EPILEPSY DETECTION USING DWT BASED HURST EXPONENT AND SVM, K-NN CLASSIFIERS
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OTKRIVANJE EPILEPSIJE UPOTREBOM DTW BAZIRANE HURSTOVE EKSPONENCIJE I SVM, K-NN KLASIFIKATORA
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ABSTRACT

Epilepsy is a typical neurological issue which influence the focal sensory system and can make individuals have seizure. It can be surveyed by electroencephalogram (EEG). A wavelet based HURST EXPONENT strategy is displayed for the analysis of epilepsy. This strategy deals with the non-linear analysis of EEG signals. Discrete wavelet transform is used to disintegrate the original EEG signal into specific sub-bands. The hurst exponent of different sub-bands is employed and then fed into two classifiers, namely SVM and KNN. The highest classification accuracy obtained in the presented work is 99% for healthy subject data versus epileptic data obtained by SVM. However, the corresponding accuracy for normal subject data and epileptic data using SVM is 99% and 93% for the eyes open and eyes shut conditions, respectively. The detailed analysis of the methodology and results has been discussed in the paper.

Keywords: Hurst exponent (HE), Support vector machine (SVM), Discrete wavelet transform (DWT), K-nearest neighbor (KNN)

SAŽETAK

Epilepsija je tipični neurološki poremećaj pod uticajem fokalnog sanzornog sistema koji može da izuzeve epi-napade kod oboljelih. Može se otkriti analizom elektroencefalograma (EEG). Razvijena je strategija analize epilepsije pomoću HURSTOVE EKSPONENCIJE zasnovane na malim talasima, koja se bavi nelinearnom analizom EEG zapisa. Koristi se diskretna transformacija malih talasa kako bi se originalni EEG zapis dezintegrisao na specifične podgrupe. Primenom Hurstove eksponencije na različite podgrupe svrstavaju se u odgovarajuće klasifikatore, pre svega SVM i KNN. Najveća tačnost klasifikacije je postignuta u navedenom radu i iznosi 99% za zdrave osobe u poredenju sa oboljelim od epilepsije primenom SVM. Međutim, odgovarajuća preciznost za razlikovanje zdravih osoba od oboljelih od epilepsije upotrebom SVM iznosi 99% i 93% u zavisnosti od toga da li su oči otvorene ili zatvorene. Detaljna analiza primenjenih metoda i dobijenih rezultata je prikazana u radu.

Keywords: Hurstova eksponencija (HE), podrška vektor mašina (SVM), diskretna transformacija malih talasa (DWT), K-najbliži komšija (KNN)

INTRODUCTION

Epilepsy is a standout amongst the most predominant neurological issues in people. It is described as repeating seizures in which strange electrical action in the mind causes the loss of awareness or an entire body shaking. Patients are unaware of the event of seizure because of the irregular way of such seizures which may expand the danger of physical damage. Surveys demonstrate that 4-5% of the aggregate total population has been experiencing epilepsy. Electroencephalogram is one of the most important tools for examination of epilepsy. Electroencephalogram is the recorded portrayal of electrical action delivered by terminating of neuron inside the mind along the scalp. For recording of EEG, terminals will be glued at some key focuses on the patient’s head. Anodes get the signs and will be recorded in a recording gadget through wires which are associated with terminals.

As total visual examination of EEG signal is exceptionally troublesome, automatic detection is preferred. Fourier transform has been mostly utilized as a part of feature extraction of EEG signals. However as EEG signal is a non stationary signal, Fourier examination does not give precise outcomes. Most effective tool is wavelet transform. Better information can be extracted from the individual frequency sub signals rather than extracting it directly

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from the EEG signal. Also by using wavelet transform, it becomes easier to get the time and frequency information of a signal together, which makes it practical to obtain the transient components in EEG. Research works in recent studies can be categorized as time domain, frequency domain, time-frequency domain and nonlinear methods of analysis. Since the EEG signals are complex, nonlinear and non-stationary in general, time-frequency domain and nonlinear analysis methods are most broadly utilized in epilepsy detection. Nonlinear components, for example, time lag (TL), hurst exponent (HE), implanting dimension (ED), relationship dimension (CD) and biggest Lyapunov exponent (LLE) are extracted from the EEG and their each sub-band to describe and distinguish the epileptic seizure.

