EpliNet: End-to-End Deep Convolution Neural Network for Epilepsy Seizure Prediction

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***Abstract*—Epilepsy is a common neurological disorder that affects the normal activity of the brain and causes multiple unpredicted seizures. The unpredictability of the episodes is a major suffering for the patients. This paper proposes an end to end solution to help epileptic patients live normally, assuring their safety and their mental health. The proposed solution is predicting the seizure an hour prior its occurrence using Deep Convolution Network -Deep ConvNet.Electroencephalography EEG- is collected using MUSE-2 Headset.This data is then sent to the deep learning model. Two types of EEG patterns are classified : interictal - which is the interval between the seizures- and preictal - which is the brain pattern before the occurrence of a seizure. If the preictal pattern is classified, a seizure is then predicted. A notification is sent via a mobile application to the patient, the intended family member and his doctor.A prediction is a privilege over detection as it gives the patients having such a chronic disorder the opportunity to control their lives and to be one step ahead of their disorder .**

***Index Terms*—Epilepsy, Deep ConvNet, flutter,firebase, mobile application**

I. Introduction

Epilepsy is a neurological disorder that affects the brain and causes multiple unpredicted episodes of shaking, muscle contraction and loss of consciousness.This is due to an abnormal electrical activity in the brain [1]. Around 65 million people globally are affected by this condition, in Egypt, 0.5% of the population are affected by epilepsy [2]. Most people are born with this disorder and 1 in 26 may be affected by this condition in anytime of their lives. Besides the physical effect of this disorder, epileptic patients suffer from a lot of anxiety disorders and depression since they have no clue when will the seizure occur. They are 5 times higher risk of suicide than the rest of population. Hence they are always living on the edge [3]. Seizures may occur due to different reasons. In this section the list of reasons causing the seizure is mentioned. First reason of epilepsy is genes, 40% of epilepsy cases are due to family history, they are born with it. Furthermore ,Brain damage due to any injury may cause epilepsy while the baby is still in the womb, like an infection during pregnancy ,poor nutrition or lack of oxygen. For elderly people, epilepsy may be caused by a tumor, head injury, Blood vessel problems, a stroke or Alzheimer's disease [4].

A. Types of seizures and symptoms

Seizures are divided into two main types: Focal and Generalized.

Firstly, focal seizures are due to an electrical abnormality in only part of the brain, it is then divided into two types: simple partial, and complex partial. In Simple partial, the patient remains conscious, may experience small sensations or jerking movements. While complex partial, the patient is usually unconscious and can't remember the seizure. Secondly, the Generalized type is when both hemispheres are affected by abnormal electrical activity and loss of consciousness. It has several sub-types, like: Tonic seizure, Atonic seizure, clonic seizure, Tonic-Clonic seizureand The Absence type. Tonic seizure is characterised by stiffness and patient will fall backward, atonic is characterised by muscle relaxation and the patient will fall forward ,clonic is known with violent muscle contractions (convulsions).The most common type is the Tonic-Clonic which is a combination of muscle tension and rapid relaxation of the muscles and finally the absence type which is losing and regaining conscious instantly [5].

B. Seizure Stages

There are various stages that the brain go through regarding the occurrence of the seizure [6] .The three epileptic seizure stages are :

- **The Precital Stage:** This is the first stage of a seizure, it happens before the occurrence of a seizure and is used for prediction.It can last for seconds or for an hour.
- **The Ictal Stage:** It is the phase when the seizure occurs.It is when the patient suffers from the symptoms that were explained in the previous subsection and patient usually needs immediate help.
- **The Interictal Stage:** it is the non-seizure phase, or the phase between two occurring seizures [7].

C. Seizure Monitoring

The most common way to monitor seizures are through using Electroencephalography(EEG) which can be measured using electrodes that are put in the scalp of the patient to read the brain waves. It was discovered that certain brain waves are common to occur before the seizure (Preictal) and other

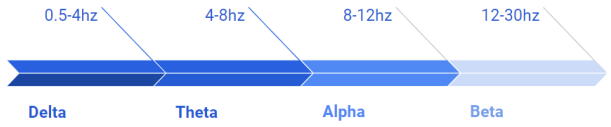

Fig. 1. Four major brain waves distinguished by their different frequency ranges

brain waves are non-seizure which are called (interictal). By detecting and classifying those two different patterns, we can predict the epileptic seizure before it occurs. [8]

