An Edge-Device for Accurate Seizure Detection in the IoT

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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 Things (IoT)

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.

Significance of Seizure Detection

- Almost 1% of world population and 3 million US population 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

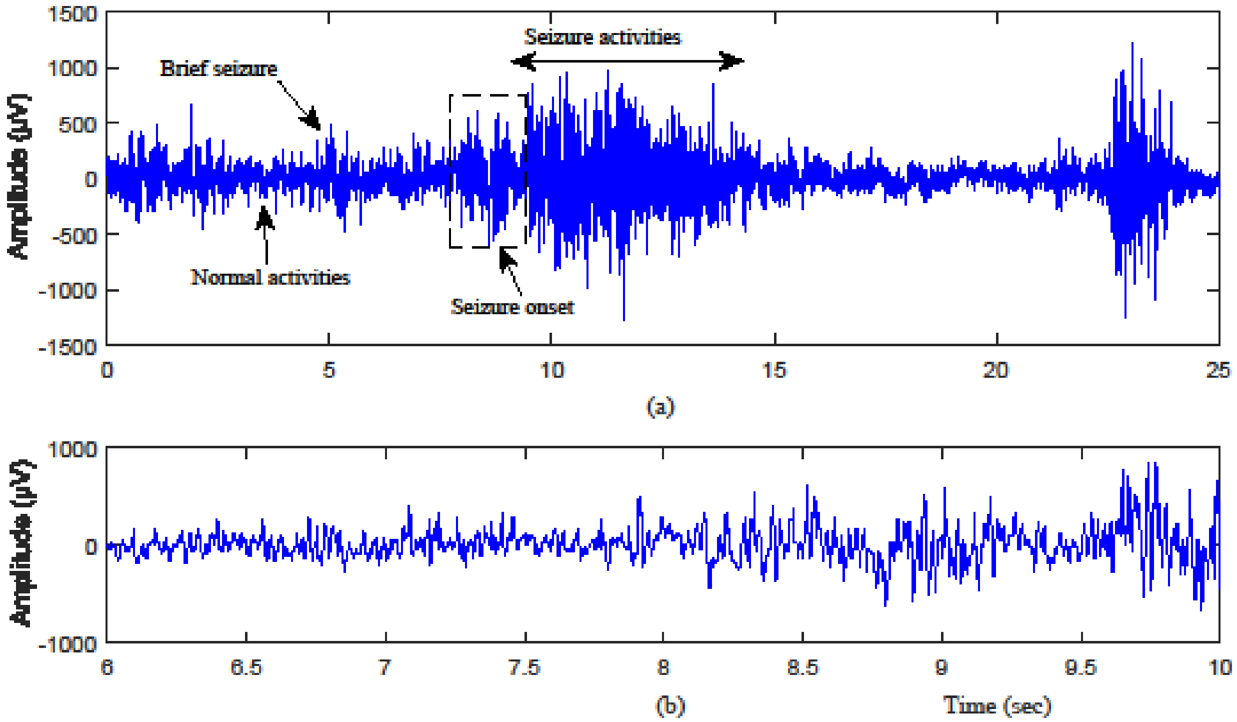

Fig. 1. Seizure characterization: (a) seizure (b) inset zoom

Internet of Things (IoT)

- 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.
- **Approach 1**: This is the first study to propose DWT based Hjorth parameters (HPs) for seizure detection.
- **Approach 2**: Deep neural network (DNN) based alternative approach.
- 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:

- Fourier transform and artificial neural network.
- DWT and approximate entropy.
- Permutation entropy and support vector machines.
- Naïve bias classifier.
- Decision tree method.
- Adaptive fuzzy logic.

