AN IMPROVED RGB ATTRIBUTE FOR FLUID OR GAS IDENTIFICATION BASED ON MP

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ABSTRACT

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One single technology cannot satisfy the requirements of reservoir identification and prediction. More technologies are being used jointly to improve the predicted accuracy of reservoir parameters. For the purpose of recognizing fluid or gas, this paper gives a method of improving red, green, blue (RGB) attributes based on the matching pursuit (MP) algorithm. This is a new attempt to use the two methods jointly in order to find oil and gas. The role of the MP algorithm in our method is different from conventional usage. An iterative process is used to select the region that has large amplitude. The approach has three steps. First, the data is divided into three frequency bands after spectral analysis. Second, the divided data is processed by a MP algorithm, which selects the region with large amplitude. This approach is based on the idea that a favourable reservoir is often a sandstone with strong reflection, which is similar to the principle of the "bright spot" technique. This analysis is the most important step and determines the final result. Third, a RGB attribute is calculated that define frequency variation by means of colour mixing or transition. The characteristic of both large amplitude and frequency variation is considered to be the signal of oil or gas. The model and real data demonstrate that this is an effective method of reservoir prediction. Compared with the common RGB attributes, this improved RGB attribute could give a more accurate prediction.

KEY WORDS: fluid or gas, RGB, MP, select, accurate prediction.

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INTRODUCTION

In oil and gas exploration, accurate location of a favourable reservoir can be a challenging issue. Many methods are being studied or improved to enhance the accuracy of reservoir prediction. A single method cannot provide the required precision, and for this reason, more technologies are being used jointly to effectively identify and describe reservoirs. A matching pursuit (MP) is a process of iteratively selecting a region with large amplitude reflection, which is helpful for finding a reservoir. The RGB blend technology is a common way of processing the seismic attributes. In this paper, we use a MP approach to improve the effect of the RGB attribute to provide a satisfactory prediction of a good reservoir.

The matching pursuit (MP) algorithm is a high accuracy time-frequency analysis method for nonlinear signals that decomposes a signal into a series of atoms according to the inner product between the atom and the signal (Mallat and Zhang, 1993; Hu et al., 2015). The method has been widely used in the field of geophysics since it was proposed. For example, Liu and Marfurt (2005) studied instantaneous frequency attributes of non-stationary seismic signals using a Morlet wavelet. The method also has advantages in interpolating or reconstructing traces under the condition of truly irregular sampling, which is a good way of improving the quality of seismic data (Özbek et al., 2009; Choi et al., 2016). Wang et al. (2016a) provided a method of improving the energy of weak signals based on a matching pursuit. In addition, MP also plays a part in time-frequency decomposition (Wang et al., 2016b), seismic inversion (Zhou et al., 2013) and seismic wave absorption attenuation compensation (Zhang et al., 2015). Based on these studies, we explore MP application to the extraction of seismic attributes and reservoir prediction.

The RGB blend technology has also played a role in the field of seismic data interpretation with the development of the seismic attribute and spectral decomposition technique (Tsagaris and Anastassopoulos, 2005; Guo et al., 2008). RGB has the great advantage of identifying the favourable reservoirs by combining information of different frequency components together (Jiang et al., 2013). The earliest use of RGB technology was to fuse near, middle and far offset seismic data (Onstott et al., 1984). The rendering of seismic attributes in colour space was proposed by Partyka et al. (1999) and developed by Dorn (2002) and Stark (2006). This approach allowed the joint interpretation of multiple attributes using red-green-blue (RGB) colour blending for direct geological interpretation (Laake, 2013). At present, RGB concepts are widely used in extracting geological structures from seismic data and detecting channels and faults (Torrado et al., 2014).

When improved by MP, the RGB attribute can be used to recognize fluid or gas in addition to discontinuity detection. After several iterations, areas with large amplitudes are selected by a MP process. Based on this analysis, a RGB attribute can provide a clearer and more accurate prediction. Prediction validity is confirmed by the model and by real data.

