A Machine learning approach to monitor Brain Health and epilepsy detection

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Abstract: Brain health is a major concern worldwide and in India. There are a ton of neurological issues that may influence the mind and one such issue is epilepsy. Epilepsy is one of the preeminent generally happening neurological issues. Electroencephalography (EEG) signals help in the examination and conclusion of epilepsy by recording the exercises inside the cortical districts of the epileptic patient. Conventional techniques for breaking down an EEG signal for epileptic seizure discovery are tedious. A proposed work of robotized seizure recognition systems utilizing an AI strategy is proposed to supplant these conventional techniques. The proposed work is completed with a real-time dataset of epileptic patients taken at a different period. The two basic steps involved during this project are pre-processing and classification. Information pre-preparing is an information mining procedure that includes changing crude information into a reasonable arrangement. Classification is the process of predicting the class of a given dataset. The classifiers used are SVM, Naive Bayes, Random Forest classifier. The random forest is most preferred for its decision trees where the model has low variance and also for its high predictive performance. The proposed system helps in daily monitoring the brain health of epileptic patients using a mobile application. This system mainly focuses on rehabilitated patients. Once when the patients use a wireless wearable headband the signal is monitored and their health condition is detected using a mobile application.

Keywords: Electroencephalography; Support Vector Machine; K-nearest neighbours; Deep neural network; Artificial Neural Network; Discrete Wavelet Transforms.

1. Introduction

The progression of AI (ML) and man-made brainpower innovations has empowered the advancement of complex frameworks that are helpful to regular daily existence. Web of Things (IoT) and distributed computing innovation acquired an upset dispersed processing and capacity. A brilliant medical care framework uses the IoT, Cloud processing, cutting edge correspondence convention, and progressed ML
advancements to offer wellbeing administrations to customers. Exactness and continuous preparing are two focal thoughts of the brilliant medical care framework. For patients in a basic condition and the individuals who need quick determination and treatment, the conclusion must be exact and continuously; something else, genuine confusions may emerge and the patient's life might be imperiled.

Epileptic seizures are caused by a disturbance in the electrical activity of the brain, which is classified into focal, generalized, and unknown. Focal seizures start on one side of the brain and depending on the patient's level of awareness during a seizure, it is again classified as simple partial and complex partial seizures. Epilepsy is a common chronic disease that causes transient brain dysfunction. It is a brain disease that occurs due to a chronic neurological disorder of neurons producing an abnormal signal. Electroencephalography (EEG) is the most important tool for studying epilepsy and plays a decisive role in the diagnosis of epilepsy. Everything in our day by day lives—from stress, terrible eating routine, absence of activity, injury, contamination, the earth, and more causes our cerebrum waves to get unequal. The unusual sign which influences the neuronal action whether it is from ailment or cerebrum harm can cause a seizure. It is brought about by the abrupt unsettling influence which shows up in the mind capacities. Our mind comprises of 5 distinct sorts of cerebrum waves-Delta, Theta, Alpha, Beta, and Gamma mind waves. Every one of those mind waves includes a typical recurrence go in which they work. Each kind of brainwave controls an assortment of conditions of cognizance beginning from rest to dynamic reasoning. There are considerably more huge amounts of neurological issues that may influence the cerebrum and one such issue is epilepsy. Epileptic seizures are brought about by upset cerebrum action – which just implies that the ordinary action of the mind is abruptly hindered and changes. Epileptic seizures can shift from brief and almost too extensive stretches of enthusiastic shaking. It might bring about physical wounds, including at times broken bones. Individuals with epilepsy will in general have more physical issues, (for example, breaks and wounding from wounds related with seizures), additionally higher paces of mental conditions, including tension and despondency. There are two types of epileptic seizures.

