Journal of Computer and Electronics Studies, Volume 1, ISSN: 2664-0309

Research on Wavelet Analysis and Its Application in Image Processing

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Keywords: Wavelet Analysis, Application, Image Processing

Abstract. Wavelet transform is a new type of mathematical tool, is the late 80s developed rapidly emerging disciplines. Wavelet transform has the characteristics of multi-resolution, in the time domain and frequency domain has the ability to characterize the local characteristics of the signal, suitable for analysis of non-stationary signal, you can gradually observe the signal by the coarse and fine. The theory and method of wavelet analysis are widely used in signal processing, image processing, speech processing, pattern recognition, quantum physics and so on. It is considered a major breakthrough in tools and methods in recent years.

Introduction

In recent years, wavelet transform as a means of signal processing, and gradually aroused the attention of various fields of research and attention, has become a new branch of mathematics. The traditional Fourier transform belongs to a pure frequency domain analysis method which reflects the whole frequency domain feature of the whole signal time, and cannot provide any local time period on the frequency information, that is, no time domain resolution. The wavelet transform has the ability to characterize the local characteristics of the signal in time domain. Wavelet analysis based on wavelet transform can use any variable window which can be scaled and translated to focus on any detail of the signal. Signal of the whole picture, but also to analyze the details of the signal, and can retain the instantaneous characteristics of the data. Therefore, wavelet analysis has a very wide application prospect in signal and image processing, pattern speech recognition, seismic survey, machine vision, medical imaging, fluid mechanics, fractal, mechanical fault diagnosis and civil structure damage detection.

The wavelet analysis method is a time-frequency localization method which can be changed by window size (ie window area) but whose shape can change, time window and frequency window can be changed. It is widely used in signal analysis, image processing, military electronic confrontation and Weapon intelligence, computer classification and recognition, language synthesis, medical imaging and diagnosis, fault diagnosis, etc. Image is a kind of spatial information with information richness, but the image data is large, Image processing applications include image compression, transmission, noise cancellation, classification, identification and diagnosis, decontamination and so on.

The Basic Concept of Wavelet Analysis

The wavelet analysis method is a time-frequency localized analysis method in which the window size (i.e., window area) is fixed but its shape is variable, and the time window and the frequency window can be changed, that is, the higher frequency resolution and the lower frequency of the time resolution, in the high frequency part has a higher time resolution and lower frequency resolution. It is this characteristic that makes wavelet analysis adaptive to the signal.

Wavelet analysis is seen as a harmonic analysis of this mathematical field for half a century since the work of crystallization has been and will be widely used in signal processing, image processing, quantum field theory, seismic exploration, speech synthesis and recognition, music, radar, CT Imaging, color copying, fluid turbulence, celestial recognition, machine vision, mechanical fault diagnosis and monitoring, fractal and digital television and other fields. In principle, the traditional use of Fourier analysis can be replaced by wavelet analysis. Wavelet analysis is superior to Fourier analysis where it has good localized properties both in the time domain and in the frequency domain.

In the signal analysis, we basically characterize the signal, often taking two basic forms, namely, the time domain form and the frequency domain form. "In this way, we face the following contradiction in the signal analysis: the local domain and the frequency domain localization contradiction, namely if we want to get accurate enough information in the time domain, we cannot get the information in the frequency domain, and vice versa.

In many practical problems, we are concerned with the characteristics of the signal in the local range, that is, the time domain and frequency domain can be combined to describe the observed signal time-frequency joint characteristics, which requires the so-called time-frequency analysis, Also known as time-frequency localization method "time-frequency localization is to find a signal representation method, it can provide the whole signal of the whole information but also in any part of the time to provide information on the degree of intense changes in the information.

In the practical application of signal analysis requirements are: high-frequency part of the signal corresponding to the fast-changing components in the time domain, such as steep front, trailing edge, sharp pulse, analysis of time domain resolution requirements, frequency domain resolution Rate is low the low frequency components of the signal correspond to the slow component in the time domain. The analysis requires low resolution in the time domain and high resolution in the frequency domain. Continuous aperture function window has a "zoom" characteristic: when a becomes smaller, the time domain observation range narrows, but the frequency observation range is widened, and the observed center frequency moves to the high frequency; when a becomes large, time domain observation The range is widened, the observation range in the frequency domain is narrowed, and the center frequency of the analysis moves to the low frequency.

Where b only affects the position of the window on the time axis on the phase plane, and a not only affects the position of the window on the frequency axis but also the shape of the window. This wavelet analysis is a step-by-step sampling step for different frequencies in the time domain: the time resolution of the wavelet analysis is poor at low frequencies and the frequency resolution is higher. At high frequencies, the time resolution of wavelet analysis is high and the frequency resolution is low, which is in line with the slow change of low frequency signal and the rapid change of high frequency signal. This is where wavelet analysis is superior to classical Fourier analysis and short-term Fourier analysis. In general, wavelet analysis has better time-frequency window characteristics than short-time Fourier analysis. Second, the commonly used wavelet function Compared with the standard Fourier analysis, the wavelet function applied in the wavelet analysis is not unique, that is, the wavelet function ψ (x) is diversity. However, a very important problem in the application of wavelet analysis is the selection of the optimal wavelet basis, because the same problem with different wavelet bases will produce different results. In the face of a specific application, We choose to compare the orthogonality, symmetry, regularity, compact support and vanishing moments of the basics of each wavelet, and pay attention to the specific application environment. At present, the results of wavelet processing are mainly used to determine the good or bad wavelet basis, and thus select the wavelet basis.