Nonlinear investigation is another prominent research strategy which could better reflect the attributes of the EEG signals. The utilization of Hurst exponent (HE) has been demonstrated to accomplish great accuracy in recognizing seizures. Also, entropies like estimated entropy (ApEn) and test entropy (SampEn) are broadly connected to uncover the shrouded complexities existing in the EEG time arrangement. In this paper, the HE is introduced to characterize the EEG signals in terms of the stronger relative consistency and less dependence on data length.

**DATA**

The complete database used in this study consists of five sets denoted as A-E, each containing 100 samples. These datasets are explained in Table 1. The signals were recorded with the 128-channel amplifier system and digitized at 173.61 samples per second using 12 bit resolution. Sets C and D is an interictal data and is recorded when the patient in pre-ictal state. Set E, which is called ictal data, contains signals recorded during the epileptic seizure. Fig. 1 depicts the sample of EEG signals for each of the five sets.

**METHODS**

In this study, DWT is used to decompose the original EEG signal into six sub-band signals using fifth level decomposition. Complexity of this EEG signal is simplified by extracting Hurst Exponent values from each sub-band signal. For classification, SVM and KNN classifiers are used. The block diagram of the proposed approach is shown in figure below fig 2.

**Discrete Wavelet Transform**

Since EEG signal is a non-stationary signal, Fourier Transform cannot be used as it can better analyse stationary signals but not non-stationary signals. It provides the signal which is localized only in frequency domain. Also, it

![Fig 2 Block diagram of proposed approach](image-url)
does not provide multi-resolution analysis. Moreover, window size is not available. These drawbacks are overcome in Wavelet transform. Wavelet change is an exceptionally helpful approach used on a signal for time–frequency representation since it utilizes the variable size of windows. Long time and short time windows are utilized to get a low and high frequency resolution data respectively. In this way, WT gives specific frequency data and time data at low frequencies and high frequencies, individually. Continuous wavelet transform (CWT) and discrete wavelet transform (DWT) are the two types of a wavelet transform. If \( x(t) \) is the input raw signal then CWT of a signal is

\[
S_{\text{a,b}}(t) = \int_{-\infty}^{\infty} x(t) \psi^* \left( \frac{t-b}{a} \right) \frac{1}{\sqrt{a}} \, dt
\]

where \( a \) is the scaling parameter and \( b \) is the shifting parameter. Now it is a difficult task to find the wavelet coefficient at each scale so the scaling and shifting parameters are converted to powers of two. DWT is defined as

\[
DWT(j,k) = \frac{1}{\sqrt{2^j}} \int_{-\infty}^{\infty} x(t) \psi^* \left( \frac{t-2^j k}{2^j} \right) \, dt
\]

First of all, input signal is made to pass through a low pass and high pass filter and output from this is referred as approximation coefficient (A1) and detailed coefficient (D1) of first level. Similarly, all the coefficients of five levels are extracted as D1, D2, D3, D4, D5, A5. At each level of decomposition, filtering is used to double the frequency resolution and down-sampling is used to half the time resolution. While analyzing a signal, the most important parameter to be considered is the number of decomposition levels, which in this case is chosen to be five. Since above 40 hz, the frequency components may not contain useful information so only fifth level decomposition is done.

**Hurst Exponent**

At the surface of brain, the response is created in the form of wavelets. A desired feature is extracted in the form of wavelets which is called as feature extraction. Hurst exponent is extracted from these wavelets only.

Hurst type (HE) is an established parameter which is utilized as a part of this case for nonlinear analysis. In a time series, this parameter is used to quantify the correlation of points.

- HE < 0.5 indicates that the sequences are long range anti-correlations and anti-persistent.
- HE > 0.5 indicates that the sequences with long range correlations.

The presence or absence of long-range dependence and its degree in a time series is assessed through HE. During interruption of seizures, HE is very much useful in identifying deviations from the normal pattern of brain activity. Commonly, HE can be estimated using rescaled range analysis (R/S) of which the equation is defined below

\[
HE = \frac{\log(R/S)}{\log T}
\]

Where \( R \) is the difference between the maximum and minimum of deviation and \( S \) represents the standard deviation of the time series. \( T \) denotes the duration of the sample data (11).

**Support vector machine (SVM)**

For binary classification tasks in machine learning and for high dimensional feature vectors SVM is a very well known tool due to its accuracy and capability to deal with a large number of predictors. For multi-class classification process, SVM gives much better results. SVM constructs \( M (M - 1)/2 \) binary sub-classifiers, where \( M \) is the number of classes. To separate a pair of classes, each binary sub-classifier is trained and a prediction is made by the majority voting technique.

