Study on Technique of Wavelet Denoising and Its Application in Seafloor Sediments Acoustic Detection

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Abstract. It is introduced in this paper the principle of wavelet de-noising, wavelet base, the choice of wavelet decomposition level, the wavelet threshold selection for signal de-noising effect is analyzed. Matlab software for simulation study is made on the wavelet noise reduction; In the seabed sediment acoustics parameters test and analysis of the seabed sediment, the ultrasonic test signal wavelet noise is reduced, and the noise reduction signal is analyzed in time domain and frequency domain, it is shown that the wavelet noise reduction can retain the signal characteristic information in each frequency band, and not cause distortion in the time domain.

Introduction

Seabed sediment identification is the foundation of marine scientific research, and it is one of the important indicators. Seafloor sediment characteristics is the important research content of marine geology , fisheries, submarines and underwater communications; The study of the seabed sediment acoustic features is to improve the offshore resource utilization levels and deep strategic resource reserves, and it is the key technology of developing undersea solid mineral resources [1]. The main means of present study on seabed sediment is the ultrasonic testing, the main parameters are sound velocity and acoustic attenuation.

In ultrasonic testing, the interference of noise on the signal is very large, so it is need to do noise reduction processing after the acquisition of signal to suppress the actual measurement noise and environmental noise and reduce the interference. Ultrasonic signals are often non-stationary signal, the useful signals are often characterized by low frequency signal, noise signal is characterized by high frequency signal [1]. But in non-stationary signal, the high frequency part usually contains the useful information needed to get in the process of testing, therefore, for non-stationary signal noise reduction processing, it is not only to eliminate noise amount of high frequency performance, but also to remain the high frequency content to reflect the important features of signals. Using traditional methods (such as Fourier transform) can not meet the requirements of non-stationary signal noise reduction processing, because it can't distinguish useful amount of high frequency and the amount of useless high frequency which belongs to noise, it also can't give how does the signal frequency domain change in a local time or time point.

Whereas the wavelet transform especially orthogonal wavelet transform has a strong elimination of data correlation, it makes the energy of useful signals concentrated in some large wavelet coefficients in high frequency parts, and the noise energy is distributed in the whole spectrum, and the variance and amplitude of noise will reduce gradually with the increase of wavelet transform scales, whereas the variances and the amplitude of the useful signal increases with the increase of wavelet transform scales instead. Therefore, after wavelet transform, the wavelet coefficient amplitude of the signal is greater than the noise coefficient amplitude, we can do de-noise processing according to the

different wavelet transform characteristics of the noise and the signal [2]. In this paper, we study the wavelet noise reduction technology in the application of sediment acoustic characteristics.

Selection of Mother Wavelet and Decomposition Layers

One key technology is the selection of the mother wavelet and the number of decomposition layers for the ultrasonic signal wavelet denoising process.

(1) Selection of mother wavelet

In ultrasonic testing, generally useful signals display mainly through the mutation part, so in order to get the correct testing information, when choosing the mother wavelet, it must be compact support in time domain, in fact the wavelet is not compact support in fact, then the attenuation speed must be fast. In addition to ensure the mother wavelet has local analysis ability in the frequency domain, it is needed that the mother wavelet has the rapid decay in frequency domain. Through analysis, to meet the ultrasonic echo signal wavelet noise reduction of the mother wavelet has three types: Symlets wavelet family, Coiflets wavelet family and Biorthogonal wavelet family. In addition, although the Daubechies wavelet family is not symmetrical or approximate symmetry, but Daubechies wavelet family has orthogonal time-frequency compactly supported, and high normality characteristics, and it is sensitive to the non-stationary signal, so Daubechies wavelet is suitable for wavelet noise reduction for ultrasonic echo signal. Based on the above analysis, we can draw the conclusion that in common several wavelet family, Daubechies wavelet family, Symlets wavelet family, Coiflets wavelet family and Biorthogonal wavelet family are suitable for ultrasonic signal analysis of wavelet. Next we will use these four kinds of wavelet to carry out denoising experiment to choose the optimum wavelet basis.

