EEG Signal Analysis for Effective Classification of Brain States

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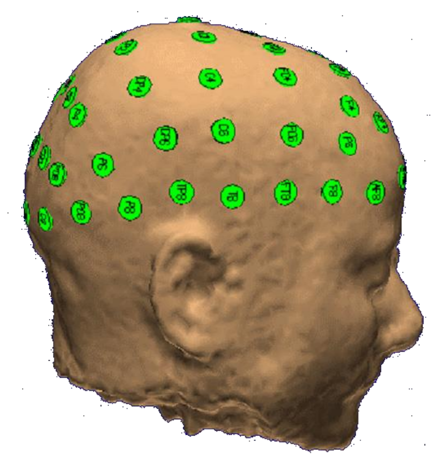
Abstract

EEG (Electroencephalogram) is a non-stationary signal that has been well established to be used for studying various states of the brain, in general, and several disorders, in particular. This work presents efficient signal processing and classification of the EEG signal. The digital filters used during decomposition of the input EEG signal have transfer functions which are simple and easily realizable on digital signal processors (DSP) and embedded systems. The features selected in this study; energy, entropy and variance; are among the most efficient and informative to analyze the EEG signal strength and distribution for detecting brain disorders such as seizure. Training and testing of the extracted features are performed using linear kernel (Support Vector Machine) SVM and thresholding in DSP algorithms and hardware, respectively. The experimental results for the digital signal processing algorithms show a high classification accuracy of 95% in the occurrence of seizure in epileptic patients. The techniques in this work are also under investigation for classifying other brain states/disorders such as sleep stages, sleep apnea and multiple sclerosis.

EEG Signal

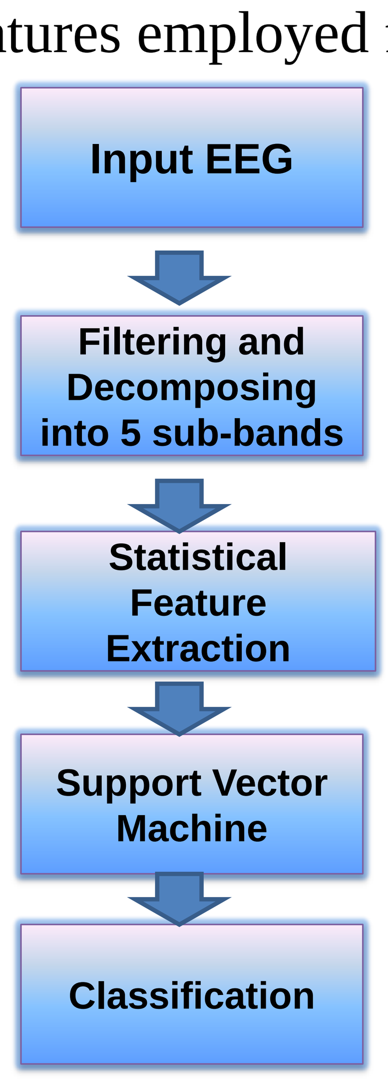
- ❑ Electroencephalogram (EEG) is the most effective signal used by physicians in assessing brain activities and diagnosing different brain disorders
- ❑EEG signal can be collected from numerous electrodes placed on the scalp

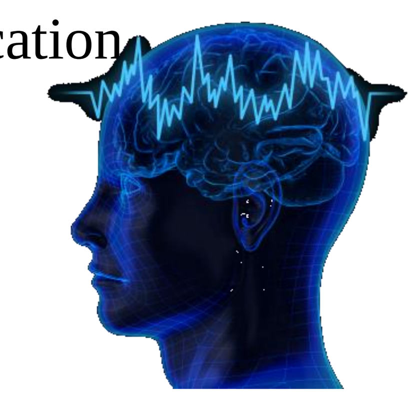


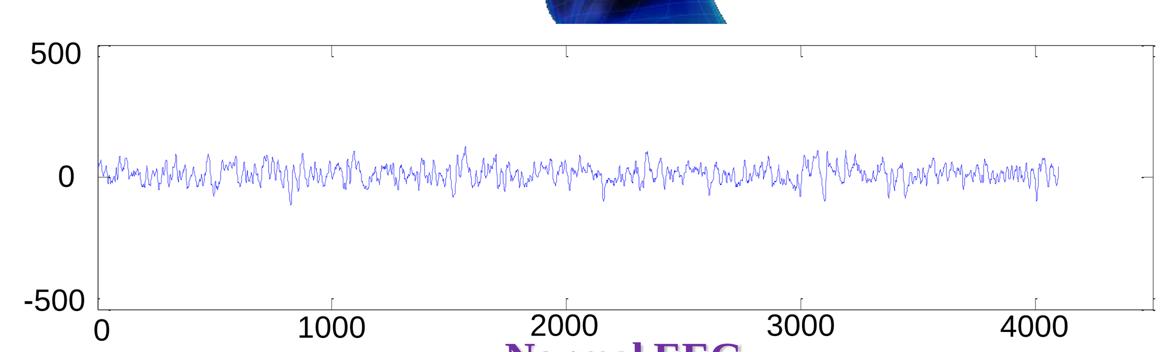
- ❑ Five EEG frequency bands: delta, theta, alpha, beta, and gamma) provide discriminative information about the brain in different states

