IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 20, Issue 4, Ver. I (Jul - Aug 2018), PP 23-33
www.iosrjournals.org

Comparative and Analysis Study of normal and epileptic seizure EEG signals by using various classification Algorithms

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Abstract :- *Epilepsy is defined as a brain activity disorder which is characterized by epileptic seizures. Electro-encephalogram (EEG) signs are one of the greatest preferable and basic methods of diagnosing Epileptic Seizures due to their practicality and simplicity. On the other hand, interpreting those signals is not an easy task, because of the non-linear and variable signal properties. In this work we offers a Data Mining classification approach by applying machine learning algorithms to detect standard and epileptic seizure from EEG brain signs, we are using t-SNE algorithm for preprocessing as adimensionality reduction algorithm onthe dataset then we applied three algorithms on the original dataset and on the preprocessed dataset to classify normal and epileptic seizure, and evaluate the performance of these three different classifiers (SVM, KNN and Random Forest), so that, the classifier with the best performance is selected to implement such system. Thus, classifiers with high accuracy than other classifiers, proposed in previous studies, are evaluated in this study, so that, better predictions accuracies are provided by these classifiers. As a result, the best classification precision was obtained at 98.52%. when the Random Forest was used.*
Keywords: -*Epilepsy Seizure, EEG time series, t-SNEalgorithm, Classification, Machine Learning Algorithm.*

I. Introduction

Brain is an important organ of the body, which is responsible for controlling the entire body. When a human does any activity whether physical or merely thinking or feeling, brain produces signals for performing those activities. Seizure is a changing in the person's behavior after the occurrence of some abnormal electric activity in the brain. One seizure at one point in time are considered to be epilepsy. Which is the world's second most common neurologic disease, second only to the strokes. It happens to nearly 1% of the people which is identified through the incidence of seizures which destroy person's quality of life[1]. Epilepsy seizures are not contagious, nor do they happen due to mental disorders. Any unusual neuron brain activity could result in a seizure, epilepsy was one of the first brain disorders to be described[2].The electric signals may be measured using a method known as the Electro-encephalography (EEG), The EGG always produces from a massive number of separate neurons[3] In this technique, numerous electrodes are attached to the human skull. Electrodes are basically done for catching the brain signal.

Currently over 1% of the people are affected by spontaneous seizures that could be traced back to epilepsy [4].

This disease is a chronic disease that is associated with people's lives for a long time it is not easy to determine that a person is healthy or sick by seeing naked or only through seizures that may occur to the patient. The use of machine learning techniques is growing rapidly, according to the capabilities of these techniques in detecting relations among input values that may be difficult, or impossible, for humans to detect, because of the complexity of these relations or the enormous number of value in the input. Different applications employ these techniques to interact with external domains, by training these techniques using sample values, so that, the knowledge extracted during training is used with future inputs. However, the performance of these techniques is different from each other, and depends on the inputs of the system. Thus, the performance of different machine learning classification techniques must be tested tochoose the most appropriate classifier whichcan provide accurate, so that, reliable detection of seizures through the brain signal with high accuracy will benefit many patients in detecting epileptic seizures to receive the appropriate treatment.

