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# Comparison on Wavelet and Wavelet Packet Transformation for an EEG Signal to Detecting an Epileptic Disorder

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***Abstract :*** *EEG (Electroencephalograph) is a technique for identifying neurological disorders. EEG signal is very weak and has very strong background noise; the average EEG signal is only about* $50\mu V$ *, the biggest* $100\mu V$. *The presence of physiological artifacts such as eye blinks, eyeball movement, muscular movement and cardiac pulses in EEG recordings obscure the underlying processes and makes analysis problematic. EEG is used for diagnosis of Epilepsy. It takes doctors a lot of time for diagnosis. So we have developed a tool for detection of Epilepsy. In this paper we propose a technique of detecting epilepsy disorder using Wavelet transform and Wavelet packet transform through MATLAB. Then we compare with Wavelet transformation and Wavelet packet transformation. This paper also provides a technique of detecting epileptic disorder with great accuracy.*
***Keywords:*** *EEG Signal, Epileptic Disorder, Wavelet, Wavelet Packet.*

## I. INTRODUCTION

Wavelet transform is particularly effective for representing various aspects of non-stationary signals such as trends, discontinuities, and repeated patterns where other signal processing approaches fail or are not as effective. **EEG (Electroencephalograph**) is a technique for identifying neurological disorders. About 1% of the people in the world suffer from epilepsy and 30% of epileptics are not helped by medication [3].Careful analyses of the electroencephalograph (EEG) records can provide valuable insight and improved understanding of the mechanisms causing epileptic disorders. In this research, discrete Daubechies and Harmonic wavelets are investigated for analysis of epileptic EEG records [4]. Wavelet transform is used to analyze and characterize epileptic form discharges in the form of 3-Hz spike and wave complex in patients with absence seizure. Through wavelet decomposition of the EEG records, transient features are accurately captured and localized in both time and frequency context [6]. The capability of this mathematical microscope to analyze different scales of neural rhythms is shown to be a powerful tool for investigating small-scale oscillations of the brain signals.

Wavelet analyses of EEGs obtained from a population of patients can potentially suggest the physiological processes undergoing in the brain in epilepsy onset. A better understanding of the dynamics of the human brain through EEG analysis can be obtained through further analysis of such EEG records [2].

## II. WAVELET TRANSFORM

The wavelet means small waves and in brief, a wavelet is an oscillation that decays quickly.
Mathematically, a wavelet is an oscillating function which satisfies the following conditions:
1. A wavelet must have finite energy

$$E = \int_{-\infty}^{\infty} |\psi(x)|^2 \, dx < \infty \qquad (1)$$

The energy $E$ equals the integrated squared magnitude of the analyzing function $\psi(x)$ and must be less than infinity.
2. A wavelet $\psi(x)$ is a function of zero average

$$\int_{-\infty}^{\infty} \psi(x) dx = 0 \qquad (2)$$

3. If $\hat{\psi}(\omega)$ is the Fourier transform of the wavelet $\psi(x)$, the following condition must hold

$$C_{\psi} = \int_{0}^{\infty} \frac{|\hat{\psi}(\omega)|^2}{|\omega|} d\omega < \infty \qquad (3)$$

This condition implies that the wavelet has no zero frequency components $(\psi(0)=0)$, i.e. the mean of the wavelet $\psi(x)$ must equal zero. This condition is known as the admissibility condition. The value of $C_\psi$ depends on the chosen wavelet [2].

**MEYER WAVELET**

The Meyer wavelet and scaling function are defined by the frequency domain:

$$\psi(x)=(2\pi)^{-\frac{1}{2}}e^{\frac{ix}{2}}\sin(\frac{\pi}{2}\vartheta(\frac{3}{2\pi}|x|-1)), \quad (4)$$

if $\frac{2\pi}{3}\le|x|\le\frac{4\pi}{3}$

$$\psi(x)=(2\pi)^{-\frac{1}{2}}e^{\frac{ix}{2}}\cos(\frac{\pi}{2}\vartheta(\frac{3}{2\pi}|x|-1)), \quad (5)$$

if $\frac{4\pi}{3}\le|x|\le\frac{8\pi}{3}$

and $\psi(x)=0 \ if \ |x|\notin[\frac{2\pi}{3},\frac{8\pi}{3}]$

Where $\vartheta(a)=a^4(35-84a+70a^2-20a^3),\ a\in[0,1]$

Scaling function $\varphi(x)=(2\pi)^{-\frac{1}{2}} \ if \ |x|\le\frac{2\pi}{3}$

$$\varphi(x)=(2\pi)^{-\frac{1}{2}}e^{\frac{ix}{2}}\cos(\frac{\pi}{2}\vartheta(\frac{3}{2\pi}|x|-1)),\ if \ \frac{2\pi}{3}\le|x|\le\frac{4\pi}{3}$$

