The Application of Multi-Wavelet Theory in Deformation Monitoring Data Processing

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ABSTRACT:

With wavelet technology used more widely in deformation analysis, the paper will talk multi-wavelet (the second generation wavelet) theory used for deformation monitoring data analysis. The paper studies signal adopting different preprocessing method, makes a study of the selection problem in optima multi-wavelet preprocessing method. The deformation monitoring signal is disposed using different multi-wavelet which adopts optima preprocessing method, and the paper makes a comparison to the conventional odd wavelet. The result confirms: multi-wavelet is more superiority than conventional wavelet, which decreases RMSE, advances SNR, obtains higher analytic precision, conforms the validity and practicability in physical problem, and offers a new road for deformation monitoring signal process.

1. INTRODUCTION

Multi-wavelet is in last few years the wavelet analysis theory on the basis of the development of a new wavelet construction theory. In signal processing, wavelet base is symmetry, short support, high order vanishing moments on processing results are often crucial. But the traditional single wavelet do not have this property, which limits the application of wavelet. Multi wavelet has these properties, it has maintained a single wavelet has good time and frequency localization characteristic, but also overcomes the defects of single wavelet, the practical application is very important in the smooth, tight support, symmetry, orthogonality of perfect together.

1.1 Multi-wavelet theory

Multi-wavelet and multire-solution analysis: In wavelet analysis, a multiresolution analysis is performed by a scaling function generation, by a wavelet function and the telescopic space base. S.Mallat establishment of multi resolution analysis in discrete form of the establishment of the wavelet decomposition and reconstruction algorithms, is a practical wavelet analysis tool. Accordingly, if a multiresolution analysis is composed of multiple scaling function is generated, composed of a plurality of wavelet function and the telescopic space base, the wavelet function is referred to as multiple wavelet. The space formed by multiple wavelets in space, space is a closed subspace sequence called heavy multiresolution analysis, it satisfies the following conditions:

1) monotony

$$\cdots \subset V_{-1} \subset V_0 \subset V_1 \cdots$$

2) approximation

$$\bigcap_{j\in z} V_j = \{0\}; \overline{\bigcup_{j\in z} V_j} = L^2(R)^r$$

3) flexible

$$f(t) \in V_j \Leftrightarrow f(2t) \in V_{j+1}$$

4) translational invariance

$$f(t) \in V_j \Rightarrow f(t-k) \in V_j, \forall k \in z$$

1.2 Wavelet transform pre-processing

Compared with the traditional wavelet transform, wavelet in practical application, the key problem that must be solved to the original signal pretreatment. Due to multiple wavelet scale function and wavelet function is multidimensional, need to handle signals in general is one-dimensional, the need for all multiple wavelet of the original signal pretreatment. On wavelet pretreatment method of the research at present is mainly divided into two categories: pre filtering method (prefilter) and uses the balanced multiwavelet (balanced multiwavelet) method.

Prefiltering method: Pre filter design method has a lot, no matter on what basis selection, all wish to maintain signal wavelet lowpass and highpass characteristics. The GHM wavelet exemple, discuss several pre filter design method

(1) GHM.init method
Assuming continuous function belongs to GHM wavelet scale function by translational space is generated, then type set:

$$f(t) = \sum_n C_{1,n}^{(0)} \phi_1(t-n) + C_{2,n}^{(0)} \phi_2(t-n) \quad (1)$$

The following sample

$$f[2n] = f(n), f[2n+1] = f(n+1/2) \quad (2)$$

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$$f\left[2n\right]=\phi_2(1)C_{2,n-1}^{(0)} \tag{3}$$

$$f\left[2n+1\right]=\phi_2(3/2)C_{2,n-1}^{(0)}+\phi_2(1/2)C_{1,n}^{(0)}+\phi_2(3/2)C_{2,n}^{(0)} \tag{4}$$

