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ANN based Sub-Classification of Epileptic Cases

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ABSTRACT
Epilepsy is a disease due to alternation in brain functions due to abnormal and excessive electrical activity of a group of neurons. In this paper two-class classification is based on Artificial Neural Network (ANN). The performance of the ANN classifier is evaluated in terms of sensitivity, specificity and classification accuracy. Classification is done on non-seizure and seizure subjects. Non-seizure subjects are further classified for hippocampal formation and epileptogenic zone. In classification of non-seizure and seizure, results obtained exhibited an accuracy of 98.7% and for hippocampal formation and epileptogenic zone an accuracy of 100% is obtained. The obtained classification accuracy confirms that the proposed scheme has potential in classifying EEG signals.

KEYWORDS: ElectroEncapheloGraph, Epilepsy, Hippocampal, Epileptogenic, Artificial Neural Network.

INTRODUCTION

ElectroEncephaloGraph (EEG) is the recording of the brain'selectrical activity over a period of time. Epilepsy is a disease due to alternation in brain functions due to abnormal and excessive electrical activity of a group of neurons. Epilepsy detection is an attractive area for researchers for past many years.
Our work involves classification of data obtained from Department of Epileptology University of Bonn. This EEG data consists of five sets A-E. Set A and Set B are normal subjects having eyes open and eyes closed data, whereas Set C, D and E are abnormal subjects. Set C and Set D both come under seizure free interval, where in set C is from the hippocampal formation of opposite hemisphere of the brain and set D is from the epileptogenic zone. Set E contain seizure activity [1]. The classification on normal and epileptic subjects, and eyes open and eyes closed subjects is done earlier by Mandeep Singh and HarleenKaur. In classification of normal and epileptic subjects an accuracy obtained is 99.2% and for eyes open and eyes closed an accuracy of 100% is obtained [2]. General detection of epilepsy using this data has been done by Mandeep Singh and SunpreetKaur [3][4][5][6]. This work shall focus on sub-classification of epileptic cases into (i) seizure and non-seizure cases, (ii) the non-seizure cases to be again bifurcated to hippocampal and epileptogenic cases.
The **hippocampal formation** (Ammon's horn) is a curved cortical structure in the medial temporal lobe of the brain. There is no consensus over which brain regions are encompassed by the term, with some authors defining it as the dentate gyrus, the hippocampus proper and the subiculum,and some closely related cortical areas in the parahippocampalgyrus, including the subicular complex (which itself is divided into the subiculum, presubiculum and parasubiculum) and the entorhinal cortex, are together referred to as the hippocampal formation [7]. The hippocampal formation is thought to play a role in memory, spatial navigation and control of attention. The neural layout and pathways within the hippocampal formation are very similar in all mammals.
Ammon's horn and the dentate gyrus can be recognized quite early in embryonic development, where they form a thin band along the medial edge of the pallium. The dentate gyrus is the most medial component of the hippocampal formation, and it lies along the "free edge" of the cortical mantle during early embryogenesis, since it is bordered along its medial aspect by the telachoroidea of the lateral ventricle caudally, and the septum ependymale and lamina terminalisrostrally. As development progresses, caudal (temporal) parts of the hippocampal region undergo considerable enlargement, whereas rostral (septal) parts develop little and come to form the indusiumgriseum dorsal to the genu of the corpus callosum. As the cortical mantle expands during development, the hippocampal region remains medial, and its main body comes to lie along the medial aspect of the inferior horn of the lateral ventricle in the temporal region. However, because of tremendous cellular proliferation, Ammon's horn folds back upon itself along the hippocampal fissure, as does the DG, which eventually forms a wedge-shaped structure. As a result, the hippocampal formation is perhaps best viewed as a series of adjacent cortical stripes that begin laterally at the rhinal fissure and consist, in order, of the lateral and medial entorhinal areas: the parasubiculum, presubiculum, and subiculum; fields CA1, CA2, and CA3 of Ammon’s horn; and the dentate gyrus.