(1) FOCAL SEIZURES (PARTIAL SEIZURES):
These are seizures that occur in, and influence, just an aspect of the mind (not each side of the cerebrum) and start from a 'point of convergence' inside the mind.
(2) Generalized SEIZURE:
Seizures that occur in, and influence each side of the cerebrum. There are various kinds of summed up seizures however every one of them include the individual getting oblivious, even just for a few seconds, and that they won't recollect the seizure itself. The chief notable summed up seizure is that the tonic-clonic (convulsive) seizure

2. Background

An electroencephalogram (EEG) is one of the most effective techniques to track and record brain wave patterns. Neurologist read and analyses these EEG records to detect and categorize the type of epilepsy diseases. The EEG examination is a visual process that needs too many hours to examine the 1-day of recording. These encourage the researchers to develop automated seizure detection with machine learning methods, using epileptic multi-channel EEG signals including EEG signal obtaining, pre-handling, highlights extraction, and order. Profound neural organizations empower adapting straightforwardly on the information without the area information expected to develop a list of capabilities. The novelty of this research is proposing a long- and short-term memory (LSTM) model to detect an epileptic seizure. The drawbacks found in this model are it is obtained only in a limited number of datasets. It faces more problems of discriminating the pre- and post-seizure parts of the signal are placed in the background.
3. Epilepsy Diagnosis

The epilepsy diagnosis is done by imaging the brain by EEG or MRI. Epilepsy can often be confirmed with an electroencephalogram (EEG). The clinical examination has uncovered that the seizure mark can be removed from the delta band and the high frequencies band. At the point when a seizure occurs during an EEG, the ordinary example of cerebrum action that is seen on the EEG understanding changes and distinctive mind movement can be seen. Epilepsy surgery or treatments may require recovery and rehabilitation for patients. The treatment can relieve from seizures, but life will change in terms of dependency on others, especially for epilepsy patients.

4. Proposed System

Today the cell phone based applications are being utilized for taking care of human genuine issues. The requirement for building up a proficient cell phone application that can screen the conduct of an epileptic patient just as sending a prompt update to the overseers. The android application is utilized to tell the mind condition of patients through sending a warning to the versatile of either gatekeeper or guardians. Prompt clinical help is required at the hour of seizure. Android system contains a rich application-based interface that assists with building and create inventive applications for tackling genuine issues. Hence, our undertaking screens the mind strength of the restored epileptic patient and built up an android based application that can give quick notices once a seizure happens to that persistent so the patient can get the best possible clinical consideration. This application gives highlights, for example, sending a prompt warning to the overseers or gatekeeper of the restored patients demonstrating the presence or nonappearance of seizure of the patient. In the proposed system EEG signals are taken from patients for both normal and abnormal person using clarity EEG device. Then the acquired EEG signals are pre-processed. After pre-processing the signals are classified under different algorithm like Support vector machine, Random forest, and Naive Bayes classifiers. The classified signals are given as input into the Raspberry pi controller and then compared with any one of the signals. The values are read by using mobile APP. If any abnormal person signal is received, the mobile APP gives an early warning message to user and patients. The below figure represents the block diagram of proposed system.

![Block diagram of proposed system](image)

4.1. Real Time Dataset

The real time EEG dataset signals are obtained from 5 patients. The dataset signal holds both the epileptic and non-epileptic patients from the hospital. The signals are obtained from CLARITY EEG device. Initially pre-processing is done for the EEG dataset in CSV format. The raw data are taken up from 16 channels (F8-F4, F4-FZ, FZ-F3, F3-F7, T4-C4, C4-CZ, CZ-C3, C3-T3, T6-P4, P4-PZ, PZ-P3, P3-T5, T6-O2, O2-PZ, PZ-O1 and O1-T5). It contains EEG raw data with sequential time period. It takes 35 minutes for collecting EEG signal for each affected patient. The parameters of 5 classes are appended
as Y column in the EEG dataset. The classes are shown in table 1. Factorize the y column of data to obtain the numeric representation of array by identifying distinct values.

| Parameters | Description |
|------------|-------------|
| 1          | The recording of seizure activity. |
| 2          | The recording in state of sleep. |
| 3          | The Hyperventilation an activation procedure. |
| 4          | The recordings of EEG signals when the patients have closed their eyes |
| 5          | The recordings taken during opening of eyes of patients |

Then the raw data of 16 channel data can be stored into one variable and the parameters of 5 classes (y column) data can be stored into another one variable. Then data is split into test data of 25% and train data of 75%. After splitting process scaling is done using standard scalar. It will transform the data such that the distribution will have a mean value 0 and standard deviation 1.

