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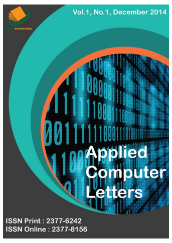

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WAVELET THRESHOLD TRANSFORM AND EMPIRICAL MODE DECOMPOSITION JOINT DENOISING OF SIGNAL

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ABSTRACT

Wavelet transforms and empirical mode decomposition are powerful tools for processing non-stationary and nonlinear signals, suitable for de-noising nuclear magnetic resonance logging echo signal. This paper introduces that signal reflect well exponential decay characteristics of echo signal after utilizing the wavelet transform to threshold processing the nuclear magnetic resonance logging echo signal, and reflect commendable adaptability after using the empirical mode decomposition dealing with the echo signal in logging. By taking advantage of processing logging echo signal through wavelet transform and empirical mode decomposition, not only can obtain higher signal-to-noise ratio compared with single method, but also get smoother signal.

KEYWORDS

Wavelet trans-form, empirical mode decomposition (EMD), joint de-noising, logging echo

1. INTRODUCTION

Based on a study, abundant geological and development data can be obtained by logging, nuclear magnetic resonance (NMR) detection is one of the advanced logging technology at present [1]. However, the echo signal from logging is very weak, that mainly because the nuclear magnetic resonance can only carry feeble energy while jumping, and the auditing quantity of low levels is very little after the nuclear spin splitting of energy levels. So, it will soon enter into the saturation zone under the stimulus of applied magnetic field, no matter how to increase the strength of applied magnetic field, the amplitude of echo signal will not be enhanced. In addition, various kinds of noise and interference can be easily introduced during the process of acquisition of echo signal, resulting in low signal-to-noise ratio (SNR), thus, de-noising processing is very necessary for NMR logging echo signal.

Since the echo signal in NMR logging is nonlinear and non-stationary, the good time-frequency characteristic of wavelet analysis is well suitable for processing non-stationary signal. The method of empirical mode decomposition (EMD) do not need prior information while processing signal, it can detect the intrinsic mode function of signal adaptively on the basis of features of signal. Therefore, using wavelet transform and EMD to denoise the measurement signal of oil and much more in line with the exponential decay characteristics of echo signal.

According to research, although the wavelet transform de-noising can process of no-stationary and nonlinear signals,

2. WAVELET TRANSFORM DENOISING OF LONG SIGNAL

Figure 1 shows a typical downhole echo signals detected by NMR logging instrument, the general trend of original data is exponential decay, it is difficult to characterize the physics information of the signal because the useful signal is annihilated by lots of noise.

Based on research, utilizing wavelet transform for denoising, take the following steps [2]:

1. Select a wavelet and determine the administrative levels of decomposition, then calculate it.
2. Select a threshold for high frequency coefficient of each decomposition scales, conduct soft and hard threshold quantization manipulation afterwards.
3. Reconfigure in accordance with the bottom of the low frequency coefficients and high frequency coefficients of wavelet decomposition.

According to the repeated experiments, select the db3 wavelet as basis function and 3 layers as decomposition layers to processing Figure 1, the effect can be shown in Figure 2. It is clear that under the same wavelet basis function, the echo signal still contains a lot of peak information after hard threshold de-noising while after soft threshold processing, the signal becomes smoother, which is repeated tests should be done to determine the wavelet basis function, threshold, dimension, etc., thus it is difficult to reflect the adaptivity of signal [3].

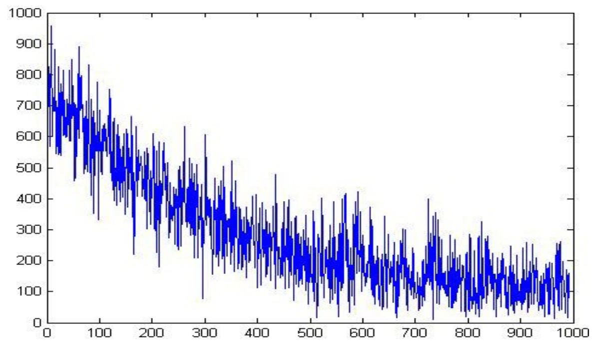

Figure 1: Signal measured by NMR logging instrument.