(2) Selection of the number of decomposition layers

Decomposition layers have obvious influence on the noise reduction effect. Studies have shown that with the increase of decomposition layers, the signal to noise ratio (SNR) increases firstly then decrease after noise reduction, when decomposition layers is selected as 3, 4, SNR is basically greater than that when choosing other decomposition layers, and the maximum SNR after noise reduction of each wavelet family appear when the decomposition layers is four. This is because that the decomposition layers is too little, the extraction of noise is not so full, which lead to poor performance of noise reduction. Decomposition layers are too much, which will cause the signal information to loss seriously, the purpose of noise reduction is still not achieve [7]. Generally, 4-5 layers are chosen.

Simulation Analysis

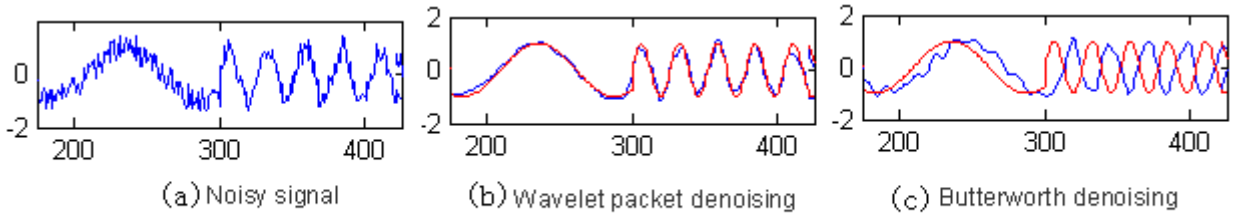

Fig. 1 Comparison chart of two kinds noise reduction effect

Digital simulation is a useful means to test the denoising effect of wavelet packet. Fig. 1a) illustrates the pure sine signal added with white noise. Fig. 1b) (the pure signal is also presented in the figure for comparison purpose) is the simulation of the signal denoised by selecting db4 wavelet basis and 3 decomposition layers. As shown in Fig. 1b), Fig. 1c) shows the waveform denoised using Butterworth low-pass filter (see the program for filtering parameters). It can be observed from the figure that after denoising, the low-frequency signal experiences not only partial waveform distortion but also waveform mismatch with the original signal.It is evident from the comparison of the wavelet packet denoising and traditional denoising methods that the former has better denoising effect.

The Application Example

With DB4 type multifunctional acoustic instrument to measure the seabed sediment samples. Planar sensor receiver receive sound waves from samples of ultrasonic transmission , after A/D conversion, the data acquisition card collect the data in designed sampling frequency to the computer. According to the ultrasonic propagation theory, the sound waves will scatter in the sediment particle interface and refract in solid-liquid interface, which will cause waveform transformation to produce noise. The amplitude of noise increases with the increase of particle size. The noise overlap in the received wave collected by the sensor to make the waveform being distorted. Fig.2 shows the ultrasonic waveform of the sediments when testing the Northern Gulf of the south China sea, Fig.3 shows the spectrum waveform by Fourier transform.