1) Brain Waves: It is important to know that brain waves differ from one person to another, it's like a fingerprint,That's why training and testing is implemented patient by patient individually .Brain waves are the frequency or the number of neurons firing electricity per second.There are five main types of brain waves as shown in the diagram 1

Firstly the delta is a very low frequency which is more dominant while sleeping,Theta is a little bit higher, dominant in meditation, Alpha is when a person is awake but relaxed, Beta is when a person is focused and Gamma is at really high focusing events. Seizure often can be predicted because changes in theta range occur before a seizure. [9]

2) Electroencephalography(EEG): Electroencephalography(EEG) is used to measure electrical activity of the brain. A number of electrodes which differ from a headset to another are put on the scalp to measure the brain waves. The problem with those electrodes is that they aren't practical, they aren't friendly looking, head must be shaved and they are really uncomfortable. That's why there are headsets that measures EEG for meditation and stress relief may be used to extract brain patterns and feed them to the deep learning model for predictions.

D. Risk of Epilepsy

The leading cause of death among people with uncontrolled epilepsy, sudden unexpected death in epilepsy (SUDEP), kills 1 in 1,000 [10] people who have the disorder. Studies on suicide in epilepsy have found a higher risk of death from suicide in people with epilepsy, ranging from 2.6 to 5 times higher than in the general population. Suicidal ideation or thoughts of suicide are also a problem for some people with epilepsy with past or current problems with mood disorders. Suicidal thoughts and mood disorders may contribute to risks of death in people with epilepsy. Regarding Car accidents, around 203 traffic accidents were suspected of being caused by epilepsy; 155 of them definitely caused by seizures were selected for study [11].

The following section introduces the related works of previous and similar research points. After that, section III describes paper methodology which mentions the main contributions in technical details.Furthermore ,section IV explains the experimental trials that were held before reaching the solution that outperformed the last highest accuracy with 14% Moreover , section V describes the results reached by our approach.Nevertheless, section VI, describes the mobile application that was implemented to have an end to end solution . Main conclusions are described in section.VII

II. Related Works

The previous papers regarding the dataset American Society for Epilepsy suggested implementing the training on only one patient.this approach was used because EEG readings differ from one individual to another so it was more practical to train each patient separately .the paper [12] suggested a Recurrent Neural Network (RNN) for training on one patient which reached 67%, Inception ResNet V3 was used one patient for better performance which reached 85% ,Finally,Efficient Net b3 was used which is a group of neural network model which reached 89%.The IEEE paper Epilepsy Seizure Prediction on EEG Using Common Spatial Pattern and Convolutional Neural Network suggested using convolutional neural network (CNN) and the Boston Children's Hospital-MIT scalp EEG dataset (CHB-MIT) which consist of 23 patient's data. This paper achieved 92.2%.

Prediction of seizures in epilepsy was found to be very crucial especially for cases that cannot be controlled by medications which represent 30% of the total epileptic patients. Epilepsy is one of the most neurological disorders that affect the brain. One-third of epileptic patients experience sudden attacks even with medications. The SUDEP (Sudden unexpected death in epilepsy) is attacking adults with 8-17% more and 34% in a children's epileptic patients. [13] The neurologists can make manual detection of epilepsy using the Electroencephalogram (EEG) but unfortunately, it's hard to constantly monitor the EEG and predict it manually. The contribution of this paper is the implementation of an end-to-end software solution for the prediction of the seizure before it happens. After the Machine learning model Predicts the seizure using the data that is constantly collected from the brain -Electroencephalography (EEG) -using a friendly Headset called Muse-2, a notification will be sent to the patient, the family members registered in the application and the intended doctor. This notification will allow the patient to take precautions and leave any hazardous task. This end-to-end solution will help the patient take control over this chronic disorder and will make him "one step ahead" of the seizure. Accuracy of the prediction reached 95%.

The contribution of this paper is that the same dataset - American Society for Epilepsy, was used for Patient 1 using a customized two layers of CNN with some fine tuning to the hyper-parameters. that led to 95% accuracy. It is also important to mention that a mobile application connected to the Machine Learning and the Database was implemented to be easily accessed by the patient,its relatives and the doctor following up the patient's state.The Mobile app notification warns the patient before the occurrence of a seizure.It also warns his relatives and his doctor to ensure his safety, the well being of his mental health and the safety of the people around him.

