Very fines layers delimitation using the Wavelet Transform Modulus Maxima lines(WTMM) combined with the DWT

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Summary

The delimitation of the very fines lithologies from seismic data is a crucial problem in geophysics, indeed the presence of the noise in seismic traces can deteriorate information and hide important hydrocarbons accumulations. For that we have to try in this paper to use a recent technique developed by A.Arneodo and his collaborators which is the wavelet transform modulus maxima lines (WTMM) combined with the discrete wavelet transform (DWT), to denoising traces and characterize each amplitude in the seismic trace by an exponent of Holder. In order to separate information that is of a significant geological lithology variation with the various noises. Our application at VSP data shows that this technique is a powerful tool of processing.
Keywords: Lithologies, noise, seismic trace, the DWT , the WTMM, Holder exponent, processing

Introduction

The wavelet transform modulus maxima lines (WTMM) is a signal processing technique based on the summation of the module of the wavelet coefficients on the chain of maxima, to calculate a new function which is called the function of partition, it covers only the part carrying information, in fractal theory the part of the signal associated with each position is called a 'singularity', each singularity is characterized by a coefficient called Holder exponent. In stratigraphic the position of each one of it probably indicates a change of facies.
The core of our work is based on the treatment of seismic amplitudes by the WTMM after denoising by the discrete wavelet decomposition in order to characterize each amplitude by an exponent of Holder.

The continuous wavelet transform and Holder exponent

In this part we make point out the theory of the fractal, revised by the wavelet transform. That is to say a signal S(x),the development of this signal at the neighborhood of x_0 is the sum of a polynomial of N degree and a function f(x) of the form $C|x-x_0|^h$, S(x) is written in the following form:

$$S(x)=Pn(x)+C|x-x_0|^h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1.a)$$

h : is called the exponent of Holder .It was shown [1] that the wavelet transform with a analysing wavelet of N>n null moment is a law of scale for bus dilatations :

$$T \approx a^{h\ldots} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.b)$$

Because the wavelet transform preserves the singularities, each singularity in the signal is represented by local maximum in the module of the wavelet coefficients .For that we will carry out the calculation of the local coefficients of Holder on the local maxima.

Proprieties of seismic data

The seismic trace is generally made up of two parts[2], a deterministic part which is the convolution of the emitted sweep with the reflection coefficients series and a random part which is due of to the various noises.

$$T(t)=W(t)*Cr(t)+b(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The emitted sweep W(t) has the form :

$$W(t)=(1-2 * \Pi^2*f^2*t^2)*\exp(-2 * \Pi^2*f^2*t^2) \quad \ldots\ldots\ldots(3)$$

f: is the wavelet centre frequency.

For centre frequencies f>10, the Holder exponents estimated by the wavelet transform of the deterministic part of the seismic trace is h=-1. On the other hand the Holder exponent of the random part is different of -1. For amplitudes which are the result of a sum of a noise and a change of lithology , the module of the wavelet coefficients for bus dilatations has the following form

$$T \approx a^{h_b} + a^{-1} \quad \ldots\ldots\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

But for the other amplitudes witch are of the various noises the module of the wavelet coefficients has the expression (2)

$$T \approx a^{h_b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5).$$

We will use this characteristic to distinguish the amplitudes of the changes of lithologies to those which are of the noises.

The processing algorithm

Our Algorithm is based on the characterization of each amplitude in the seismic trace by an exponent of Holder to separate amplitudes of significant lithologies of those of the various noises. Its flow chart is detailed in the figure(1)

Application on a synthetic seismic trace without noises

In order to check the theory developed previously, we calculated the seismic response of a geological model made up of eight layers, the parameters of this model are represented in table 1. The seismic response of this model is represented in the figure(2.a) .The calculation of the local maxima of the module of the WT of this trace showed the existence of seven maxima lines figure (2.b) , each line points towards the point of the change of medium. The estimate of the Holder exponent at these points gave us seven coefficients (table 2.). What shows that the amplitudes recorded are really of the change of lithology.