METHODS

The theory of MP

Matching Pursuit (MP) decomposition is an algorithm used to find the best matches for a nonstationary signal (such as a seismic trace) with a given dictionary D of possibilities. MP decomposes a signal into a series of atoms with a single frequency component. For a provided dictionary, matching pursuit will first find the "atom" that has the largest inner product with the signal and the weighting factor; then, the projection of this atom onto the signal is calculated by a weighting factor. The result is that the input signal subtracts the projection that is regarded as the new input signal. The iteration does not stop until the residual error, or the iterative number, meets a certain precondition.

The time-frequency distribution of the original signal is expressed by the linear combination of the spectra of these atoms. This is an iterative process to select the atom (in fact, it is the wavelet of seismic waves) that has the maximum correlation with the input signal in the database. The reconstructed signal is expressed as follows:

$$\mathrm{s(t)} = \sum_{\mathrm{i=1}}^{\mathrm{m}} \mathrm{a_i W(t - t_i, f_i, \emptyset_i) + R_s^{(m)}(t)} \quad , \tag{1}$$

where s(t) is the band-limited seismic signal, $\mathrm{Rs}^{(m)}(t)$ is the residual signal, m is the number of atoms (or wavelets), and a_i, t_i, f_i, and φ_i are the controlled parameters of the atoms.

The atom that is sufficiently significant determines the final result. The closer the atom type is to the seismic wavelet, the more accurate the matching process is. It is understood that a Ricker wavelet is the closest match to the seismic wavelet. However, a typical Ricker wavelet is zero-phase, the expression of which is shown as eq (2). To build an over-complete dictionary, we modify the Ricker wavelet as in eq. (3):

$$g(t) = [1 - 2(\pi f_m t)^2] e^{-(\pi f_m t)^2} \quad , \tag{2}$$

where f_m is the dominant frequency of the Ricker. Thus,

$$g(a_i, \mathrm{t} - t_i, f_i, \emptyset_i) =$$

$$\mathrm{IFFT}\{\mathrm{FFT}\{a_i[1 - 2(\pi f_i(t - t_i))^2] e^{-(\pi f_{ij}(t-t_i))^2}\} e^{j\emptyset_i}\} \quad , \tag{3}$$

where FFT and IFFT are the Fourier transform and the inverse Fourier transform respectively. We process in the frequency domain to add the phase parameter ϕ_i.

Generally, a larger amplitude is the signal of a favourable reservoir. Based on this idea, we apply the MP algorithm to processing seismic data. As the MP process prioritizes the atom that has the maximum correlation with the input signal at every iteration, the area with a strong reflected energy (or amplitude) can be selected by setting a small iterative number (it could be 5 or less, depending on the data) or a large residual error (60% or more) as the decision condition. After extracting the atoms and reconstructing the data, an approximate prediction of the reservoir can be provided.

RGB blend technology

To an interpreter, colour is the visual property that describes the interaction of the human eye to light that has a specific spectral composition and intensity. Fig. 1 displays the international colour standard, mapping the full range of human visual perception. The primary colours (red, green and blue) cannot be created by mixing other colours, while other colours can be reproduced by mixing the three primary colours. Different proportions generate different spectral compositions and intensity. The colour black represents the intensity 0, while the colour white represents the intensity 1.

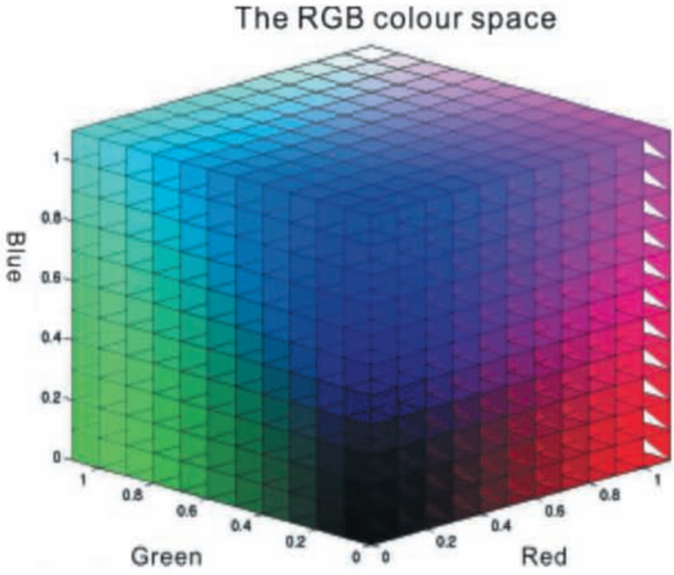

Fig. 1. The RGB colour space.