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III. Technical Approach

In this section,The system used to predict the seizure is described . A deep neural network is used for the classification and then the output is sent to the mobile application as described in the fig 2.The simple convolutional neural network(CNN) used is described 3to classify between two classes, interictal (which is the brain pattern of non-seizure) and the preictal (which is the brain pattern before a seizure). when preictal pattern is detected ,or when a seizure is predicted, an alert will be sent to the user on a mobile application, It was executed using the Dataset American society for epilepsy and reached 95% accuracy.

A. The Dataset

The Dataset - American Society for Epilepsy - is consisting of EEG data clips of the two classes , preictal and interictal.Files in each folder of the dataset are in.mat format.Folders are organised containing training and testing data of Intracranial EEG data clips of human or canine subjects. The training data consists of 10 minutes EEG clips (15 channel) and are labelled "Preictal" for data preceding a seizure or "Interictal" for non-seizure data. The training data are labelled and ordered but test data are random. Each.mat files consists of the data matrix of EEG data (electrode vs. time),the time duration for each data row, sampling frequency, channels which is the list of electrodes,the sequence which is the index of data segment within one hour of the EEG clip.

B. Data Pre-processing

The preprocessing is performed to convert the.MAT of the dataset to spectrogram.A spectrogram can be generated by an optical spectrometer, by band pass filters, by Fourier transform or by a wavelet transform.Fourier transform was used as it showed better performance. The short-time Fourier transform (STFT), is a Fourier-related transform used to determine the sinusoidal frequency and phase content of local sections of a signal as it changes over time. Hence Spectrogram is a visual representation of the spectrum of frequencies of a signal as it varies with time. this will give the chance to detect the different frequency patterns of EEG signal over time necessary for the classification (Interictal and Preictal classification). A sample of 1 second was sampled from a single channel before computing the spectrogram using scipy.signal python package.This gives a visual representation of the data which will be easily classified by the CNN network used for training. It is clear based on figure 4 that there is a visual difference between intercital (non-seizure) and preictal (pre-siezure) data.

IV. Experimental Trials for Training the Dataset

Experimental approaches were considered for training according to different resources before coming to the final result.The trials based on different resources are shown in the following table.Our result outperformed the previous resources with 14% accuracy. Accuracy,Test loss,precision and recall were compared through the different resources and previous papers.Firstly the accuracy is a metric that describes the number of correct predictions/Total number of predictions.Secondly ,The Test loss is a number indicating how bad the model's prediction was on a single example.Thirdly , The precision is a measure which describes that out of all predictions ,how many of them the model got it right. The first number in the precision column defines how many of all predictions the model actually predicted it as interictal - the model has an output 1 in case of interictal , the second number in the precision column is a measure of how many of all predictions were actually preictal -the model has an output 0 in case of preictal . Finally, A recall indicates that out of all true predictions , how many were actually right. The first number in the recall table defines how many of all interictal predictions the model actually predicted it as interictal and the second number in the recall table defines how many of all preictal predictions the model actually predicted it as preictal.

Technique	Accuracy	Precision	Recall
Resnet Model [12]	0.67166 %	0.77688	.48166
Inception Resnet v3 [12]	0.85416 %	0.84219	0.87166
Efficient Net b3 [12]	0.89333 %	0.88562	0.90333
Proposed Method1	75 %	-	-
Proposed Method2	86.3 %	-	-
Proposed Method3	95 %	0.97	0.93

TABLE I

TABLE SHOWING THE DIFFERENT TRAINING TRIALS AND COMPARASION WITH OTHER REFERENCES USING THE SAME DATASET AND THE SAME NUMBER OF PATIENTS BUT WITH DIFFERENT NETWORKS.

The Previous table shows that our results "Proposed Method3" outperformed the last previous attempt using the same dataset by 14% .