$C_{1,n}^{(0)}$, $C_{2,n}^{(0)}$ The type is

$$C_{1,n}^{(0)}=\frac{\phi_2(1)\,f[2n+1]-\phi_2(1/2)\,f[2n+2]-\phi_2(3/2)\,f[2n]}{\phi_2(1)\phi_1(1/2)} \tag{5}$$

$$C_{2,n}^{(0)}=\frac{f[2n+2]}{\phi_2(1)} \tag{6}$$

(2) Haar method

$$C_{1,n}^{(0)}=\frac{1}{\sqrt{2}}(f\left[2n\right]+f\left[2n-1\right])$$

$$C_{2,n}^{(0)}=\frac{1}{\sqrt{2}}(f\left[2n\right]-f\left[2n-1\right]) \tag{7}$$

$$Q(\omega)=\begin{bmatrix}\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}}\\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}}\end{bmatrix} \tag{8}$$

2. BASED ON MULTIWAVELET DE-NOISING PRINCIPLE

Multi wavelet transform and the traditional wavelet denoising principle is the same, namely in the multi wavelet decomposition coefficients based on a priori knowledge, according to the noise, set the soft threshold processing multiwavelet coefficients, and noise corresponding to multiple wavelet transform coefficients to zero, then the use of wavelet reconstruction algorithm of signal reconstruction. Compared with traditional wavelet denoising, wavelet can be simultaneously with the symmetry, orthogonality, short support, high order vanishing moments. So based on multi wavelet transform not only retain the integrity of traditional wavelet denoising of advantages, but also more flexible and more practical features.

The current multi wavelet denoising methods generally use the traditional wavelet denoising methods;

Through appropriate pretreatment method and wavelet decomposition algorithm to obtain the wavelet high frequency coefficient;

The use of soft threshold processing high frequency coefficient, for the original signal sampling, noise variance estimation;

Using multiple wavelet reconstruction algorithm and the corresponding treatment method of signal reconstruction.

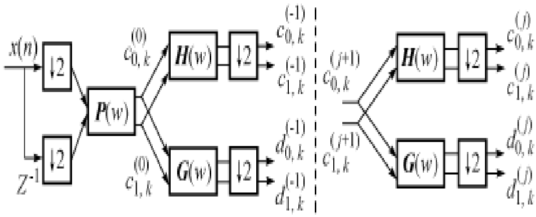


Figure 1. Sketch map of wavelet preconditioning and decomposition

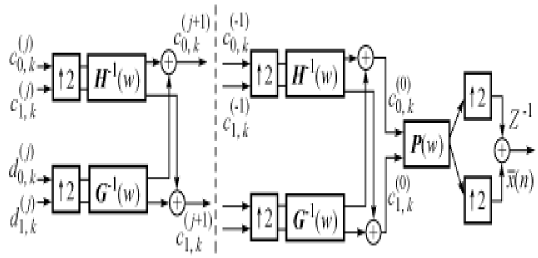
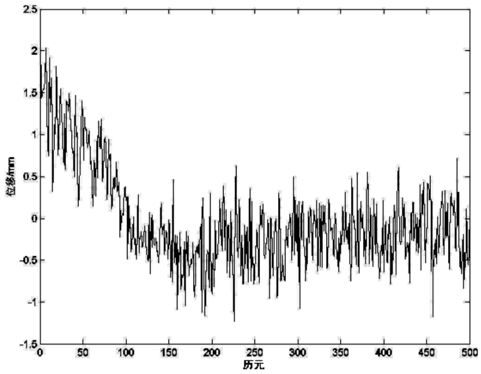


Figure 2. Sketch map of wavelet reconstruction and after filting

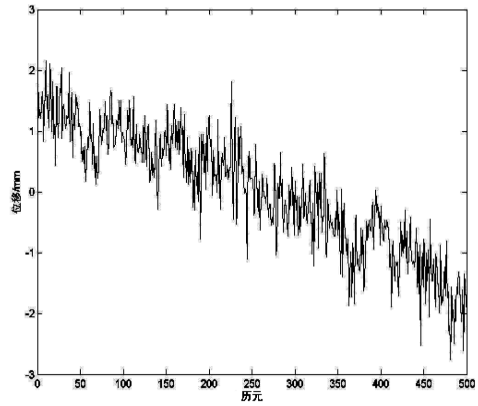
3. WAVELET IN GPS DYNAMIC MONITORING DATA PROCESSING APPLICATIONS

The use of GPS positioning technology for deformation monitoring, geographical environment and vegetation, and usually environment GPS observation is significantly different. Tell from whole, observation conditions is usually poor, relates to the error sources have more often very narrow, field of view, large number of occultation, may produce significant interference signals and effects of GPS observation quality. Therefore, further weakening and separation of jamming signal, will help to improve the accuracy of GPS deformation observation.

