Non-Linear Analysis of Expert and Non-Expert Meditators using Machine Learning

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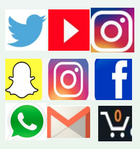
Introduction

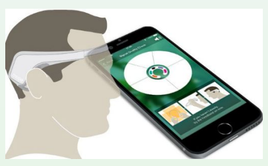
Digital Advancement [1]



Digital Distraction

Meditation [2]

No Feedback [3]



EEG Headset [4]

- Unprecedented advancement of technology and systems increase usage of digital technology among all age groups.
- Poses several challenges, decrease attention, concentration, and increased stress and anxiety, with other physiological symptoms.
- Meditation as a technique of mental training as a non-invasive methodology has been found to be an effective tool to increase attentional engagement, well-being, and states of flow.
- But what is challenging, there is no such feedback provided to the naive participants for his/her meditative performance which in turn can be frustrating and less rewarding.
- EEG headset technology provides a mechanism for individuals to track his/her progress.
- Classifying EEG signals that can predict the brain state of a mediator which would further help participants to navigate their performance in a more customizable and flexible manner through feedback.

Methods

Feature Extraction

➔ Processing EEG signals and extracting features are crucial for classifying the different brain states.

➔ EEG data sets generally contain many features out of which several are redundant and irrelevant for the classification task.

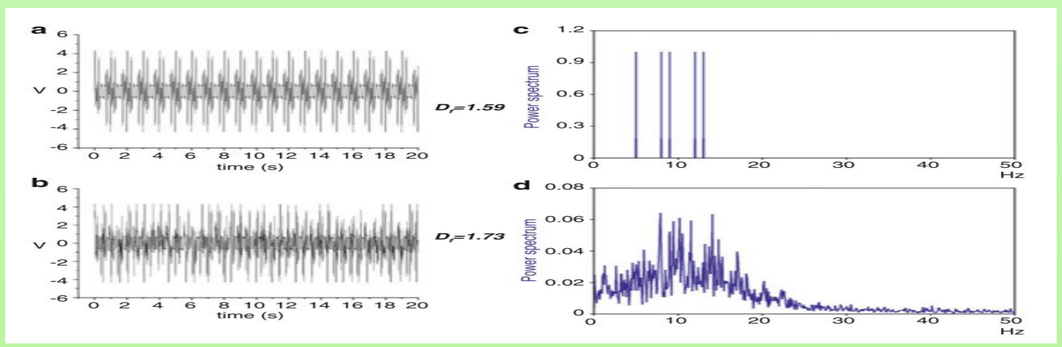
➔ Feature extraction plays an important role to identify the correct sets of features that in turn provides the robust representation and for deriving a significant conclusion.

Fractal Analysis

- EEG signals are non linear and non stationary.
- A fractal is a geometric concept used to describe the scaling of physical objects in space.
- View the brain as a fractal, self-similar in both neuroanatomical structures and neurophysiological time series.

Fractal Dimension

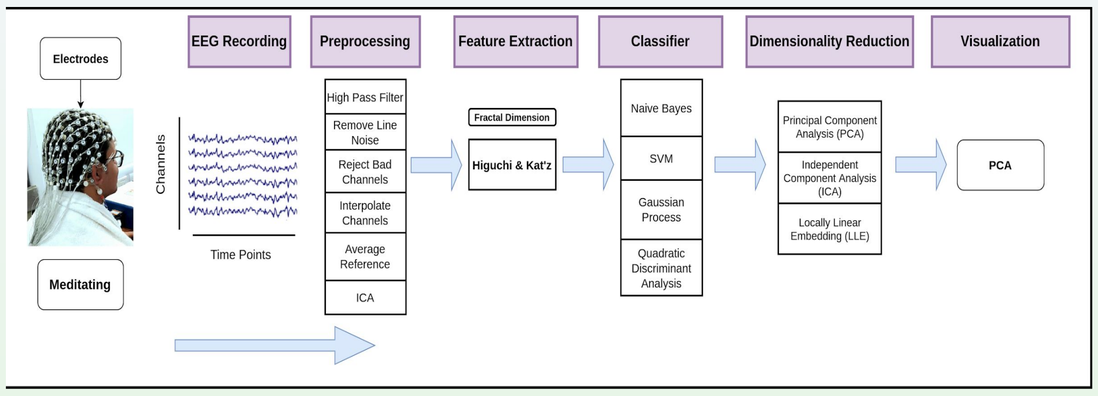
- Fractal methods characterize signals by the quantity called fractal dimension (FD).
- Time domain-based FD algorithms are more effective than the frequency domain-based algorithms.
- Previous Studies - monitoring the depth of anesthesia, sleep staging, seasonal affective disorder (SAD), and major depressive disorder.



