A Novel Computer Aided Detection System for Detection of Focal and Non-Focal EEG Signals using Optimized Deep Neural Network

S. Saminu[1,2], G. Xu[1], S. Zhang[1], A. E. K. Isselmou[1], A. H. Jabire[3], Y. K. Ahmed[2], H. A. Aliyu[4], M. J. Adamu[5], A. Y. Iliyasu[6,7] and F. A. Umar[6]

1. School of Electrical Engineering, Hebei University of Technology, Tianjin, China
2. Biomedical Engineering Department, University of Ilorin, Ilorin, Nigeria
3. Electrical and Electronics Department, Taraba State University, Jalingo, Nigeria
4. Jigawa State Polytechnic Dutse, Jigawa State, Nigeria
5. School of Microelectronics, Tianjin University, Tianjin, China
6. School of Electrical Engineering, Universiti Teknologi, Malaysia
7. Kano University of Science and Technology Wudil, Kano, Nigeria

{saminu.s,ahmed.yk}@unilorin.edu.ng, {gzxu,zs}@hebut.edu.cn, {isselmou_kader,hajabdulkarim,alhaji323}@yahoo.com, adamu.jabire@tsuniversity.edu.ng, mainajajere@tju.edu.cn, faizaaliumar84@gmail.com

Epilepsy is a neurological disorder affecting people of all ages. This disorder is reported to affect over 50 million people, with a majority residing in developing countries [1]. It is a sudden and unprovoked seizure that occurs due to an erratic change in the brains' electrical activity often accompanied by loss of consciousness, uncontrolled motions, jerking, and loss of memory [2][3]. These inconvenient and undesirable effects undermine the quality of life of epilepsy patients as it's difficult for patients and doctors to predict when and where these seizures would occur. Therefore, it is highly imperative to develop an automated system for monitoring epileptic seizures and to assist clinicians in proper and efficient diagnosing of this disease [4][5].

Focal and non-focal Electroencephalogram (EEG) signal features have been effectively used for the identification of areas in the brain that are affected by epileptic seizures known as the epileptogenic zone. Detection of focal EEG signals as well as time and location of occurrence are very significant in aiding doctors to treat focal epileptic seizures using the surgical method. Figure 1 shows an example of focal and non-focal EEG signals.

The development and integration of modern, smart, portable, and low-cost devices in our health care system which is known as internet of medical things (IoMT) that can monitor, track, and transmit data wirelessly with an online consultation in a real time scenario is highly desirable [6]. For epileptic seizure applications, the efficiency of these devices largely depends on their level of accurate classification of physiological signals which depends on the quality of feature extraction methods employed to extract the relevant signal's information that characterize different signal's properties [7][8].

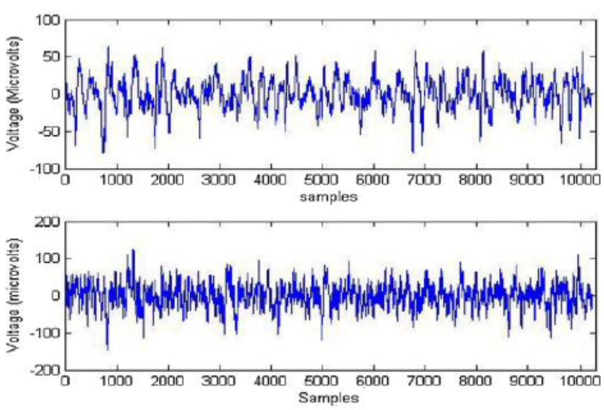


Figure 1. Focal (top) and non-focal (bottom) EEG signals

This work uses intracranial EEG signal from the University of Bern, Switzerland Department of Neurology. It is publicly available and popularly known as Bern-Barcelona database. The dataset was recorded from five epilepsy patients with temporal lobe epilepsy that have undergone a surgical treatment. These signals were sampled at 512Hz and it contains 10240 samples. The dataset consists of focal and non-focal classes with each class contains 3750 pairs of EEG signals denoted

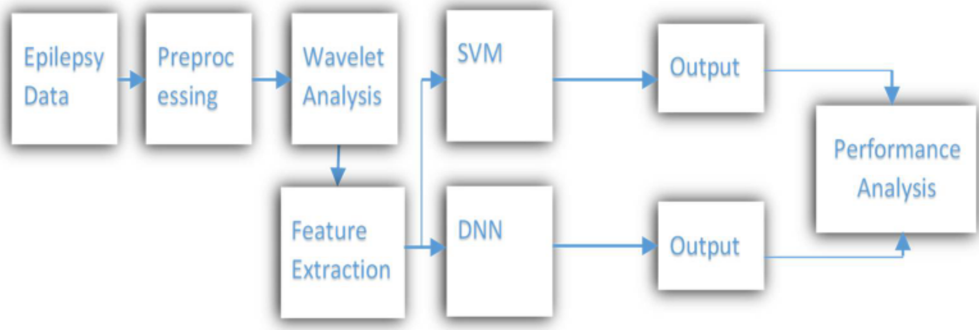


Figure 2. Block diagram of the proposed technique

as x and y. Band pass filters were used to eliminate artifacts in a preprocessing stage [9]. After preprocessing the data, the features were extracted and fed to the SVM and DNN classifiers. For the training and testing the networks, the dataset was divided randomly for each pair using a standard 70% for testing and 30% for validation with 10-fold cross validation scheme employed.