The RGB attribute is a kind of colour blend attribute where the colours red, green and blue represent the attribute extracted from different frequency bands. The brightness is related to the amplitude, with larger amplitudes being brighter. The large amplitude often indicates a sandstone or a favourable reservoir. Similarly, colour is related to the frequency. Warm colours represent high-frequency components, while cool colours represent low-frequency components. The transition of colour on an RGB attribute symbolizes the existence of oil or gas. Combining the two characteristics (amplitude and frequency) makes it possible to predict the location of oil or gas.

In practice, the RGB attribute can identify a favourable reservoir, but it cannot highlight the hydrocarbon reservoir. There is no transition of colour in certain areas, because the amplitude in these areas is so large that the colour is often white on the RGB attribute. It is difficult to analyze frequency characteristics of these areas which means we cannot determine if the large amplitude is caused by hydrocarbon or other factors. This indecision is why it is common to use a discontinuity detection (such as channels or faults) rather than conventional oil reservoir identification. The oil and gas identification effect of conventional reservoirs needs to be improved, which is the significance of this study.

Method of improving the RGB attribute based on MP

Based on the study of MP and RGB, we developed a novel method of computing the RGB attribute for predicting the location of oil or gas more accurately. The extraction of a RGB attribute is based on the selected results of MP.

First, we divide the seismic data into three bands by the generalized S-transform (GST) which is a high precision time-frequency analysis method with an adaptive window. Second, every frequency dividing the data is processed by the MP algorithm. Third, the RGB attribute is calculated based on the reconstructed data and analyzed to give a predicted result. The processing flow is shown in Fig. 2.

The screening process of the MP is so important that it may decide the final result. The question is when to terminate the iterative process. We test two possibilities:

1. The number of iterations: This parameter is often used as the judging condition;

2. The threshold value: Because we want to select areas with large amplitudes by the MP, we use a threshold value or percentage (the ratio between the amplitude of the atom and the maximum amplitude of the signal) to decide whether the iteration should be stopped or not.

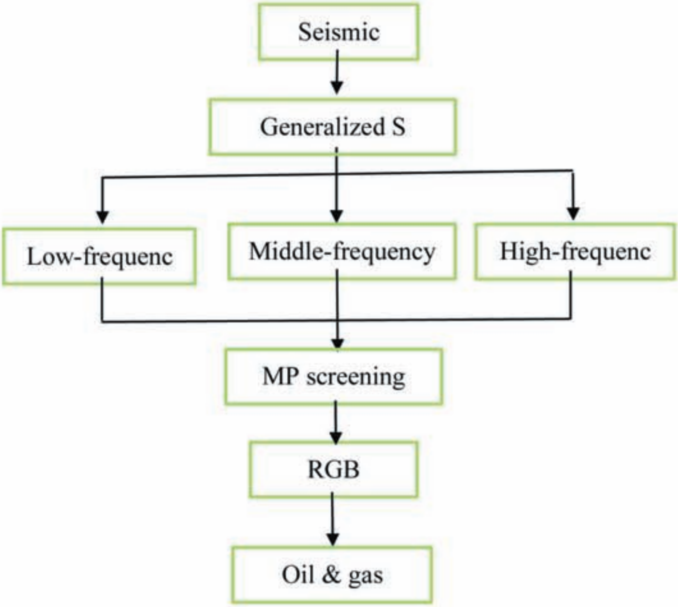

Fig. 2. The flow of oil and gas prediction using the improved RGB attribute.

To compare these two ways of terminating the process, we use a simplified model [Fig. 3(a)]. In this model, the red colour indicates oil, the yellow colour indicates gas and the blue colour indicates water. These units exist in the form of lenses and thin interbeds.