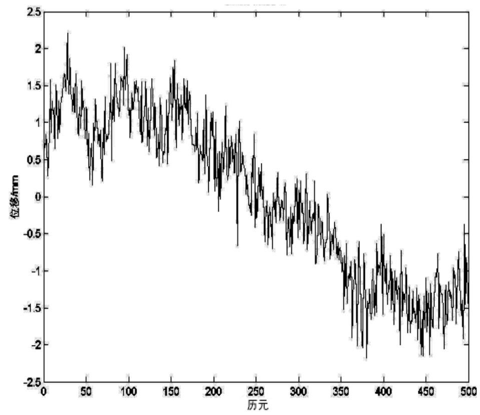
In order to validate multiple wavelet denoising effectiveness, this paper uses a GPS 's data analysis. Experiments using Beijing Institute of remote sensing technology developed by GNSS single frequency receiver, sampling interval of 1s (a sampling frequency 1HZ), data in December 1, 2003 5: 34 collection, were observed 500 epochs, as the total of 8 satellites (PRN31 04 08 20 28 07 27 11), the highest PRN31 as a reference on the satellite, data by software baseline settlement, points to be obtained in the WGS-84 coordinates in different epoch when the coordinate series. Coordinate with X, Y and Z representation, analysis, mean value coordinates deducted from sequences of coordinates. The settlement after the point to be determined in different epoch when its three-dimensional coordinates as shown below:



(a) X direction



(b) Y direction

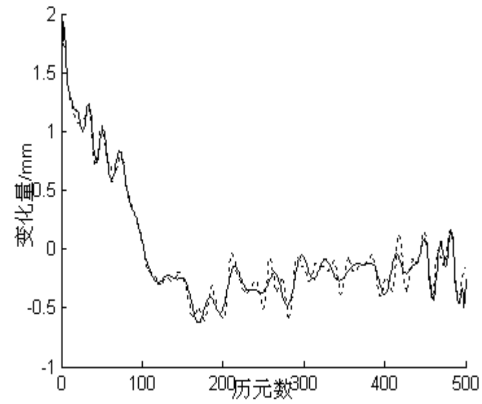


(c) Z direction

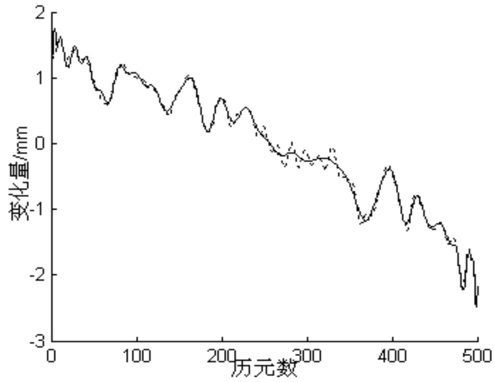
Figure 3. GPS coordinate sequence variation curve

From the graph 4 shows, GPS displacement observation sequence data containing many burrs, is affected by noise (such as multi path effect, random noise), monitoring point submerged in noise change trend. For from the complex changes in extraction of deformation trend, using wavelet to carry on the processing, analysis. From the front of the pretreatment method of knowable, GHM Multiwavelet Based on low frequency approximation method, the CL multiwavelet by Haar method and uses the balanced multiwavelet method can obtain good denoising effect. Now wavelet for signal processing, and with the traditional single wavelet is compared.

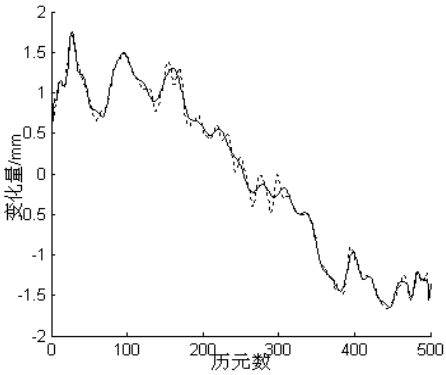
3.1 GHM GPS multiwavelets in signal denoising applications



