WAVELET TRANSFORM BASED DENOISING TECHNIQUES FOR EARTHQUAKE SIGNALS

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***Abstract*: In this paper, wavelet transform is proposed to remove noise from the earthquake signal. With the use of HAAR and DB wavelet transform the magnitude of the signals were determined. The Daubechies wavelets, based on the work of Ingrid Daubechies, are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function (called the *father wavelet*) which generates an orthogonal multiresolution analysis. We have proposed four different noise removing techniques such as Rigrsure, Sqtwolog, Minimax, Heursure for removing noise in earthquake signal.**

I. INTRODUCTION

An **earthquake** (also known as a **quake**, **tremor** or **temblor**) is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in size, from those that are so weak that they cannot be felt, to those violent enough to propel objects and people into the air and wreak destruction across entire cities. The seismicity, or **seismic activity**, of an area is the frequency, type, and size of earthquakes experienced over a particular time period. The word *tremor* is also used for non-earthquake seismic rumbling.

Where plate boundaries occur within the continental lithosphere, deformation is spread out over a much larger area than the plate boundary itself. In the case of the San Andreas fault continental transform, many earthquakes occur away from the plate boundary and are related to strains developed within the broader zone of deformation caused by major irregularities in the fault trace (e.g., the "Big bend" region). The Northridge earthquake was associated with movement on a blind thrust within such a zone. Another example is the strongly oblique convergent plate boundary between the Arabian and Eurasian plates where it runs through the northwestern part of the Zagros Mountains. The deformation associated with this plate boundary is partitioned into nearly pure thrust sense movements perpendicular to the boundary over a wide zone to the southwest and nearly pure strike-slip motion along the Main Recent Fault close to the actual plate boundary itself. This is demonstrated by earthquake focal mechanisms.

Kishor Kumar Reddy and Narasimha Prasad (2015) proposed a method for reading seismic signal. Initially, the seismic signals are taken as input for the experimentation, as these are the only signals that are feasible for the proper detection of Earthquake occurrence. In general, no particular data is that accurate as it consists of some sort of discrepancies in them, correspondingly these signal may also includes jangles within them. Since noise corrupts the signals in a significant manner, therefore it must be removed from the data in order to proceed with further data analysis, The process of noise removal is generally referred to as a signal processing or simply de-noising. The wavelet transform acts as a tool for signal processing that have been successfuly used in many scientific applications such as signal processing. In the present research DB wavelet transform are used for the de-noising of signal.

In the meantime, several definitions of the Haar functions and various generalizations have been published and used. They were intended to adapt this concept to some practical applications, as well as to extend its application to different classes of signals. Thanks to their useful features and possibility to provide a 'local' analysis of signals, the Haar functions appear very attractive in many applications as for example, image coding, edge extraction, and binary logic design. The sample applies to many related concepts as the SHT, or the Watari transform and the real multiple-valued Haar transform. These transforms have been applied, for example, to spectral techniques for multiple-valued logic etc. A quantized version of the Haar transform was recently developed. Ashish Khare(2010) proposed Daubechies complex wavelet transform is used due to its approximate shift invariance property and extra information in imaginary plane of complex wavelet domain when compared to real wavelet domain. A wavelet shrinkage factor has been derived to estimate the noise-free wavelet coefficients.

II. DATA COLLECTION

The Pacific Earthquake Engineering Research Center (PEER) ground motion database includes a very large set of ground motions recorded worldwide of shallow crustal earthquakes in active tectonic regimes. **The PEER research program** aims to provide data, models, and software tools to support a formalized performance-based earthquake engineering methodology. Within the broad field of earthquake engineering, PEER's research currently is focused on four thrusts, these being Building Systems, Bridge and Transportation Systems, Lifelines Systems, and Information Technologies in support of the methodology implementation.