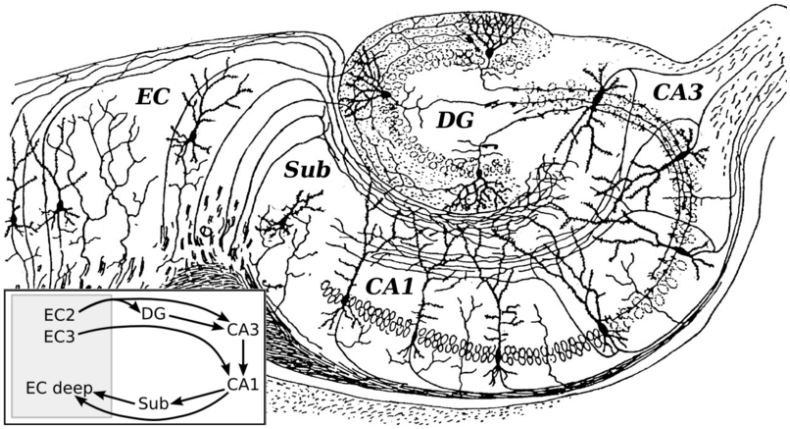

Figure 1: Hippocampal formation

The **epileptogenic zone** is an area of cortex that is necessary and sufficient for initiating seizures and whose removal (or disconnection) is necessary for complete abolition of seizures [8]. Localization of epileptogenic focus is most important step in screening patients with medically intractable focal epilepsy for potential surgical cures. The locations of epileptogenic zones are found using the clinical criteria produced by the sum of noninvasively acquired findings, such as clinical semiology, EEG, Magnetic Resonance Image (MRI), Positron Emission Tomography (PET), and Single Photon Emission Computed Tomography (SPECT). Surgery is the only option inthese situations and requires a previous precise localization of the epileptogenic zone [9].

DATA USED

The EEG data considered for this work was obtained from EEG database of University of Bonn. It contains three different cases: 1) healthy, 2) epileptic subjects during seizure-free interval and 3) epileptic subjects during seizure interval [1].

In Earlier work data sets were used for the classification of normal and epileptic subjects, and for eyes open and eyes closed subjects [2]. In this paper, data sets used for the classification of non-seizure and seizure subjects, and for hippocampal formation and epileptogenic zone subjects. In this work, we use three data sets, set C, D and E for training and testing of neural network [2].

APPLIED METHODOLOY

Discrete wavelet transform (DWT) is a spectral analysis technique used for analyzing non-stationary signals, and provides time-frequency signals [4]. Sub-band decomposition of EEG signal in all the three set (Set C, D and E) is done by using DWT. Features were extracted from the five sub-bands (delta, theta, alpha, beta and gamma) of EEG signals. These features are (i) variance, (ii) power spectral density max, (iii) power spectral density min, (iv) entropy and (v) energy. Thus we have a total of 25 features. None of these features resulted in non-overlapping range [2].

This works aims at achieving two different types of classifications in epileptic cases:

i. To classify non-seizure subjects and seizure subjects (two-class classification).
ii. To classify non-seizure subjects with hippocampal formation and epileptogenic zone (two-class classification).

From the 25 features extracted, it was observed that:

i. For 100 subjects in non-seizure class and 50 subjects in seizure class, none of the features had non-overlapping range. Thus a simple threshold based two class classification is not possible.
ii. For 50 subjects of non-seizure hippocampal formation and 50 subjects of non-seizure epileptogenic zone, none of the features had non-overlapping range. Thus a simple threshold based two class classification is not possible.

In order to achieve two-class classification using the 25 features extracted, we propose an Artificial Neural Network(ANN) based classifier.

An **ANN** based classifier is utilized the 25 features in its input vector for the classification. This ANN is designed with 25 input nodes, one output node and one hidden layer. We chose training function in all the layers as tansig. Further we chose 70% of the subjects for training, 15% for testing and 15% for validation. Since this is a two-class classification, the target values are determined as 0 and 1. The topology chose is Feedforward back propagation neural network. Of 25 input parameters, combinations of 10 input parameters are selected at a time with an aim to

obtain good accuracy, sensitivity and specificity. This is done to keep the neural network light and computationally effective. In this work classification is performed on three data sets i.e. set C, D and E. This paper outlines the classification of non-seizure subjects and seizure subjects as phase-I. Sub-classification of non-seizure subjects into hippocampal formation and epileptogenic zone is done as phase-II.