Numerous approaches were presented for the sake of detecting epilepsy seizures, we review some existing approaches and their effectiveness.One of the first epileptic seizure detection algorithms was developed by Gotman[5]. The algorithm searches for rhythmic actions with a leading frequency in ambit of (3 – 20) Hz. A seizure is detected if this activity has an amplitude of 3 times larger than normal EEG, is present on at least 2 channels and persists for at least 4 seconds. It is very effective for seizures with a fundamental frequency which is less than 20 Hz. However, it fails to detect seizures with a mixture of frequencies, a low amplitude or a fundamental frequency above 20 Hz. Because of its simplicity it is known to detect many fractions of normal EEG as a seizure, such as sleep spindles. In other study[6] they introduced a pattern identification approach cross-correlation assisted SVM based classifier. The presented method was used for EEG signal binary classification. The binary classifiers use proper characteristics that have been obtained from cross correlograms of EEG signals. Those cross-correlation assisted SVM classifiers were utilized about bench-mark EEG indications and presented approach that can reach a classification precision of up to 95.96%.This study[7] proposed system consists of: preprocessing, feature extraction, and classification. They suggested a solution that relied on a new method of auto-regressive EEG time series modeling and combines an estimator of (least-squares) parameter for EEG property abstraction with SVM in binary classification among pre-ictal/ictal and inter-ictal states. Results have exhibited (100% sensitivity), and because of a new regularizing of SVM classifier depending on Kalman filter technique significantly improve the system performance in terms of false alarm rate.Other study[8] compared mother wavelet with Daubechies wavelet in EEG processing they developed Wepilet by using Genetic Algorithms (GA). Frequency sub-band properties are first extracted with the use of wepilet for the EEG signal surface channel. Those properties are inserted into (SVMs) to be classified into pre-ictal and interictal categories (PER). Results indicate the efficiency of optimized mother wavelet in EEG processing with accuracy 69.31 % but with Daubechies the accuracy 62.95 %. In this work[9], the authors suggested a different level of fuzzy rule based approach for enabling the recognition of epilepsy seizures. Properties that are utilized for the implementation of the suggested approach included average amplitude, rhythmicity (co-efficient of amplitude variation), entropy and dominant frequency. For the sake of combining all properties, an adaptive fuzzy subsystem has been presented, the result of which was utilized in a process of thresholding for the determination of the final output, which resulted in a precision rate of up to 95.8%, with an average finding latency of 15.8 sec. with false detection proportion of 0.26/h. In this paper[10] they utilized a property selection on the basis ofmRMR approach and SVM to find an optimal combination of feature-channel for seizure prediction from EEG signs. The classification outcomes werecompared, and the comparison showed that the classification outputs were almost identical, the elimination of dimension by property selection enhanced the computation expenses and permitted for an easier feature interpretation, the reduction of computation costs is of a high degree of importance for real-time predictor implementation. This study[11] aimed to improve sensitivity of prediction and to reduce (FPR), The combinations of subband spectral powers of EEG recordsthrough all potential canalhubbies have been used to track gradual variations that preceded the occurrence of seizures. They utilized property selection approach to fed SVMs for the discrimination of the cerebral case as pre-ictal or non-preictal, the results of sensitivity 75.8% and (FPR) 0.1 h^{-1}. This research [12] proposed automated system which presented a new approach which focused on the automating the detection of seizures and classifying EEG signals as normal or otherwise, work steps: Preprocessing, property extraction, property selection and classification via (kNN, SVM and GMM). Signal classification was monitored by a hybrid classifier that carried a basis of 3 widely used classifiers in the domain, the result of accuracy as 86.93 %. In this study[13] the automated system presented in this study presented an approach for the automation of detecting seizures, performing 4 distinct steps: Preprocessing, property extraction, property selection and hybrid classifying. The hybrid classifier uses a combination of the k-NN, GMM and SVM classifiers. The system has reached a precision value of up to 88.10%. In this research[14] EEG signals from healthy and epileptic people have been denoted via parameters of recurrence that were obtained via plot of recurrence. The properties that have been obtained from the plot of recurrence are applied to multi-layered ANNs, k-NNs, and SVM classifiers after the procedure of property selection. The classification precision reached up to 95.4% for support vector machines and 96.4% for k-nearest neighbors and the classification accuracy was achieved at 97.05% for ANN.In this study[15], they proposed a coalition approach of variational mode decomposition VMD, and auto regression(AR) for property mining and random forest classifier. They decomposed the raw EEG to a limited amount of band-limited inherent mode functions (BLIMFs), after thatapply logarithmic procedure, AR ledto all BLIMFs based on quadratic feature extraction thereafter the obtained feature vectors feed to (RF) classifier, the outcome of experimentations showed the accuracy of 97.35%.

This study for detection of epileptic seizures, uses the concept of machine learning which is a field of AI dealing with the construction of a machine or a model that draws from the data given to it. As the performance of the epileptic seizures, is affected by the accuracy of the predictions provided by the classifier, the aims of this workare evaluating the efficiency of different classifiers are (KNN, SVM, and RF).The classifier with the best performance is selected to implement such system, so that, better predictions accuracies are provided by this study.