$$\varphi(x)=0 \ if \ |x|>\frac{4\pi}{3}$$

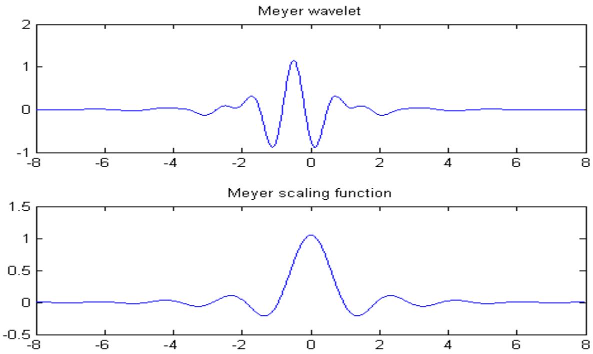



Fig.1 Meyer wavelet and Meyer scaling function

**DISCRETE APPROXIMATION OF MEYER WAVELET**

In discrete wavelet transform (DWT), ECG, EEG and MRA Signal are performed using a Meyer wavelet, since the Meyer wavelet has the lowest RMS errors [7].So, we are using the discrete approximation of Meyer wavelet**.** It can be represented by

$$d_{j-1,k}(f(x))=\sum_{j\in Z}d_{j,k}(f(x))\varphi_{j,k}+\sum_{k\in Z}c_{j,k}(f(x))\psi_{j,k}$$

The mother wavelet is the Meyer wavelet is given by

$$\varphi(x)=(2\pi)^{-\frac{1}{2}}e^{\frac{ix}{2}}\cos(\frac{\pi}{2}\vartheta(\frac{3}{2\pi}|x|-1)),\ if \ \frac{2\pi}{3}\le|x|\le\frac{4\pi}{3}$$

$$\varphi(x)=0 \ if \ |x|>\frac{4\pi}{3}$$

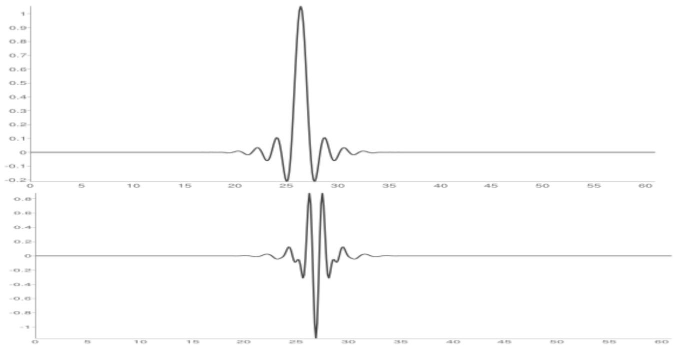


Fig. 2 Discrete approximation of Meyer scaling function and Meyer wavelet

## III. WAVELET PACKET TRANSFORM

Wavelet packets are particular linear combinations of wavelets [9]. They form bases which retain many of the orthogonality, smoothness, and localization properties of their parent wavelets. The coefficients in the linear combinations are computed by a recursive algorithm making each newly computed wavelet packet coefficient sequence the root of its own analysis tree. The wavelet packet method is a generalization of wavelet decomposition that offers a richer range of possibilities for signal analysis [6].

The wavelet packet is defined by the following equation (Wickerhauser 1991):

$$u_{2n}^{(j)}(t) = \sqrt{2}\sum_k h(k) u_n^{(j)}(2t-k) \qquad (6)$$

$$u_{2n+1}^{(j)}(t) = \sqrt{2}\sum_k g(k) u_n^{(j)}(2t-k) \qquad (7)$$

Where $n = 0,1,2,...............$ and $k = 0,1,2,..........,m.$

With $u_0^{(0)}(t)$ being the scaling function $\varphi(t)$, that is $u_0^{(0)}(t) = \varphi(t)$ and $u_1^{(0)}(t)$ being the base wavelet function $\psi(t)$, that is, $u_1^{(0)}(t) = \psi(t)$ (Wickerhauser 1991). The Superscript $(j)$ in (6) and (7) denotes the $jth$ level wavelet packet basis, and there will be $2^j$ wavelet packet bases at the $jth$ level [10].

## IV. EEG SIGNAL AND EPILEPTIC DISORDER

An electroencephalograph (EEG) is the recorded electrical activity generated by the brain. In general, EEG is obtained using electrodes placed on the scalp with a conductive gel. In the brain, there are millions of neurons, each of which generates small electric voltage fields. The aggregate of these electric voltage fields create an electrical reading which electrodes on the scalp are able to detect and record. Therefore, EEG is the superposition of many simpler signals. The amplitude of an EEG signal typically ranges from about $1\mu V$ to $100\mu V$ in a normal adult, and it is approximately $10$ to $20mV$ measured with subdural electrodes such as needle electrodes [9].