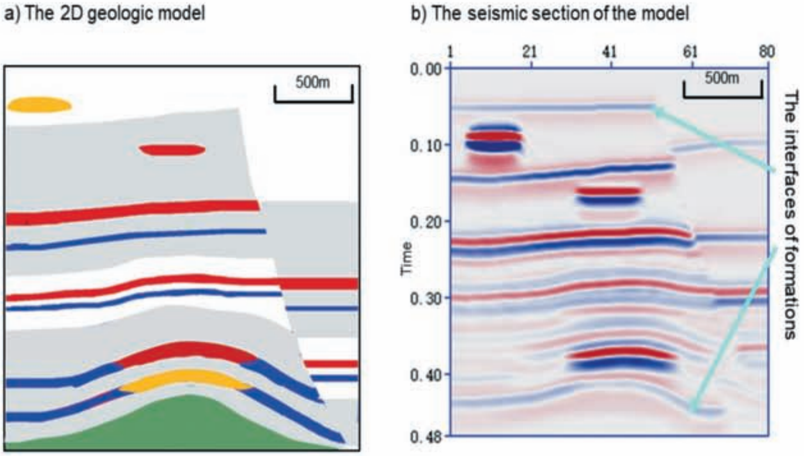

Fig. 3. (a) The 2D geologic model; (b) The seismic section of the model. Blue arrows indicate the interfaces of formations.

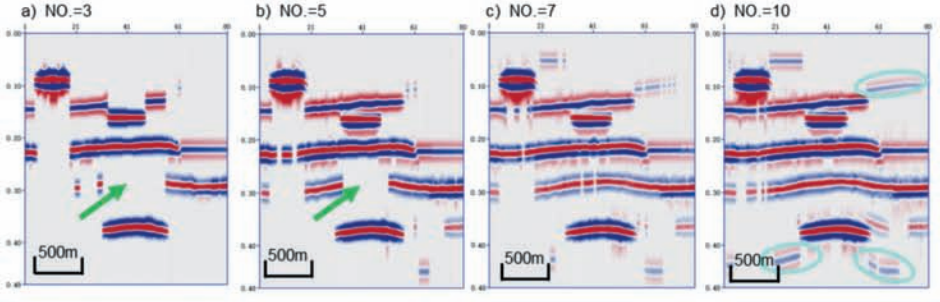

Fig. 4. Results of different number of iterations.

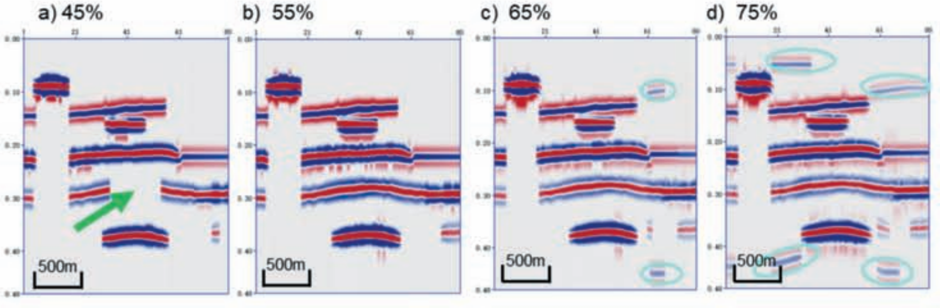

Fig. 5. The ratio between the amplitude of the atom and the maximum amplitude of the signal. In this method, the second results (55%) is recommended.

We tested the two methods of stopping the iterations. The results are: in Figs. 4 and 5, green arrows indicate the lack of oil-gas bearing layer and blue ellipses indicate the unsuppressed reflection of the interface. Fig. 4 indicates that the reconstructed data become more integrated as the number of iterations increases. To select the fluid-gas bearing area (characterized by strong amplitude) and to suppress the reflection of interfaces, the appropriate number of iterations would be 7. Applying this same screening principle to the second method in Fig. 5, 55% is the recommended amplitude ratio. When these two results are compared, the 55% screening results is better than the 7 iterations method. Therefore, we choose the second method to filter data in real applications.

RESULTS

Test Model

A generalized s transform (GST) was used to obtain low, middle and high frequency data, using a MP, based on option 2 (Fig. 5). The optimized results are shown in Fig. 6.