II. Methodology

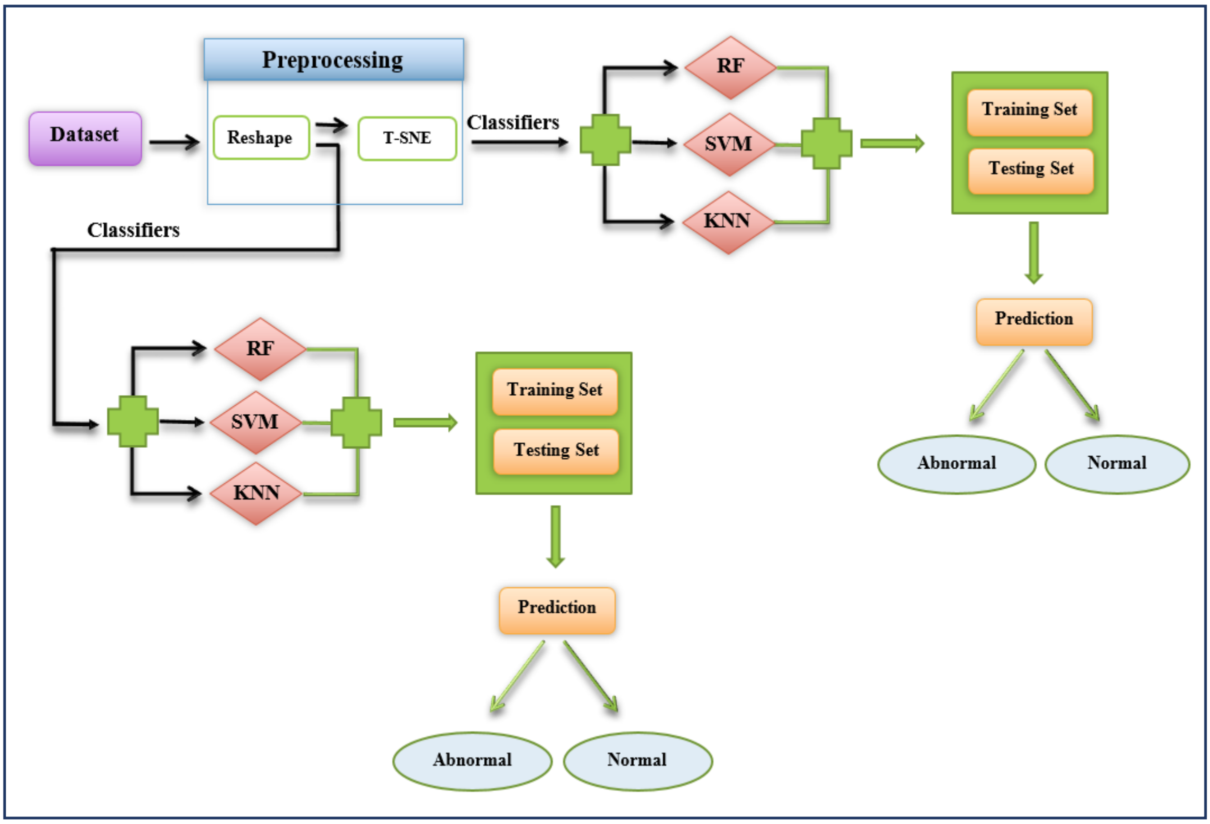

Fig (1): Steps of Methodology

The diagnosis of epilepsy in our study is divided into several steps. Fig: 1 above illustrates the proposed model and the steps which the data passed to detection of epileptic seizures.

The first steps shown in the figure above begin with the dataset on which this data is come into the pre-processing process, the proposed system includes two basic steps: pre-processing and classification. The preprocessing of the dataset was taken from the UCI machine learning repository to build a pre-processing training database, including reshape of the data and utilizing T-SNE algorithm, which is considered as one of the most widely-used algorithms for preprocessing. The classification process is divided into two parts according to the data feed back to the classifier. In the first step of the classification process, the reconstructed and pre-processed data are fed to three of the most recent algorithm's studies in this field(RF, SVM, KNN) classifiers, on other hand, applied these algorithms on the reconstructed data and without going through the pre-processing process through t-SNE algorithm. After the preprocessing and data splitting into training data and testing data, this data is entered the classifiers already mentioned. The final output of the system is the detection of the epileptic seizures as "abnormal" and the normal seizures as "normal", as shown in the lower part of the Fig: 1 above.

2.1 Software

Each programming system writes in a specific programming language that meets the purpose of performing the system, our study used anaconda environment for building the code in Python programming language which consideredas amultipurpose and highlevel of programming language. It is open source distribution of programming languages for Python to handle large-scale data, predictive analyzes, and scientific computing, with the aim of simplifying package management and deployment[16].

2.2 Dataset Description

The dataset is a recent dataset for epileptic seizure taken from UCI Machine Learning Repository were used in the experiments an EEG database recorded in the Epileptology Department of the University of Bonn in Germany and open to public access[17], this dataset described in[3]. There are five different folders in the original dataset, each one of those files consist of one-hundred files, a person/subject is being represented by each one of those files, also the activity of the brain for 23.6 seconds is being recorded in each file. Considering timeseries is being appraised to (4097) data points. All these data points have EEG values that is recorded at a different point in time. A category of 178-Dimesnional input vector is contained by the feature y (outcome). Particularly, y in 1, 2, 3, 4 and 5 where the number five represent eyes open, the number four eyes closed, number 3 indicate the tumor's region in brain, also it does record the activity of the EEG in the healthy are of the brain, the number 2 is recording the activity of EEG in region where the swelling detected. The people in the classes (two, three, four, and five) can be defined as persons who didn't suffer epileptic seizure while the number one represent recording of seizure activity. All 178-dimensional vector in a row, expresses a 1-sec long sample that is being selected in a random way taken from single file. Call to mind that all files are considered as brain activity recording in 23.6 sec.

2.3 Training and Testing

Generally, data we utilize is usually divided to testing data and training data. Training package contains known outputs and the model learns about these data to be circulated to other data later. In this work to detect epileptic seizures testing mode is set to 15% of the data set as a testing group, the rest is for training 85%.

2.4 Preprocessing

The dataset we utilized is in restructured/reshaped and pre-processed. A large amount of data-set may include hundreds of characteristics (variables), also we do not have full comprehension on in which domain the data is contained. It is expected to recognize the data hidden patterns, also analyzing and exploring the data-set. Smoothing process is the method that we utilize for discovering significant patterns in data and neglecting things that are considered not important, filtering is utilized for performing smoothing. The purpose of using smoothing is to create slow value alterations in order that it becomes simpler to track trends in data[18].