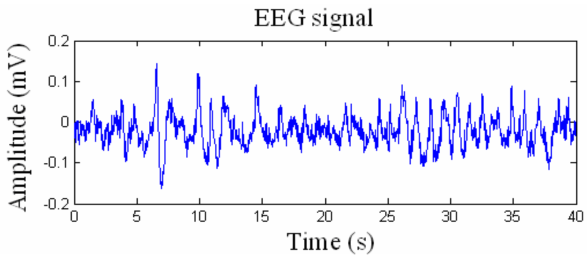



Fig.3 An EEG Signal

Epilepsy is a neurological disorder and can be defined as a symptom where a sudden and transient disturbance occurs in the normal electrical activity of the brain (İnan & Kuntalp, 2007). Multiple factors can trigger epilepsy, such as brain injury, disease, light stimulation, and genetics. People may be born with the disorder; however, the exact underlying epilepsy mechanism is still uncertain [16]. Epilepsy is a chronic neurological disorder that affects more than 50 million people worldwide, characterized by recurrent seizures (World Health Organization [WHO], 2006). This electrical hyperactivity can have its source in different parts of the brain and produces physical symptoms such as short periods of inattention and loose of memory, a sensory hallucination, or a whole-body convulsion. The frequency of these events can vary from one in a year to several in a day. The majority of the patients suffer from unpredictable, persistent and frequent seizures which limit the independence of an individual, increase the risk of serious injury and mobility, and result in both social isolation and economic hardship (Friedman & Gilliam, 2010). Epilepsy affects four to five percent of the world's population at some point in their lives and 1% of the world's population suffers from chronic epilepsy (Betts, 1998). According to the Epilepsy Foundation of America, more than two million people in the United States have a seizure disorder. In Taiwan, about 200 thousand people suffer from this disorder (Wang, 1998).

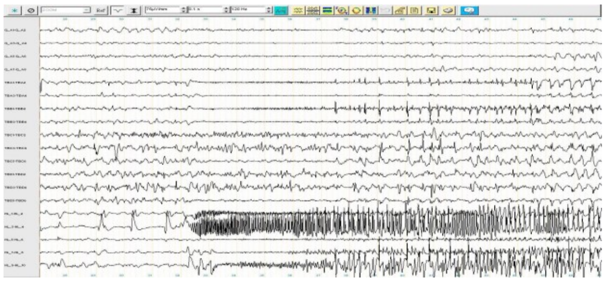


Fig.4 Epileptic Activity in the EEG

## V. DETECTION OF EPILEPTIC DISORDER IN EEG SIGNAL USING WAVELET AND WAVELET PACKET TRANSFORMATION

Brain is the most important organ which controls the functioning of the human body including heart beat and respiration. It is the portion of the vertebrate central nervous system that is enclosed within the cranium, continuous with the spinal cord, and composed of gray matter and white matter. It also is the primary center for the regulation and control of bodily activities, receiving and interpreting sensory impulses, and transmitting information to the muscles and body organs.

A "wavelet" is a small waveform which has its energy concentrated in time. Wavelet Transforms are used to convert a signal into a series of wavelets. The wavelet transform is an important tool for analysis of EEG signals. Comparing techniques of seizure detection developed by diverse groups is filled with problems because of no objective definition of the appearance of a seizure in the EEG.A powerful method to perform time-scale analysis of signals is the wavelet transforms (WT).

