A Fast and Accurate Approach for Real-Time Seizure Detection in the IoMT

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Outline of the talk

- ❑ Introduction
- ❑ Novel Contributions
- ❑ Design of the Proposed System
- ❑ Implementation and Results
- ❑ Conclusions and Future Research

Introduction

- Epilepsy and Seizures
- Significance of Seizure Detection
- Internet of Medical Things (IoMT)

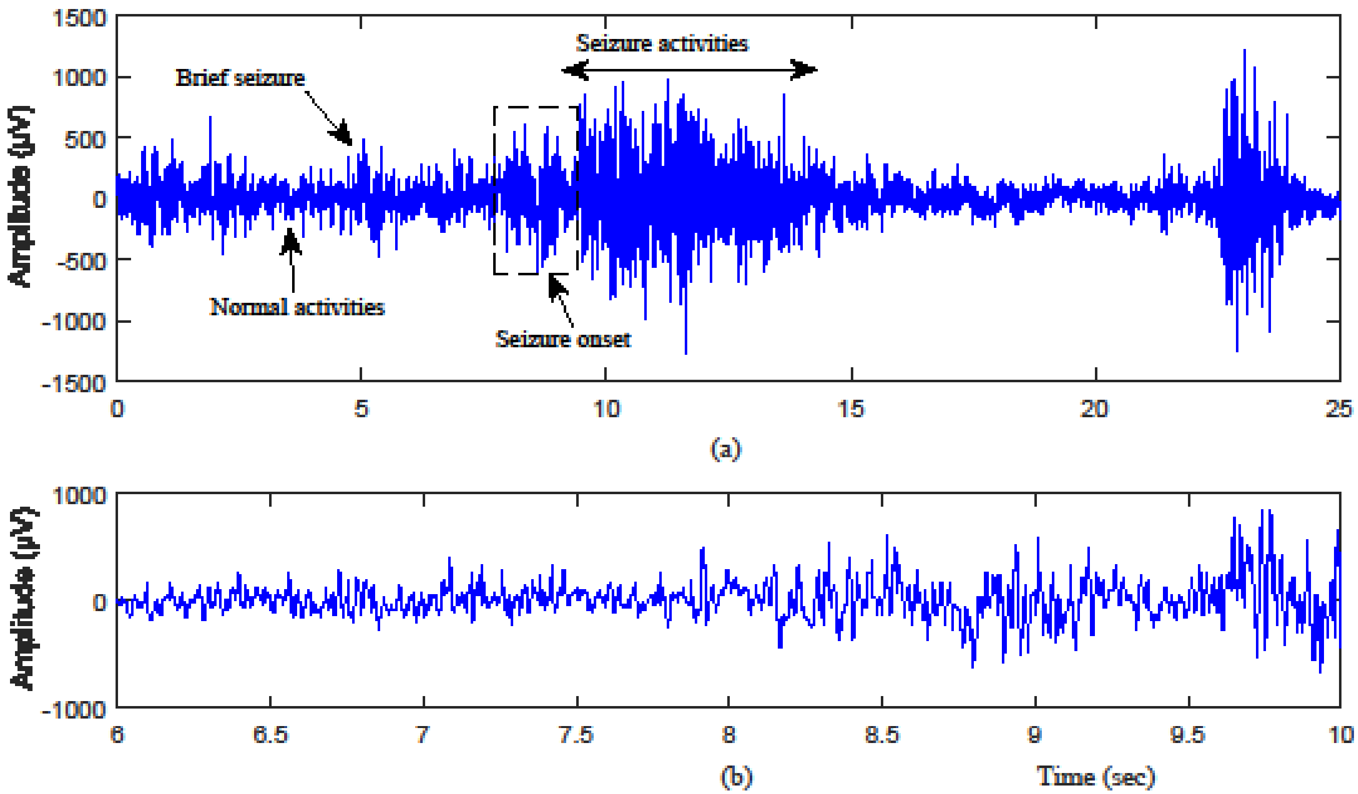
Epilepsy and Seizures

- Epilepsy is a neurological disorder characterized by recurrent seizures.
- A seizure is an abnormal activity in the brain marked by convulsions or loss of consciousness.
- The seizure onset EEG morphology includes low voltage fast activity, high voltage fast activity and rhythmic spikes.

Motivations: Seizure Detection

- Almost 1% of the world population and 3 million people in the US are affected by seizures.
- Anti-epileptic drugs are used to control seizure, but 30% of patients are refractory to medication.
- Surgery is restricted to cases where there can be no damage to the eloquent cortex.
- There is a high rate of sudden unexplained death (SUDEP) in epilepsy in comparison to the general population.