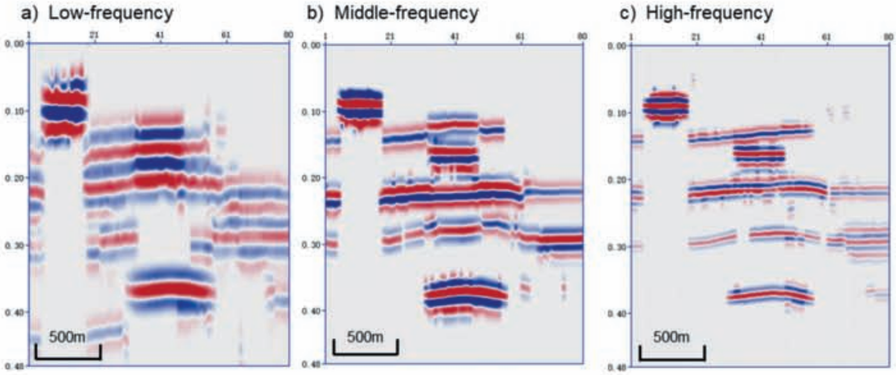

Fig. 6. Multi-band data after MP.

After the frequency-division and MP process, a RGB attribute was computed (Fig. 7). Comparing the RGB attribute before and after data pass processed by the MP, we obtain several findings:

1. The energy of the lenses is so strong that the colour is white. The oil and gas areas are bright and the colour transforms from warm to cold, which indicates that the dominant frequency changes from high to low. The reason why the frequency changes in this way is that high-frequency components are absorbed by oil and gas.

2. After the MP, the positons of oil and gas areas are more accurate. The improved RGB attribute [Fig. 7 (b)] defines fluid and gas areas while eliminating other regions (the white arrows).

3. Compared to a fluid-filled reservoir, the reflection of the gas-bearing reservoir is stronger. Because of this, a gas-bearing area may shield underlying strata (blue rectangle).

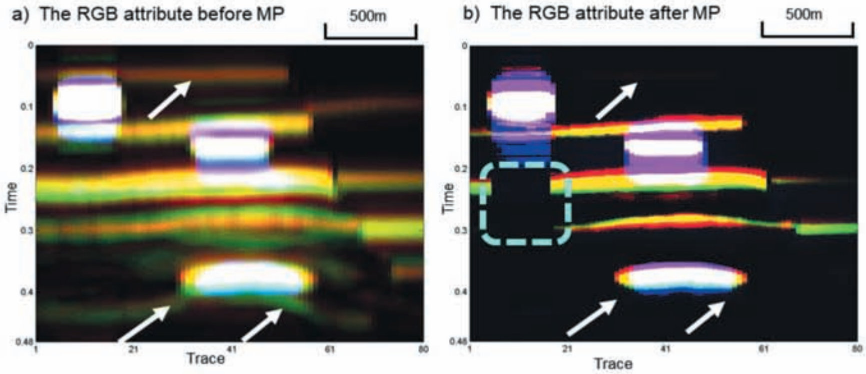

Fig. 7. The RGB attribute of the model before (a) and after (b) the MP process.

Real application

The method is now applied to real data (Fig. 8). The data is from the Chengdao Oilfield located in the south of the neritic area in the Bohai Gulf. Several periods of faulting and denudation occurred during some tectonic movements in this area, which resulted in good conditions for hydrocarbon accumulation. There are two wells in the seismic section. Drilling data indicates that well A is an oil well and well B is a dry well. The identification result of commonly used attributes such as the RMS amplitude is inconsistent with the drilling data, which can be seen from Fig. 9.

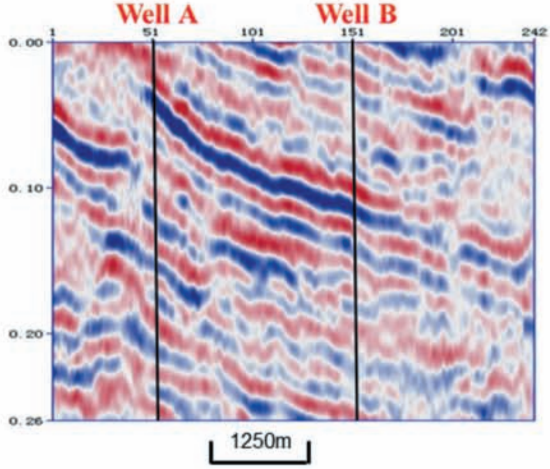

Fig. 8. The seismic profile.