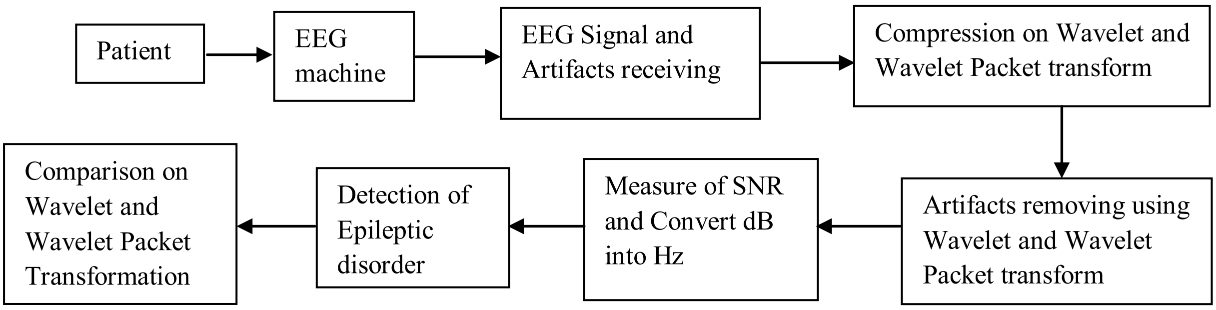



Fig.5 Epileptic Disorder Detection Process

**METHODOLOGY:** The methods for implementing the above system structure are listed as follows:

**EEG DATA RECORDINGS**

The EEG database contains invasive EEG recordings of 4 patients suffering from medically intractable temporal and frontal epilepsy. Subjects within the age group from 21 to 40 were selected for this study. The nervous system sends commands and communicates by trains of electric impulses. When the neurons of the human brain process information they do so by changing the flow of electrical current across their membranes. This requires a patient to under-go surgery for electrodes to be placed inside the head. This is not acceptable because of the risk to the patient. Researchers therefore collect recordings from the scalp receiving the global descriptions of the brain activity. Because the same potential is recorded from more than one electrode, signals from the electrodes are supposed to be highly correlated. These are collected by the use of an electroencephalograph and called electroencephalogram (EEG) signals [8].

**COMMON ARTIFACTS IN EEG RECORDS**

By artifacts it is understood all signals that appear in the EEG record which don't come from the brain. The most common artifacts in the EEG signal appear during the acquisition due to different causes, like as bad electrodes location, not clean hairy leather, electrodes impedance, etc. There is also a finding of physiological artifacts, that is, bioelectrical signals from other parts of the body (heart and muscle activity, eye blink and eyeball movement) that are registered in the EEG (Sörnmo & Laguna, 2005). The problem of those artifacts is that they can made a mistake in the analysis of a EEG record, either in automatic method or in visual inspection by specialist (Wang et. al., 2008) [24].

The muscle disturbances are introduced in the EEG by involuntary muscle contractions of the patient, thus generating an electromyogram (EMG) signal present in the EEG record. The EMG and other biological artifacts have not been analyzing in the present work.

**DE-NOISING THE EEG SIGNAL USING WAVELET AND WAVELET PACKET:**

**EEG SIGNAL COMPRESSION USING WAVELET AND WAVELET PACKET**

Due to the time-scale properties of the WPT, the signal components are localized in time (time position) and scale (frequency band). This phenomenon helps to compress efficiently the different zones of the time-scale plane, according to the WPT coefficients values obtained in each case. When the signal to be compressed is appropriately segmented and the WPT is applied to it, some functions from the WP basis in the WPT can be highly correlated with the most relevant signal waveform components. As a consequence, the coefficients with highest absolute values, among those resulting from the application of the WPT to the signal, are the best representatives of it [5]. On the other hand, the WPT coefficients that have low absolute values correspond to signal segments with low relevance that is well located in the time-scale plane.
Signal Compression rate is defined as

$$CR = \frac{\text{Signal storage demand before compression}}{\text{Signal storage demand after compression}}$$

There are many types of wavelet functions; this paper is using Discrete Meyer wavelet.

**RETAINED ENERGY (RE) AND NUMBER OF ZEROS (NZ)**

Results are observed in terms of percentage of zeros, percentage of energy retained. The results are presented in tabular form for wavelet and wavelet packet transform respectively for having percentage of number of zeros (NZ) and percentage of energy retained (RE) as follows [23]:

$$NZ = \frac{100*(ZCD100)}{No\ of\ coefficients}$$

$$RE = \frac{100*(V_n(CCD,2))^2}{(V_n(Originalsignal))^2}$$

Where $V_n$ is the vector norm.

$CCD$ is the coefficients of the current decomposition, and $ZCD$ is the Number of zeros of the current decomposition. In this test Shannon entropy criterion is used to construct the best tree. Shannon entropy criteria find the information content of signal '*S*'.

**PERCENT ROOT MEAN SQUARE DIFFERENCE (PRD)**

The measurement of these distortions is a difficult problem and it is only partially solved for biomedical signal. In most EEG compression algorithm [16], the percentage root mean-square difference (PRD) measure defined as:
Percent Root-Mean Square difference normal (PRDN):

$$PRDN\% = 100\sqrt{\frac{\sum(x(n)-\tilde{x}(n))^2}{\sum(x(n)-\bar{x})^2}}$$

Where $x(n)$ is the original signal, $\tilde{x}(n)$ is the reconstructed signal which does not depend on the signal mean value $\bar{x}$.

**SIGNAL TO NOISE RATIO (SNR)**

Basically signal to noise ratio (SNR) is an engineering term for the power ratio between a signal and noise [16].

It is expressed in terms of the logarithmic decibel scale and the Signal-to-Noise ratio also defined as:

$$SNR = -20\log(0.01*PRDN)$$

**EPILEPTIC DISORDER RANGE**

EEG is used for diagnosis of Epilepsy [4]. All EEG records were initially filtered with a second order, bidirectional and Butterworth $50\,Hz$ notch filter in order to remove the power line interference. Then, the EEG Signals were band-pass filtered with a second order, bidirectional and Butterworth filter with a bandwidth of $0.5-60\,Hz$.