In our study the preprocessing consists of reshaped and applying t-SNE as preprocessing algorithm. We re-structured the dataset through transform the target feature into binary 0 or 1; zero represent normal brain and one represent an epileptic seizure and then we utilized T-SNE algorithm for this process.

T-Distributed Stochastic Neighbor Embedding algorithm:T-SNEcan be defined as nonlinear algorithm with dimensionality reduction. Kernel uses of this algorithm is a dimensionality reduction algorithm, which has its focus on preserving the distances of the data points as much as possible. Dimensionality reduction can be defined as method to represent multi-dimensional data (means that some data with multiple characteristics that have a connection between them) in two or three dimensions.Data explicitly could be represented through the assistance of dimensionality reduction algorithm,[18]. Thealgorithm discovers data patterns via recognizing observed clusters depending on the data points similarity with characteristics, also it could be utilized in clustering and classification via utilizing the output of it as an input feature for the other classification algorithms.

2.5 Classification

The process of determining the concluding feature set permit us to categorize all EEG signals which works out as classifier's input, as abnormal or normal, based on the information included in it. Three classification algorithms were used in the classification process(SVM, KNN, RF) classification techniques utilized is under supervision where that data is being divided into 2 distinguished subsets in a random way: training and testing sets. At first, and with the assistance of the labeled data, the classifier goes into a training stage, that allocate a class to all samples[19], then testing data is utilized for understanding the amount of accuracy that were attained through the classifier.

2.6 Evaluation performance measures

The performance of this algorithms is tested using common performance descriptors. There are four known measure to evaluate the classification algorithms which are(true positiveTP, true negative TN, false positives FP and the number of false negative FN)[20]. In our study, we used three of the common measures for analyzing the results of classification algorithms (accuracy, precision, and AUC).

Accuracy: Accuracy can define as a proportion overall number of true forecasts and computed as the percentage between the number of properly classified cases, and entire number of cases[21].An accuracy represents the ratio of summation the number of (TP, TN) on the summation of (TP, FP, TN, FN).Accuracy measure is calculated as:

$$\textbf{Accuracy} = \frac{TP+TN}{TP+FP+TN+FN}$$

Precision: It represents the ratio of the number of TP by the summations ofTP and FP. Precision is the intuition of the ability of classifier. We cansay that the value (1) is the bestwhile the worst is (0)[22].The precision measure is defined as:

$$\textbf{Precision} = \frac{TP}{TP+FP}$$

Area Under ROC Curve: The (ROC) curve of diagnostic test may be utilized in a form of a summary measure due to its discriminative capability, every point on the ROC curve denotes a sensitivity/specificity pair that corresponds to a specific threshold of decision [23]. AUC is a ration of how well the parameter is capable of distinguishing between 2 sets of diagnostics (diseased/normal).

III. III. ExperimentResults

The experimentation, conducted within this research, has main goal it aimed to analyzing the ability of classification methods with three types of classifiers (Random Forest, SVM, and KNN) firstly with preprocessed dataset via t-SNE algorithm, and secondly without preprocessed operation for the dataset to detect epileptic seizures. We have also compared our results with modern techniques in other study. Two types of experiences will be discussed. The first type includes the results obtained from applying of three algorithms on the preprocessed data through t-SNE reduction algorithm. The second type includes the results obtained from applying the three algorithms on the original data without going to preprocessing. It should be mentioned here that the characteristics used for each algorithm are the same in both cases.

3.1 Performance results

We used python language to apply three classification algorithms to motivate the model for detecting normal and epileptic seizures from EEG signals. The algorithms were RF (Random Forest), SVM, and KNN. Table 1 shows test results forour study for applying three algorithms firstly on the pre-processed data "smooth data" via t-SNE algorithm, secondly on the original dataset.

Algorithms	PreprocessedDataset			Original Dataset		
	Accuracy	Precision	AUC	Accuracy	Precision	AUC
RF	95.30%	94.36%	90.00%	98.52%	97.30%	97.00%
SVM	94.26%	93.51%	87.00%	98.17%	98.58%	96.00%
KNN	95.74%	87.85%	93.00%	96.52%	100.00%	91.00%

Table 1: The results of applied algorithms on the preprocessedand original dataset

Table 1. indicates the results of classifiers used, the table is divided into two main sections, the first section represents the results obtained from applying algorithms on the preprocessed dataset and second section of the table represents the results obtained from applying the algorithms on the original data. A simplified explanation will be given to the names of the columns in the table. The first column of the table represents the names of the algorithms, the second column shown the accuracy of the results, which is the proportion of the total number of correct predictions. While the third column in the table represents precision, which is the intuition of theability classifier. And fourth column be a symbol for (AUC), which is a measure of how well parametersare capable of distinguishing between two diagnostic sets, which are diseased/normal. As well as the rest of the table. In the table, shows the results of classifiers when we apply them on the original dataset are better than the result of apply these algorithms on the preprocessed dataset. We will present each classifier separately with the results obtained from the smooth and original dataset.