Proposed Methodology

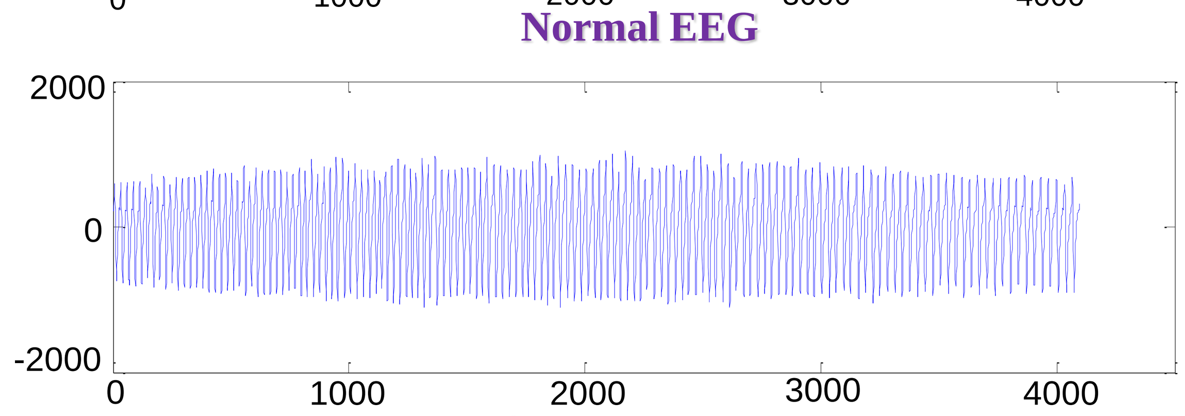
- ❑ The objective is to build a portable hardware device for analyzing EEG signals to reduce the cost of monitoring
- ❑ We focused on algorithms that can be easily implemented on any embedded system device
- ❑ EEG Filtering and decomposition performed using Infinite Impulse Response (IIR) Butterworth band-pass filters
- ❑ Minimum order of N and proper cut-off frequency of ω_c used to design the filters
- ❑ Energy E, entropy EN and variance (or standard deviation STD) features employed for SVM classification