Phase-I: Classification of non-seizure subjects and seizure subjects.
As described earlier, we have 100 non-seizure subjects and 50 seizure subjects. For optimizing the accuracy of ANN, we tried various possible combinations of extracted features from all five sub-bands, with different number of neurons in the hidden layer. The result of this classification is given in table 1. It is found that ANN with seven neurons in hidden layer and 10 inputs, namely variance and entropy from all the five sub-bands, gives maximum accuracy. This accuracy is 98.7% and is quite satisfactory.

Phase-II: Classification of non-seizure hippocampal formation and epileptogenic zone subjects.
As described earlier, we have 50 hippocampal formation subjects and 50 epileptogenic zone subjects. For optimizing the accuracy of ANN, we tried various possible combinations of extracted features from all five sub-bands, with different number of neurons in the hidden layer. The result of this exercise is given in table 2. It is found that ANN with seven neurons and 10 inputs, namely variance and entropy from all the five sub-bands gives maximum accuracy. This accuracy is 100% and is quite satisfactory. It may be maintained explicitly here that 100% accuracy was also obtained in some other combinations. The choice of seven neurons in hidden layer and variance & entropy in features is made to have consistency in the structure of ANN used for similar previous work [2].

Table 1 : Accuracies achieved for classification of non-seizure and seizure dataset

rameter → / urons ↓	Variance and PSD	Variance and Entropy	Variance and Energy	PSD Max and Entropy	PSD Max and Energy	Entropy and Energy
2	92%	87.3%	98.3%	66.7%	87.3%	81.3%	94%	95.3%
3	73.3%	77.3%	96%	73.3%	70%	68.7%	86.7%	80.7%	96.7%	92%
4	94%	70%	95.3%	90%	68.7%	84.7%	94%	87.3%	94%	94%
5	82%	78.7%	95.3%	84.7%	68%	82%	94.7%	85.3%	95.3%	92.7%
6	86.7%	82%	95.3%	89.3%	70.7%	80%	96%	90.7%	96%	95.3%
7	86.7%	77.3%	98.7%	80%	72.7%	84%	93.3%	75.3%	96.7%	95.3%
8	92.7%	82.7%	96.7%	94.7%	76.7%	68%	93.3%	67.3%	98%	95.3%
9	89.3%	76%	96.7%	85.3%	66.7%	86%	67.3%	85.3%	66.7%	96.7%

Table 2 : Accuracies achieved for classification of hippocampal and epileptogenic dataset

Parameter → / Neurons ↓	Variance and PSD Max	Variance and PSD Min	Variance and Entropy	Variance and Energy	PSD Max and PSD Min	PSD Max and Entropy	PSD Max and Energy	PSD Min and Entropy	PSD Min and Energy	Entropy and Energy
2	97%	94%	99%	97%	98%	98%	97%	88%	97%	80%
3	54%	54%	100%	68%	97%	99%	96%	47%	47%	71%
4	96%	99%	100%	96%	98%	100%	96%	92%	93%	85%
5	96%	98%	100%	93%	97%	99%	98%	95%	86%	83%
6	99%	98%	100%	97%	95%	98%	95%	94%	96%	92%
7	98%	89%	100%	96%	97%	100%	97%	97%	86%	82%
8	94%	95%	99%	83%	95%	99%	98%	93%	91%	89%
9	98%	97%	100%	94%	97%	98%	97%	84%	90%	92%

RESULT AND CONCLUSION

From this study, we conclude that,

i. Variance and entropy from all the five sub-bands are optimum for classification of EEG signals.

ii. A hidden layer with seven neurons is best suited for this classification.