3. THE EMPIRICAL MODE DECOMPOSITION DENOISING OF LOGGING SIGNAL

Based on experiments, utilizing empirical mode decomposition (EMD) for de-noising, take the following steps [4]:
1. First, calculate all the local extreme points of original signal x (t), then link all the local function
2.Calculate the mean of the maximum

$v_{min}(t)$ as $m_1(t)$,

envelope $v_{max}(t)$ and the minimum envelope

$$m_1(t)=\frac{v_{max}(t)+v_{min}(t)}{2} \qquad (1)$$

$m_1(t)$ subtract from the original signal $x(t)$

obtains a residual component which has removed the low frequency component, i.e.

$$h_1(t)=x(t)-m_1(t) \qquad (2)$$

Estimate whether the residual component h1 (t) would meet the conditions of the intrinsic mode function definition, if meet, the residual component will be preserved as an intrinsic mode function component.
(3) If $h_1(t)$ does not meet the conditions, it can be seen as a raw data, then repeat the above steps

$$m_2(t)=\frac{v^1_{max}+v^1_{min}}{2}$$

$$h_2(t)=h_1(t)-m_2(t)$$

$$\ldots \qquad (3)$$

$$m_k(t)=\frac{v^k_{max}(t)+v^k_{min}(t)}{2}$$

$$h_{k+1}(t)=h_k(t)-m_k(t)$$

(3) If $h_{k+1}(t)$ meets the conditions of intrinsic mode function, note it

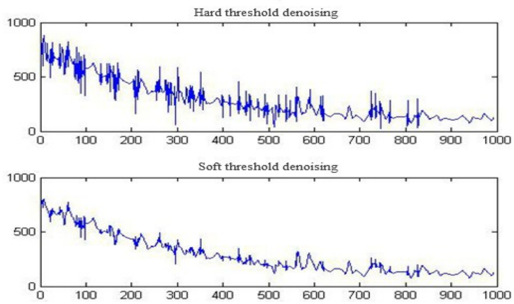

Figure 2: Wavelet threshold transform denoising.

curve, fitting out the maximum envelope maximum and minimum points with cubic spline $v_{max}(t)$ and minimum envelope $v_{min}(t)$. All the data of the signal should be between these two envelopes atthis point.

$$c_1(t)=h_{k+1}(t) \qquad (4)$$

Consider $c_1(t)$ as the first intrinsic mode function component of original signal, note it

$$r_1(t)=x(t)-c_1(t) \qquad (5)$$

(4) Consider $r_1(t)$ as an original data and repeat step (1) to

(3), obtain the second intrinsic mode

function component $c_2(t)$, repeat n times until the NTH intrinsic mode function component is obtained, or when the

residual component rn (t) is a monotonic function or constant, EMD process is terminated.

Finally, fit n order intrinsic mode function components and the final residual component to reconstruct the original signal:

$$x(t)=\sum_{i=1}^{n} c_i(t)+r_n(t) \qquad (6)$$

In general, the EMD decomposition process can be shown in Figure 3.

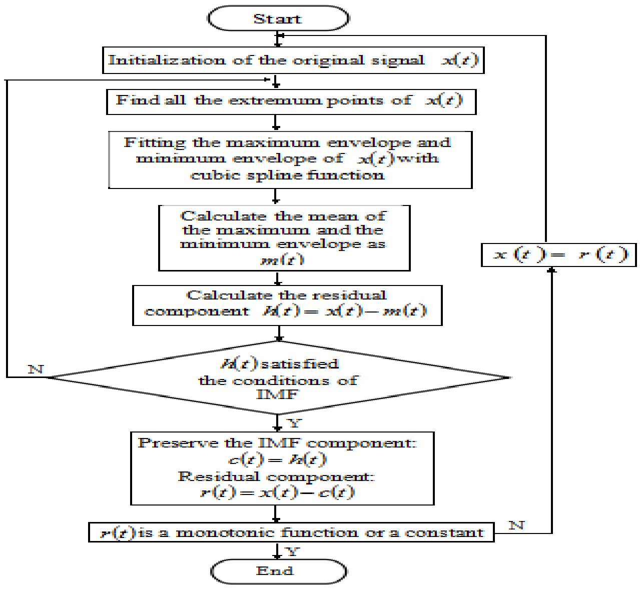

Figure 3: EMD decomposition flow chart.

Processing the NMR measurement signal shown in Figure 2 with the eight layers of EMD can obtain intrinsic mode function (IMF) components under different decomposition levels, the components have different amplitude and frequency, as shown in the Figure 4 [5]. Low scale shows high. Low scale shows high frequency filtering and the residual component presents monotonicity. In the first three intrinsic mode function components, the characteristic time scale is relatively small, the signals which belong to high frequency signals are very intensive. It indicated that a lot of noise exist, and most of the useful information are reserved in the low frequency component of the intrinsic mode functions. Therefore, wipe off the first three intrinsic mode function components and refit the rest components, the effect of signal denoising can be shown in Figure 5. It is clear that after removing the high-frequency components of intrinsic mode functions and refit the low-frequency components of intrinsic mode function, a large number of high-frequency signal noises are filtered out.