Details of the Proposed Approaches

- IoT 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

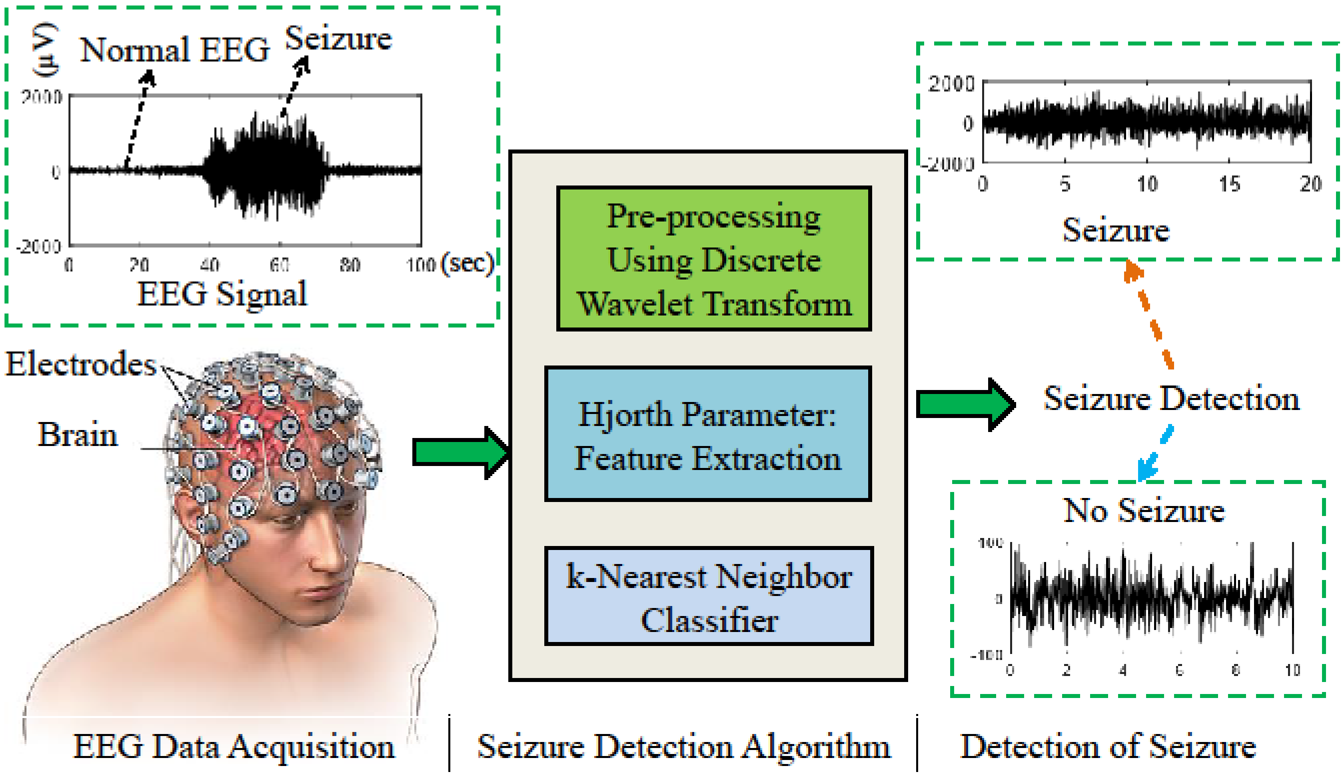

Fig. 2. A schematic overview for the proposed seizure detection paradigm

Automatic Seizure Detection in the IoT

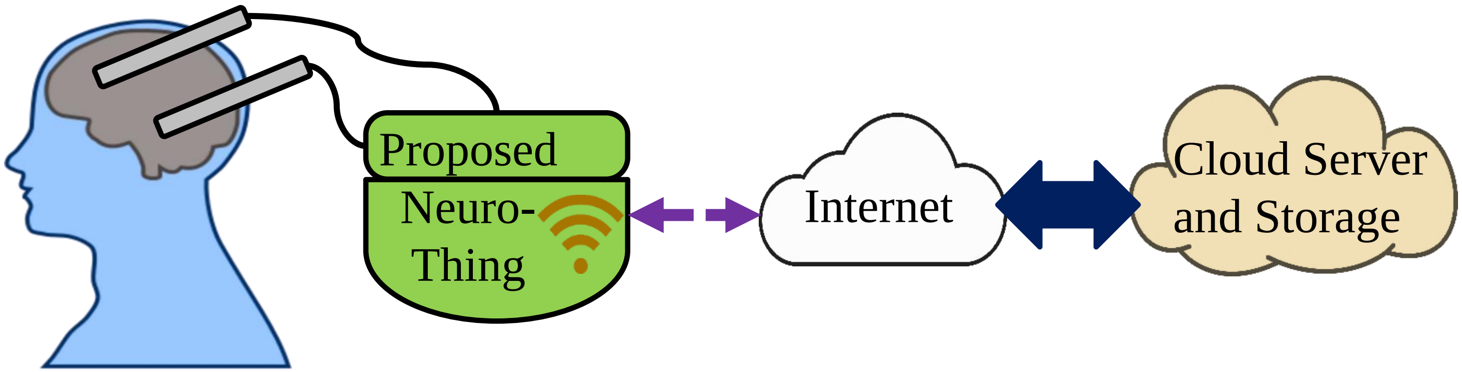

Fig. 3. Edge device for automatic seizure detection in the IoT