Epileptic Seizure



Internet of Medical Things (IoMT)

- The inclusion of the IoT (Internet of Things) enables remote health monitoring of epilepsy patients.
- The IoT provides universal connectivity with ambient intelligence.
- The IoT allows health professionals access to healthcare data and to provide remote healthcare services, if necessary.

Novel Contributions

- An accurate seizure detection approach has been proposed.
- This is the first study to propose DWT-based Hjorth parameters (HPs) for seizure detection.
- The inclusion of IoT with the proposed system provides universal connectivity with other healthcare applications.

Related Research

Several seizure detection methods have been proposed.

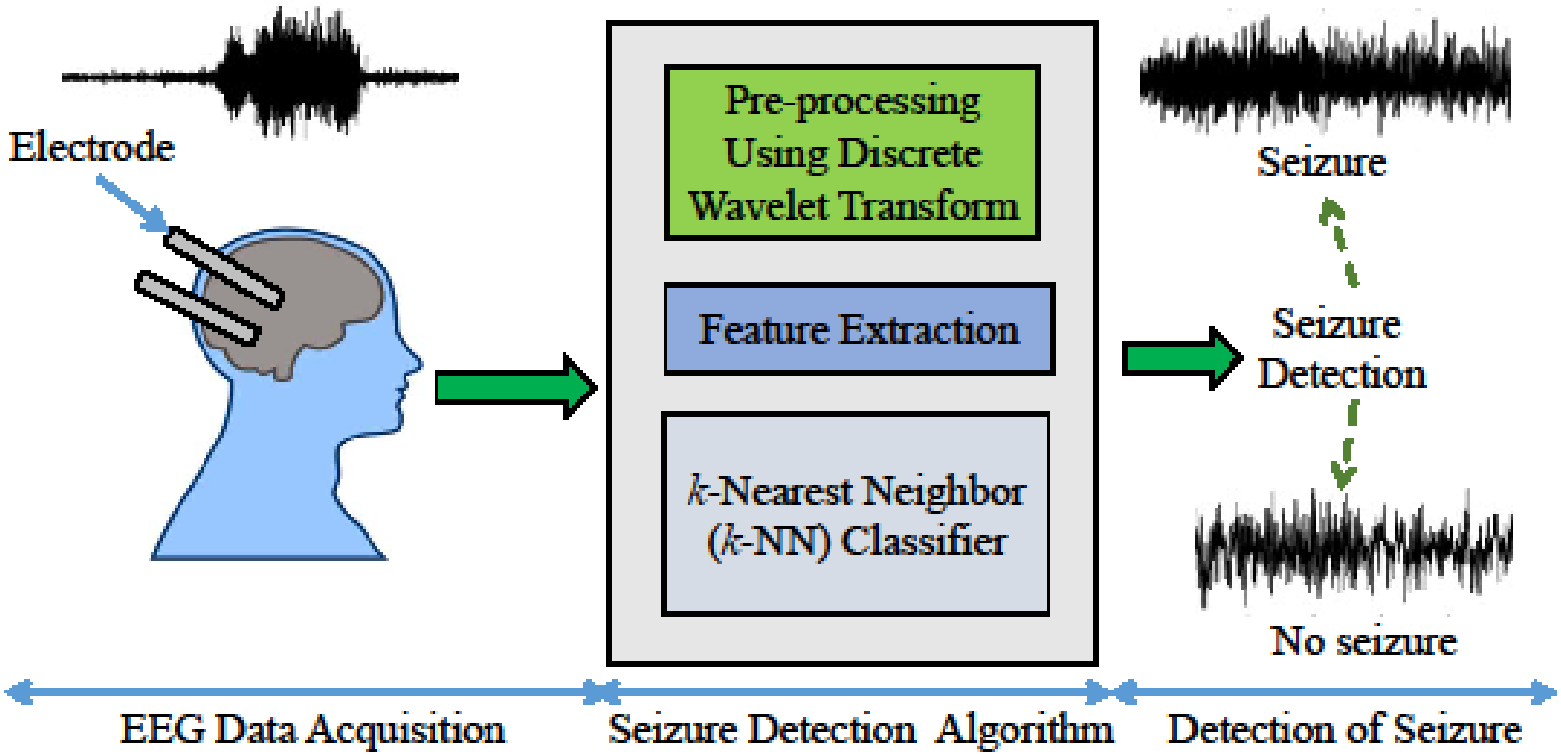
The algorithms are based on the following:

- Cepstral analysis and generalized regression neural network (Yavuz, et al. 2018).
- Weighted Permutation entropy and support vector machines (Tawfiq, et al. 2016).
- DWT and neural network classifier (Kumar, et al. 2014).
- Permutation entropy and support vector machines (Nicolaou, et al. 2012)

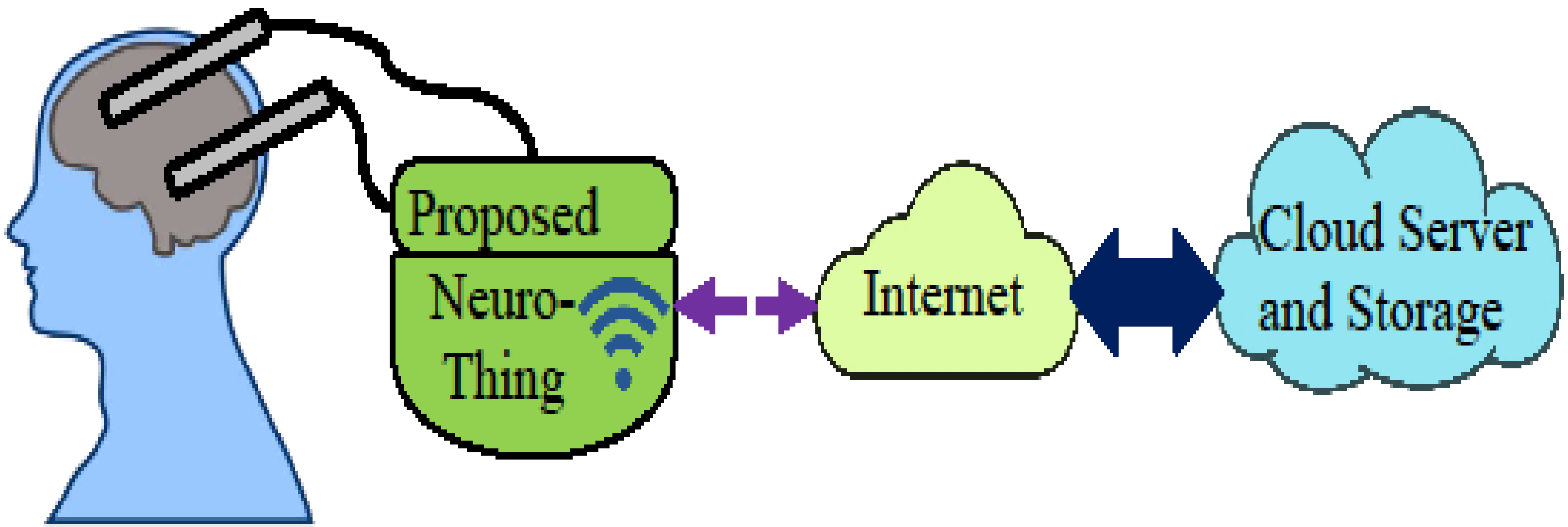
Details of the Proposed Approaches

- IoMT based system for seizure detection
- DWT based Preprocessing
- HP Feature Extraction and k-NN Classifier
- HP Feature Extraction and DNN based classifier