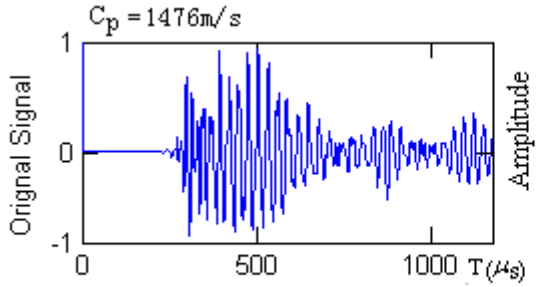

Fig.2 Receiving ultrasonic time-domain waveform

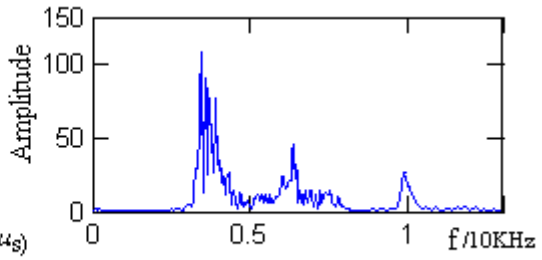

Fig.3 Spectrum of receiving ultrasonic wave

From the time domain waveform shown in Fig.2 and spectrum diagram shown in Fig.3, the collected signal contains noise, the noise reduction process is the precondition of signal analysis and processing. Traditional noise reduction method is to use low pass or band pass filter, due to the short time low energy transient signal after smoothing filter in the case of low SNR, not only the SNR can't be improved, buit also the location of the signal is fuzzy, which will cause the difficulty of the eigenvalue extraction. This paper uses the soft threshold wavelet transform method to do noise reduction, its characteristic is that using different scale and different threshold, and the threshold is associated with the corresponding signal variance, and it has the function of adaptive for noise reduction of the white noise, as well as the amount of calculation is small. [7]. Fig.4 (a) shows the time domain signals after traditional Butterworth denoising, Fig.4 (b) is the spectrum after noise reduction; Fig.4 shows the time domain waveform after wavelet noise reduction,Fig.5 (a) shows the signal after wavelet threshold de-noising, Fig.5 (a) shows the spectrum graph.

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Contrast Fig.4 and Fig.5, we can see that the signal after wavelet threshold denoising processing, the time domain waveform is closer to the original signal, while the signal after Butterworth de-noise way filter the high frequency part of the signal. After the Fourier transform of denoising signal, the corresponding spectrum is shown in Fig.4 (b) and Fig.5 (b). It can be seen from the spectrum diagram that after wavelet noise reduction, the spectrum in the whole frequency shaft reserve spectrum

information, while after Butterworth denoising, the information of high frequency part of the spectrum is basically eliminated.

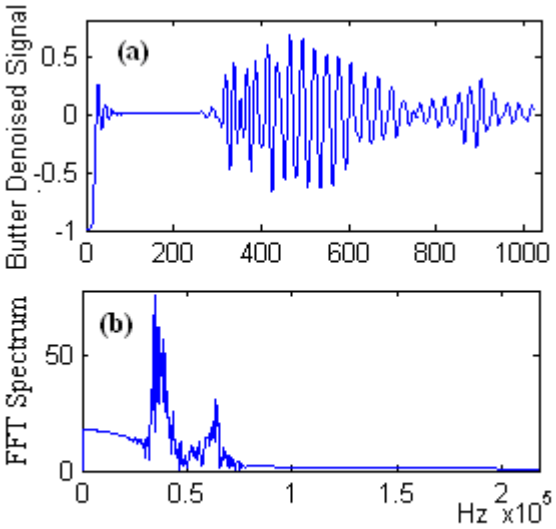

Fig.4 (a) Butterworth denoised signal
(b) The spectrum of its spectrum

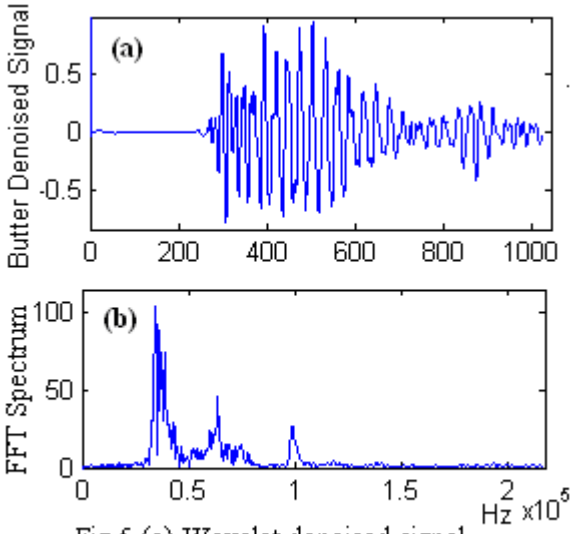

Fig.5 (a) Wavelet denoised signal
(b) The spectrum of its spectrum

Conclusions

This paper is based on signal processing theory and the characteristic of the ultrasonic signals, analyzed the wavelet base selection method suited for the ultrasonic signal to do wavelet processing, studies have shown that Daubechies wavelet, Symlets wavelet, Coiflets wavelet and Biorthogonal wavelet are suitable for ultrasonic signal analysis, the decomposition levels are 4-5 layers advisable, the selection of wavelet threshold method is also analyzed. Through the seabed sediment acoustics parameters detection example, it is proved that the soft threshold wavelet transform denoising method has good performance, and it can retain the signal characteristic information in various frequency bands without position distortion.

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