Overview of the Proposed Architecture

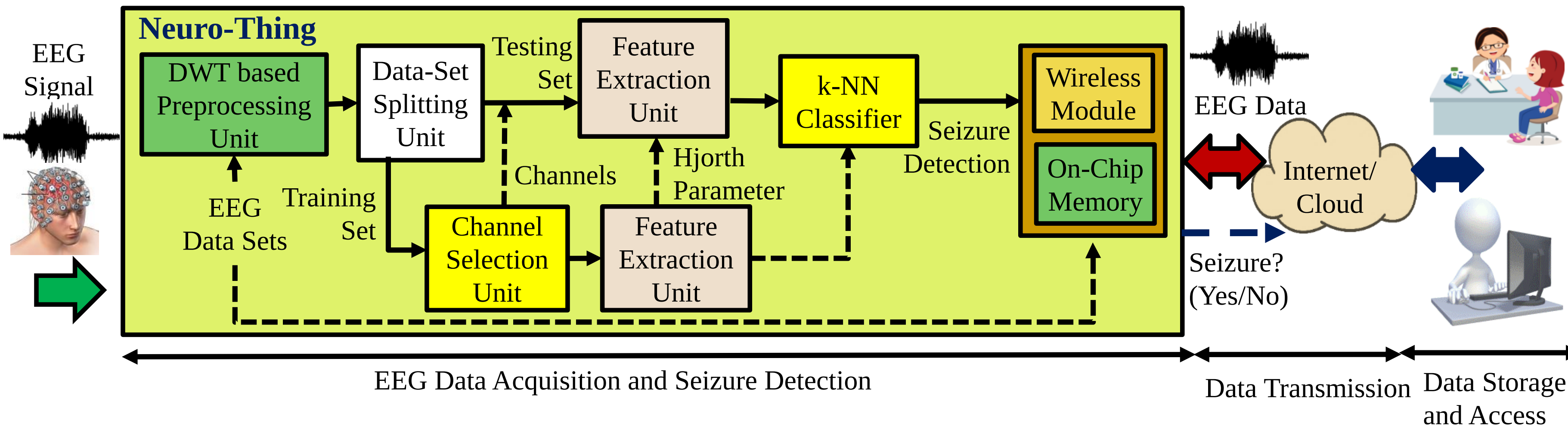

Fig. 4. Block diagram of the proposed architecture

Flowchart of the Proposed System

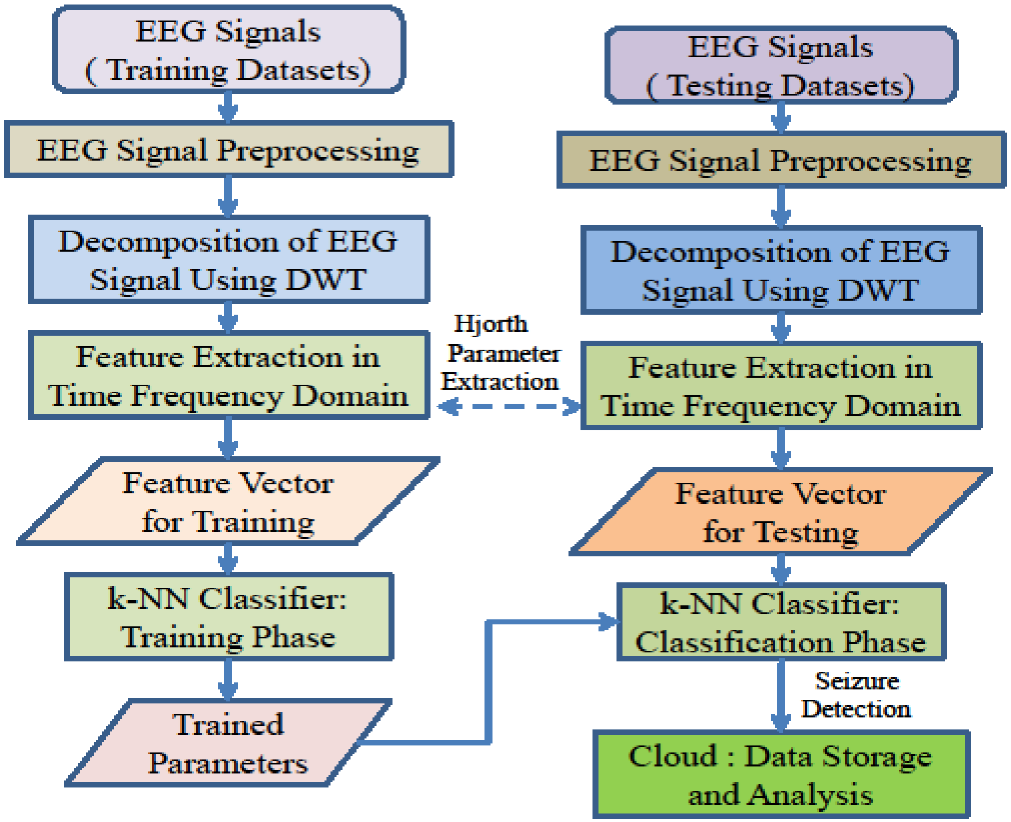

Fig. 5. Flowchart of the proposed system

Discrete Wavelet Transform (DWT) Processing Unit

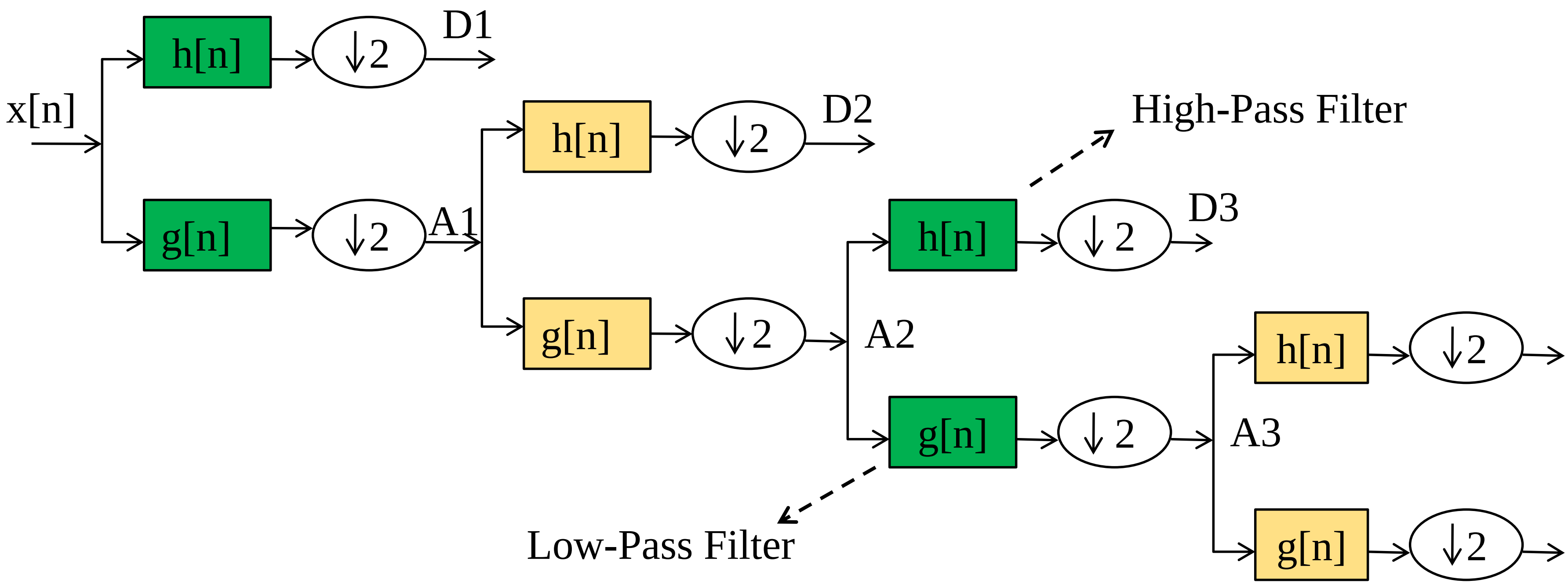

