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Seizure Detection in EEG Signals using Convolution Neural Network (CNN)

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ABSTRACT: An electroencephalogram (EEG) is normally used ancillary test for the diagnosing of encephalopathy. The electroencephalogram signal consists of statistics concerning brain electrical activity. Neurologists use direct visual examination to become aware of epileptiform abnormalities and this technique may want to also be time-consuming that offers variable outcomes secondary to reader experience level and is proscribed to identify the abnormalities. Since it's integral to advance a computer-aided prognosis (CAD) device to automatically distinguish the lessons of electroencephalogram alerts victimization computing device mastering techniques. In the proposed methodology, EEG signals are decomposed into approximate and particular wavelet coefficients the use of butter well worth filter design. The statistical points such as mean, standard deviation, kurtosis, skewness and so on are extracted from selected wavelet coefficients to test the convolution neural network (CNN) for evaluation of electroencephalogram signals. During this work, 8-layer CNN algorithmic application is implemented to notice normal, preictal, and seizure classes. This technique completed companion common accuracy as high as possible as greater than 90% severally.

I. INTRODUCTION

An epileptic seizure is described with the useful resource of the International LeagueAgainst Epilepsy (ILAE) as transitory occurrence of signs and signs and symptoms and/or signs due to uncommon excessive or synchronous neuronal exercise in the intelligence. It used to be suggested that sixty five million human beings of all a whilst have the epilepsy. Owing to the influences of epileptic seizures, which can lead to neuronal injuries, sufferers with recurrent or extended seizures need to be reviewed by neurologists for a on the spot diagnosis and therapy. For these with refractory reputation epilepticus unresponsive to medication, neurologists normally screen the sufferers with non-stop video-EEG monitoring. This is a combination of EEG and video, recorded concurrently to take a appear at brain activities in correlation with a scientific change. Nevertheless, this challenge is nonetheless a time-consuming technique for the neurologists to evaluate the continuous EEG.Therefore, an computerized epileptic seizure detection the use of EEG indications is developed to facilitate the interpretation of long-term monitoring .Ictal EEG sample is a sequence of spike, sharp wave, and gradual wave when seizures occur.

Epilepsy, which is labeled as a neurological disorder that affects the brain, influences about 2% of the world population main to a reduction in their productivity and imposing restrictions on their each and every day life. Diagnosis of epilepsy is performed by way of inspecting electroencephalogram (EEG) signals, as nicely as affected individual behavior. EEG signals has two types: scalp EEG and intracranial EEG(iEEG). Scalp EEG indications are generally collected with electrodes positioned on the scalp the utilization of some form of conductive gel after treating the scalp vicinity with the light abrasion in order to limit the impedance ensuing from dead skin cells. Commonly, 19 recording electrodes in addition to a floor and machine reference are placed on the scalp location in accordance to specs with the useful aid of the International 10–20 system. However, fewer electrodes are used when the EEG indicators are recorded

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for neonates. Each of these electrodes collects an EEG signals, which is centrally recorded for post-processing. On the other hand, in iEEG, electrodes are placed barring prolong on the uncovered flooring of the Genius at some stage in a surgical method to document electrical challenge from the cerebral cortex. For the seizure detection mission in the case of epilepsy patients, it is required to analyze these EEG warning signs closer to a preference of the existence, or absence, of an epileptic seizure. If a seizure exists, in addition evaluation ought to be made for more draw close of seizure behavior.

From the machine learning (ML) point of view, recognition of epileptic and nonepileptic EEG indicators is a challenging task. Usually, there is a small amount of epilepsy facts handy for coaching a classifier due to infrequently occurring of seizures. Further, the presence of noise and artifacts in the information creates subject in getting to know the brain patterns related with normal, ictal, and non-ictal cases. This difficulty will increase further due to inconsistency in seizure morphology amongst patients. The present automatic seizure detection methods use usual sign processing (SP) and ML techniques. Many of these techniques show appropriate accuracy for one problem however fail in performing precisely for others e.g.they classify seizure vs. non-seizure case with a properly accuracy but show terrible overall performance in case of everyday vs. ictal vs. inter-ictal. Its still a challenging problem due to three reasons, i) a generalized mannequin does no longer exist which can classify binary as nicely as a ternary trouble (i.e. regular vs. ictal vs. inter-ictal), ii) much less on hand labeled data, and ii) low accuracy. To help and aid neurologists, we need a generalized automatic system that offers suitable overall performance even with fewer coaching samples.