3.1.1.Result of (RF)

Random forest algorithm is one of the most important algorithms in medical work,RFis a high-level of classification precision resisting overtraining, the capability of efficiently working with large datasets, there is no necessity to normalize features and only few needed parameter optimizations. Two Figures below show the results of this classifier. Fig: 2 below demonstrates the results of the random forest algorithm testing on the preprocessed dataset, our results obtained according to performance measures with accuracy 95.30%, precision 94.36% and AUC 90.00%.

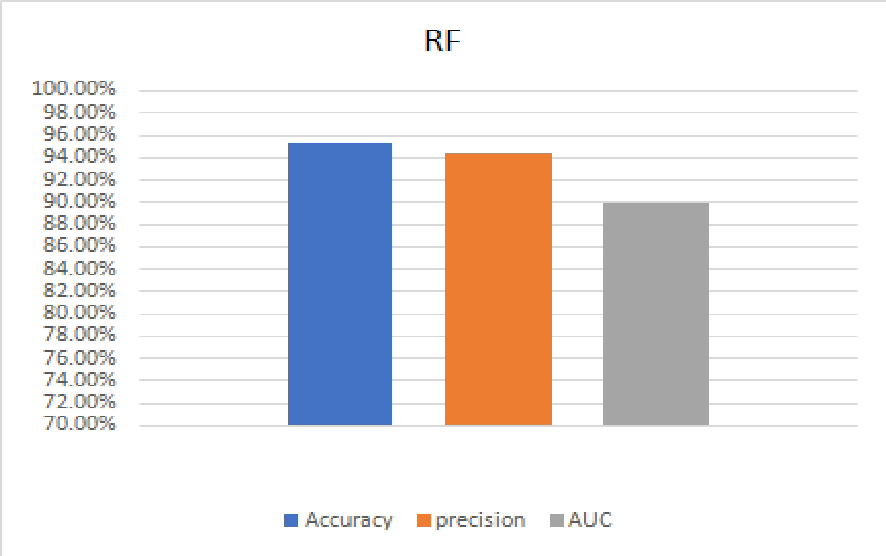

Fig (2): Result of RF on preprocesseddataset

Fig: 3 offer the results of random forest algorithm testing on the original dataset, according to performance measures with accuracy 98.52%, precision 97.30% and AUC 97.00%.By applying it on the original data, we see very high results in all fields of performance measures used in the work, with high results of this algorithm, which can be relied upon in the diagnosis and discovery of cases in the data we worked on.

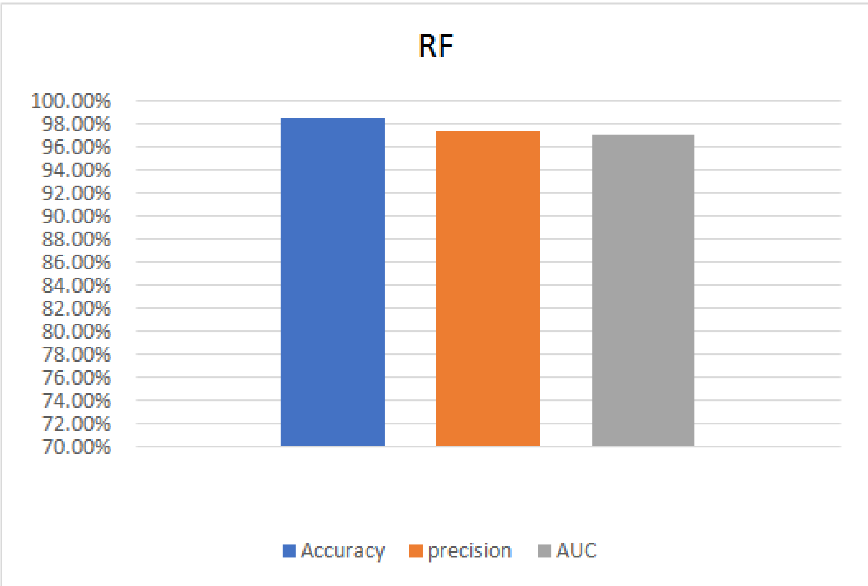

Fig (3): Result of RF on original dataset

3.1.2 Result of (SVM)

Despite of good results of SVM algorithm it showed less results than previous algorithm RF in state of preprocessedand original dataset. This is because the efficiency of RF algorithm for this type of medical data that has been worked on. Fig:4 and Fig: 5 below expression the outcomes of SVM testing on the preprocessedand original dataset. on the preprocesseddataset this classifier presented results according to performance measures with accuracy 94.26%, precision 93.51% and AUC 87.00%. Fig: 4.