Fig. 7. Four level wavelet decomposition of EEG

Hjorth Parameter Extraction

- Signal Complexity
- Signal Mobility
- Signal Activity

K-Nearest Neighbour Classifier

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

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

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

Deep Neural Network (DNN) Classifier

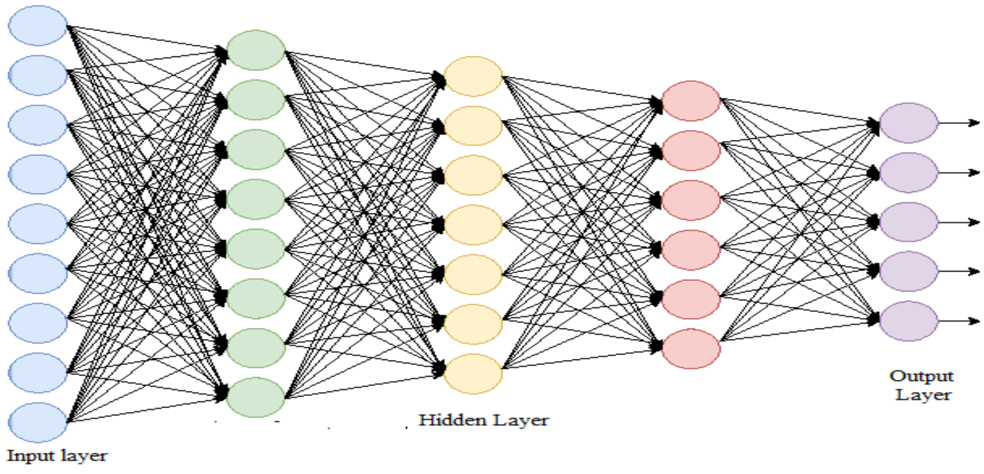

Fig. 8. Multilayer perceptron neural network

- Sigmoid transformation has been used as activation function.
- The optimization is performed using back propagation which is based on gradient descent algorithm.
- Hidden layers (H=2) have been used in this work.

