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A Combination method of Wavelet Transform and Image Processing to Identify Abnormal Geological Range

ZHANG Jian-qing[1] ,Yongxiang CAI[2], LIU Ting[2],MA Sheng-min[1]， HU Kezhen[3],*

1 Yangtze Geophysics (probe) Wuhan Ltd. , Wuhan Hubei 430010, China

2 School of Geosciences, Yangtze University, Wuhan Hubei 430010, China

3 Geological Survey of Canada, Calgary, AB T2L 2A7, Canada

Summary

For the issue of how to identify abnormal geological range in engineering exploration, a combination data mining method based on wavelet transformation and image processing has been proposed in this paper. Firstly, histogram equalization has been done in the interpolated raster data of apparent resistivity to achieve enhanced visual expression based on ArcGIS platform in this method; secondly, one-dimensional dyadic wavelet analysis has been used to find singular points in apparent resistivity array; and finally, combining them to identify abnormal geological range. This method depends on processing and analysis of data so as to reduce the dependence of interpreters' background knowledge and experience. In early exploration of Yunnan water diversion project, we apply this method to identify abnormal geological range on the 2nd line profile. The identification results can not only be explanted reasonably based on the corresponding geological data, but also are more refined than those conventional interpretations by engineering geophysicists, which can provide better decision support for the prediction and forecast in geological engineering.

Introduction

Engineering geological conditions include properties of rock, geological structure, topography, hydrogeological conditions, adverse geological etc., faults, fractures, folds, karst and lithological changes seriously affect the safety and cost of mountain tunnel construction, hydraulic tunnel and other projects. Therefore, to identify the construction site engineering geological conditions have important guiding significance for construction[1]. Currently, identify the abnormal geological range mainly according to the inference and interpretation based on relative values of apparent resistivity, contour shape and other borehole data, geological data etc[2-4]. This method influenced by topography[2], has a high reliance on interpretation staff's experience, geological anomalies range inferred relatively loosely, difficult to define the boundary.

The boundary of abnormal geological range is actually the place of resistivity curve dramatic changes, the detection of abnormal mutation is essentially the detection of singular point based on an ordinal apparent resistivity data. Wavelet transform is a time-frequency analysis tool, known as the "magnifying glass" and "microscope" on the mathematical analysis. Not only have the ability to time-frequency analysis of the local, and time resolution and frequency resolution can be adjusted. Currently, the signal mutation detection has become an important aspect of wavelet transform application[5]. The coefficients modulus maxima of discrete dyadic wavelet is closely related with the local signal singularity, and use these maxima can identify the singularity. In this paper, this feature of the wavelet transform is used to detect the anomalies point in the apparent resistivity data.

Rock fracture zones, cracks, corrosion, changes in lithology, groundwater, which would cause a sharp decline in apparent resistivity. In this paper, image enhancement method is used to displayed the level of resistivity data on the grayscale image, and then combined with abnormal demarcation points detected by wavelet transform to identify anomalies geological range.

1. Method to identify abnormal geological range

In this section, we present an data mining method, which combines image enhanced expression with wavelet transform to identify geological abnormal based on the apparent resistivity data. This method can be divided into three steps: the apparent resistivity data visualization, detection of abnormal demarcation point, overlay analysis and divide the abnormal region, shown in Figure 1.

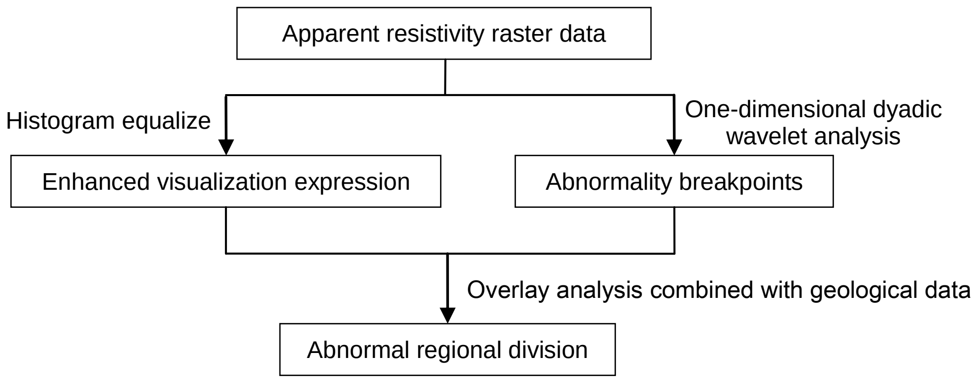

Fig.1 Step of Recognition of geological abnormal range

1.1 Histogram equalization

The basic principles of histogram equalization is to make the image on each gray level have broadly similar number of pixels through the gray-scale transformation. Let s=T(r) is a gradation conversion function of the histogram equalization, the variable r is the gray level of the image to be reinforced, the enhanced gray level corresponding to variable s. Before the use of histogram equalization, the original image pixel have a uneven distribution at different grayscale, histogram equalization process is to find an appropriate *T (r)* mapping to the original gray level, the mapping must be met [6]:

(1) Within $0 \leqslant r \leqslant 1$ range, T (r) mapping is a single-valued increasing function, monotonically increasing ensure the reversal does not occur before and after the gray level change, to avoid the partial image brightness are reversed, the output image generating grayscale inversion phenomenon;

(2) $0 \leqslant s \leqslant 1$ when $0 \leqslant r \leqslant 1$, this condition is to ensure a consistent gray value range after the transfomation.