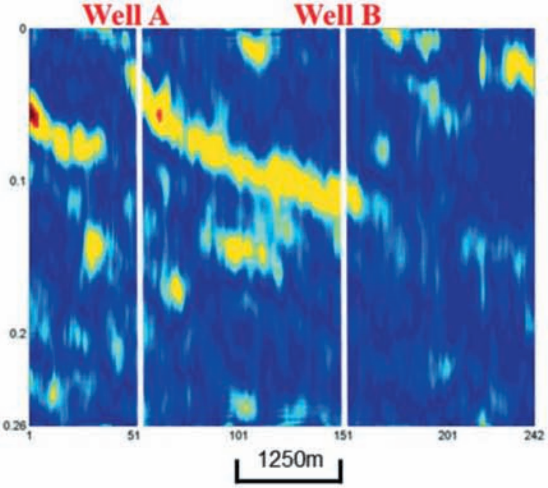

Fig. 9. The RMS amplitude attribute.

The RMS amplitude of three bands was extracted to calculate the RGB attribute. On the RGB attribute, the colours represent different frequencies and a strong intensity of the colour indicates a large amplitude, which often indicates a favourable reservoir [such as the elliptical area in Fig. 10(a)]. The results show that the original RGB attribute [Fig. 10(a)] could not give the predicted result clearly on the seismic profile, whereas when improved by our method, a more clear and direct result was obtained [Fig. 10(b)].

According to our method, the MP algorithm is used to select areas with large amplitudes before calculating a RGB attribute. It can be seen from Fig. 10(b) that the area marked by the white dashed line is recommended by the MP. This target can be divided into two parts according to the number of colours. The yellow elliptic region is predicted as the oily or gassy reservoir because of the frequency changes that are often associated with oil and gas. The other part with only one colour is ruled out by the method. This result is consistent with the drilling data.

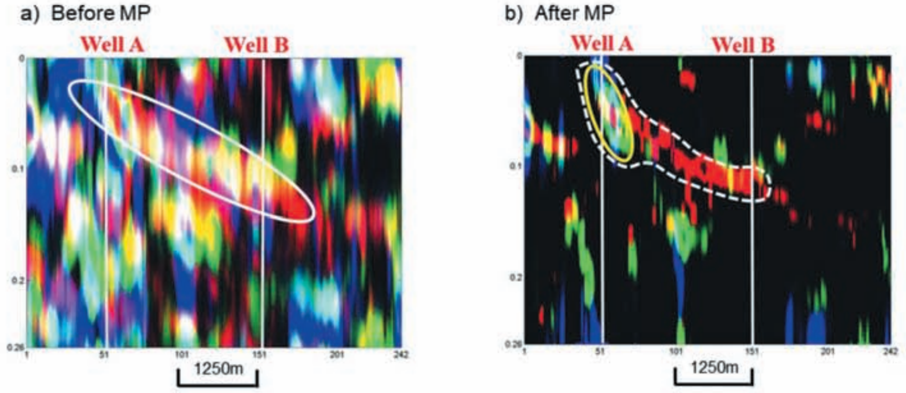

Fig. 10. The RGB attribute of the real data before (a) and after (b) the MP process.

CONCLUSION

Locating oil and gas is the ultimate aim of reservoir prediction. This paper gives a method of multi-attributes which is based on MP screening and RGB attributes. The role of the MP algorithm is to select the region with large amplitude. Therefore, the process takes only several iterations. This is the difference between our method and the conventional use of the MP algorithm. Another part of the method is the RGB blend technology. The RGB attribute has great advantages in recognizing special lithologic reservoirs and tectonic feature because it shows frequency changes directly by colour mixing or transition. Based on the MP selected result, the effect of a RGB attribute is improved significantly. The model data and real data used in this paper indicate that our method can give a more accurate and clearer prediction of the locations of oil and gas reservoirs. However, it also has limitations:

1. It cannot distinguish between oil and water.

2. For a region containing only fluid or only gas, the effect is better than if both fluid and gas are contained. The reason is that the reflection from gas is often stronger than the reflection from fluid, which will make it difficult to define an accurate threshold for the MP. In addition, a gas-bearing layer may shield the underlying strata.

The authors will continue to explore a better approach based on the present work.

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