We know that,

$$1\ dB = 0.10610329495\ hertz$$ [15, 16]

Range of two types of Epileptic Disorder is given below:

Temporal (delta): $0.5\ Hz$ to less than $4\ Hz$.

Frontal (Theta): $4\ Hz$ to less than $8\ Hz$.

**WAVELET BASED AND WAVELET PACKET BASED OF AN EEG SIGNAL PROCESSING TO DETECTING AN EPILEPTIC DISORDER**

**EXPERIMENT 1**

First we need to collect an EEG Signal of a Patient. Two neurologists with experience in the clinical analysis of EEG signals separately inspected every recording included in this study to score epileptic and normal signals. Each event was filed on the computer memory and linked to the tracing with its start and duration. These were then revised by the two experts jointly to solve disagreements and set up the training set for the program, consenting to the choice of threshold for the epileptic disorder [7].

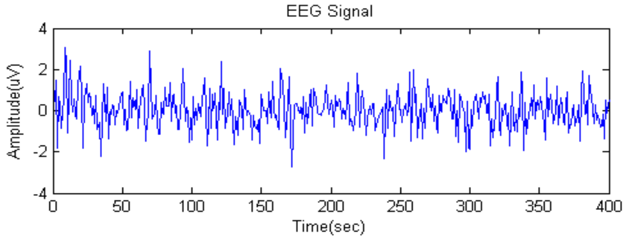
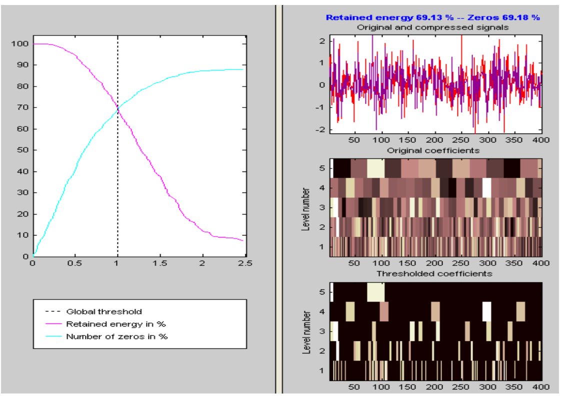



Fig.6 First Patient of an EEG Signal

Wavelet Transform




Wavelet Packet Transform

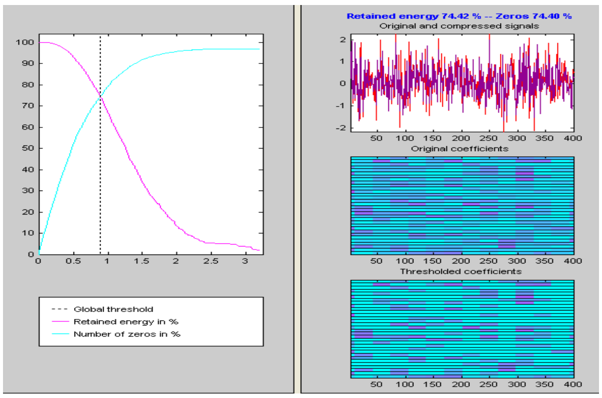
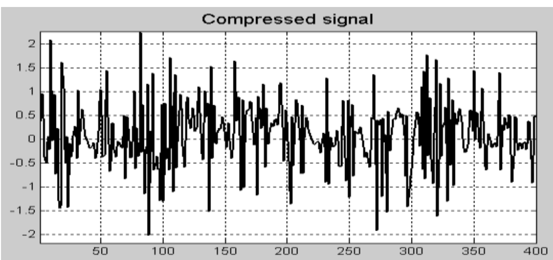



Fig.7 Representation of Retained energy and Number of zeros of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform




Wavelet Packet Transform

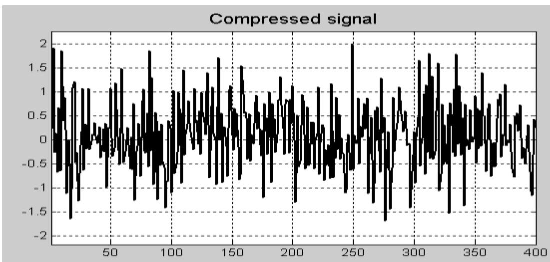



Fig.8 Representation of Compressed signal of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform Wavelet Packet Transform