The accelerated amount of data also lets in the neurologist to seem to be for inter-ictal abnormalities. Seizures can be partial and exists in one part of the intelligence only, or they can be common and affect each halves of the brain. During a focal seizure, the man or woman may be conscious and unaware that a seizure can taking place, or they may have uncontrollable actions or uncommon emotions and sensations. A diagnosis of epilepsy is made with the help of an electroencephalogram (EEG). EEG recordings are many times visualized as charts of electrical energy produced by the brain and plotted in opposition to time. The visual interpretation of these indicators is susceptible to inter-observer variabilities. Therefore, for an accurate, fast, and objective diagnosis a computer-aided diagnosis (CAD) device is advocated.

An Electroencephalography (EEG) sign is capable to discover any neurons misfiring or immoderate neural activity which can be a sign of a neurological disorder. Epileptic seizure monitoring require enormous quantity of long-term collected EEG signals. It can be used as an accurate rate of the seizures especially when seizures manifest in an invisible manner.An epileptic seizure is frequently identified as a slow-spike waveform.To unpredicted nature ofthese seizures makes the daily life immobile with transient impairments of perception, speech, memory, awareness and might also lead to an increased risk of injury or loss of life. Nearly 4% of world population trip seizure at some stage of their life out of which 1% are epileptic. In interictal recordings, epileptic seizures are generally activated with photostimulation, hyperventilation, and different methods.An 8-layer deep convolutional neural network (CNN) is developed to categorize the normal, preictal, and seizure class.

II. EXISTING WORK

The methodology used in this system is the Convolutional NeuralNetwork(CNN) algorithm. It uses a 13-layer deep learning convolutional neural network algorithm for automated EEG analysis. The dataset used for this analysis is taken from Bonn University, Germany(http://epileptologie-bonn.de/)[7][10]. The dataset consists of 100 EEG signals each with a duration of 23.6s. It is broadly classified into Normal, Preictal and Seizure.

The architecture comprises three different layers namely: Convolutional Layer, Pooling Layer, and Fully connected layer. Therefore the model of this work contains five Convolutional layers, five max-Pooling layers, and three fully-connected layers. This work used a conventional back propagation (BP) technique of batch size 3 to train CNN.BP is

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used to calculate the gradient of the loss function with respect to its weights. C.Nagarajan *et al.* proposed the dataset is used for training and the remaining 10% is used for testing[5][6]. This working system used 150 epochs for a training run of the model. An epoch means iteration of one full training run of the model.(i.e) 1epoch=1 forward pass + 1 backward pass. Around 30% of the total 90% of the Training set is used for validation.For validation, they have used K-Fold cross-validation, where nine out of ten signals were taken for training and the remaining one-tenth of a signal is used for testing the performance of the system. This technique repeated for further ten times by changing testing and training signals. The advantage of the model presented in this paper, however, is separate steps of feature extraction and feature selection are not required in this work. Nevertheless, the main drawback of this work is the lack of huge EEG database.The existing system produced an accuracy of 88.67%, the sensitivity of 95% and the specificity of 90%.

III. PROPOSED SYSTEM

Flow of the proposed system

The EEG sign dataset are pre-processed to dispose of noisy data. This preprocessed signal is then classified using Convolutional Neural Network (CNN)[8][5]. Finally, the algorithm predicts whether or not the patient is prone to epilepsy sickness or not. By this prediction the patient can similarly confirm their current state of affairs and proceed with treatment.The typical block layout of the process. The activation feature is used to introduce non-linearity, so that the community can study non-linear features also. The fee characteristic calculates the distinction between the anticipated and actual outputs. The Convolutional neural network is used for prediction process. The implementation was once finished in windows 10 environment the use of Python with TensorFlow library.