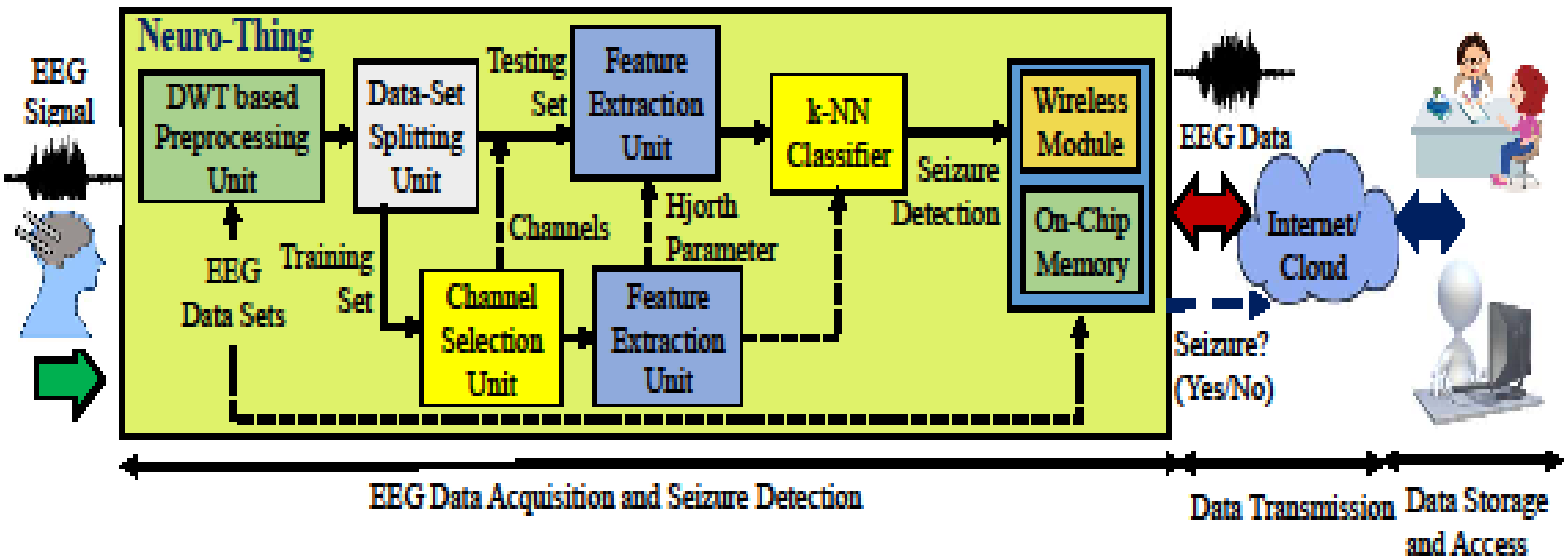
Epileptic Seizure Detection



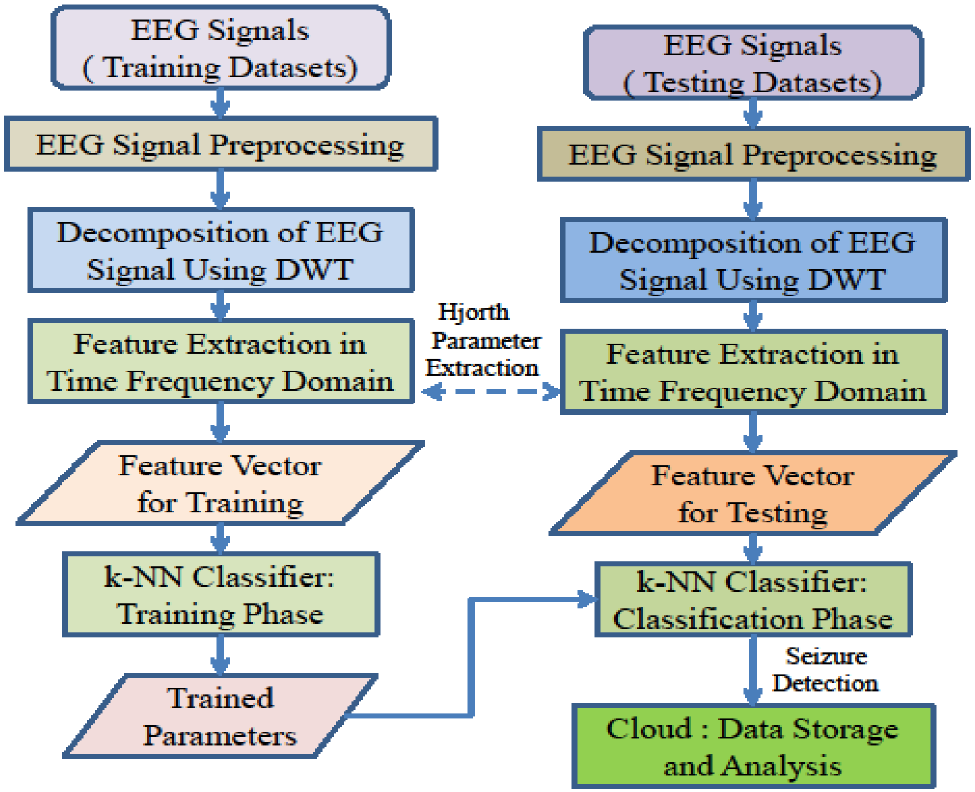
Automatic Seizure Detection in the IoMT



Overview of the Proposed Architecture



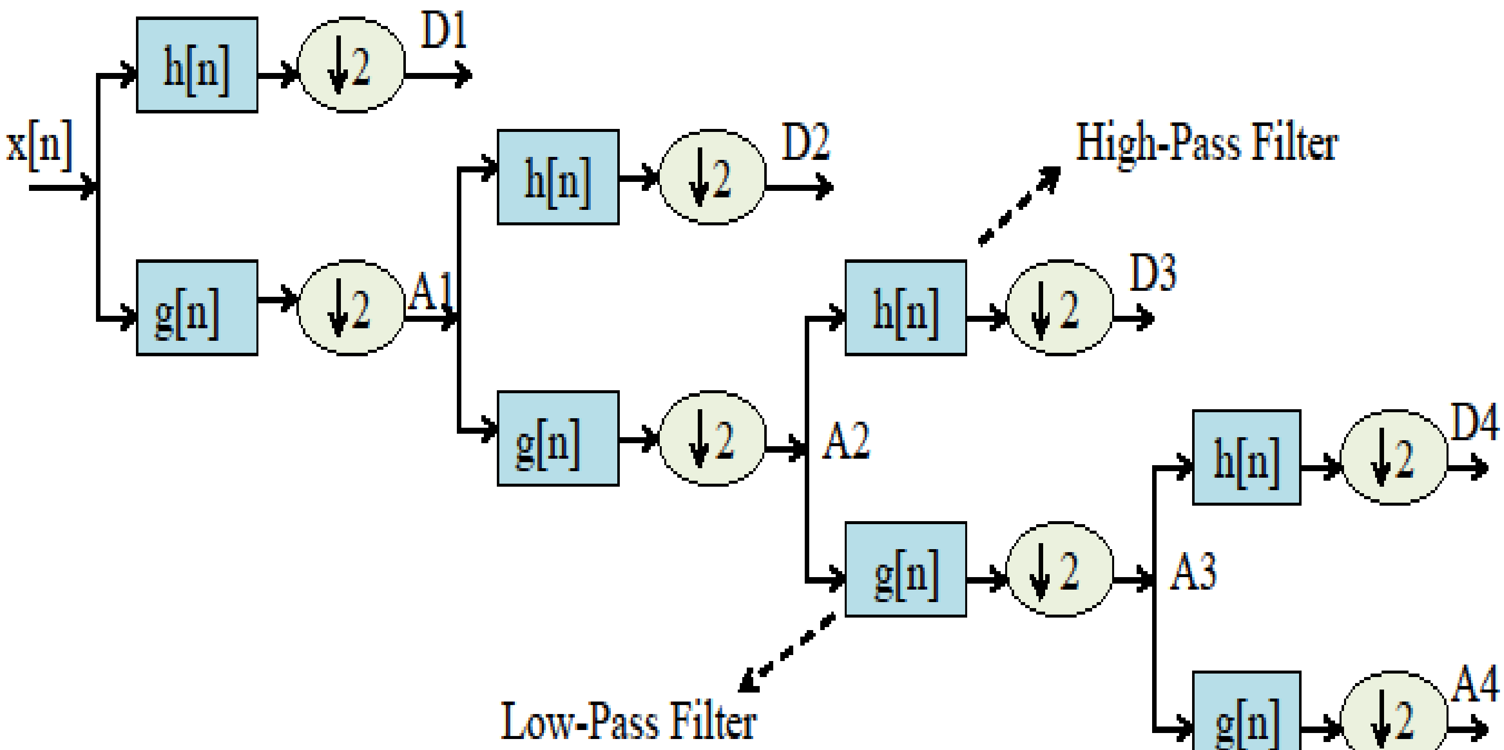
Flowchart of the Proposed System



Flowchart of the Proposed System

- The EEG is acquired and decomposed into several sub-bands using DWT.
- HP values are extracted from the different sub-bands to form a feature vector.
- The feature vectors are submitted to the k-NN classifier.
- The wireless module enables data to be transferred to clinical care staff through the internet.

Discrete Wavelet Transform (DWT) Processing Unit



Hjorth Parameter Extraction

- The Hjorth Parameters are: signal complexity, signal mobility and signal activity.
- Signal complexity and signal mobility quantify the level of variations along the signal.
- Hjorth parameters are highly effective for capturing complex dynamics of brain signals.