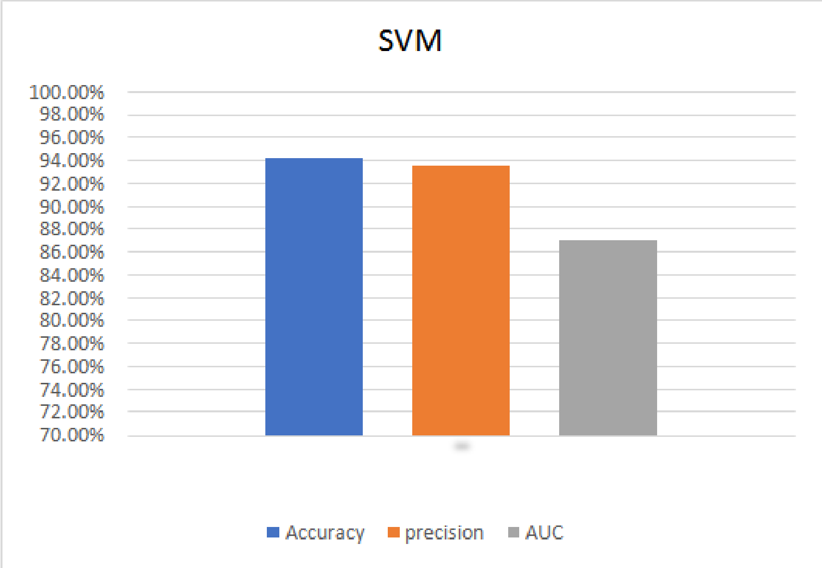

Fig (4): Result of SVM on preprocesseddataset

On the original dataset this classifier presented results according to performance measures with accuracy 98.17%, precision 98.58% and AUC 96.00%. Fig: 5 SVM algorithm provided an unobservable accuracy in the discovery. This algorithm came in slightly less than the results of the RF algorithm when applied to the original data. These results of algorithm are reliable accuracy in diagnosis or discovery.

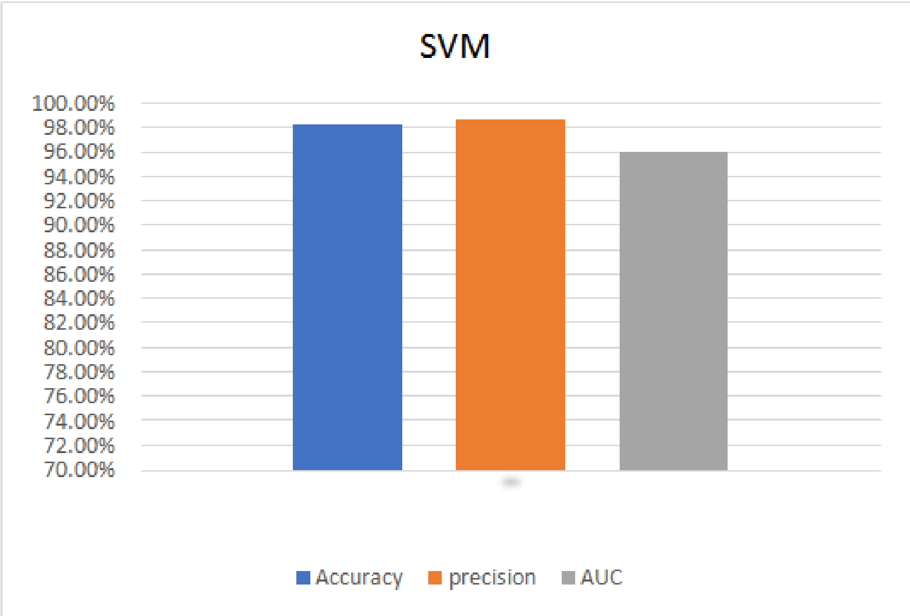

Fig (5): Result of SVM on original dataset

3.1.3 Result of (KNN)

In pattern identification, the third classifier KNN algorithm, which is a non-parametric approach utilized for classification. In the preprocesseddataset we obtained better results with this algorithm in field of accuracy and AUC Fig: 6 below shows the results of KNN algorithm testing on the preprocesseddataset, according to performance measures our results with accuracy 95.74%, precision 87.85% and AUC 93.00%.

