognitive neuroscience and meditation research. The library provides a unified framework for filtering, artifact removal, spectral analysis, and connectivity estimation. It enables researchers to efficiently process EEG datasets and extract meaningful cognitive features, supporting reproducibility and accessibility in EEG studies.

I. INTRODUCTION

Meditation has been shown to enhance cognitive functions such as attention, emotional regulation, and self-awareness. EEG is a widely used non-invasive method for investigating brain activity associated with these processes. However, existing EEG analysis tools are either closed-source or lack an integrated workflow tailored to meditation and cognitive experiments.

BrainSurf was developed to fill this gap. It streamlines EEG workflows through modular functions for preprocessing, power spectral analysis, and cognitive feature extraction. Researchers studying meditation, neurofeedback, or cognitive enhancement can use BrainSurf to perform reproducible EEG analyses with minimal setup.

II. STATEMENT OF NEED

EEG-based meditation studies typically require extensive preprocessing pipelines and custom scripts for feature extraction. Manual implementation of these steps can be time-consuming and error-prone, especially for beginners in signal processing or neuroscience.

BrainSurf addresses this by:

- providing modular, well-documented functions for EEG preprocessing (filtering, epoching, artifact removal);
- supporting multiple EEG file formats (EDF, CSV, MFF, XLSX);
- integrating visualization and statistical modules for EEG feature interpretation;
- including sample datasets and Jupyter notebooks for quick experimentation.

By open-sourcing BrainSurf, we aim to make EEG analysis transparent, reproducible, and accessible to students and researchers alike.

III. FUNCTIONALITY AND FEATURES

BrainSurf's architecture is organised into the following modules:

- **Preprocessing:** High-pass and low-pass filtering, Common Average Referencing (CAR), ICA-based artifact removal, and epoch segmentation.
- **Analysis:** Power spectral density (PSD), wavelet transforms, multifractal analysis, and coherence-based connectivity.
- **Cognitive Analysis:** Indices for arousal, engagement, and neural activity during meditation or cognitive tests.
- **Visualization:** Topographic mapping, power spectrum plots, heatmaps, and correlation graphs.
- **Machine Learning:** Modules for EEG classification using RNNs, LDA, or SVMs.

IV. EXAMPLE USAGE

```
import brainsurf.visualization as vis
import brainsurf.analysis.power_spectrum as psd

freqs, psd = psd.psd_welch(bandpass_filtered_eeg,
                           sampling_freq)
print(bandpass_filtered_eeg)
```

AVAILABILITY AND REUSE POTENTIAL

BrainSurf is available on the Python Package Index (PyPI) and can be installed easily using:

```
pip install brainsurf
```

The source code is hosted on GitHub at:

<https://github.com/preethihiremath/brainsurf>

BrainSurf is distributed under the MIT License. Contributions are welcome through issues and pull requests. The modular design allows researchers to extend it with new algorithms, preprocessing techniques, or visualization methods.

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