K-Nearest Neighbour Classifier

The nearness of the datasets has been calculated using the Euclidean distance metric:

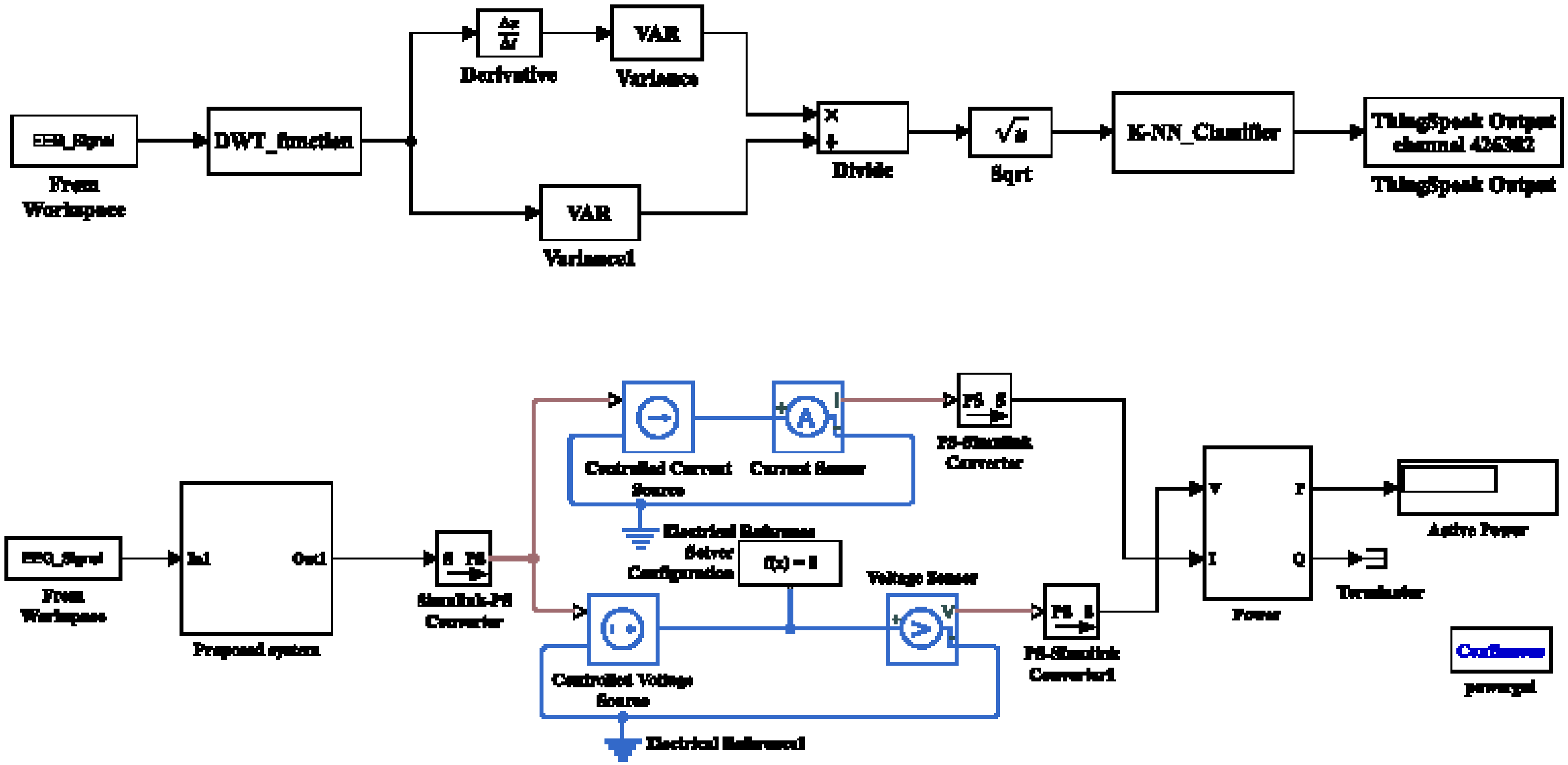
$$\|\vec{x} - \vec{y}\| = \sqrt{\sum_{i=1}^{d} (x_i - y_i)^2}$$

The classification accuracy depends on the distance metric and the value of k.

