Abstract

In this work we have evaluated the Performance of Support Vector machine and Particle Swarm Optimization technique for robust Classification of Epilepsy from EEG signals. Epilepsy is a brain disorder in which the normal neural activity is hampered because of unusual firing of neurons. Millions of people around the world are affected by epilepsy. EEG analysis of brain waves provides a good way to diagnose epilepsy. We have used EEG dataset of twenty epileptic patients in this work. The EEG signals are sampled and artifacts are removed. To deal with the curse of higher dimensionality, Power spectral density estimation is implemented here. Finally both Support vector machine with various kernels and particle swarm optimization technique are used as post classifiers and their performance is compared. High Performance index and Quality Value of 98.24% and 24.19 is achieved with RBF SVM when compared to value of 95.11% and 22.1697 with the PSO technique. Among SVM Kernels, the RBF with gamma value 10 performs best followed by polynomial kernel. Hence from above investigation we find that SVM is good at Classifying epilepsy risk level than the PSO technique. This method can be employed as cost effective way of Epilepsy diagnosis which can provide better life for many patients.

Keywords: Epilepsy; EEG; Power Spectral Density; Support Vector machine; SVM kernels; Particle Swarm Optimization; Performance Index; Quality Value.

I. Introduction

Epilepsy is a serious brain disorder which involves interruption of the normal activity of the human brain [1][2]. The person experiences seizures which can be life threatening. During the epileptic attack, the neurons present in brain begins to fire rapidly and losses their coordination [3]. This results in loss of consciousness and convulsions [4]. The symptoms of...
Partial epileptic seizure involves only a part of brain while generalize seizures involves the hampering of the entire brain activity. The early diagnosis of epilepsy is vital. The Electroencephalogram is the most widely used technique for brain wave analysis [6]. It is a non invasive diagnostic technique with no harmful effects to the patient with little discomfort. EEG collects the electrical activity of neurons [7]. Epilepsy leads to change in the normal EEG wave forms. A set of 21 electrodes are placed over the scalp which picks up the EEG signals form brain [8]. The brain waves are classified into four types namely alpha, beta, gamma, theta based upon the frequency and amplitude [9].

Their normal rhythm and characteristics is altered during epileptic attack. These brain signals are analyzed for seizure detection. This paper is further organized as follows. Section II reviews the materials used for the study and describes the methods proposed for epilepsy risk level classification. Section III combines the result of two techniques namely SVM and PSO and discussion is done. Section IV describes our conclusion.

II. Materials and Methods

A. EEG Data Acquisition

To investigate the performance of Support Vector Machine and Particle Swarm Optimization for epilepsy risk level classification, we have collected EEG signals from twenty epileptic patients. These patients were under treatment and examination in the Neurological Department of Sri Ramakrishna Hospital, Coimbatore. The paper record of EEG signals is obtained using 16 channel EEG monitoring system. The electrode placement on the scalp follows standard 10-20 system, adopted by American EEG Society. The raw EEG signals directly collected from the patients are contaminated by noise and artifacts. Some of the main causes of artifacts are from movement of patients, respiratory movements, ocular movement, EMG, ECG electrode contact impedance and interference from electronic instruments in the room [10]. The artifact free EEG signals are selected with the help of Neurologist and scanned using Umax 6696 scanner having a resolution of 600dpi. The EEG records obtained are filtered between 0.5Hz to 50 Hz using a band pass filter having five poles. These signals were continuous for thirty minutes, and they are divided into two second epochs which are sufficient to detect any changes in brain activity. The highest frequency component of EEG signal is 50Hz hence the sampling frequency is set as 200Hz . Each and every patient has three epochs and each epoch has got 16 channel values.
This leads to large dimension of EEG data set. The proposed methodology involves reducing the dimensionality of the preprocessed EEG signals using Power Spectral Analysis. Further Support Vector Machine using various kernels and particle Swarm optimization technique is applied to spectral values.

The performance parameters and plot for both the techniques are compared. The overall methodology is given below in Figure 1.

**B. Power Spectral density as a Dimensionality Reduction Technique.**

Each sample of preprocessed EEG signal has got 400 values which contribute to large data space. In our work we have considered power spectral values as feature. Other dimensionality reduction techniques like principal component analysis, singular value decomposition and Independent Component Analysis fails in case of complex and non linear data [11][12]. We have opted spectral analysis for dimensionality reduction. For each sample data spectral value is determined. These values provide the frequency information present in the data. For this purpose rectangular window is applied. The power spectral density of a signal x(t) is given by

\[ P(f) = \text{Re}^2 \{X(f)\} + \text{Im}^2 \{X(f)\} \]

where X(f) is the Fourier transform of signal x(t) and P(f) is power spectral density of x(t) [13]. P (f) gives the information present in EEG signals in frequency domain. Only the maximum spectral values are selected for further analysis [14]. This reduces the large data space. After the feature estimation both support vector machine and particle swarm optimization are performed on them.