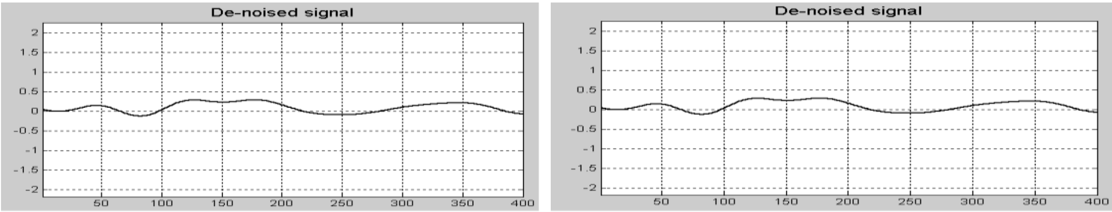



Fig.9 Representation of De-noised signal of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform Wavelet Packet Transform

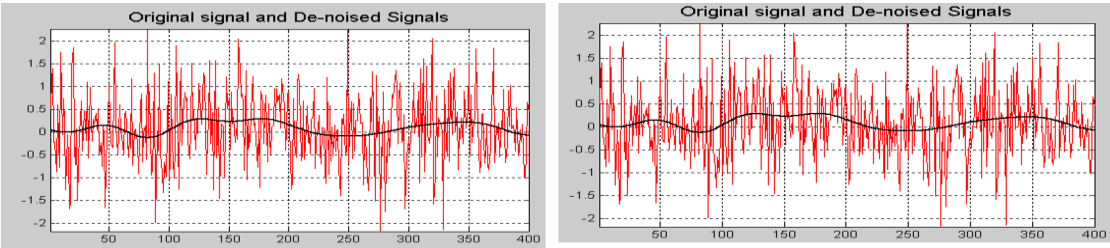



Fig.10 Difference between Original signal and De-noised signal of that EEG Signal Using wavelet and wavelet packet based transform

TABLE I
FIRST PATIENT OF EPILEPTIC DISORDER TYPE

| **Patient-1** | **Retained Energy** | **Number of Zeros** | **Compression Ratio (CR) %** | **Signal to Noise Ratio(SNR) dB** | **Epileptic Disorder (Hz)** |
|---|---|---|---|---|---|
| **Wavelet** | 69.13 | 69.18 | 1.002 | 27.29 | 2.895 |
| **Wavelet Packet** | 74.42 | 74.40 | 0.8921 | 29.26 | 3.105 |

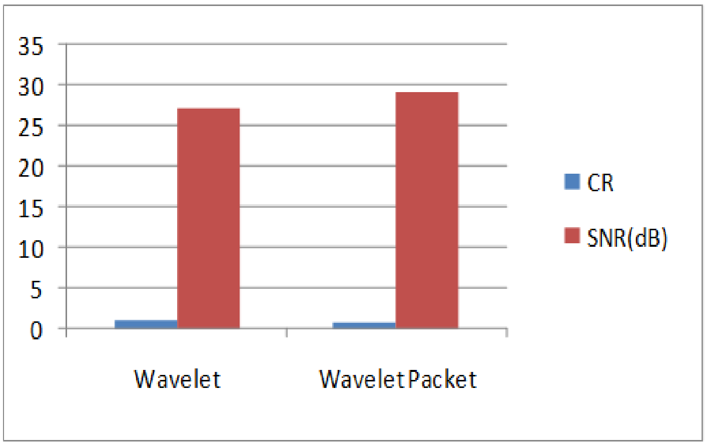



Fig.11 Comparison on Wavelet and Wavelet Packet Transform

**EXPERIMENT 2**

In the same way, we collect an EEG Signal of a different patient. Then we are repeating the whole method and then we get,