Implementation & Results

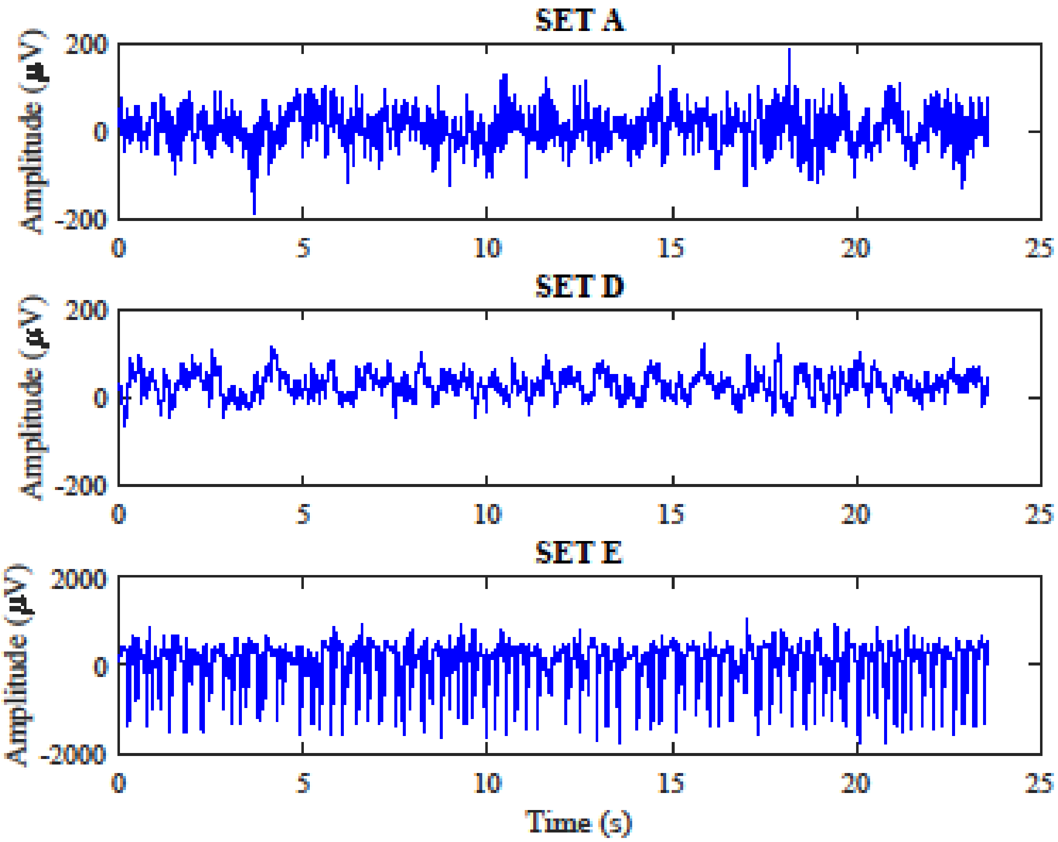
- Simulink Implementation
- Results and Discussion

Implementation of the Proposed System



Simulink Implementation (Top) System Power measurement set up (Bottom)

Results



Example of Normal EEG (Top), Inter-ictal EEG (Middle), and Ictal EEG (Bottom)

