Applications of Chaos Theory in Analyzing EEG signals under Different Psychological Conditions

Neural Signal Processing
Grant Proposal Abstract

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Abstract

The Electroencephalogram (EEG) is a useful representative of the condition of the brain. Useful information about the state of the brain can be extracted from the shape of the wave. Even on a cellular level, the dynamical behaviour of individual neurons is non-linear as it is governed by threshold and saturation phenomena. The dynamical nature of the signals can be elucidated from the application of non-linear time series analysis(Kannathal et al. 2005). *Such non-linear dynamical systems are capable of self-organization, one variety of which is deterministic chaos. Although Poincare first described chaos in the 1800s, scientists began to apply chaos theory to EEG only in the 1980s. There have been several applications in recent years to characterize EEG signals from patients suffering from epileptic seizures and Alzheimer's. One of the neurological parameters used in non-linear dynamics called Largest Lyapunov Exponent has been used to characterize different stages of sleep*(Agrwal, Singh, and Kumar 2013). *Hence, we can see that chaos theory has immense implications in the field of Neural Signal Processing.*

We plan to use various non-linear EEG dynamic features to characterize the EEGs obtained from various open data sets under different psychological phenomena. The parameters we intend to use are the Largest Lyapunov Exponent (which helps to differentiate between chaotic and periodic signals), Correlation Dimension (is a measure of the multidimensional complexity of a signal), Approximate Entropy(Agrwal, Singh, and Kumar 2013) *(used to quantify regularity and unpredictability of fluctuations of a time series), Detrended Functional Analysis (useful for analyzing time-series that appear to be long-memory processes) among others. These measures have been successfully used in previous research, for instance, the correlation dimension has been seen to decrease in patients with reduced brain activity (hence a less chaotic system), such as in alcoholics and Alzheimer's patients and in conditions exhibiting hyper-synchrony such as epilepsy. Based on the above we believe that these parameters will help us identify new patterns in EEG signals from different psychological conditions such as ADHD*(Khoshnoud, Nazari, and Shamsi 2018).

We have obtained data from various open datasets with EEG records categorized as:

1. *Patients suffering from ADHD*(Lázaro et al. 2018)
2. *Data recorded during a state of Sleep and Meditation*

3. *Data recorded while listening to Music*

Based on the knowledge of the psychological conditions and the functioning of the brain, one would expect the EEG from ADHD patients to be more 'chaotic' than the control, while those of sleeping subjects (especially non-REM sleep) to be less 'chaotic' than control. Practices such as listening to music and performing meditation that is thought to 'calm' the brain in a way similar to sleep would be also expected to exhibit a lower degree of chaos. We shall test these notions quantitatively using measures of chaos as listed above.

References:

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