In general, the symmetry and orthogonality of the wavelet basis are incompatible, for example, the DAUBECHIES wavelet with orthogonality does not have symmetry. Regularity is a description of the degree of smoothness of the function and is a measure of the energy of the function domain. We mean that the wavelet is a compact function f (x), which means that the range of the value of x that makes the function f (x) not equal to zero is limited, and the smaller the range, the shorter the length of the wavelet support Set the more tight. k-order vanishing moment refers to the m_k that makes the above formula zero. The actual effect of vanishing moments is that the signal energy is relatively concentrated in a few wavelet coefficients, and the wavelet vanishing moments are closely related to the length of the wavelet support.

The Multi-Resolution Analysis

Meyer creatively constructed a smooth function with some attenuation in 1986, and its binary expansion and translation constitute the normalized orthogonal basis of 2L (R), so that the wavelet can be real development. In 1988, S.Mallat proposed the concept of multi-resolution analysis (MRA) in constructing orthogonal wavelet bases. The multiresolution characteristics of wavelet were statistically described from the concept of space, and all the previous orthogonal The construction method of wavelet wavelet is given, and the construction method of orthogonal wavelet and the fast algorithm of orthogonal wavelet analysis are given, namely Mallat algorithm. The position of Mallat algorithm in wavelet analysis is similar to that of fast Fourier analysis in classical Fourier analysis.

Multi-resolution analysis is only one step decomposition of the low-frequency part, while the high-frequency part is not considered another emphasis, here is only a layer decomposition to explain, if further decomposition, you can split the low-frequency part of the low-frequency part of 4A And high frequency part 4D, the following decomposition is analogy available. In the multiresolution analysis, the ultimate goal of decomposition is to construct a quadrature wavelet basis that is highly approximated to 2L (R) space in frequency. These orthogonal wavelet bases with different frequency resolution are equivalent to band-pass filters with different bandwidths. From the above multi-resolution analysis tree structure can be seen, multi-resolution analysis only low-frequency space for further decomposition, making the frequency resolution becomes higher and higher.

The Application of Wavelet Analysis in Image Processing

The application of wavelet analysis in image processing is mainly embodied in the following aspects: image compression, image denoising, image enhancement, image smoothing and image fusion.

Image Compression. Image data often has redundancy of various information such as spatial redundancy, information entropy redundancy, visual redundancy and structural redundancy. If fast or real-time transmission and mass storage are required, the image data Compression and transmission can transfer more image information, which can improve the communication ability. Wavelet analysis for image compression with high compression ratio, compression speed, compressed to maintain the characteristics of the image is basically the same characteristics, and in the delivery process can be anti-dry worry.

Wavelet analysis of the basic principles of image compression is: according to the two-dimensional wavelet decomposition algorithm, an image for wavelet decomposition, you can get a series of different resolution images, and the performance of an image of the most important part of the low-frequency part, if removed The high frequency part of the image and only keep the low frequency part, you can achieve the purpose of image compression.

Image Denoising. In the process of being collected, transmitted and restored, the image is inevitably polluted by noise. Using wavelet technology to effectively perform the image denoising process, the steps are as follows: ¹ Wavelet decomposition of the image signal. Select a wavelet and wavelet decomposition Level N, and then calculate the decomposition of signal s to the Nth layer. Threshold quantization of the high frequency coefficients For each layer from 1 to N, a threshold is selected and the high frequency coefficients of this layer are subjected to soft threshold quantization The reconstruction of the two-dimensional wavelet is performed, and the wavelet reconstruction of the image signal is calculated based on the low frequency coefficients of the Nth floor of the wavelet decomposition and the modified high frequency coefficients from the first to N layers.

The result of two de-noising of the wheel image containing the Gaussian noise is analyzed by the two-dimensional wavelet analysis technique. It can be seen from the above output that the first image denoising has filtered out most of the high frequency noise, but Noise reduction image and the original image can be seen compared to the first image after the noise reduction still contains a lot of high-frequency noise; the second noise reduction is based on the first noise reduction, filter again of the high-frequency noise, the results can be seen from the noise reduction, it has a better noise reduction effect

Image Enhancement. Wavelet transform breaks an image into components of different sizes, positions, and directions that can change the size of certain coefficients in the wavelet transform domain before doing inverse transforms so that the components of interest can be selectively amplified and attenuated The image contour is mainly reflected in the low frequency part, and the details of the part is reflected in the high frequency part. Wavelet transform splits an image into components whose size, position, and direction are not the same. Before performing the inverse transformation, the size of the coefficients can be changed for different components in different positions and in different directions as needed, so that some of the components of interest are amplified to reduce some unnecessary components.

Image Fusion. Image fusion is the synthesis of two or more images of the same object in a pair of images so that it is easier for people to understand than any of the original images. Image fusion is to register the image data of the same object with different sources, and then use a certain algorithm to combine the information superiority or complementarity contained in each image data to rescue the new image data of water and fire. It can reduce or suppress the ambiguity, imperfectness, uncertainty and error that may be present in the perceived or environmental interpretation, and maximize the use of information provided by various sources of information.

Conclusion

This paper mainly introduces the basic principle of wavelet analysis and its application in image processing. Wavelet transform overcomes the shortcomings of traditional methods. Because wavelet transform has a "centralized" ability, the energy of a signal can be concentrated on a few coefficients in the wavelet transform domain. At the same time, the digital image can be processed in the wavelet domain at the same time. The inverse discrete wavelet transform is performed to recover the processed image. So that the image processing to achieve better results. The experimental results show that wavelet transform has the ideal effect and high engineering value in image processing.

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