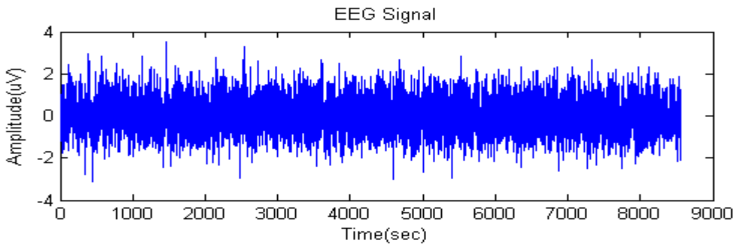



Fig.12 Second Patient of an EEG Signal

Wavelet Transform | Wavelet Packet Transform

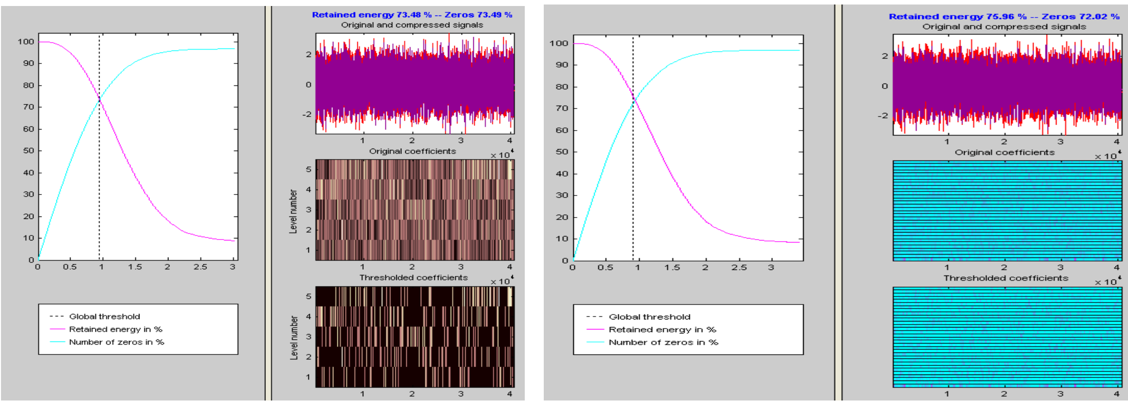



Fig.13 Representation of Retained energy and Number of zeros of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform | Wavelet Packet Transform

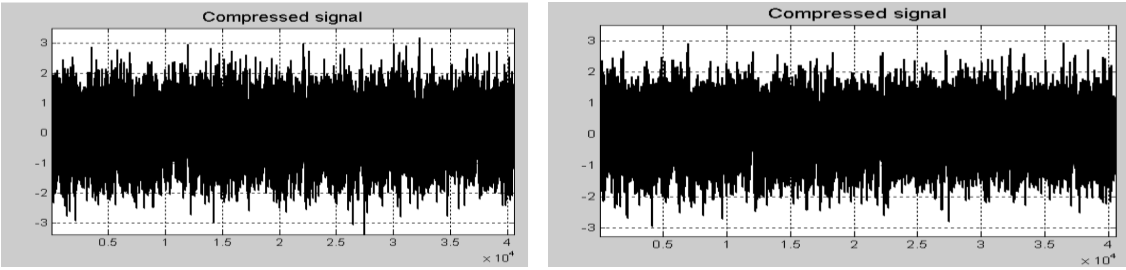



Fig.14 Representation of Compressed signal of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform | Wavelet Packet Transform

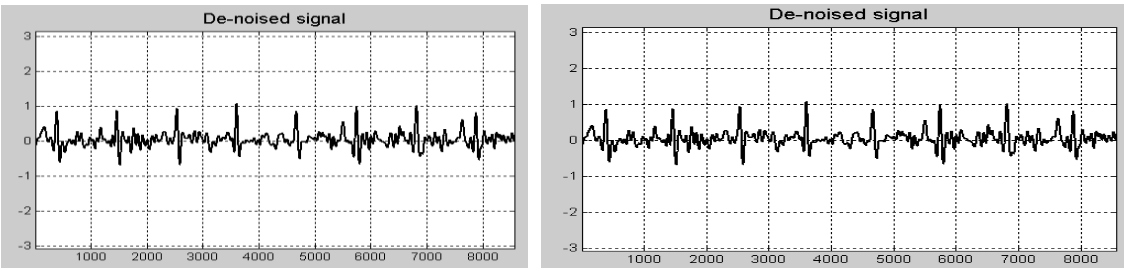



Fig.15 Representation of De-noised signal of that EEG Signal Using wavelet and wavelet packet based transform

Wavelet Transform | Wavelet Packet Transform

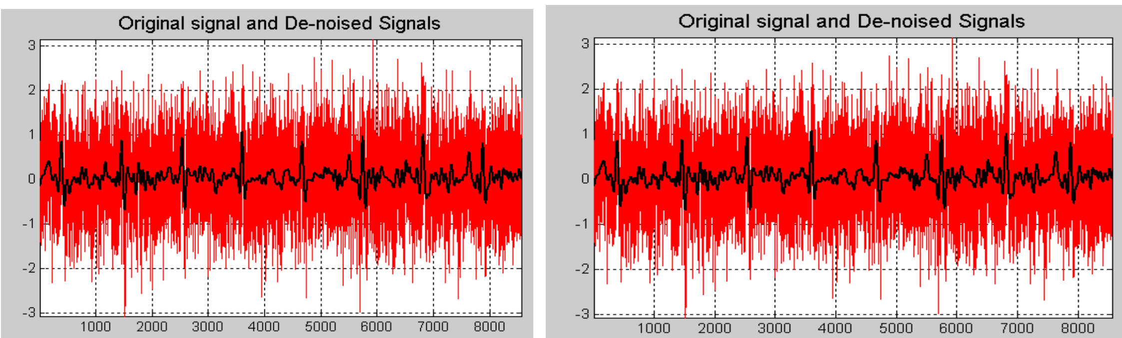



Fig.16 Difference between Original signal and De-noised signal of that EEG Signal Using wavelet and wavelet packet based transform

