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On Applications of Wavelets in Engineering and Technology

Dr. E. Jebamalar Leavline

Department of ECE, Anna University, BIT Campus, Tiruchirappalli, Tamilnadu, India

ABSTRACT:

Wavelet is an efficient mathematical tool that facilitates multiscale representation of signals or data. It is computationally efficient and suitable for reliable hardware implementation. It provides the time and frequency information simultaneously and hence the analysis of non-stationary signals becomes easier. Thanks to these advantages, wavelets and its variants find their applications in various fields of science, engineering and technology. This paper presents various applications of wavelets in the diverse field of engineering and technology.

Key words: *Wavelet transform, engineering applications, multi resolution, Fourier transform*

1. INTRODUCTION

Wavelets are a family of mathematical functions that posses certain distinct properties. A mathematical function that integrates to zero, well localized and satisfies admissibility condition can be called as a wavelet [1]. Originally the Fourier transform was found suitable for many applications in engineering. However, Fourier transform only gives the information about what frequency components exist in the signal. The time and frequency information cannot be seen at the same time. But, most of the real time signals are non-stationary and hence the Fourier transform (FT) fails to explore the time – frequency information simultaneously. Wavelet transform (WT) comfortably overcomes this issue. Similar to FT, the result of the WT are called as wavelet coefficients [2].

The continuous wavelet transform (CWT) is the sum over all time of the signal, multiplied by scaled and shifted versions of the wavelet function. For easier calculation the continuous signal can be discretized and as a result we have a grid of discrete values (Discrete wavelet transform) that is called dyadic grid. It is an important property of wavelets that the wavelet functions are compact (e.g. no over calculating). The DWT behaves like a filter bank and it can be implemented with efficient filter structures called subband coding. There are different wavelets for continuous wavelet transform such as Gaussian, Morlet and Mexican Hat wavelets. The DWT family includes Daubechies wavelets, Symlets, Coiflets, Biorthogonal spline wavelets, Complex wavelets and etc [1].

The multiresolution analysis (MRA) is another attractive feature of wavelet transform. MRA yields good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. This helps as most natural signals have low frequency content spread over long duration and high frequency content for

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short durations. Hence the wavelet transforms are very much suitable for solving real time engineering problems [3].

2. APPLICATIONS OF WAVELET TRANSFROM

This section discusses various applications of wavelet transform in the field of engineering, science and technology. The applications of wavelet transform cover areas that are beyond our imagination.

Signal processing

The role of wavelet transform is inevitable in signal, image and video processing. DWT is the basic building block used in the JPEG 2000 compression standard [4]. Wavelet transform is also used in speech signal processing and compression [5]. Wavelet shrinkage denoising is another important area of wavelet application. This concept has been extended to image [6, 7] and video denoising too [8]. Detection of discontinuities in signals, local minima, local maxima etc, can also be performed with wavelet transform.

Computer vision

Feature extraction plays a vital role in computer vision and image analysis. The features derived from wavelet coefficients are useful in pattern recognition and classification problems. In conventional and multi modal biometrics, wavelet features are used for facial, corneal and fingerprint recognition [9, 10]. Wavelet transform also offers dimensionality reduction in the feature space hence it is computationally efficient [11].

Communication Engineering

The perfect reconstruction property of wavelet transform makes it useful in communications to perform source and channel coding [12]. There is no loss due to transformation using wavelets. Thanks to the energy compaction property of wavelet, wavelet coefficients of the data can be transmitted over wireless channels in energy aware networks [13].

Biotechnology and bio informatics

Wavelets are useful for pattern analysis in biotechnology to distinguish the normal from the pathological membranes [14]. It has also been used to monitor cell concentration in bioprocesses [15] and DNA pattern analysis [16].

Biomedical engineering

Biomedical Engineering is another key area of application in which the analysis of bio signals such as EEG, ECG, EMG, etc is performed. Biomedical image processing and analysis, segmentation, and disease diagnosis can be carried out on many diagnostic modalities such as ultrasound, magnetic resonance imaging, X-ray etc [17, 18].

Data analysis

Wavelets have been used for biological data analysis such as gene selection [19], pattern recognition and classification. Seismic data processing [20] uses wavelets for the evaluation of earthquake-induced structural damages [21] and evaluation of hydrocarbon reservoirs [22] such as oil and coal bed.

Management

Most of the business data are collected as time series data. Wavelets are able to efficiently analyze and predict time series data. Due to this fact, wavelets are widely used in management for business cycle analysis, economic data analysis and forecasting. In financial management, wavelets act as a tool to explore the variation of stock prices and trend detection [23, 24, 25].

Electrical engineering

It is another major application area of wavelets. Detecting monthly stratigraphic discontinuities of wind speed data is essential in modern wind power systems [26]. Wavelets are employed to classification of power quality disturbances, power system faults and transients [27]. Signal denoising in electric drive applications [28] and Fault identification in transmission lines by analyzing three phase currents at different locations are the classic applications in electrical engineering [29]. Detection of partial discharge (PD) as a symptom of insulation breakdown in high voltage (HV) applications is also possible [30].

Instrumentation & Control

Nondestructive evaluation / testing in the back bone of system design and instrumentation such as ultrasonic data analysis for nuclear power plant pipe inspections and fault diagnosis [31]. In control engineering wavelet processing can be incorporated in supervisory loops for parameter estimation and System identification [32].

Transportation

Some researchers have reported the application of wavelets even in transportation engineering for better interpretation of traffic simulation that may lead to effective traffic management [33].

Civil engineering

Even the civil engineering field is not an exception. Some applications of wavelets in civil engineering include structural monitoring and damage detection in beams [34] using edge detection techniques, characterization of intra-seasonal oscillations in environmental parameters such as sea surface temperature, wind stress, and sea level, analysis of geo-topographic data for reconnaissance / object identification [35].

Astronomy

Multiresolution property of wavelets is useful to study the distant universes as the galaxies form hierarchical structures at different scales [36].

Wavelet Networks

Wavelet transform employed as a basic computing element in a network structure is termed as wavelet network similar to neural networks as shown in Figure 1. It facilitates real time learning of unknown functions and learning from sparse data [37].

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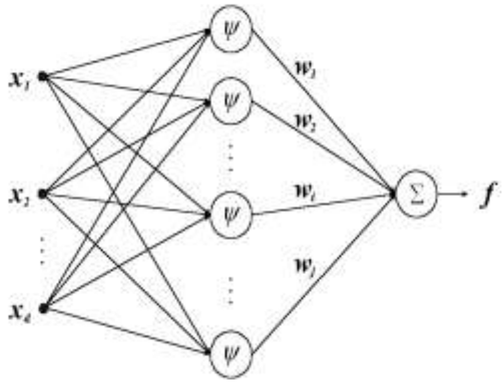

Figure 1: Wavelet neural network

Fractal analysis

Fractals are self similar patterns. Fractal analysis is a contemporary method that makes use of nontraditional mathematics to patterns that hold up understanding with traditional Euclidean concepts. Daubechies wavelets perfectly fit for analyzing fractals. Many fractal structures have been identified in nature [38, 39].

3. CONCLUSION

Wavelet has been an efficient computational tool to represent and model real world problems as it explores time – frequency information simultaneously. This paper presented a summary of some of the applications of wavelets in various fields like science, engineering, technology and management.

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