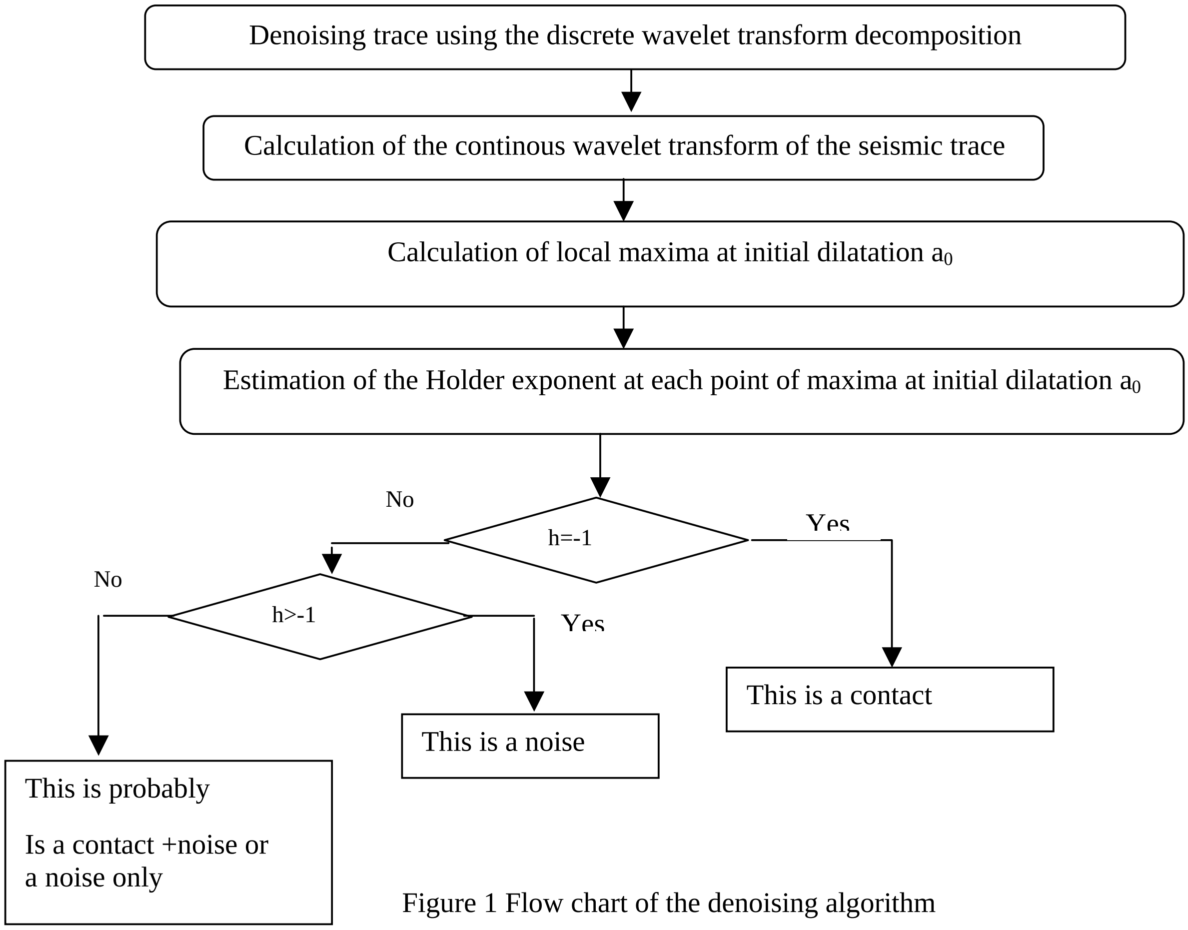

Figure 1 Flow chart of the denoising algorithm

	Vp(m/s)	ρ(g/cm^3)	h(m)
1	1000	2.1	100
2	1200	2.2	20
3	1400	2.3	20
4	1600	2.4	20
5	1800	2.5	20
6	2000	2.6	20
7	2200	2.7	20
8	2400	2.8	20