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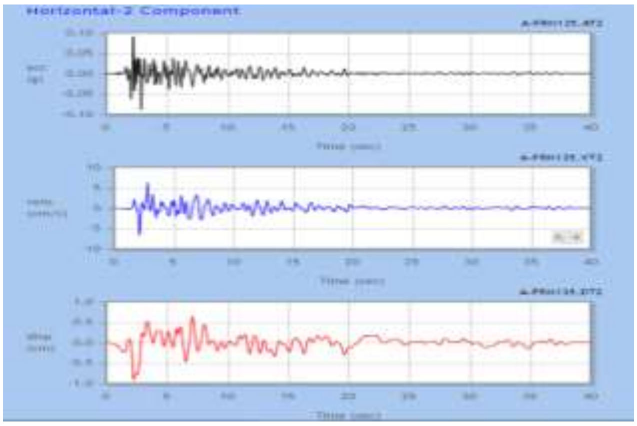

Figure 1 Horizontal-2 component

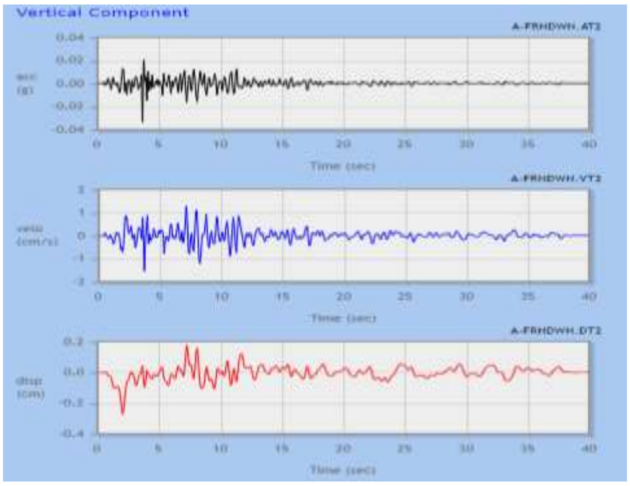

Figure 3 Vertical component

III. WAVELET TRANSFORM

In Fourier analysis, the Discrete Fourier Transform (DFT) decompose a signal into sinusoidal basis functions of different frequencies. No information is lost in this transformation; in other words, we can completely recover the original signal from its DFT (FFT) representation. In wavelet analysis, the Discrete Wavelet Transform (DWT) decomposes a signal into a set of mutually orthogonal wavelet basis functions. These functions differ from sinusoidal basis functions in that they are spatially localized – that is, nonzero over only part of the total signal length. Furthermore, wavelet functions are dilated, translated and scaled versions of a a common function φ, known as the mother wavelet. As is the case in Fourier analysis, the DWT is invertible, so that the original signal can be completely recovered from its DWT representation. Unlike the DFT, the DWT, in fact, refers not just to a single transform, but rather a set of transforms, each with a different set of wavelet basis functions. Two of the most common are the Haar wavelets and the Daubechies set of wavelets. Here, we will not delve into the details of how these were derived; however, it is important to note the following important properties:

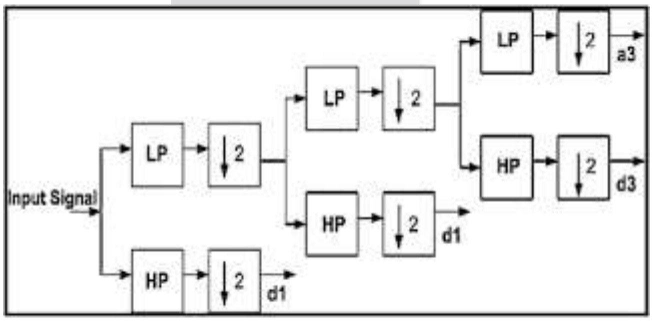

Figure 4 Block diagram of wavelet transform

The (one-dimensional) DWT operates on a real-valued vector x of length 2n, n ∈ {2, 3, . . . }, and results in a transformed vector w of equal length. First, the vector x is filtered with some discrete-time, low-pass filter (LPF) h of given length (in the Figures, we use length four for illustration purposes) at intervals of two, and the resulting values are stored in the first eight elements of w.

Second, the vector x is filtered with some discrete-time, high-pass filter (HPF) g of given length (again, for illustration purposes, we use a filter of length four) at intervals of two, and the resulting high-pass values are stored in the last eight elements of w.