Results

TABLE I
EXTRACTED FEATURE COEFFICIENTS OF SETS A AND E

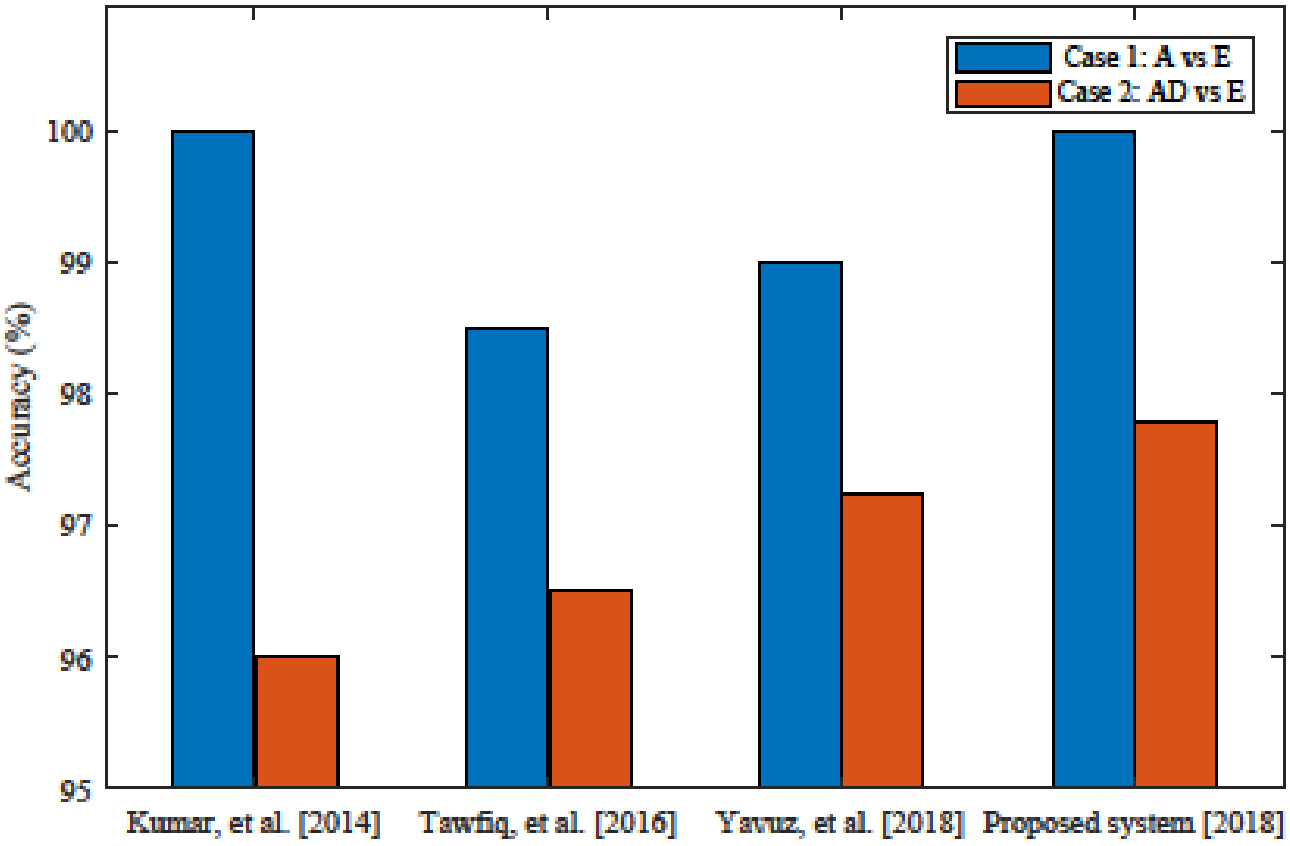
Dataset	Features	D1	D2	D3	D4	A4
A	Activity	18.44	362.5	3.88e+03	7.33e+03	1.91e+04
	Signal Complexity	0.9371	0.4688	0.7145	1.2315	1.4909
	Signal Mobility	1.4586	1.8296	1.7259	1.1894	0.7691
E	Activity	1.4e+03	5.82e+05	5.45e+05	3.07e+05	6.33e+05
	Signal Complexity	0.7797	0.3881	0.5904	0.6281	0.7126
	Signal Mobility	1.5579	1.8398	1.7613	1.8007	1.7968

Results – HP and k-NN

TABLE II
PERFORMANCE OF THE PROPOSED SYSTEM

Normal VS Seizure	
Accuracy	100%
Sensitivity	100%
Specificity	100%
Inter-ictal VS Seizure	
Accuracy	97.85%
Sensitivity	94.6%
Specificity	98.14%

Results - Comparison



Results

- It is evident that signal complexity is higher in normal EEG compared to ictal EEG. On the other hand, activity and signal mobility is higher for dataset E recorded during seizure.
- For case 1 (A-E): the classification accuracy was 100% for combined and individual features.
- For case 2 (AD-E): the highest accuracy obtained was 97.85% for individual feature AC (signal activity).

Conclusion and Future Research

- The experimental results show that the DWT based Hjorth parameters are highly effective in distinguishing EEG signals, leading to an improved classification accuracy.
- The proposed IoT framework can be expanded to include wireless wearable icEEG sensors to detect patients' seizure activities.

References

1. J. Birjandtalab, M. Heydarzadeh, and M. Nourani, “Automated EEG-Based Epileptic Seizure Detection Using Deep Neural Network ,” in *Proc. International conference of the IEEE Healthcare Informatics*, Park City, UT, USA, Aug. 2017.

2. M. A. Sayeed, S. P. Mohanty, E. Kougianos and H. Zaveri, "An energy efficient epileptic seizure detector," *2018 IEEE International Conference on Consumer Electronics (ICCE)*, Las Vegas, NV, 2018, pp. 1-4.

3. M. T. Salam, M. Sawan and D. K. Nguyen, "A Novel Low-Power-Implantable Epileptic Seizure-Onset Detector," in *IEEE Transactions on Biomedical Circuits and Systems*, vol. 5, no. 6, pp. 568-578, Dec. 2011.

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