**Figure 1. System Overview.**
C. Support Vector Machine

Support Vector Machine was introduced by Vapnik in 1963. Since then it is widely used for pattern recognition, Classification and regression [15]. SVM works on minimizing the structural risk rather than minimizing objective function [16].

Support vector machine doesn’t require any prior knowledge of data. Hence the performance on SVM on outside data is better when compared to other classification algorithms. A hyper plane is constructed which acts as decision surface. The decision boundary must separate the negative and positive values such a way that the margin of separation is high. SVM is also known as large margin Classifier [17]. Greater the margin of separation higher will be the generalization ability of SVM classifier.

SVM can act on both the linear and non linear data well. In case of linear data simple hyper plane is enough to classify the data accurately. The decision boundary is defined by function.

\[ f(x) = w^T x + b \]

The margin of separation is given by

\[ b = \frac{2}{\| w \|} \]

In our case, the EEG data is non linear which necessities the need for non linear Classifier. Here the kernel trick of non-Linear SVM is employed. The kernel function maps the non linear data into high dimension state where they can be easily separated by hyperplanes [18].

Most commonly used kernel functions are linear, Polynomial, Radial Basis function and sigmoid. In our work, we have implemented non linear SVM using linear, Polynomial with order 2 and RBF with varying value of gamma.

The functions for the above kernels are given below [17].

Linear function: \( K(X, Y) = (X^T Y + 1) \)

Polynomial function: \( K(X, Y) = (X^T Y + 1)^d \)

Radial Basis Function: \( K(X, Y) = \exp \{ \gamma \| X - Y \|^2 \} \)

Linear kernel is the simplest one. While polynomial kernel is slightly modified one with user defined d and c values. These values determine the classification efficiency. Radial Basis kernel is the most commonly used which gives better accuracy for non linear data.
The value of sigma determines the spreading of the function. In our work we have considered two values of sigma 5 and 10 respectively.

The following steps are done to implement SVM for epilepsy risk level classification.

1. For the Power spectral values k-Means clustering is carried out with different centroid values.
2. The centroid values obtained for each cluster is mapped into higher dimension using kernel function to achieve a proper shape.
3. Finally linear separation is done with the help of SVM.

The accuracy of this algorithm is manipulated using various performance measures which are discussed in the next section.

D. Particle Swarm Optimization

Particle Swarm Optimization technique is developed by James Kennedy and Russell Eberhart in 1995 for continuous non linear functions [19]. It is inspired by bird flocking and fish schooling concept. It also has roots related to Evolutionary computing and Swarm theory [20]. The birds while searching for food in the nature exchanges their position and velocity. This inspired the formation of PSO methodology. Each Particle in the swarm is assumed to have same behavior and characteristic [21]. Each particle explores the search space for optimal solution and keeps track of their position and velocity which is eventually shared among particles for social interaction. The velocity function alters the position towards the solution.

The velocity and position update equation is given below [22].

\[
V_i (k + 1) = w * V_i + C_1 * \text{rand}_1 (...) * (P_{best_i} - X_i (k)) + C_2 * \text{rand}_2 (...) * (G_{best} - X_i (k))
\]

\[
X_i (k + 1) = X_i (k) + V_i (k)
\]

Where \(V_i (k)\) and \(X_i (k)\) represent the velocity and position of particle \(i\) at iteration \(k\), \(P_{best}\) is the personal best position of particle and \(G_{best}\) is the global best solution obtained by any particle in the population, \(w\) is the inertial weight which controls the effect of previous velocity on the current velocity, \(\text{rand}_1\) and \(\text{rand}_2\) are uniformly distributed random numbers in the range 0 to 1, \(C_1\) is known as coefficient of self recognition and \(C_2\) is called as coefficient of social recognition. Larger inertial value gives greater global exploration and smaller one leads to local exploration.

The algorithm of particle swarm optimization is given below [23].
1. Initialize all the particles in the population with random position and velocity vector.

2. Formulate fitness function for each particle.

3. Calculate the best position achieved by each particle, if current is better than previous update pbest with current value.

4. Calculate the best position achieved by any particle in the population if current is better than previous update gbest.
   
   With current value.

5. Update the velocity and position of each particle using (6) and (7).

6. Terminate algorithm if desired criteria (maximum iteration or good fitness function) is achieved else go to step 3.

Until the desired target is achieved the velocity and new position is calculated iteratively. PSO algorithm is applied to spectral values in our work. The values of $C_1$ and $C_2$ are set as 2 which are normally used in almost all applications. The results of PSO applied to PSD values are tabulated below in section III. Further the comparison between different SVM kernels and PSO technique for epilepsy risk level classification is done.