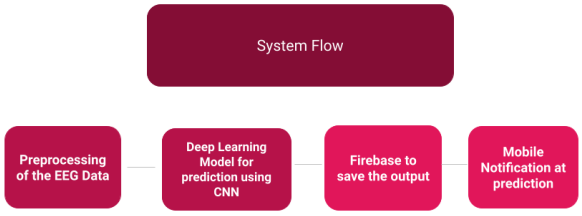

Fig. 2. System Flow

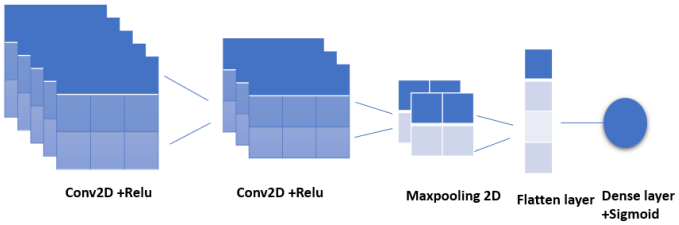

Fig. 3. Convolutional Neural Network

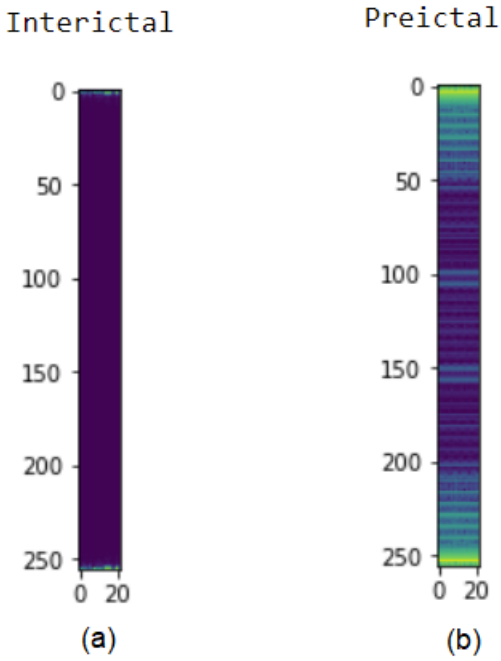

Fig. 4. (a) One second of data from channel 0 of Patient1's interictal segment size (256,22),(b) One second of data from channel 0 of Patient1's preictal segment size (256,22)

A. Training

Training was performed using A CNN network on Patient1 folder.The prepossessed data are fed to the CNN network using an input shape of (256,22,1).In the training the interictal class was set to be represented as 1 while the preictal class is represented as 0. The network consists of two layer convolutional neural network kernel size was 16 with dimensions (3,3), the second layer consisted of 32 kernel size was dimensions (3,3), Dropout layers were 0.25 and 0.5 ,Dense layers were 32 with a Relu then a sigmoid function respectively. This approach led to an accuracy of 75%, A second approach based on a paper [12] reached 86.3%, Our approach consisted of changing some parameters which are Two layers, the first with kernel size 32 and dimensions (5,5), the second layer consisted of 64 kernel size with dimensions(3,3), dropout layers were increased to 0.6. this reached an accuracy of 95% .

V. Results

The Data was splitted into train /test images leaving 600 samples for testing ,The output of the test data will be sent to Firebase and a notification will pop up on the mobile application when the seizure is predicted (test images has an output of 1 from the prediction).A confusion matrix 5 is also generated. It is a matrix to evaluate the performance of a classification mode. it compares the target value by that generated from the machine learning

The approach reached a validation accuracy of 95%-which was 14% higher compared to previous implementations on the same dataset and same number of patients [12].This accuracy was accomplished after increasing the number of kernels to 64 and 32 respectively, increasing the kernel size of the first layer to (5,5) and increasing the dropout to 0.6.

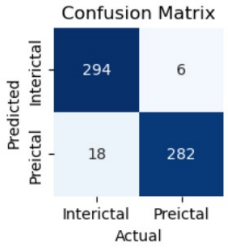

Fig. 5. Confusion Matrix

VI. Mobile Application

A mobile application was used to observe that when a seizure is predicted in the back-end, a notification is sent to the user so that the patient is aware that he is having a nearby seizure.The notification will also be sent to relatives and his doctor who registered on the application.

A. Experimental Setup

"Flutter" Cross-platform was used to accomplish the mobile application and "Firebase" was the back-end used. Real-time Database was linked through a script in python. This script sent the predicted output to the real-time database so that whenever the app detects a preictal output "0".

B. Experimental Results

The Application sends a warning notification with a sound whenever firebase detects a preictal output coming from the deep learning technique. This will guarantee safety and reassurance for the epileptic patient.

VII. Conclusion

This project will help with predicting an epileptic seizure an hour before it occurs to give the chance to epileptic patients to live normally, safely and without any anxiety.The project Contributed by increasing accuracy by 14% on the same dataset and the same number of patients used by [12] and also an end to end solution was provided by sending these predictions via a mobile notification.the project uses the EEG patterns to classify between the interictal(non-seizure) and preictal(pre-seizure) phases using Deep Learning. It then sends a notification via the mobile app if a seizure is predicted to easily access the patient and warn him or his relative or hospital about an upcoming seizure. This project was trained and tested on a single patient because the brain activity is unique for each individual, so this product will be uniquely trained and tested for each individual.As a future work , hypothesis should be made to convert it into a commercial prototype.

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