Let us elaborate the results further with general confusion matrix explained earlier by Mandeep Singh and HarleenKaur [2].

For seizure detection, we ask is the subject has seizure? Answer may be Yes or No. Our results for the chosen ANN are given in table 3.

Table 3: Confusion matrix for non-seizure and seizure detection

		Predicted Class	
	Class	**Yes**	**No**
Actual Class	**Yes**	50	0
	No	2	98

Accuracy = [(50+98) / (50+98+0+2)] x 100 = (148/150) x 100 = 98.7%

Sensitivity = [50 / (50+0)] x 100 = (50/50) x 100 = 100%

Specificity = [98 / (98+2)] x 100 = (98/100) x 100 = 98%

For hippocampal and epileptogenic detection, we ask is the subject having hippocampal formation? Answer may be Yes or No. Our results for the chosen ANN are given in table 4.

Table 4: Confusion matrix for hippocampal and epileptogenic detection

		Predicted Class	
	Class	**Yes**	**No**
Actual Class	**Yes**	50	0
	No	0	50

Accuracy = [(50+50) / (50+50+0+0)] x 100 = (100/100) x 100 = 100%

Sensitivity = [50 / (50+0)] x 100 = 100%

Specificity = [50 / (50+0)] x 100 = 100%

The results are finally shown in table 5.

Table 5: Final result

Case	**Accuracy**	**Sensitivity**	**Specificity**
Non-seizure and seizure classification	98.7%	100%	98%
Hippocampal and epileptogenic classification	100%	100%	100%

Needless to mention, the results are very encouraging and need no more refinements.

SCOPE FOR FUTURE WORK

In this work, we have classified epileptic subjects (Set C, D and E). Work has been done on two-class classifier where accuracy achieved is very high. But the method is time consuming so further work can be done using a multi-

class classifier for epilepsy detection. This classifier should be able to place the subject in one of the five classes, namely:

(i) Normal eyes open,
(ii) Normal eyes closed,
(iii) Hippocampal,
(iv) Epileptogenic and
(v) Seizure.

REFERENCES

[1] Time series data (Department of Epileptology University of Bonn). http://www.meb.unibonn.de/epileptologie/science/physik/eegdata.html.
[2] Mandeep Singh, HarleenKaur,"ANN based Epilepsy detection using EEG", *International Journal of Information Technology & Knowledge Management*,Vol 7, No. 1, Dec 2013, [in press].
[3] Mandeep Singh, SunpreetKaur, "Epilepsy Detection Using EEG: An Overview", *International Journal of Information Technology & Knowledge Management*, 2012, Vol 6, No.1, Dec 2012.
[4] Mandeep Singh, SunpreetKaur, Epilepsy, "Frequency Band Separation for Epilepsy Detection Using EEG",*International Journal of Information Technology & Knowledge Management*,Vol 6, No. 1, Dec 2012.
[5] Mandeep Singh, Sun preetKaur, Epilepsy , "Feature Selection for Epilepsy Detection using EEG", *InternationalJournal f Information Technology & Kowledg e Management*, Vol6, No.1, Dec2012.
[6] Mandeep Singh, SunpreetKaur, "A Novel Scoring system for Epilepsy Detection Using EEG ", *International Journal of Information Technology and Knowledge Management* Vol. 6, No. 1, Dec 2012.
[7] JH.Martin (2003). "Lymbic system and cerebral circuits for emotions, learning, and memory". Neuroanatomy: text and atlas (third ed.). McGraw-Hill Companies, p. 382.
[8] Hans O. Lüders, ImadNajm, Dileep Nair, Peter Widdess-Walsh and William Bingman, "The epileptogenic zone:general principles",*Epileptic disorders: international epilepsy journal*, 2006.
[9] Jae Sung Lee, Seok-Ki Kim, Dong So0 Lee, MyungChul Lee andKwang Suk Park, "A Neural Network Classifier for The Automatic Interpretation of Epileptogenic Zones in F-18FDG Brain PET",*International Conference of the IEEE Engineering in Medicine and Biology Society*, Vol. 20, No 3, 1998.