This work proposed a computer aided detection (CAD) system for detection and classification of focal and non-focal EEG signal. It is an efficient feature extraction technique suitable for smart IoMT devices due to its less computational complexity and classification algorithm using the proposed optimized deep neural network. The proposed technique as depicted in Figure 2 consists of employing time frequency features, statistical, and non-linear approaches to form a robust features extraction technique. Support Vector Machine (SVM) and Deep Neural Network (DNN) with a proposed gradient descent and adaptive learning rate as an optimization function have been employed in classification of focal and non-focal EEG signals. The proposed feature extraction and classification technique proved to be effective and suitable for smart Internet of Medical Things (IoMT) devices as performance parameters such as accuracy, sensitivity, and specificity are higher than using SVM classifier and some recently related works with a value of 99.8%, 99.5%, and 99.7% respectively. While the SVM classifier reported the values of 98.8%, 97.5%, and 98.0% respectively. The performance parameters are mathematically described as:

$$Sensitivity\ (Recall) = (TP/(TP + FN)) * 100\% \quad (1)$$
$$Specificity\ (Selectivity) = (TN/(TN + FP)) * 100\% \quad (2)$$
$$Accuracy = ((TP + TN)/(TP + FN + TN + FP)) * 100\% \quad (3)$$

where TP is True Positive (correctly identified), FP is False Positive (incorrectly identified), FN is False Negative (incorrectly rejected), TN is True Negative (correctly rejected).

ACKNOWELDGEMENTS

Research reported in this publication was most recently supported in part by the National Natural Science Foundation of China under Grant No. 51737003 and Grant No. 51977060. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Natural Science Foundation of China.

REFERENCES

[1] World Health Organization. Available online: *http://www.who.int/newsroom/fact-sheets/detail/epilepsy* (accessed on 17 February 2020).

[2] R.S. Fisher, C. Acevedo, A. Arzimanoglou, A. Bogacz, J.H. Cross, C.E. Elger, J. Engel, L. Forsgren, J.A. French, M. Glynn, "*ILAE official report: A practical clinical definition of epilepsy*," *Epilepsia,* vol. 55, pp. 475–482, 2014.

[3] J.J. Falco-Walter, I.E. Scheffer, R.S. Fisher, "The new definition and classification of seizures and epilepsy," *Epilepsy Res.* vol.139, pp. 73–79, 2018.

[4] S. Siuly, Y. Zhang, "Medical big data: Neurological diseases diagnosis through medical data analysis," *Data Sci. Eng.* vol. 1, pp. 54–64, 2016.

[5] A.W. Yuen, M.R. Keezer, J.W. Sander, "Epilepsy is a neurological and a systemic disorder," *Epilepsy Behav.* vol. 78, pp. 57–61, 2018.

[6] S. Siuly, Y. Zhang, *EEG Signal Analysis and Classification: Techniques and Applications*; Springer: Berlin/Heidelberg, Germany, 2017.

[7] J. Gavvala, N. Abend, S. LaRoche, C. Hahn, S.T. Herman, J.Claassen, M. Macken, S. Schuele, E. Gerard, "Critical Care EEG Monitoring Research Consortium (CCEMRC). Continuous EEG monitoring: A survey of neurophysiologists and neurointensivists. *Epilepsia,* vol. 55, pp. 1864–1871, 2014.

[8] S. Saminu, G. Xu, S. Zhang, A.K. Isselmou, A.H. Jabire, Y.K. Ahmed, I.A. Karaye, I.S. Ahmad, "A Recent Investigation on Detection and Classification of Epileptic Seizure Techniques Using EEG Signal,". *Brain Sci.* vol. 11 (5); 668, 2021.

[9] R. G. Andrzejak, K. Schindler, and C. Rummel, ''Nonrandomness, nonlinear dependence, and nonstationarity of electroencephalographic recordings from epilepsy patients,'' *Phys. Rev. E, Stat. Phys. Plasmas Fluids Relat. Interdiscip. Top.,* vol. 86(4), 2012.