5. Methodology

5.1. EEG Recording

The multi-class seizure type classification was implemented using the EEG signals collected from dataset of 5 patients. This scalp EEG signal recordings were recorded according to the International 32 system electrode placement at a sampling rate of 250 Hz.

5.2. Electrode Placement System

5.2.1. 10/20 Electrode System

The 10/20 cathode framework is a technique is utilized to depict the area of scalp terminals. The number ‘10’ and ‘20’ allude to the separation between contiguous cathodes are either 10% or 20% of all out front-back or right-left separation of the skull.

5.3. Classification

In AI, grouping is a directed learning approach during which the pc program gains from the info information and makes new arrangement. The classifiers used are Random forest, Naive Bayes and Support vector machine classifier. Random forest is a supervised classification algorithm. It consists of many decision trees. It is used for both classification and regression tasks. But it is mainly used for classification only. It creates decision trees on data samples then gets the prediction from each of them and eventually selects the simplest solution. Overfitting is one of critical problem that makes worst result, so in random forest there are enough trees in the forest, the classifier can’t over fit the model. The main advantage is it can handle the missing values. Naive Bayes is the simplest supervised learning algorithm. This algorithm works in most straight forward and faster classification, which is suitable large chunk of data. It utilizes Bayes hypothesis of likelihood for the expectation of obscure classes. In characterization, it has two stages, a learning stage, and the assessment stage. In the learning stage, a classifier prepares its model on a given dataset, and in the assessment stage, it tests the classifier execution. Execution is assessed based on different boundaries, for example, exactness, mistake and accuracy, and review. Backing Vector Machine, a directed AI calculation is equipped for performing arrangement, relapse, and
even anomaly location. It is fast and dependable classification algorithm that perform very well in limited amount of data. The signals are classified by using non-linear SVM with kernel function. A non-linear transformation is to make a dataset into higher dimension space. SVM algorithm uses a set of mathematical function that are classed as kernel. In this process Radial Basis Function is used in kernel. The function of kernel is to require data as input and transform it into the specified form.

5.4. Hardware Description

5.4.1. Raspberry Pi Controller

Raspberry pi is a series of small single-board computers. Raspberry pi 3 model b+ is used. It is upgraded version of raspberry pi 3. In this controller open the python terminal and create the new directory. When a signal is sent to the controller after the classification, controller detects whether the signal obtained from the patient is normal or abnormal and from the controller data is sent continuously to the cloud.

5.5. Mobile Application

It is a software application developed specifically for use on small wireless computing device such as desktop, smart phone, tablets etc. In our project mobile app is developed by using android tools. In this mobile APP first signup with our necessary detail and login the user page. The user page shows the stored value from the cloud. If the data is in normal it monitoring continuously. If data is in abnormal it sends warning message to that of registered number.

6. Results and Discussion

The data’s obtained from the persons are pre-processed and classified using machine Learning algorithms such as Support Vector Machine, Naive Bayes and Random Forest.

6.1. SVM Classifier

Confusion matrix allows the visualization of the performance of an algorithm. The data model is divided into 5 classes as mentioned in table1. The diagonal elements of confusion matrix represent the number of predicted elements of particular class equal to the number of actual elements of that particular class. From the below table 3 represents the confusion matrix of SVM classifier, the epileptic seizure recording is correctly classified as 8343 out of 8557, sleep recording as 882 out of 2022, hyperventilation as 451 out of 3934, closed eye recording as 58 out of 527 and open eye recording as 90 out of 512. While testing actual value, in SVM classifier the class 2 is misclassified more with class 1 and class 3. Class 4 is misclassified more with class 3 with count of 214, little less with class 1 of count 178 and class 2 with count of 77.