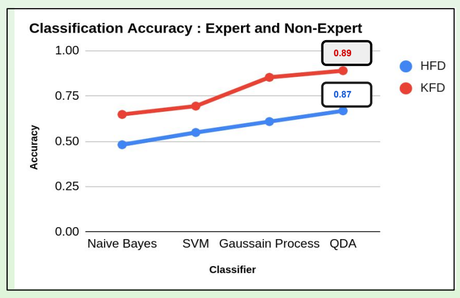
C, Fractal Analysis of Electroencephalographic Time Series (EEG Signals).*The fractal geometry of the brain* (p. 585). New York, NY: Springer.

- Fractal methods characterize signals by the quantity called fractal dimension (FD).
- Time domain-based FD algorithms are more effective than the frequency domain-based algorithms.
- In the Figure, the stationary signal was generated by adding five harmonic waves of different frequencies that are well seen in its Fourier spectrum then randomly chosen small segments were removed from this stationary signal.
- The decomposition of this nonstationary signal shows “rich” spectrum of frequencies, hence it becomes difficult to recognize five original frequencies whereas one of the fractal methods Higuchi gives similar values of average fractal dimension for both signals.
- Previous Studies - monitoring the depth of anesthesia, sleep staging, seasonal affective disorder (SAD), and major depressive disorder.

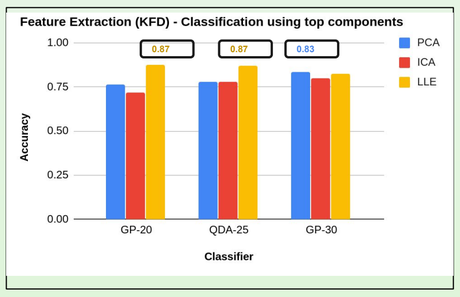
Results



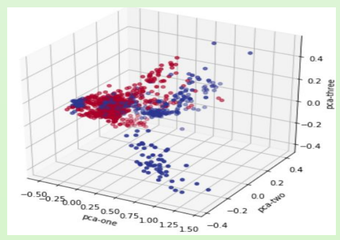
Classifier Performance



Dimensionality Reduction



Visualization



E, NE

- We utilize open access EEG Dataset comprising twelve experts and twelve non-expert meditators.
- First, pre-processing is done to clean the dataset, followed by Feature extraction by two fractal methods, which are Higuchi and Kat’z algorithm.
- Once features are extracted, we employ four machine learning classifiers to classify the brain states of expert and non-expert meditators.
- We reduce the feature dimension by three techniques and later visualize the three components of expert and non-expert.
- We classify the states successfully by 89% in Katz algorithm by Quadratic Discriminant Analysis.
- We further reduced the feature dimension from 64 to 20, 25, and 30 components and obtained the maximum accuracy of 87% using Locally Linear Embedding.
- Structure shows the visualization of Expert and Non-Expert fractal features in three dimensions.

Discussion and Future Work

1. Classified the brain states associated with expert and naive using fractal analysis.
2. In the future, we can decompose the signals into five frequency bands and further understand the role of each frequency band.
   a. Delta (1- 3 Hz), Theta (4 - 7 Hz), Alpha (8 - 13 Hz), Beta (13 - 30 Hz) and Gamma (30 - 70 Hz)
   b. Cross-coupling between bands.
3. Explaining the predictions of machine learning classifier : Why some algorithm works, and why not?
4. We hope this research will help us to understand the different stages involved during meditation by identifying neural correlates in each stage.

References

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[7] Brandmeyer, T. and Delorme, A., 2016. Reduced mind wandering in experienced meditators and associated EEG correlates. *Experimental Brain Research*, 236(9), pp.2519-252.