A Novel Computer Aided Detection System for Detection of Focal and Non-Focal EEG Signals using Optimized Deep Neural Network

S. Saminu[1,2], G. Xu[1], S. Zhang[1], A. E. K. Isselmou[1], A. H. Jabire[3], Y. K. Ahmed[2], H. A. Aliyu[4], M. J. Adamu[5], A. Y. Iliyasu,[6,7] and F. A. Umar[6]

1. School of Electrical Engineering, Hebei University of Technology, Tianjin, China
2. Biomedical Engineering Department, University of Ilorin, Ilorin, Nigeria
3. Electrical and Electronics Department, Taraba State University, Jalingo, Nigeria
4. Jigawa State Polytechnic Dutse, Jigawa State, Nigeria
5. School of Microelectronics, Tianjin University, Tianjin, China
6. School of Electrical Engineering, Universiti Teknologi, Malaysia
7. Kano University of Science and Technology Wudil, Kano, Nigeria

The 2021 IEEE Signal Processing in Medicine and Biology Symposium (IEEE SPMB 2021)

Science Education and Research Center, Temple University, 1925 North 12th Street, Philadelphia, Pennsylvania, 19122, USA

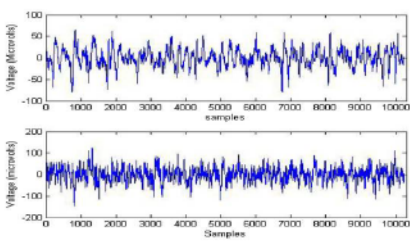
DECEMBER 4, 2021

Abstract

- Epilepsy is a neurological disorder affecting people of all ages.
- This disorder is reported to affect over 50 million people, with a majority residing in developing countries.
- It is a sudden and unprovoked seizure that occurs due to an erratic change in the brains' electrical activity often accompanied by loss of consciousness, uncontrolled motions, jerking, and loss of memory.
- These inconvenient and undesirable effects undermine the quality of life of epilepsy patients as it's difficult for patients and doctors to predict when and where these seizures would occur.
- Therefore, it is highly imperative to develop an automated system for monitoring epileptic seizures and to assist clinicians in proper and efficient diagnosing of this disease.

Focal and Non-Focal EEG Signal

- Focal and non-focal Electroencephalogram (EEG) signal features have been effectively used for the identification of areas in the brain that are affected by epileptic seizures known as the epileptogenic zone.



- Focal (top) and non-focal (bottom) EEG signals

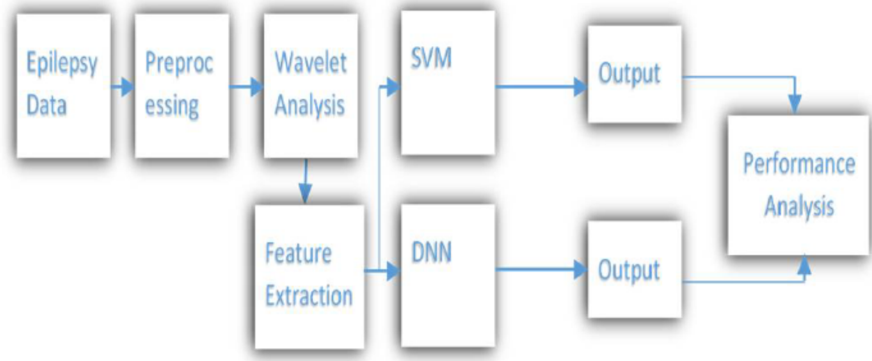
Significance of the Study

- The development and integration of modern, smart, portable, and low-cost devices in our health care system which is known as internet of medical things (IoMT) that can monitor, track, and transmit data wirelessly with an online consultation in a real time scenario is highly desirable.
- For epileptic seizure applications, the efficiency of these devices largely depends on their level of accurate classification of physiological signals which depends on the quality of feature extraction methods employed to extract the relevant signal's information that characterize different signal's properties.

Datasets

- Intracranial EEG signal from the University of Bern, Switzerland Department of Neurology known as Bern-Barcelona database.
- The dataset was recorded from five epilepsy patients with temporal lobe epilepsy that have undergone a surgical treatment.
- The dataset consists of focal and non-focal classes with each class contains 3750 pairs of EEG signals denoted as x and y.
- These signals were sampled at 512Hz and it contains 10240 samples.
- Band pass filters were used to eliminate artifacts in a preprocessing stage

Methodology



Block diagram of the proposed technique

Methodology

- The proposed technique consists of employing time frequency features, statistical, and non-linear approaches to form a robust features extraction technique.
- Support Vector Machine (SVM) and Deep Neural Network (DNN) with a proposed gradient descent and adaptive learning rate as an optimization function have been employed in classification of focal and non-focal EEG signals
- For the training and testing the networks, the dataset was divided randomly for each pair using a standard 70% for testing and 30% for validation.
- 10-fold cross validation scheme employed.

Performance Measures

$$Sensitivity\ (Recall) = (TP/(TP + FN)) * 100\%$$

$$Specificity\ (Selectivity) = (TN/(TN + FP)) * 100\%$$

$$Accuracy = ((TP + TN)/(TP + FN + TN + FP)) * 100\%$$

- where TP is True Positive (correctly identified), FP is False Positive (incorrectly identified), FN is False Negative (incorrectly rejected), TN is True Negative (correctly rejected).

Results

Classifier	Sensitivity (%)	Specificity (%)	Accuracy (%)
SVM	97.5	98.0	98.8
DNN	99.5	99.7	99.8

Acknowledgements

- Research reported in this publication was most recently supported in part by the National Natural Science Foundation of China under Grant No. 51737003 and Grant No. 51977060. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Natural Science Foundation of China.