Table 2. Represents the support measure of each classes.

| CLASSES  | SUPPORT MEASURE |
|----------|-----------------|
| CLASS 1  | 8557            |
| CLASS 2  | 2022            |
| CLASS 3  | 3934            |
| CLASS 4  | 527             |
| CLASS 5  | 512             |
| TOTAL    | 15552           |
Table 3. Confusion matrix of SVM Classifier

| Predicted | 1   | 2   | 3   | 4   | 5   |
|-----------|-----|-----|-----|-----|-----|
| Actual    |     |     |     |     |     |
| 1         |     |     |     |     |     |
| 2         |     |     |     |     |     |
| 3         |     |     |     |     |     |
| 4         |     |     |     |     |     |
| 5         |     |     |     |     |     |

6.2. NAIVE BAYES classifier

The confusion matrix of Naïve Bayes has shown low performance when compared to SVM classifier. The correctly classified results for epileptic seizure recording are 1998 out of 8557, for sleep recording 1515 out of 2022, for hyperventilation 1378 out of 3934, for closed eye recording is 59 out of 527 and open eye recording is 93 out of 512. While testing the actual value, Naïve Bayes shows that the class 1 is misclassified more with class 2 with a count of 4290, little less with class 3 as 1450, least in class 4 with a count of 44, less with class 5 with 775. Similarly class 3 is misclassified more with class 2 with count 2209, little less with class 1 of 246, less with class 4 of 90 and least with class 5 of 11.

Table 4. Confusion matrix of Naïve Bayes

| PREDICTED | 1   | 2   | 3   | 4   | 5   |
|-----------|-----|-----|-----|-----|-----|
| ACTUAL    |     |     |     |     |     |
| 1         |     |     |     |     |     |
| 2         |     |     |     |     |     |
| 3         |     |     |     |     |     |
| 4         |     |     |     |     |     |
| 5         |     |     |     |     |     |

6.3. RANDOM FOREST Classifier

The confusion matrix of Random Forest has shown better results than the above two classifiers- SVM and Naïve Bayes. When compared to SVM classifier Random Forest Classifier has predicted a greater number of data correctly for classes 4 and class 5. The epileptic seizure recording is correctly classified as 8402 out of 8557, sleep recording as 1378 out of 2022, hyperventilation as 3077 out of 3934, closed eye recording as 223 out of 527 and open eye recording as 303 out of 512.
Table 5: Confusion Matrix of Random Forest Classifier

| Predicted | 1   | 2    | 3     | 4    | 5    |
|-----------|-----|------|-------|------|------|
| Actual    |     |      |       |      |      |
| 1         | 8402| 39   | 110   | 1    | 5    |
| 2         | 443 | 1378 | 192   | 9    | 0    |
| 3         | 695 | 147  | 3077  | 11   | 4    |
| 4         | 121 | 70   | 111   | 223  | 2    |
| 5         | 154 | 10   | 45    | 0    | 303  |

6.4. Classification Report of Classifiers

The classification report comprises of precision, recall, f1-score of each class. Precision is the result of positive class prediction belonging to actual positive class.

\[
\text{Precision} = \frac{\text{True positive}}{\text{True positive} + \text{False positive}} \quad (1)
\]

Recall is the positive class prediction out of all positive class (i.e., it includes false negative value).

\[
\text{Recall} = \frac{\text{True positive}}{\text{True positive} + \text{False negative}} \quad (2)
\]

Figure 2. Bar graph representing the precision measure of five different classes using three classifiers.

The above graph shows the average precision score of five classes for three different classifiers. SVM classifier holds 77% as the average precision score of five classes whereas Naive Bayes holds 60% as average precision score and Random forest classifier holds the highest average precision score of 86%. Recall is the positive class prediction out of all positive class (i.e., it includes false negative value).
**Figure 3.** Bar graph representing the recall measure of five different classes using three classifiers

SVM classifier holds 76% as the average recall score of five classes. Random Forest classifier holds the highest average recall score of 86% whereas Naïve Bayes holds the least average score of 32%. F1-score balances between both precision and recall. It gives the harmonic mean of precision and recall.

\[
F1\text{-Score} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}
\]  

**Figure 4.** Bar graph representing the F1-score measure of five different classes using three classifiers

Random forest classifier holds the maximum average F1-score of 85%, SVM classifier holds 73% and Naïve Bayes holds 34% as average F1-score of five classes. From the above figures, it is to infer that...
Random forest classifier possess the maximum percentage value in the classification report.