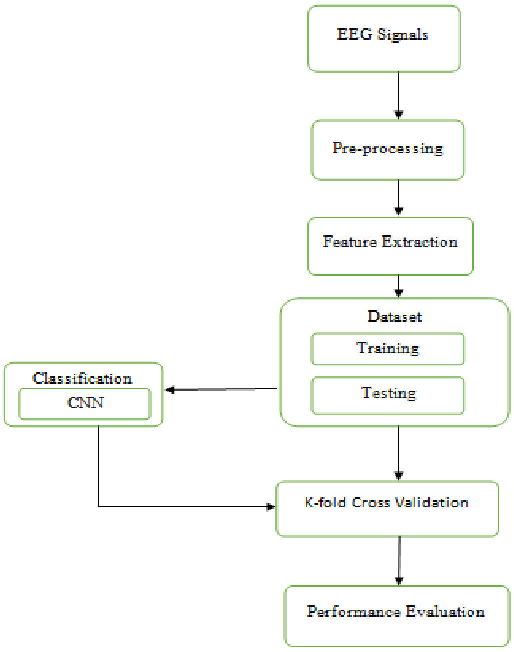

Fig-1: Flow of the proposed system

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Preprocessing of input data

Suitable filtering techniques have been brought to get rid of noise and artifacts. A Butterworth filter sketch of order 5 with a higher cutoff frequency of 60 Hz, sample rate of 256 Hz and a decrease cut-off frequency of 0.5 Hz was once applied to hold the EEG rhythms of activity in the data. EEG alerts are decomposed into approximate and wavelet coefficients[2] using butter worth filter design. Apply filter to statistics the usage of zero digital filtering and artifacts were eliminated from the filtered EEG ,the usage of appropriate filtering technique[3][6].

Feature Extraction

Selecting considerable aspects is critical for the perfect classification of epileptic seizures. The variety of extracted elements have to be much less and convenient to compute with decreased computational time. The significant characteristic of an epileptic EEG is a gradual wave accompanied with the aid of a spike. The epileptic EEG frequency, period, complexity, etc. Considering all these parameters, the following ten facets were selected for our lookup work:Time and wavelet domain[1][9].Out of these mean, median, standard deviation, skewness, kurtosis, root mean square, minimum, maximum are taken from time domain and band power& average Welch's energy spectral density estimate are taken from wavelet domain[4][9].

Convolutional Neural network

An improved and recently-developed neural network, viewed as convolutional neural neighborhood (CNN)[8][5] is employed in this research. The accelerated ANN is each shift and translational invariance. The convolution operation in CNN is a subset of deep studying which has attracted a lot of pastime in present day 12 months and used in graphic awareness such as evaluation of x-ray scientific images, magnetic resonance images, and computed tomography images. A convolutional neural neighborhood (CNN) is one of the most well-known algorithms for deep gaining knowledge of with pix and videos. Like special neural networks, CNN is composed of an input layer, an output layer, and many hidden layers in between.

Feature detection layers:

These layers perform one of the three types of operations on the data: convolution, pooling, or rectified linear unit (ReLU).

1. Convolution layer: puts the input images through a set of convolutional filters, each of which activates certain features from the images.

$$y_k = \sum_{\hbar=0}^{N-1} x_n h_{k-n} \quad (1)$$

Where x is signal,

h is filtered,

n is the number of elements in x,

y is the output vector .

The subscripts denote the nth element of the vector.

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2. Pooling layer: simplifies the output by performing nonlinear down sampling, reducing the number of parameters that the network needs to learn about.

3. Rectified linear unit (ReLU) allows for faster and more effective training by mapping negative values to zero and maintaining positive values

$$f(x) \equiv \begin{cases} x & \text{if } x > 0 \\ 0.01x & \text{otherwise} \end{cases} \qquad (2)$$

Where x is signal.

These three operations are repeated over tens or hundreds of layers, with each layer learning to detect different features.

Classification layers:

After feature detection, the structure of CNN shifts to classification layer.