Implementation & Results

- Simulink Implementation
- Results and Discussion

Implementation of the Proposed System

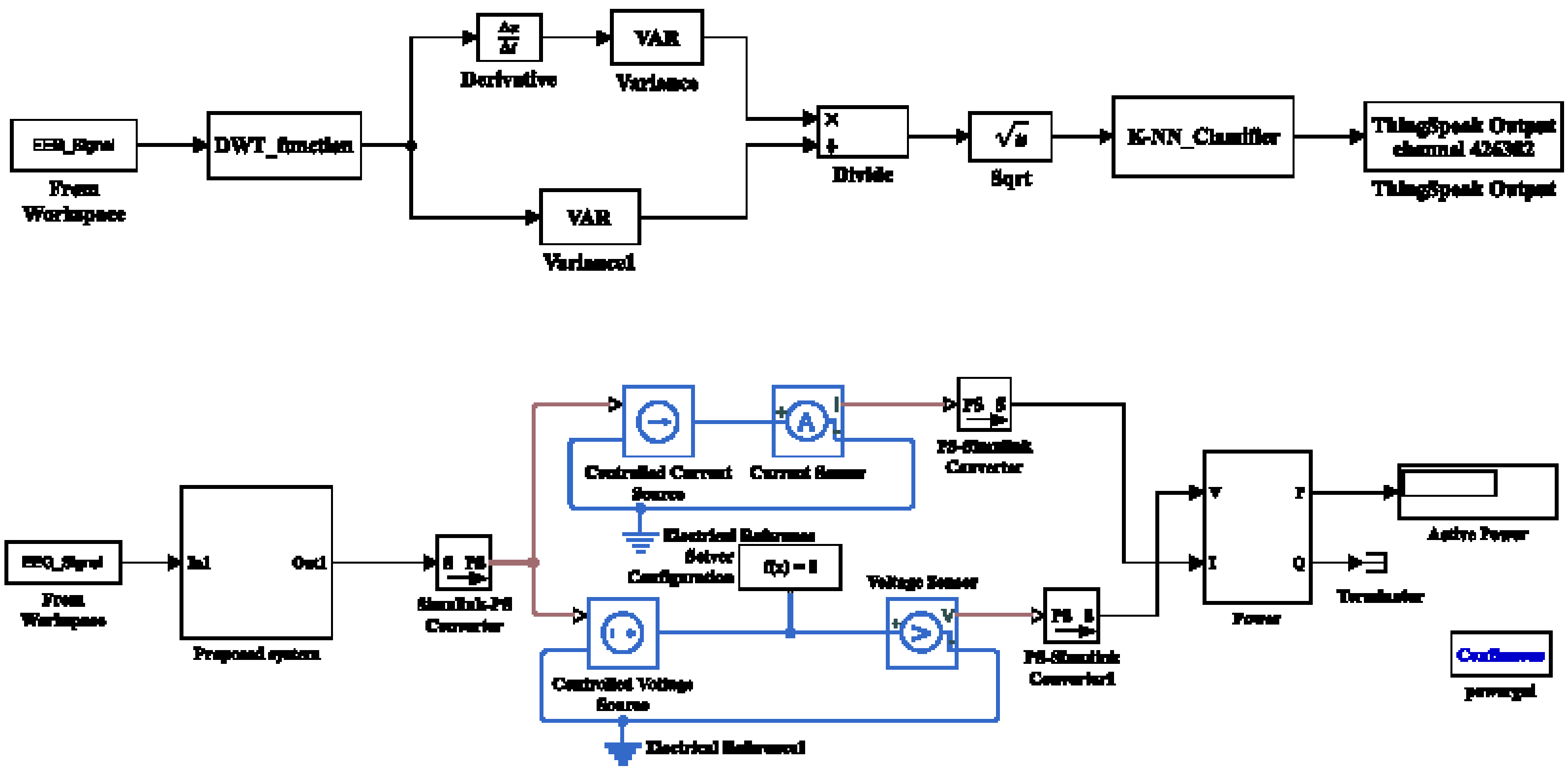

Fig. 9. Simulink Implementation (Top) System (Bottom) Power measurement set up

Results

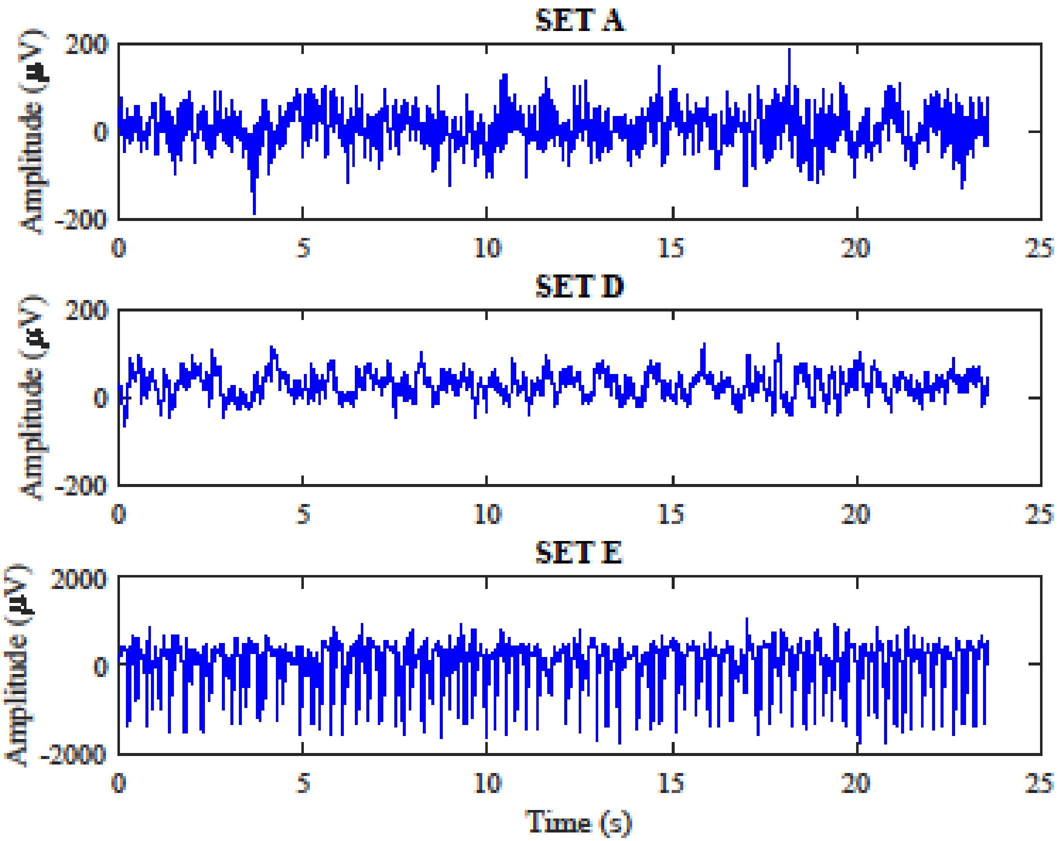

Fig. 10. Example of (Top) Normal EEG (Middle) Inter-ictal EEG (Bottom) Ictal EEG

Results

TABLE I
EXTRACTED FEATURE COEFFICIENTS OF SET A AND E

Dataset	Features	D1	D2	D3	D4	A4
A	Activity	6.31e-08	5.09e-06	1.29e-04	6.05e-04	5.61e-02
	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	7.79e-07	9.03e-05	3.19e-03	7.29e-02	2.93e-01
	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 – HP and DNN

TABLE III
PERFORMANCE OF THE PROPOSED SYSTEM

Normal VS Seizure	
Accuracy	99.51%
Sensitivity	98.71%