TABLE II
SECOND PATIENT OF EPILEPTIC DISORDER TYPE

| Patient-2 | Retained Energy | Number of Zeros | Compression Ratio(CR) % | Signal to Noise Ratio(SNR) dB | Epileptic Disorder (Hz) |
|---|---|---|---|---|---|
| **Wavelet** | 73.48 | 73.49 | 0.9453 | 40.49 | 4.296 |
| **Wavelet Packet** | 75.96 | 72.02 | 0.9014 | 40.64 | 4.312 |

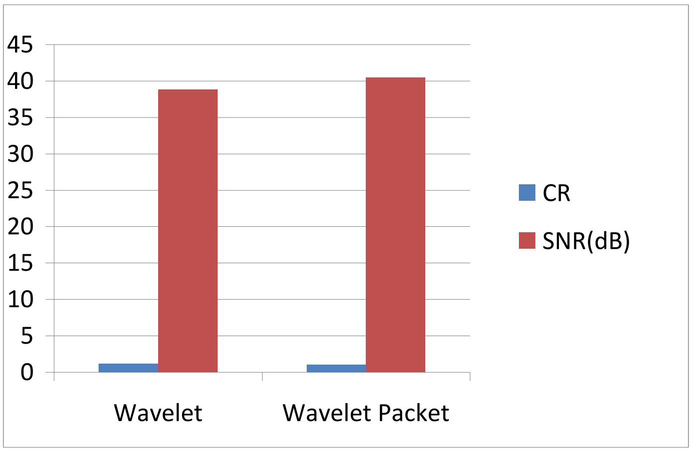



Fig.17 Comparison on Wavelet and Wavelet Packet Transform

# VI. RESULTS

## RESULTS OF FIRST PATIENT

Epileptic disorders are manifestations of epilepsy. The detection of epileptiform discharges in the EEG is an important component in the diagnosis of epilepsy. As EEG signals are non-stationary, the conventional method of frequency analysis is not highly successful in diagnostic classification. In this paper we have presented a novel approach to detect disorders based on a set of diverse feature. The most important advantage of the proposed method is the reduction of data size as well indicating and recognizing the main characteristics of signal.

In this paper, both Wavelet Transform and Wavelet Packet Transform methods are applied to electroencephalogram (EEG) of possibly epilepsy patients. The signal on the basis of relative energy has been analyzed and is compared. Temporal and Frontal are the two basics type of Epileptic disorders. We calculated the Compression Ratio (CR), Signal to Noise Ratio (SNR) and Epileptic Disorders range to detect the disorders.

In the First Patient, we calculated the whole process and see that it is a **Temporal** disease. Because the range of **Temporal** disease is **0. 5 Hz to less than 4 Hz.** So if the doctor found out the disease as early as possible then the disease should be removed totally. The results of this study are compared with previous studies. The comparison of results shows that the Wavelet transform and Wavelet Packet transform are suited for detecting epileptic disorders. But Wavelet Packet transform is better than Wavelet transform showed in the following **Figure.**

## RESULTS OF SECOND PATIENT

In the Second Patient, we calculated the whole process and see that it is a **Frontal** disease. Because the range of **Frontal** disease is **4 Hz to less than 8 Hz.** So if the doctor found out the disease as early as possible then the doctor should advise the patient to live carefully and have some medicine. Because it is not removed totally and it is serious stage. The results of this study are compared with previous studies. The comparison of results shows that the Wavelet transform and Wavelet Packet transform are suited for detecting epileptic disorders. But Wavelet Packet transform is better than Wavelet transform showed in the following **Figure**.

# VII. CONCLUSION

In conclusion we have developed skills in working with pattern recognition methods. In our case we worked with information obtained from the brain by an EEG. EEG technology is widely used in cerebral medical diagnostics. An increasing range of researches are growing using this technology. We have worked in a real research environment.

Our first project was developed in MATLAB. The aim has been to focus on some basics of pattern recognition. To ensure signal without distortion, it is better to choose wavelet de-noising and soft threshold de-noising. So, they are widely used in signal processing. These experiments provide experimental verification that the use of this tool can be used for detection of epilepsy within few seconds. This paper proposes a technique of detecting epilepsy disorder using discrete wavelet transform through MATLAB. In this study, the accuracy of the diagnosis of Temporal and Frontal epilepsies achieved is of about **96%.**We are also able to detect the epileptic disorder with accuracy up to **96%.**

On the other hand, although predictability of disorders from the EEGs (both temporal and frontal) has been approved, more research is necessary to increase accuracy.

## Acknowledgments

Temporal and Frontal frequency variations of variables are detected by wavelet transforms and wavelet packet transforms. We may be able to develop a mechanism to predict future seizures for epileptic patients. These experiments provide experimental verification that the use of this tool can be used for detection of epilepsy within few seconds and other disease.

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