(a) X direction



(b) Y direction

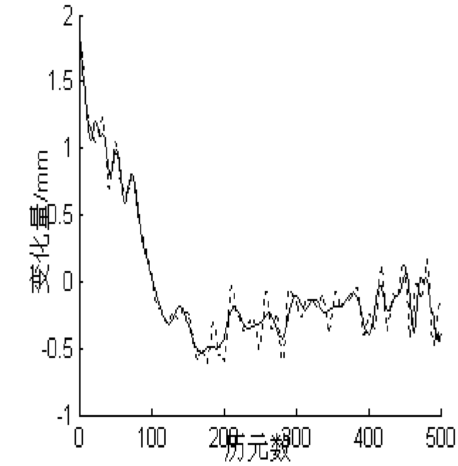


(C) Z direction

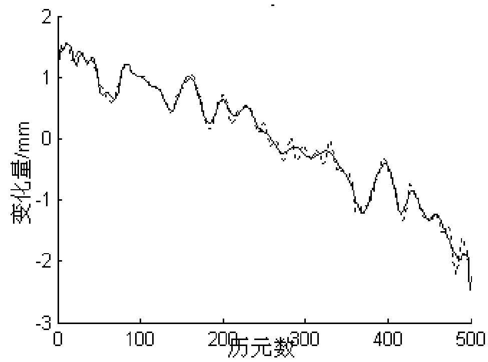
Figure 6 GHM multiwavelet and db4 in X, Y, Z direction correlation curve

The solid line is DGHM wavelet denoising curve, the dotted line DB4 wavelet denoising curve. As can be seen, DGHM wavelet filtering signal in the smoothness and the spikes and mutation than single wavelet is better, the de-noising error than single wavelet small. DGHM multiwavelet is more suitable to mutation and transient signal denoising, wavelet de-noising precision than DB4 is much smaller, get the original signal change trend.

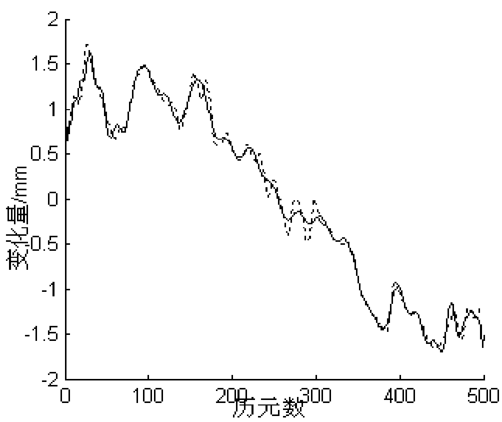
3.2 CL GPS multiwavelets in signal denoising applications



(a) X direction



(b) Y direction



(c) Z direction

Figure 7 CL multiwavelet and db4 in X, Y, Z direction correlation curve

Figure 7 shows, the CL multiwavelet showed better denoising character, remove the noise of signal after filtering, GPS measurement of dynamic deformation amplitude accuracy up to 2mm.

Table 1 the GHM wavelet, wavelet, CL Cardbal3 DB4 Multiwavelet and wavelet denoising in SNR and RMSE of comparison, GHM Cardbal3 multiwavelet multiwavelet, using suitable pretreatment method for denoising can achieve even better than single wavelet denoising effect, improves the signal to noise ratio, lower the RMS error. CL wavelet denoising effect compared to the other methods is poor, is the most suitable for image compression wavelet

Wavelet base	Signal	SNR	RMSE
DB4	X	5.5231	0.0223
	Y	8.5706	0.0212
	Z	11.1224	0.0192
GHM	X	5.5831	0.0194
	Y	8.6736	0.0118
	Z	11.1086	0.0149
CL3	X	5.4844	0.0286
	Y	8.5606	0.009
	Z	11.149	0.0078

Table 1 Effect of multiwavelets in X, Y, Z direction denoising effect comparison

4. CONCLUSION

This chapter firstly introduces the pretreatment method of the necessity, as well as several wavelet pretreatment methods, and then described in detail based on different pretreatment methods and CL3 GHM multiwavelet multiwavelet de-noising and balanced multiwavelets denoising, then select the best pretreatment method, and its application to deformation monitoring signal denoising, and with the traditional wavelet denoising results are compared and analyzed, it was proved that the wavelet transform in deformation monitoring signal denoising is feasible and effective.

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