Continuous Wavelet Transform (CWT)

$$T(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, \psi^{*} \frac{(t-b)}{a} dt$$

Discrete Wavelet Transform (DWT)

$$T_{m,n} = \int_{-\infty}^{\infty} x(t)\, \psi_{m,n}(t)\, dt$$

Denoising refers to manipulation of wavelet coefficients for noise reduction. Coefficient values not exceeding a carefully selected threshold level are replaced by zero followed by an inverse transform of modified coefficients to recover denoised signal. Denoising by thresholding of wavelet coefficients is therefore a nonlinear (local) operation

Mathematically, thresholding of the coefficients can be described by a transformation of the wavelet coefficients Transform matrix is a diagonal matrix with elements 0 or 1. Zero elements forces the corresponding coefficient below or equal to a given threshold to be set to zero while others corresponding to one, retains coefficients as unchanged.

Coefficients above threshold level are also modified where they are reduced by the threshold size. Donoho refers to soft thresholding as 'shrinkage' since it can be proven that reduction in coefficient amplitudes by soft thresholding, also results in a reduction of the signal level thus a ' shrinkage'.

IV. RESULTS AND DISCUSSION

This section discusses the results obtained after applying different denoising techniques. Figure 5 shows three different earth quake signals considered for analysis.

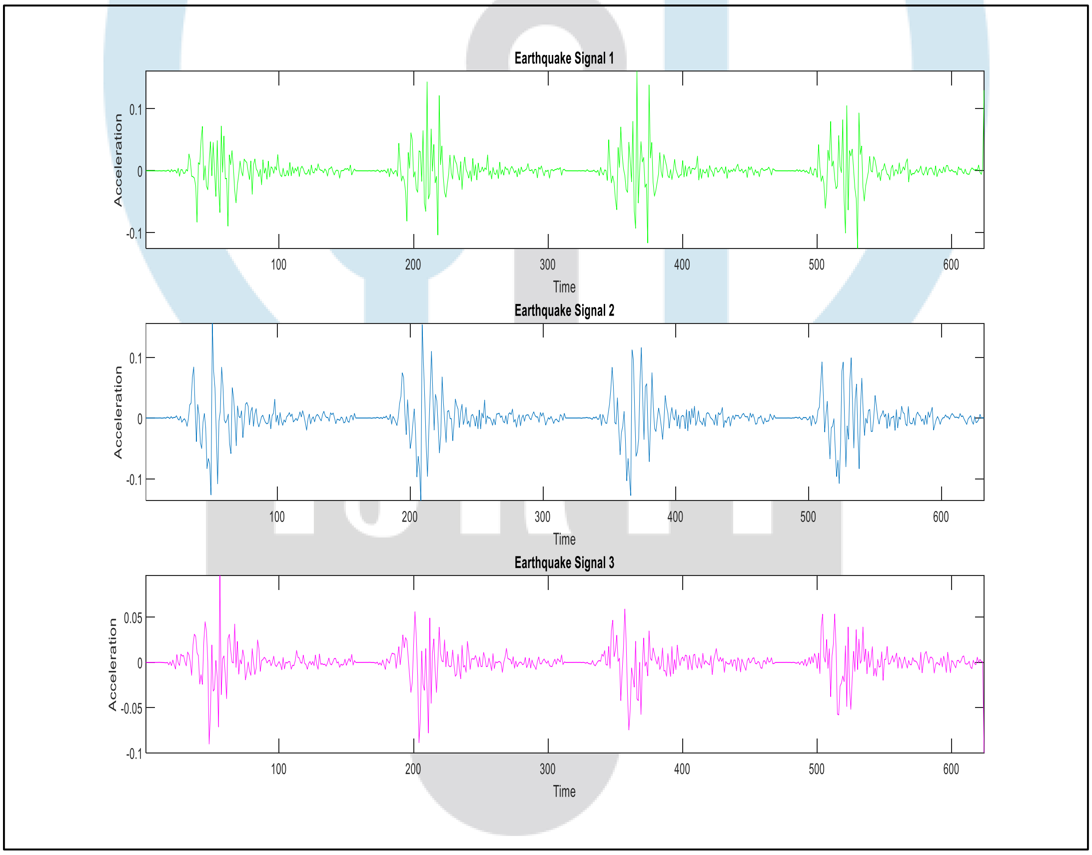

Figure 5 Earth quake signals

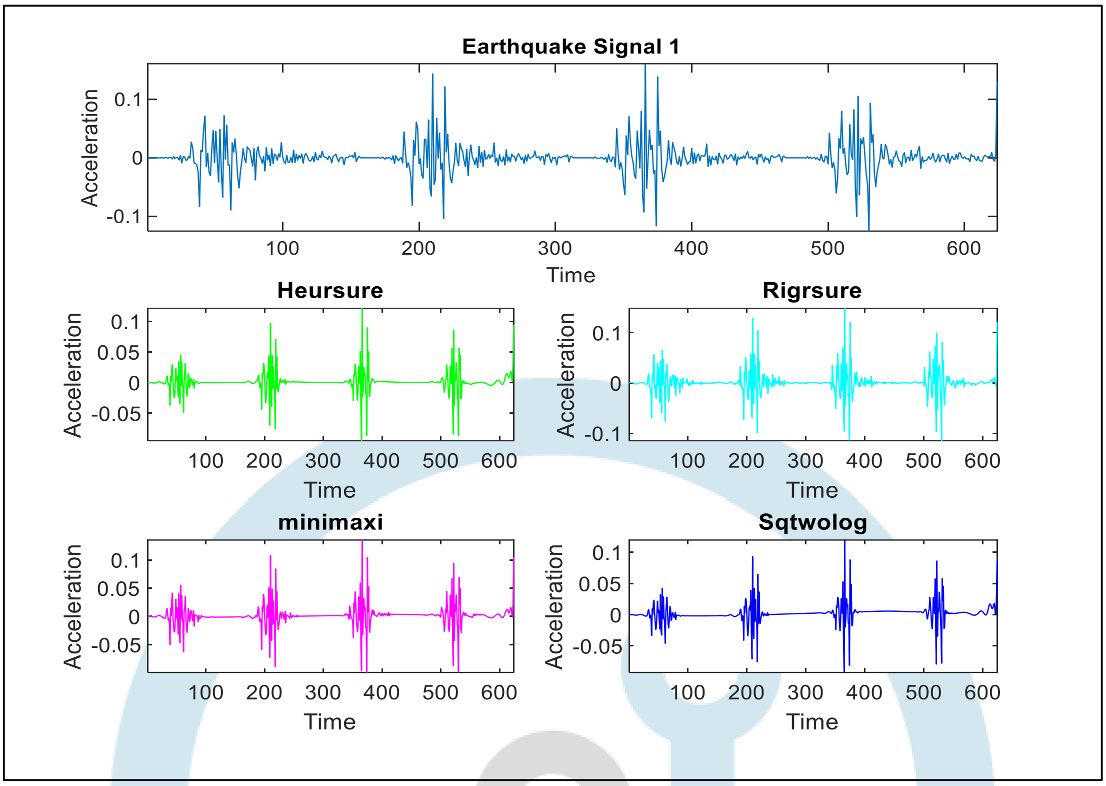

Figure 6 Earth quake signal 1

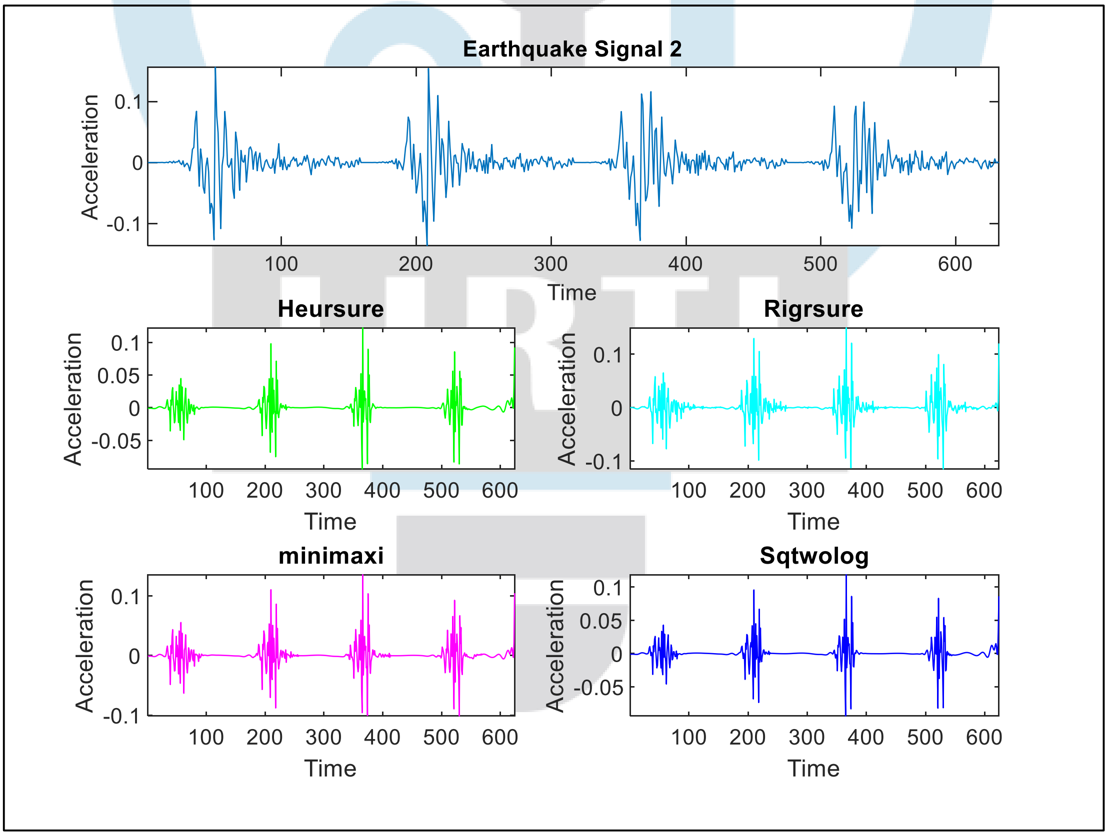

Figure 7 Earth quake signal 2

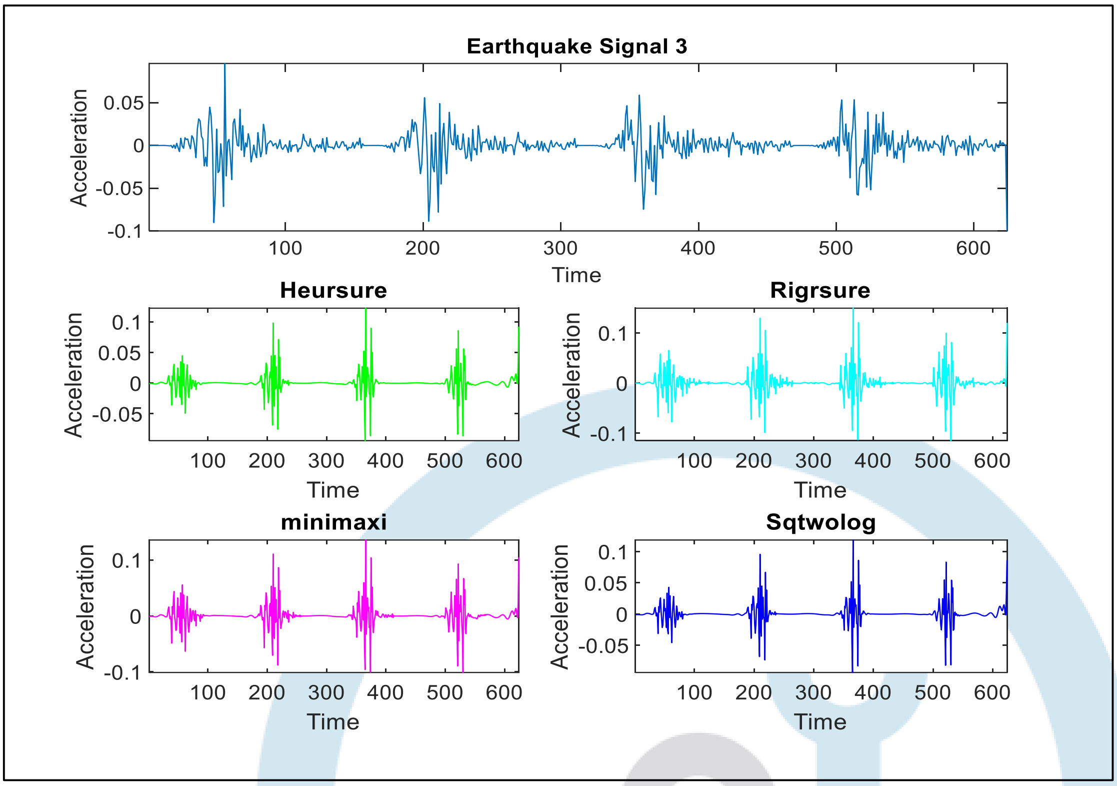

Figure 8 Earth quake signal 3

Three different types of Wavelet denoising techniques are applied to the input earth quake signals and the results are shown Figure. The Signal to Noise Ratio (SNR) can be calculated and the values are given in the Table 1.