### III. Results and Discussion

To evaluate the performance of different SVM classifiers and particle Swarm Optimization we determine two parameters namely performance index and Quality value [24]. With RBF SVM we have got a higher performance index value when compared to other SVM and PSO. For RBF SVM with gamma 10 the quality value obtained is 24.1995 and the performance index value is 98.2486%. Following RBF SVM the Quality value achieved with Polynomial SVM of order 2 is high as 23.4378. With PSO technique the Quality value got is 22.1697 and Performance index is 97.5696. The false alarm values for different SVM are equal to zero but in PSO we got false alarm rate of 2.2449%. The formulas to calculate various performance parameters [2], [17] are given below.

$$PI = \frac{PC - MC - FA}{PC} \times 100$$

where PC – Perfect Classification, MC – Missed Classification, FA – False Alarm,

The Sensitivity, Specificity and Accuracy measures are stated by the following

$$Sensitivity = \frac{PC}{PC + FA} \times 100$$

$$Specificity = \frac{PC}{PC + MC} \times 100$$
With SVM we got sensitivity of 100% for all three kernels linear, polynomial and RBF whereas with Particle swarm optimization the value is 97.5696 %. Another important parameter called Quality factor is employed to measure the robustness of classifiers.

The Quality factor is a value which shows the overall performance of the classifier. The Quality factor value depends on four factors. The factors are false alarm detected, the perfect classification percentage, the risk levels that are missed and the delay value encountered [2][5][17][24]. The formula is given below.

$$Q_v = \frac{C}{(R_{fa} + 0.2) \times (T_{dly} \times P_{dct} + 6 \times P_{msd})}$$

Where, C is scaling constant which is set to 10 as this scales the value of Qv obtained into a range which is readable.

- $R_{fa}$ - the number of false alarm per set,
- $P_{dct}$ - the percentage of perfect classification
- $P_{msd}$ - the percentage of perfect risk level missed
- $T_{dly}$ - the average delay of the onset classification in seconds

A higher quality value means the classifier is efficient. Table I describes the performance parameters of linear SVM, Polynomial SVM, RBF SVM and PSO methodology. Figure 1 shows the ROC of SVM kernels and PSO. It is evident that SVM is more stable than PSO. Figure 2 shows the specificity and sensitivity measures. Figure 3 shows the plot between Quality value and Time delay of both classifiers. The Quality value comparison and Average detection rate of SVM and PSO is shown is Figure 4 and Figure 5 respectively.

**Table-I: Performance Comparison of Support Vector Machine and Particle Swarm Optimization.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Linear SVM</th>
<th>Polynomial SVM order-2</th>
<th>RBF SVM with Gamma-5</th>
<th>RBF SVM with Gamma-10</th>
<th>PSO</th>
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<tr>
<td>Perfect Classification (%)</td>
<td>91.2337</td>
<td>94.9322</td>
<td>90.5046</td>
<td>98.2486</td>
<td>95.4135</td>
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<tr>
<td>Missed Classification (%)</td>
<td>8.8858</td>
<td>3.9575</td>
<td>6.5920</td>
<td>1.8735</td>
<td>2.2911</td>
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<td>False Alarm (%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.2449</td>
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### Table

<table>
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<tr>
<th>Weighted delay in Seconds</th>
<th>2.3055</th>
<th>2.1555</th>
<th>2.2871</th>
<th>2.0654</th>
<th>2.0443</th>
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<tbody>
<tr>
<td>Performance Index (%)</td>
<td>93.2337</td>
<td>94.2334</td>
<td>90.5046</td>
<td>98.2486</td>
<td>95.1075</td>
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<tr>
<td>Sensitivity (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>97.5696</td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>92.0597</td>
<td>96.0457</td>
<td>92.7735</td>
<td>98.3988</td>
<td>97.7778</td>
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<tr>
<td>Average Detection (%)</td>
<td>96.0885</td>
<td>98.0217</td>
<td>95.1194</td>
<td>99.0968</td>
<td>97.7086</td>
</tr>
</tbody>
</table>

### Figures

**Fig. 1.** Sensitivity and Specificity measures of different SVM kernels and PSO technique.

**Fig. 2.** Quality value and Time delay measures of different SVM kernels and PSO technique.
IV. Conclusion

The prime aim of our work is to classify epilepsy risk level from EEG signals using different Support Vector Machine kernels and Particle Swarm Optimization method with high performance index, Quality value and less False alarm and missed Classification. Initially the EEG waveforms are preprocessed and digitized. Then the Power Spectral density values for the EEG signals is calculated which are used as feature vectors. Finally SVM with different kernels and Particle Swarm Optimization technique is applied to PSD values. The results shows that RBF SVM with gamma value 10 outperforms Particle swam optimization technique and other SVM kernels. SVM kernels produced nil false alarm rates and PSO got 2.2449 for the same. RBF SVM has highest perfect classification rate of 98.2486% with Quality value of 24.1995. Using this methodology a system to identify epilepsy risk levels in patients can be effectively formulated.
References


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