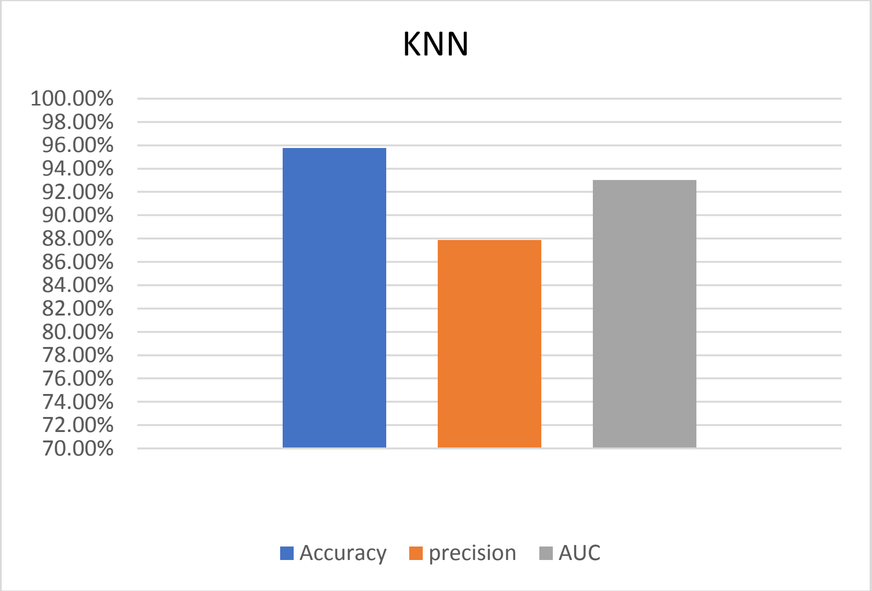

Fig (6): Result of KNN on preprocesseddataset

In scope of applied KNN algorithm on original dataset we obtained good results with this algorithm in field of accuracy and AUC and the better result with precision. Fig: 7 below shows the results of KNN algorithm testing on the original dataset, according to performance measures our results with accuracy 96.52%, precision 100.00% and AUC 91.00%.

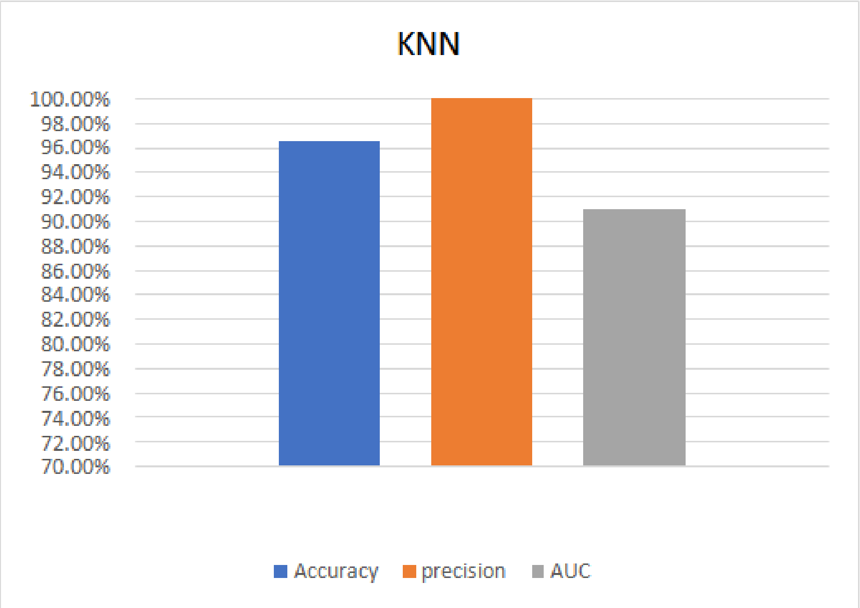

Fig (7): Result of KNN on original dataset

3.2 Comparative Study of Proposed Model in Field of Accuracy

Two types of implementation have been worked out in the proposed model, implemented on preprocessed data and other implementation on the original dataset to achieve best accuracy in the discovery. Fig: 8 below shows the comparison between the accuracy of results when we classification the dataset "Before" preprocessed and "After" preprocessed.

