Can Geophysical Processing Improve Medical Imaging Applications?

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Summary

Medical imaging applications typically use pre-processing steps to improve the quality of the recorded signals for diagnosis and treatment options. This is especially true for electroencephalograms (EEG's), which record passive signals from the brain using a series of electrodes placed on the scalp. The processing flow typically includes the application of a boxcar filter, Fourier analysis, artifact removal (eye-blinks, muscle tics), and division of frequencies into relevant bands. Information about the brain's response at rest and during tasks allows neurologists and psychologists to differentiate between healthy individuals and those with brain disorders, like epilepsy and depression. It also provides a means of understanding normal brain function. For example, EEG signals are expected to change during the learning process for a task where people make word or non-word decisions. In fact, brain variability is expected to increase as people explore new ways to respond quickly and efficiently, and then to decrease once they settle on the optimal way to produce a response. Recent research suggests that moment-to-moment variability or plasticity in brain signal is important for brain function, and may be useful as a marker of information processing capacity, namely our ability to learn [1, 2].

Unfortunately, the recorded EEG signal not only measures cerebral activity, but also other unwanted internal and external sourced artifacts. This measurement noise is especially detrimental for analyses that focus on moment-to-moment fluctuations in signal (i.e., variability analyses). The aim of this research is to investigate whether geophysical signal processing and analytic tools can provide more effective information extraction than standard EEG pre-processing. Application of different geophysical filters and noise suppression techniques will be adapted to EEG's to highlight brain signal, minimize measurement noise and isolate key metrics for statistical analysis.

Introduction

EEG is a non-invasive method to measure and record the electrical activity of the brain [3]. Using a series of electrodes placed on the scalp, voltage differences from neurons within the cerebral cortex can be detected to assess and localize brain function [4]. Until recently, much of functional neuro-imaging research focused on average activation patterns in the brain. Although the mean or "central tendency" has provided important information about the neural substrates that underlie cognition, recent studies suggest that variability in brain signal is also an informative metric [1, 5, 6]. This variability allows for rapid and flexible responses to environmental stimuli and appears to represent information processing capacity [7]. Thus, where **activity** highlights areas of the brain supporting task performance, **variability** provides information about the capacity of the brain to support task performance.

One way to make the brain more capable of supporting a task is to undertake training on a particular

task. EEG's provide a means of measuring how the brain changes during training, while people engage in a classic visual word recognition task: the lexical decision task (LDT) [8]. To facilitate this analysis, we plan to enhance EEG pre-processing by developing signal processing and analytic tools garnered from geophysical exploration processing. EEG and seismic signal analysis bear similar characteristics, namely the same frequency band of 1-100 Hz, the necessity for filtering to remove unwanted noise from artifacts (eye-blinks and muscle movement in EEG, versus wind or cable vibrations, multiples in seismic), and both seek to understand the source pulse inherent in the data. This endeavor will thus use a multi-disciplinary approach by applying geophysical algorithms specifically coded for noise attenuation and frequency enhancement on seismic data [9], to EEG data.

Method

Process EEG data from 12 subjects with the standard pre-processing flow, as well as a pre-processing flow that includes more enhanced geophysical filtering/noise suppression techniques.

Statistically analyze learning-related changes in brain signal variability using appropriate metrics. The comparison of results using the standard EEG pre-processing technique to that of an enhanced geophysical signal processing flow, will identify which pre-processing procedure is best at extracting fundamental information about the brain.

Impact

Establishing a multidisciplinary EEG signal processing flow to elicit key brain metrics related to brain variability will serve as a guideline for future psychological research, as well as other imaging modalities.

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References

1. McIntosh, A.R., N. Kovacevic, and R.J. Itier, Increased brain signal variability accompanies lower behavioral variability in development. PLoS Computational Biology, 2008. 4(7).
2. Wang, H., et al., Age-related multiscale changes in brain signal variability in pre-task versus post-task resting-state EEG. Journal of Cognitive Neuroscience, 2016. 28(7): p. 971-984.
3. Luck, S., J., An Introduction to the Event-Related Potential Technique. 2005, Cambridge, Massachusetts, USA: The MIT Press. 374.
4. van Hees, S., Seyffarth, S., Pexman, P. M., Cortese, F., Protzner, A. B., , An ERP Investigation of Vertical Reading Fluency in Scrabble Experts, in PLOS ONE. 2016. p. 23.
5. Arieli, A., et al., Dynamics of ongoing activity: Explanation of the large variability in evoked cortical responses. Science, 1996. 273(5283): p. 1868-1871.
6. Laskaris, N.A., L.C. Liu, and A.A. Ioannides, Single-trial variability in early visual neuromagnetic responses: An explorative study based on the regional activation contributing to the N70m peak. NeuroImage, 2003. 20(2): p. 765-783.
7. Neumann, J., et al., Within-subject variability of BOLD response dynamics. NeuroImage, 2003. 19(3): p. 784-796.
8. Keuleers, E., et al., The British Lexicon Project: Lexical decision data for 28,730 monosyllabic and disyllabic English words. Behavior Research Methods, 2012. 44(1): p. 287-304.
9. Kumar, S., Kumari, K., Biswal, A.,, Frequency Enhancement of Seismic Data - a comparative study. Canadian Society of Exploration Geophysicists, 2008. 33(4): p. 6.