Discrete Wavelet Transform

Although the Fourier transform has been the mainstay of transform-based digital signal processing since time immemorial, a more recent transformation, called the *wavelet transform*, is making strides in DSP applications following some of its unique advantages.

Wavelets have their energy concentrated in time. Sinusoids (Fourier Transform) are useful in analyzing periodic and time-invariant phenomena, while wavelets are well suited for the analysis of transient, time-varying signals. Since most of the real-life signals encountered are time varying in nature, the Wavelet Transform suits very well for many applications.

Wavelets in Audio

DWT can be used to analyze temporal and spectral properties of non-stationary signals such as audio. Unlike the Fourier transform, whose basic functions are sinusoids, wavelet transforms are based on small waves, called wavelets, of varying frequency and limited duration. That reveals not only what notes (or frequencies) to play but also when to play them. Conventional Fourier transforms, on the other hand, provide only the notes or frequency information; temporal information is lost in transformation process.

Some of audio applications where DWT could offer considerable improvement are extraction of beat attributes from music signals and automatic classification of non-speech audio signal using statistical pattern recognition. Shrinking of transform coefficients towards zero in wavelet domain is one of the wavelet techniques, which offers advantage of removal of noise in wide variety of signal types while preserving non-smooth features.

Wavelets in Video

Wavelet basis functions are obtained from single wavelet by transformation and scaling of mother wavelets. Also, multi-resolution concept, satisfied by almost all useful wavelet functions, makes it very useful in analyzing “real world” signals.

Multi-resolution theory is concerned with the representation and analysis of signals at more than one resolution. The multi-resolution of videos has an advantage of scalability. i.e. possibility to transmit the same sequence at different resolution as high-resolution television, videophone and videoconferencing. DWT offers better approximation at half the width and half as wide translation steps. This is conceptually similar to improving frequency resolution by doubling the number of harmonics in Fourier series expansion.

While DCT-based image coders like JPEG perform very well at moderate bit rates, at low bit rates the image quality degrades rapidly because of the blocking artifacts introduced by the block based DCT transform. JPEG-2000 is an emerging standard in image processing that uses DWT to achieve far superior image quality at very low bit rates because of overlapping basis functions and better energy compaction property of wavelet transformation.

Wavelets in Wireless applications

The analysis, design and measurement of antennas have been extremely important in the development and success of wireless communication and applications. Unfortunately mathematical simulations of antenna are extremely complex and require extensive computation and large amount of memory. Use of wavelets in conjunction with other techniques in the numerical methods involved in solving the current distribution on the antenna offers many advantages. The use of wavelets in such simulations propose reduction in computation, aids in reducing errors as well as enables us to get closer to the true values of such computation.

With the recent developments in wireless communication technologies, video streaming and the image compression techniques are very important for wireless application to transmit multimedia content over wireless channels. As wireless channels are very noisy and have narrow bandwidth, higher compression is required for both image and video signals, use of wavelet transform as image compression technique in wireless applications could be a good choice because of its advantage of providing better compression at higher bit rates.

Wavelets in Neural Networks

Neural Networks (NN) have emerged as a powerful tool for data mining applications due to their ability to learn patterns and relationships in complex, multi-dimensional data sets.

The effectiveness of any NN-based solution is largely dependent on a range of factors such as scalability of the network, generalization capability, dimensionality of the parameter space and host of other factors and often restrict the effectiveness of the NN. As such, any methods, which are able to increase the quality or accessibility of the input data, will be invaluable. It is here that wavelets are likely to be extremely useful. NN's are useful in conjunction with wavelets, with the latter serving as a preprocessing tool that transforms hidden patterns into a more recognizable form suitable for use as a training set.