Normal EEG

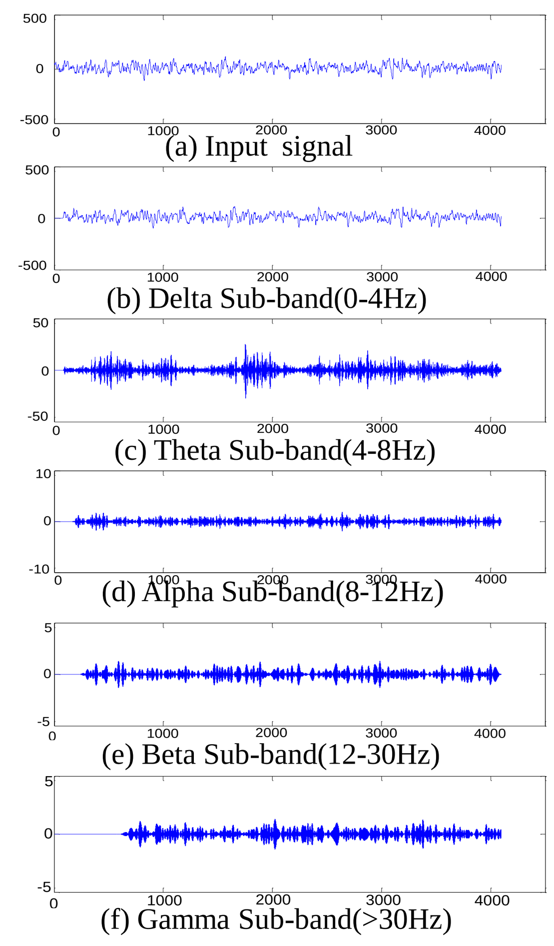


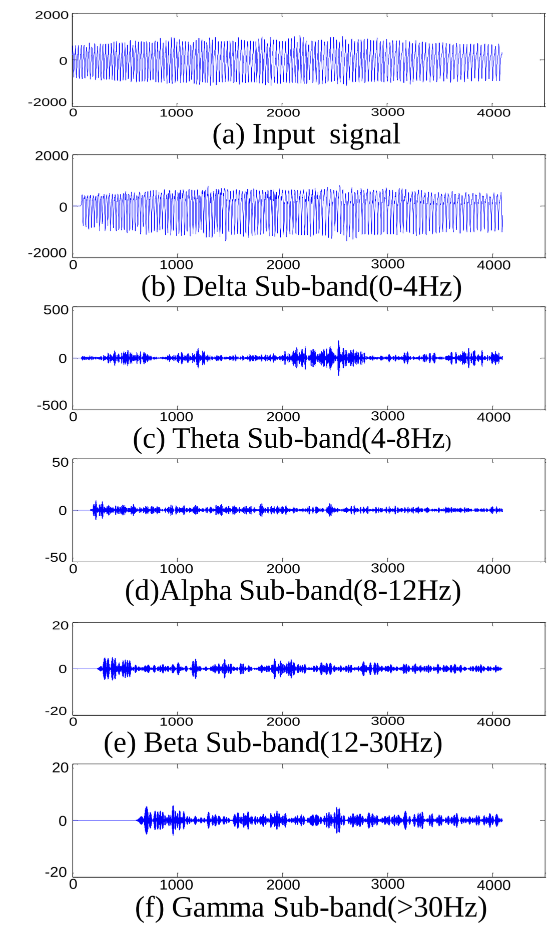
EEG of a patient with seizure

$$N = \frac{1}{2} \times \frac{\ln(G_p / G_s)}{\ln(\omega_p / \omega_s)} \qquad \omega_c = \frac{\omega_s}{(G_s)^{1/2N}}$$

$$E = \sum_{n=1}^{N} \left| x_i[n] \right| \qquad EN = \sum_{i=1}^{N} (X^2{}_{ij}) \log(X^2{}_{ij}) \qquad STD = \sqrt{\frac{1}{N-1} \sum_{n=1}^{N} \left(x[n] - \frac{1}{N} \sum_{n=1}^{N} x[n]\right)^2}$$

Results of EEG Filtering



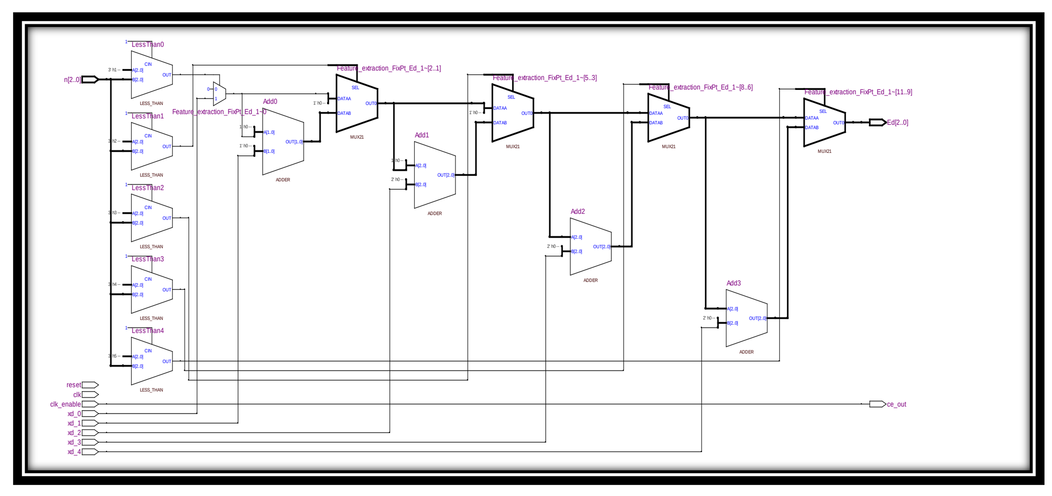


Classification and Hardware Implementation

- ❑ EEG signals taken from a publicly available database at the Epilepsy Center, University of Bonn, Germany, as well as PhysioNet.org

Energy	Delta	Theta	Alpha	Beta	Gamma
Non-seizure Signal	6.2109×10^{4}-1.0945×10^{6}	8.7665×10^{3}-1.0502×10^{5}	1.1387×10^{3}-1.0928×10^{4}	784.974-7.3433×10^{3}	749.542-6.9197×10^{3}
Seizure Signal	3.3429×10^{5}-1.9593×10^{6}	1.8582×10^{4}-3.7046×10^{5}	1.5476×10^{3}-4.4666×10^{4}	1.1621×10^{3}-3.0607×10^{4}	1.2328×10^{3}-2.8527×10^{4}

Category	No. Trained signal	No. tested Signal	Correctly detected	Acc.%	Se.%	Sp.%
Training and Testing phase	160	40	158	95	90	100



Register Transfer Level view of the system hardware

Outcome

The proposed less complex, quick and feasible design make our work attractive for implementation within hand-held embedded systems for monitoring a patient at risk in even telemedicine platforms. The research presented is also being investigated on different data sets for many other health complications that can be diagnosed by EEG signal analysis; such as sleep apnea and sleep stage identification, fatigue, drowsiness, multiple sclerosis, autism, neural bursting activities in Parkinson's disease, and many more.

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