Abstract

One of the primary difference of mankind from other species is his ability to communicate verbally. The brain upon framing a sentence, coordinates with the oro-pharyngeal-laryngeal muscle groups to produce the speech with the help of vocal cord and mouth aperture. However, some individuals due to congenital or illness, may loose their ability to speak in spite of their brain framing speech. Speech impairment leads to severe dissociation of the individuals from surrounding due to lack of communicable means. Although there are several alternate assistive communication techniques, verbal communication remains the most effective and fluent mean with an addition of expressing emotions. Most of the speech impairments do not hinder speech imagination process in the individuals. Research on speech restoration through brain computer interface (BCI) is still at an early stage. Electroencephalography (EEG) based decoding of speech imagery is getting popular in recent days towards the goal of their rehabilitation.

The thesis presents two distinct approaches, namely, multifractal detrended fluctuation analysis (MFDFA) and Chaos analysis, to explore the nonlinearity of the EEG for vowel imageries at different EEG subband levels. Initial exploration through Spanish vowel (a,e,i,o,u) imageries resulted into promising outcome with MFDFA. Four multifractal features, namely, spectrum width ($\boldsymbol{\Delta\alpha}$), spectrum peak ($\boldsymbol{\alpha_0}$), spectrum skewness ($\boldsymbol{B}$), and Hurst's exponent ($\boldsymbol{H}$) were extracted from EEG and its subbands, namely, α, β, and γ for such analysis. It has also been found that different speech modalities possess significantly varying multifractal parameters across different brain regions. Further detailing has been opted with International Phonetic Alphabets (IPA) vowels for overall standardisation of the vowel phonemes. The vowels were categorised into two categories, namely, soft vowels and diphthongs. Evaluation of regional efficacy in each type of vowel formation through different visualisations of the statistics of the parameters indicated strong dominance of left hemisphere and further strengthening classical brain language model in speech imagery. Besides, three chaos parameters, namely, correlation dimension (CD), largest lyapunov exponent (LLE), and approximate entropy (ApEn) were extracted from EEG during IPA vowel imageries to explore the chaotic nature of them. In this regard, effect of the chaos parameters in the imageries contributory soft vowels in diphthongs has also been analysed.

Based on the analysis, a regression model has been proposed between the chaos parameters of acoustic voice signal and EEG signal for different IPA vowels. The EEG channels were selected based on their higher contribution towards the first principal component. Goodness of fit parameters were evaluated for the regression analysis to explore the most suitable chaos parameters. Similar model has also been evaluated for the vowel imagery and corresponding voice signal in this due process.

Keywords: EEG, MFDFA, chaos, Speech Imagery, vowel imagery