The SVMs tend to find an optimal hyper-plane in high dimensional feature space in order to maximize the distance between this hyper-plane and the nearest data point of each class. SVM classifiers gives much better results as compared to other classifiers. Standard optimization software can be used to find optimum parameters. General quadratic programming software will often fail for large sample sizes and to solve the optimization special-purpose optimizers need to be used. (25–29).

**K-nearest neighbor (KNN)**

It is a simple machine learning algorithm. A majority vote of neighbors is used to classify an object, with the object being assigned to the class most common amongst its \( k \)-nearest neighbors. \( K \) is a positive integer whose value is typically small. \( k = 1 \) implies that the object is assigned to the class of its nearest neighbor. To avoid tied votes in binary classification problems, \( k \) should be an odd number.

Assume each sample of our dataset has \( n \) attributes and an \( n \) dimensional vector: \( x = (x_1, x_2, \ldots, x_n) \) is formed by combining these attributes. These attributes are independent variables. The problem that we have to solve is that we have a new sample where \( x = u \). We want to find the class of this sample. In the event, if we knew the function \( f \), we could compute \( v = f(u) \) to classify this sample. But in this case we don't know about \( f \).

The thought in k Nearest Neighbor strategies is to distinguish \( k \) samples in the training set whose autonomous factors \( x \) are like \( u \), and to utilize these \( k \) tests to characterize this new specimen into a class. On the off chance that all we are set up to accept is that \( f \) is a smooth function, a sensible thought is to search for samples in training data that are close to it and after that to figure out from the estimations of \( y \) for these samples. When we discuss neighbors we are inferring that there is a separation that we can compute.
between samples in view of the autonomous factors. For the minute we will concern ourselves to the most prominent measure of separation: Euclidean separation (7).

We observe that the sort of separation utilized has little impact on accuracy. We actualized the k-nearest neighbor calculation on dimensionally lessened information. As we probably are aware dimensional diminishment lessens the connection between elements. We attribute the dimensional lessening to be the explanation behind unaffected characterization precision with separation sort.

**Statistical parameters**

To evaluate the performance of the classifier, two different parameters are employed, namely sensitivity and accuracy. Mathematically, these parameters are defined as,

\[
\text{Sensitivity (Sen)} = \frac{\text{true positives}}{\text{true positives} + \text{false negatives}} \times 100%
\]

\[
\text{Accuracy (A)} = \frac{\text{correct classified patterns}}{\text{total patterns}} \times 100%
\]

**RESULTS**

DWT technique was used to decompose all the 500 epochs of normal, interictal and epileptic (ictal) EEG data sets. The sub-bands were divided as follows: A5 (0–2.70 Hz), D1 (43.4–86.8 Hz), D2 (21.7–43.4 Hz), D3 (10.85–21.7 Hz), D4 (5.43–10.85 Hz) and D5 (2.70–5.43 Hz). Fig 3 represents decomposition of a sample dataset A into different sub-bands.

The approximation and detail coefficients of all sub bands of the entire 500 EEG epochs were used to calculate HE values. For five data sets A-E the value of HE for entire 500 epochs are plotted in figure 4,5 and 6. Data set A and B have higher HE value as compared to data set E, this proves that the data set E is in more ordered form than the data sets A and B. Similarly the data sets C and D tends to have higher HE values than the data set E and lesser than data sets A and B. Hence we can conclude that data sets C and D are more ordered than the data sets A and B and are less regular than E.

Tabulation of average HE values for wavelet coefficients of the six sub bands (D1 to D5 and A5) of data sets A,B,C,D and E is given in table 2. We can come to a conclusion that epileptic EEG i.e. set E is more regular or less complex as compared to normal i.e. set A and B and data sets representing interictal periods i.e. sets C and D. We also observed that the complexity of data sets C and A is almost similar, when recorded for normal subjects. Conversely, the complexity of data set E is lower than the complexity of data set D, when recorded from epileptic patient throughout the ictal period.
A significant difference was found between the DWT based HE values of different sub bands of all the data sets, this fact is very much evident from data in table 1. The differences in these values is used to formulate feature vector of an entire band (0-86.8 Hz) of EEG signal. The SVM and KNN classifiers thus uses these six features as an input in or-
order to further classify the EEG as healthy, interictal and ictal. The following cases have been taken up for consideration.