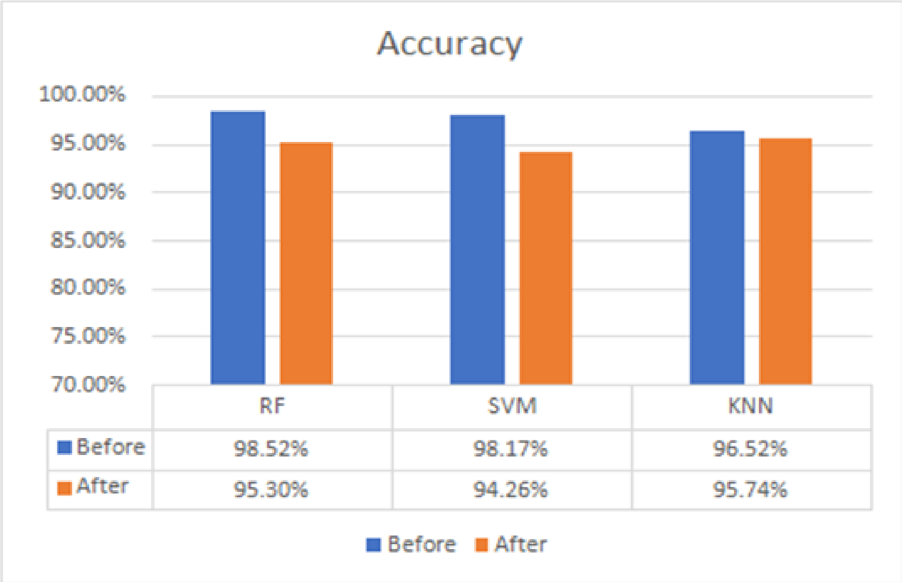

Fig (8): Comparative of our Proposed Model

As we pointed out previously, we used t-SNE algorithm for preprocessing, it is a dimensionality reduction approach, gives a sufficient way for visualizing a complicated data-set. It efficiently uncovers hidden structures in the data, shedding light on the natural clusters and smooth non-linear variations along the dimensions, it finds patterns in the data via the identification of the observed clusters according to similarity of data points with numerous properties.

The efficiency of this algorithm varies according to the data we are working on. after the experiment and applying this algorithm on the data to detect the disease, the results showed that the work of the t-SNE algorithm in reducing distances for this data despite of the good results did not show the appropriate efficiency, and by looking at the results in Fig: 8 above, we note that the accuracy of the results for each classifier decreases with the use of T-SNE algorithm, while the other results of the applying of three classifiers on the data before the preprocessing showed a highest accuracy and reliable in the detection of epileptic seizures.

IV. Comparison with Previous Works

As we pointed out formerly, to make sure that we have chosen the best way for classification of brain signs EEG between normal and abnormal, we compare our results with previous works, as we shown in Table 2 below.

References	RF	SVM	KNN	Data Source
[14] **(2017)**	---	95.4%	96.4%	The dataset is same as our dataset.
[15]**(2017)**	97.35%	---	---	The dataset is same as our dataset.
Our Study (2018)	98.52%	98.17%	96.52%	The dataset from UCI used in the study is an EEGdatabase recorded in the Epileptology Department of the University of Bonn in Germany and open to public access[17]

Table 2: Comparison our study with previous work

The first study, used machine learning algorithm for seizure detection, feature selection and classification were the main operations. they proposed a synthesisprocess of variational mode decomposition (VMD) and auto regression (AR) for feature extraction and random forest classifier, the extracted feature vectors fed into RFtechnique the newoutcomes were accuracy of 97.35%. The second work for EEG signs from intact and epileptic subjects signifiedthrough recurrence parameters gainedvia recurrence plot. The features extracted from recurrence plot are applied to (SVM, KNN, and multi-layered ANN) classifiers after feature selection procedure. An accuracy of this work was achieved at around 95.4% for support vector machines and 96.4% for k-nearest neighbors. Although many techniques and methods were developed for diagnosis of epilepsy, but the accuracy of diagnosis is an important factor, and this is evident in our work we have done where we obtained the best accuracy was reachedabout 98.52% when random forest algorithm was used, 98.17% with support vector machines and 96.52% for k-nearest neighbors. By achieving this accuracy of the results in the classification, we have achieved the required to detect epileptic seizures and distinguish between normal seizures and epileptic seizures.

V. CONCLUSION

Epileptic seizures are affecting a considerable number of people worldwide. The normal process includes acquiring EEG from the brain, which is afterwards spotted by a neurologist who classifies it as healthy or patient. This process is both time consuming and must be with the help of expert neurologists. To help the patients, an automated system to replace this whole process is a pressing need. It has been set that the methods of Digital Signal Processing are highly crucial for automating of seizure detection. Research institutes have worked extensively in order to find methods in this area. In this work we proposed system to detect the signals brain as normal or abnormal by used two steps to achieve the best classify include "pre-processing" and "classification". For pre-processing we utilized T-SNE algorithm as a dimensionality reductionalgorithm to find patterns in the data via the identification of the observed clusters according to the similarity in data points with numerous properties, for classification we used Random Forest, SVM, and KNN classifier because of their simplicities and good performances in data mining classification. Through the implementation of our proposed system in python programing language the results showed highest accuracy and reliable in the detection of epileptic seizures when we applied classifiers available on the original dataset such as Random Forest classifier 98.52% and less efficiency when we applied classifiers available on the smooth dataset via t-SNE algorithm such as the accuracy of Random Forest classifier 95.30%. Fig 8.

The performance of the epileptic seizures is affected by the accuracy of the predictions provided by the classifier, we evaluated the performance of different classifiers, classifier with the best performance was selected to implement such system. Thus, classifiers with high accuracy than other classifiers, proposed in previous studies, were evaluated in this study, so that, better predictions accuracies were provided by these classifiers and achieved reliable detection model of epileptic seizures which helps us to detect epileptic seizures more quickly and more dependably.

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IOSR Journal of Computer Engineering (IOSR-JCE) is UGC approved Journal with Sl. No. 5019, Journal no. 49102.

* Seferkurnaz “ Comparative and Analysis Study of normal and epileptic seizure EEG signals by using various classification Algorithms." IOSR Journal of Computer Engineering (IOSR-JCE) 20.4 (2018): 23-33.