4. WAVELET TRANSFORM AND EMPIRICAL MODE DECOMPOSITION JOINT DENOISING OF LOGGING SIGNALS

Based on research, the method of wavelet transforms can denoise non-stationary and nonlinear signals [6]. But during the denoising, different wavelet basis functions, threshold and scales selection should be texted which makes the denoising signals lack of information. It turns out that wavelet transform denoising cannot reflect the commendable adaptation of original signal. Wiping off the noise of high frequency components and refitting the low-frequency components are the essence of using EMD algorithm to denoising. Although this method can be adaptive to the signals themselves, the high frequency components of intrinsic mode function are also filtered in the process of denoising, losing part of the information of the useful signals. Therefore, combine wavelet analysis with empirical mode decomposition to deal with nuclear magnetic resonance logging signals. Using the EMD algorithm first to decompose signals, so that the signals can be maintained adaptability and get more information about them. Then use the wavelet transform method to extracting useful information from signals which have been removed high frequency of intrinsic mode function (IMF)

Table 1. It is clear that the SNR of wavelet threshold transform and EMD joint denoising is 32.9480, bigger than the SNR of wavelet threshold transform denoising and of EMD denoising. This shows after the process of denoising, the reconstructed signal has more energy and more useful information which play a very important role in signal analysis and processing.

Table 1: SNR after denoising the logging signal.

	wavelet transform denoising,	*EMD denoising*	*wavelet transform and EMD joint denoising*
SNR	31.6250	32.8423	32.9480

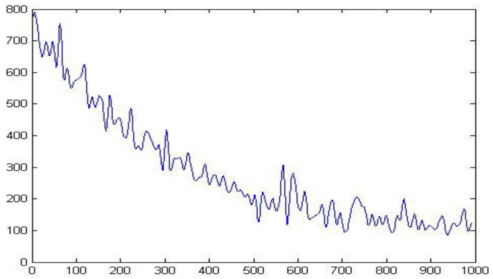

Figure 6: Wavelet transform and EMD joint denosing of logging echo signal.

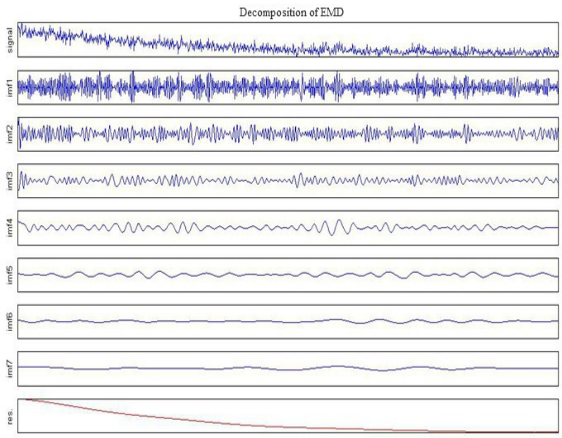

Figure 4: EMD denoising of NMR logging signal.

components by EMD. It concluded that two algorithms joint denoising not only can compensate for their shortcomings, but also achieves better effect of denoising.

The following steps show how to process NMR logging signal with wavelet analysis and EMD joint denoising:

1) Process signal with EMD to obtaining intrinsic mode function components.
2) Differentiate each intrinsic mode components on the basis of different requires and noise forms, select appropriate components to fitting.
3) Utilize wavelet transform to denoising high frequency intrinsic mode components.
4) Refit the high-frequency components which denoised by wavelet transform and the rest of the low-frequency components to getting the reconstructed signal.

The curve in Figure 6 shows the wavelet transform and EMD joint denoising of logging echo signal. It can be seen that the signal is much smoother with less noise content and the peak information has been well eliminated.

The SNR of wavelet transform denoising, of EMD denoising and of joint denoising are shown in

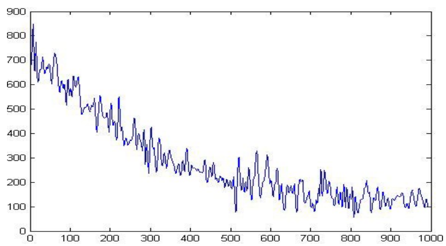

Figure 5: The effect of EMD denoising after removing the first three intrinsic mode function components.

5. CONCLUSIONS

Wavelet analysis has good time-frequency characteristic that is well suitable for processing non-stationary oil and gas nuclear magnetic resonance (NMR) logging signal, but this method is difficult to reflect the adaptivity of signal. Empirical mode decomposition(EMD) denoising can be adaptive to the signal itself, but the high frequency components of intrinsic mode function are also filtered in the process of denoising, losing part of the information of the useful signals. Compared with single denoising method, wavelet transform and EMD joint denoising can obtain higher signal-to-noise ratio (SNR) and smoother signal.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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