While processing class 0 is allotted value 1 and class 2 is allotted as 1 in the target vector, for all the cases. Implementation of SVM is done using MATLAB software version 7.8.0 (R2016a). The input feature vector thus obtained is divided randomly into training data set and testing data set. For training the SVM the training data set is used, whereas the accuracy and effectiveness of the trained SVM for given EEG signal is determined using the training set. Similar procedure is carried out for classification using KNN classifier.

The input data matrix which is prepared from the HE values has 100 rows and 6 columns in this work. In this matrix each row represents one observation and its column is one feature. In the same way, the feature vectors of sets B, C, D and E have 100 observations each. Present binary classifier task comprise of 200 observation of six features for case 1 to case 4, 300 observation with six features for case 5 to case 11, 400 observation with six features for case 12 to case 14 and 500 observation with six features for case 15. For testing of classifier 50% of input data set is used and remaining 50% is used for training.

### Comparison with existing state-of-art work

The work done by various researchers in this field of epilepsy detection is tabulated in Table 2. We have drawn here a comparison between the results obtained in other methods and our proposed approach. For making the results more realistic only the methods using same data sets and similar cases is incorporated.

For case 1 and case 3, the classification accuracy obtained from our work 99% (using SVM) is one of the best presented for these data sets. Tzallas et al.’s (38) work also represent this result by using the method of time-frequency analysis combined with ANN.

For case 2 and case 4, the accuracy obtained after classification process is 95%, 93% (using SVM) are the best presented. Nicolaou et al. (23) also looked upon these cases and reported their accuracy as 82.8% and 79.94% respectively. His method comprises using permutation entropy with SVM for the same data sets.

For case 12, the accuracy obtained after classification process is 95% (using both SVM and KNN). This particular case was also presented in Guo et al.’s (41) work, which were obtained by using the line length features centered on multi resolution decomposition combined with ANN.

Case 6 to Case 12 and case 15 is presented in our work for the first time and has given satisfactory results. As already mentioned the approach used by us involves using wavelet analysis (using DWT) for EEG signal decomposition combined with extracting HE (for all six sub bands) and using SVM and KNN classifiers for the classification process.

### CONCLUSION

Manual detection of epileptic seizure is a very costly and time consuming process. In this work Hurst exponent has been employed which simplifies automatic seizure detection process. Fifth level decomposition of EEG signals has been performed to decompose the signal into different sub-bands by DWT to obtain the detail wavelet coefficients (\(D_1-D_5\)) and approximate wavelet coefficients (\(A_5\)). The HE values are calculated from \(D_1-D_5\) and \(A_5\) which provides the best detection rates. The 99% classification accuracy is obtained using SVM for cases 1 and 3 and 98% accuracy is obtained using KNN classifier. It can be concluded that using DWT based

### Table 1: Statistical parameters of SVM and k-NN

<table>
<thead>
<tr>
<th>Sets</th>
<th>SVM</th>
<th>KNN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accuracy (%)</td>
<td>Sensitivity (%)</td>
</tr>
<tr>
<td>A-E</td>
<td>99.00</td>
<td>100.00</td>
</tr>
<tr>
<td>B-E</td>
<td>95.00</td>
<td>95.91</td>
</tr>
<tr>
<td>C-E</td>
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<td>100.00</td>
</tr>
<tr>
<td>D-E</td>
<td>93.00</td>
<td>97.77</td>
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<td>BCD-E</td>
<td>91.50</td>
<td>85.10</td>
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<td>AB-E</td>
<td>94.67</td>
<td>88.89</td>
</tr>
<tr>
<td>AC-E</td>
<td>97.33</td>
<td>94.23</td>
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<tr>
<td>AD-E</td>
<td>93.33</td>
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<tr>
<td>BC-E</td>
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<tr>
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<td>CD-E</td>
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<td>ABC-E</td>
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</tr>
<tr>
<td>ACD-E</td>
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<td>85.71</td>
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<tr>
<td>ABD-E</td>
<td>92.50</td>
<td>85.71</td>
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<tr>
<td>ABCD-E</td>
<td>93.20</td>
<td>81.13</td>
</tr>
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</table>
Hurst exponent method using SVM classifier gives more satisfactory results as compared to other methods. The presented method may prove to be a useful tool in epilepsy detection.

**DECLARATION**

The authors declare no conflict of interest.

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