Table 1. Synthetic model parameters

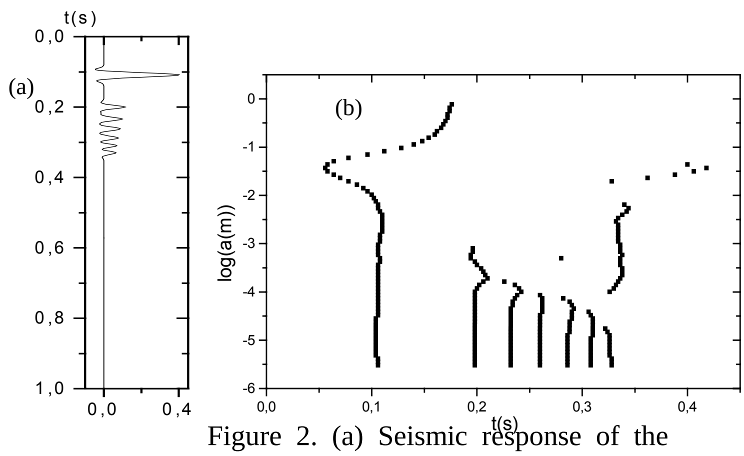

Figure 2. (a) Seismic response of the geologic model detailed in table 1

(b) Squelete of the wavelet coefficients

t(s)	h estimated
0.104000	$-1.009 \pm 5.281E-4$
0.196000	-0.955 ± 0.010
0.232000	-1.007 ± 0.003
0.260000	-1.0051 ± 0.002
0.286000	-0.962 ± 0.025
0.308000	$-1.0012 \pm 7.113E-4$
0.326000	-1.002 ± 0.001

Table 2. Holder exponent estimated at each local maxima

Application at a PSV trace

We applied our algorithm to a VSP trace which is represented in the figure.3, obtained results are represented in the figure. 4 . The step of sampling is equal to 0.002(s)

Results interpretation

Obtained results show the existence of three beaches of Holder exponent :
h <-1, h=-1 and h >-1 .According to the theory developed previously , first the range of amplitudes represented in the interval of time C1 are purely a noise on the other hand the amplitudes represented in the C2 interval are probably a noise or a reflection and the range of amplitudes represented in C3 represents a change of lithology.

Conclusion

We established an algorithm of separation of amplitudes based on the calculation of the exponent of Holder at each point of maxima , experience on synthetic model shows that the Holder exponents calculated for the amplitudes which are of a change of facies are equal to-1.
Generally the amplitudes which have an exponent of Holder greater than -1 are of the various noises. For amplitudes characterized by an exponent less than -1 are of either a change of facies or a noise for that it is necessary to enhance our algorithms by other techniques of filtering. Application on a PSV trace shows that the proposed technique gave results which can improve the seismic treatment. It remains that to apply it on big numbers of data and to compare it with the other filters.

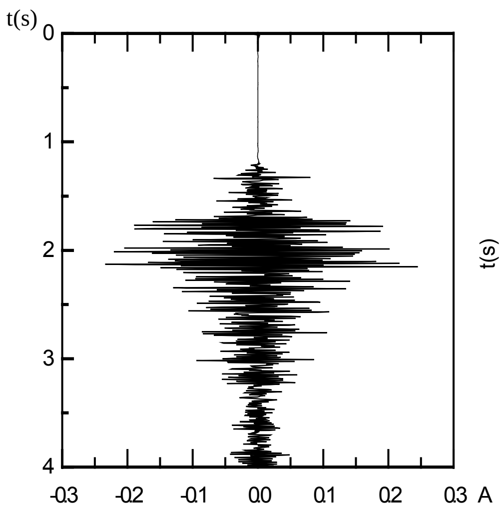

Figure 3. PSV Seismic trace

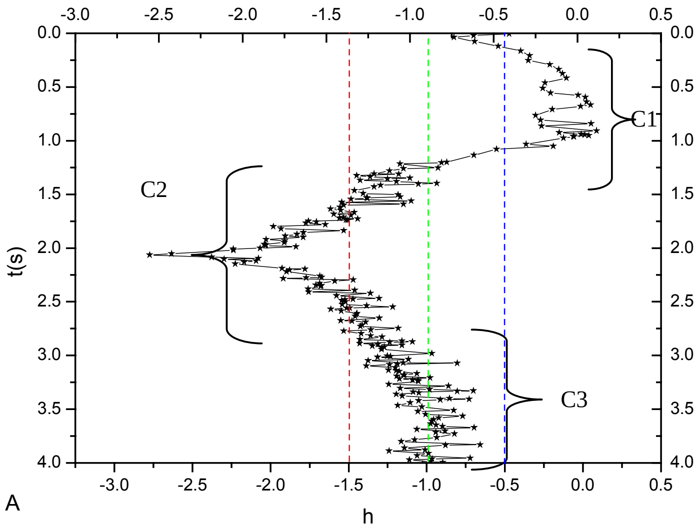

Figure 4. Analysis of the PSV trace by the algorithm of separation of amplitudes

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