Table 1 SNR using db1

Signal	Signal to Noise Ratio (SNR)			
	Method 1	Method 2	Method 3	Method 4
	Rigrsure	**Minimax**	**Heuristic**	**sqtwolog**
Decomposition level 1				
Earthquake signal 1	-11.5213	-11.6704	-11.6986	-10.0405
Earthquake signal 2	-11.3388	-11.5483	-9.0036	-10.2147
Earthquake signal 3	-9.5563	-8.8650	-8.7343	-8.4765
Decomposition level 2				
Earthquake signal 1	-11.9640	-12.4339	-12.6929	-8.9463
Earthquake signal 2	-8.9795	-7.5546	-8.6700	-5.9229
Earthquake signal 3	-8.9077	-7.6985	-6.7951	-3.8711
Decomposition level 3				
Earthquake signal 1	-11.9792	-12.3632	-12.3947	-2.0777
Earthquake signal 2	-10.1785	-9.2330	-8.5582	-4.0842
Earthquake signal 3	-8.8402	-7.5274	-6.5541	-3.4864
Decomposition level 4				
Earthquake signal 1	-11.9169	-12.2915	-12.3191	-1.2688
Earthquake signal 2	-12.4636	-12.0348	-12.1258	-2.7646
Earthquake signal 3	-9.9922	-6.7564	-5.7288	-2.0012
Decomposition level 5				
Earthquake signal 1	-11.9149	-12.0687	-12.0450	**8.2439**
Earthquake signal 2	-12.3609	-12.6052	-12.8275	**9.5401**

Earthquake signal 3	-11.5677	-10.6112	-8.7439	**9.3071**
Decomposition level 6				
Earthquake signal 1	-11.8897	-12.0027	-11.9601	**11.2080**
Earthquake signal 2	-12.3518	-12.5797	-12.8146	**9.4999**
Earthquake signal 3	-11.0162	-13.4592	-12.8425	**10.5623**
Decomposition level 7				
Earthquake signal 1	-11.9035	-11.9998	-11.9554	**1.4014**
Earthquake signal 2	-12.3661	-12.5884	-12.8225	**7.7810**
Earthquake signal 3	-11.7325	-13.4386	-12.8682	**9.1944**
Decomposition level 8				
Earthquake signal 1	-11.9024	-11.9949	-11.9500	-6.1988
Earthquake signal 2	-12.3718	-12.5784	-12.8149	-14.8551
Earthquake signal 3	-11.7070	-13.4514	-12.8886	-17.2365
Decomposition level 9				
Earthquake signal 1	-11.9025	-11.9952	-11.9502	-76.3349
Earthquake signal 2	-12.3621	-12.5771	-12.8125	-Inf
Earthquake signal 3	-11.6849	-13.4536	-12.8859	-76.3349
Decomposition level 10				
Earthquake signal 1	-11.9019	-11.9927	-11.9502	-7.3416
Earthquake signal 2	-12.3597	-12.5721	-12.8125	-7.6319
Earthquake signal 11	-11.6916	-13.4568	-12.8859	-7.4078

V. CONCLUSION

In this paper we had used wavelet transform for the removal of noise from the earthquake signal. Wavelet series is a representation of a square-integrable (real- or complex-valued) function by a certain orthonormal series generated by a wavelet. This article provides a formal, mathematical definition of an orthonormal wavelet and of the integral wavelet transform. While the Fourier transform creates a representation of the signal in the frequency domain, the wavelet transform creates a representation of the signal in both the time and frequency domain, thereby allowing efficient access of localized information about the signal. The key advantage of the Wavelet Transform compared to the Fourier Transform is the ability to extract both local spectral and temporal information.

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