6.5. Parameter percentage of classifiers

The performance parameters such as Specificity, Sensitivity, Precision are found for various classifiers as shown below. SVM classifier has 95.24% specificity which denotes that patients are without epilepsy disease that test negative. 92.37% sensitivity denotes that patients are with epilepsy disease that test positive. The precision score for SVM is 99.47%. SVM holds low recall percentage but high precision. Therefore, SVM model can’t detect the class well but it is highly trustable. Naive Bayes has 26.09% of Specificity denotes that patients are without epilepsy disease. 95% sensitivity denotes that patients are with epilepsy diseases. The precision score is 31.77%. Low recall value and low precision value states that the classes are poorly handled by Naïve Bayes model. Random Forest classifier has the greatest percentage of 97.24% for Specificity denotes that patients are without epilepsy disease. Sensitivity denotes that 94.99% patients are with epilepsy disease. The precision score is 99.53%. Random Forest holds good percentage of sensitivity, specificity, precision because it fits number of decision trees on various samples of dataset. It avoids overfitting problem.

Table 6. Classification Report of SVM, Naive Bayes, Random Forest Classifiers

| PARAMETERS     | SVM    | NAIVE BAYES | RANDOM FOREST |
|----------------|--------|-------------|---------------|
| SPECIFICITY    | 95.25% | 26.09%      | 97.24%        |
| PRECISION      | 99.48% | 31.77%      | 99.53%        |
| SENSITIVITY    | 92.37% | 95.0%       | 94.99%        |

6.6. Comparison of algorithms

The above bar graph represents the comparison of specificity, precision, sensitivity among the three classifiers namely SVM, Naive Bayes, Random Forest. Random forest shows the highest percentage score among the rest two classifiers.
6.7. **Hardware result**

The model is saved to joblib file. The joblib file is loaded in the raspberry pi. When a row of input signal is given to the raspberry pi it predicts the class of the input signal whether the given input signal is normal or abnormal. The output from the hardware is stored in Thing Speak cloud. The output from hardware is shown in fig 7 and fig 8.

![Hardware setup diagram](image)

**Figure 6.** Hardware setup diagram

```plaintext
pi@raspberrypi:~ $ cd jawa
pi@raspberrypi:~/jawa $ sudo nano mock1.py
pi@raspberrypi:~/jawa $ python3 mock1.py
/home/pi/.local/lib/python3.7/site-packages/scikitlearn-externals/joblib/__init__.py:38: FutureWarning: You may need to re-serialize those models with scikit-learn 0.21.
warnings.warn(msg, category=FutureWarning)
```

```
[[6 16 0 1 0 ... 3 0 -1 0]
 [1 rows x 16 columns]]
```

**Figure 7:** Raspberry pi predicting the class for the row of input data showing abnormal state of patient
6.8. Notification message from mobile app

Initially, User name and Password of user or patient’s guardian should be given to the Mobile app. Mobile app gives a notification message to the user of the app about the presence or absence of seizure. This helps in monitoring the brain health of affected patients. Notification message from mobile app is shown in figure 12 and figure 13.

Figure 8: Raspberry pi predicting the class for the row of input data showing normal state of patient

Figure 9. User page  

Figure 10. Login page

The above figure 9, figure 10 represents the login page of mobile app.
Figure 11. Notification message
The above figure 11 shows the receiving of signal data from thing speak cloud to the mobile app.

Figure 12. Alert message
The above figure 12 shows an alert message from the mobile app indicating the presence of seizure.
Figure 13. Notification message

The above figure 13 shows an alert message from mobile app indicating absence of seizure.

7. Conclusion

Epilepsy is a typical neurological issue whose outcomes are impacted socially and socially, particularly in India. The proposed system is implemented in concern for rehabilitated epileptic patients. SVM, Naïve Bayes, Random Forest are the various classifiers applied in the proposed system. It results in an accuracy score of 92.37% for SVM, 95% for Naïve Bayes, and 94.99 % for Random Forest. The mobile app helps in monitoring the brain health of rehabilitated epileptic patients. The guardians or caretakers could install this mobile app which provides an alert message to identify the presence or nonattendance of seizure of the concerned patient. In the future this proposed system in real-time signal acquisition could be done by using a wearable EEG headband which should contain 16 channels and 32 electrodes.

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