1. The next-to-last layer is a thoroughly related layer (fc) that outputs a vector of okay dimensions where ok is the wide variety of instructions that the network will be able to predict. This vector consists of the possibilities for each category of any photo being classified.

2. The remaining layer of the CNN architecture makes use of a softmax characteristic to furnish the classification output

$$p_j = \frac{e^{xj}}{\sum_1^k e^{xk}} \text{for} j = 1 \dots k \qquad (3)$$

where x is the net input.Netinput is a product of the input times the weight plus the bias

Output values of p are between 0 and 1 and their sum equals to 1.

Activation functions

The activation characteristic is used to introduce non-linearity in the network.Convolutional layer used to notice features(1). Without non-linearity, the output can solely be a linear combination of the inputs. But the dataset may additionally contain sequences whose underlying function can't be approximated to a linear combination of inputs. Thus, non-linearity is required to efficaciously learn such sequences. Common activation functions include rectified linear feature (2)and softmax(3). Rectified linear unit (ReLU) allows for faster and more fine training by way of mapping negative values to zero and retaining positive values.

IV. RESULTS AND DISCUSSION

Dataset

The pattern normal, interictal, and seizure EEG indicators from the Bonn University database(http://epileptologie-bonn.de/cms/upload/workgroup/lehnertz/eegdata.html) is used as dataset[7][10]. The dataset got from 5 sufferers contains three classes of data, namely, Set A&Set B as normal, Set C& Set D as preictal, and Set E as a seizure. There is a complete of 100 EEG signals in every dataset. Each record is a single channel EEG

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signal with a period of 23.6 seconds. The ordinary dataset involves of EEG signals got from 5 healthy subjects, each containing 100 cases. Likewise, the preictal type carries a hundred data from 5 epileptic patients, when they did no longer undergo seizure in the course of the time of acquisition. The seizure class consists of one hundred instances with the identical topics when they had been having epilepsy all through the time of signals acquisition.

Class	**A**	**B**	**C**	**D**	**E**
Patient Stage	Healthy	Healthy	Epilepsy Patient	Epilepsy Patient	Epilepsy Patient
Segments	Total of 100 segments	Total of 100 segments	Total of 100 segments	Total of 100 segments	Total of 100 segments
Duration	Duration of each segment 23.6s	Duration of each segment 23.6s	Duration of each segment 23.6s	Duration of each segment 23.6s	Duration of each segment 23.6s
Patient State	Eyes open recording	Eyes closed recording	Pre-Seizure recording from the hippocampal half sphere	Pre-seizure record from the epileptic area	Record during the seizure

Table-1: Characteristics of each cluster

The above table [Table-1] briefly describes the different classes B,D &E.In which the patient stage(Healthy or Epileptic) was concluded based on the different recordings.The different recordings were taken for the total of 100 segments and their duration of 23.6s(for each segment).

Evaluation Metric

Nine out of ten portions of EEG signals are used to teach the CNN while the closing one-tenth of the EEG indicators are used to check the performance of the system. This approach is repeated ten times by way of moving the check and coaching dataset. The accuracy cost is used as comparison metric.The accuracy value of greater than 90% have been got primarily based on quantity of epoch used.

Experiment & Result

A whole of 300 epochs of education had been run in this work. An epoch refers to one generation of the full training set. After each new release of an epoch, our algorithm validates the CNN via the usage of 90% of the complete training dataset and 10% of the checking out dataset in the model.

V. CONCLUSION

A novelty of this proposed model is being the application of neural network for EEG-based seizure detection. An 8-layer deep learning CNN algorithm is implemented for the automated EEG analysis. An average accuracy of greater than90.00% is obtained. The performance (accuracy) of proposed model is slightly lower than some of the works summarized. The advantage of the model presented in this paper is it uses 13 different types of features used for feature extraction and feature selection are used, Huge EEG data samples are used in this work. So the performance of this technique improved by applying a bagging algorithm. The performance of this technique can be improved by increasing the number of samples.The future work requires the confusion matrix for the calculation of specificity and sensitivity.Further the work will extract another three features from the signals for the better accuracy value.

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