Specificity	99.27%
Inter-ictal VS Seizure	
Accuracy	97.35%
Sensitivity	94.35%
Specificity	97.45%

Results - Comparison

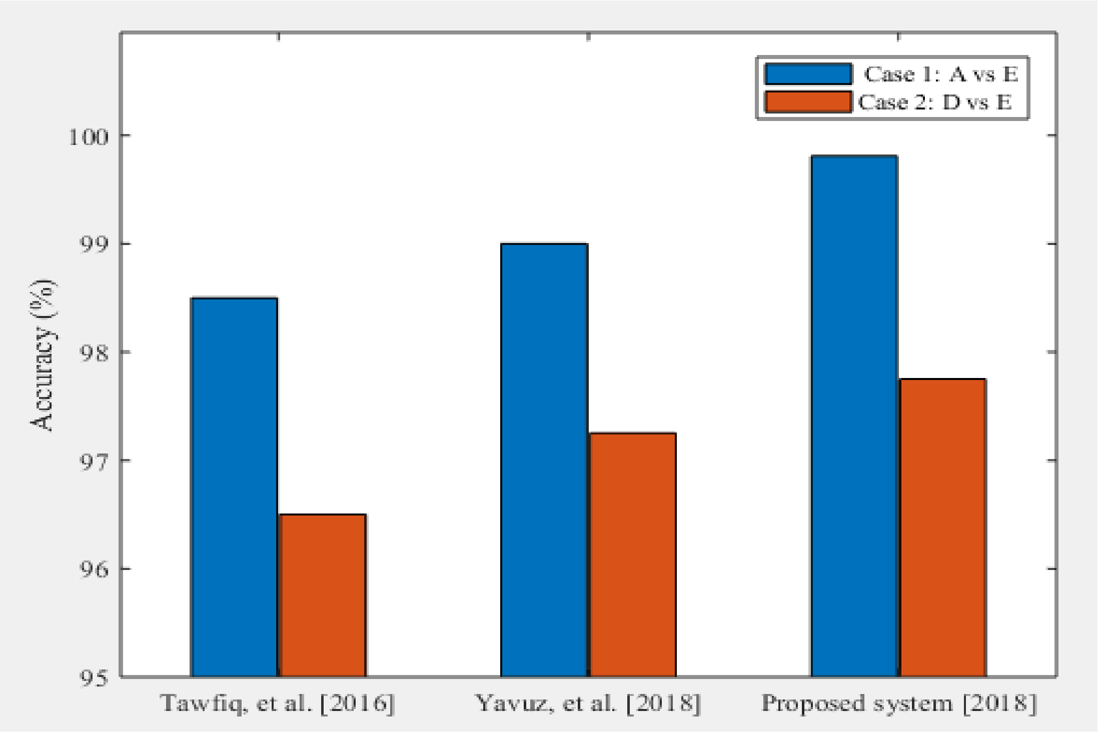

Fig. 11. Comparison of accuracy with existing methods

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. H. Wang, W. Shi, and C. Choy, "Integrating channel selection and feature selection in a real time epileptic seizure detection," in *Proc. of the 39th annual international conference of the IEEE Engineering in Medicine and Biology Society*, July 2017.

3. M. T. Salam, D. K. Nguyen and M. Sawan, "A low-power implantable device for epileptic seizure detection and neuro-stimulation," *2010 Biomedical Circuits and Systems Conference (BioCAS)*, Paphos, 2010, pp. 154-157.

Thank You !!!

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