1.2 One-dimensional dyadic wavelet analysis

The one-dimensional dyadic wavelet transform coefficients' maximum value is closely related to local singularity point position of the signal[7].

Set $f(t)$ to be an input signal, $\theta(t)$ is a low-pass smoothing function, $\psi(t)$ is the first derivative of $\theta(t)$,as $\psi(t)=\frac{d\theta}{dt}$, mark $\theta_{2^j}(t)=\frac{1}{2^j}\theta(\frac{t}{2^j})$, then the wavelet transform of scale 2^j is:

$$\mathrm{W}_{2^j} f(t)= f(t)*\psi_{2^j}(t)= f(t)*(2^j \frac{d\theta_{2^j}(t)}{dt})=2^j \frac{d}{dt}[f(t)*\theta_{2^j}(t)] \tag{1}$$

$\psi_{2^j}(t)$ make a wavelet transform to $f(t)$ is equivalent to that $f(t)$ is smoothed by the $\theta_{2^j}(t)$, and then seek the first derivative for *t*, wavelet transform coefficients' modulus maxima correspond to the partial sharp change point(singular point) of signal $f(t)$.

2. Application case

Shek Kwu Wangchengpo Xianglushan tunnel is the most critical control project of the Yunnan Water Diversion. This paper selected the second-tier of centre to research and analysis. Apparent resistivity data is the inversion of magneto telluric geophysical exploration data, whose horizontal spacing is 50m, longitudinal spacing is a range of 0.2 ~ 200m , total length on the measuring line is about 56km.

Firstly, we use the inverse distance weighting method to interpolate with the apparent resistivity data, and then get the apparent resistivity raster data shown in Figure 2. Figure 2 is a partial display of the apparent resistivity grayscale image. Basically the image is dark; it is difficult to reflect the level of detail.

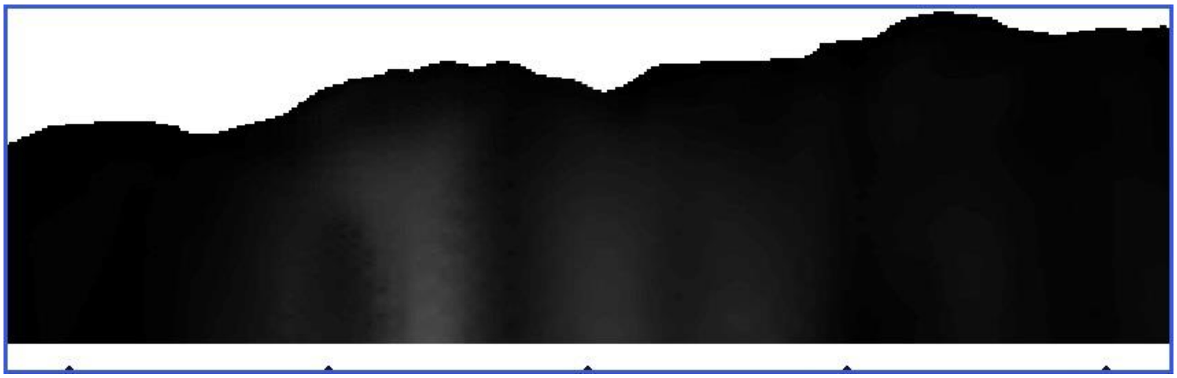

Fig.2 grayscale image of the apparent resistivity raster data between stack DLII 014+000 and DLII 018+000

After histogram equalization, the gray scale from black to white corresponds to the apparent resistivity changes from low to high, and has significant contrast in local differences. Fig.3 is the histogram equalization result of fig. 2.

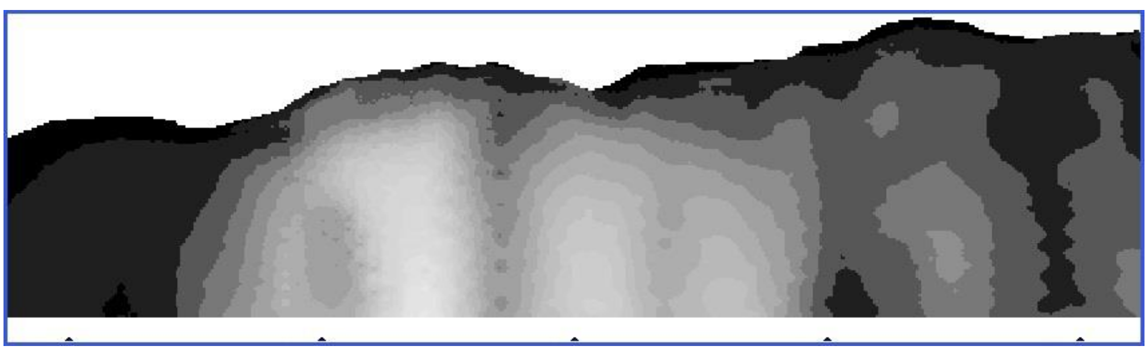

Fig.3 histogram equalization of the apparent resistivity raster data between stack DLII 014+000 and DLII 018+000

Secondly, take a longitudinal apparent resistivity data as a one-dimensional signal along with the depth *t* change, the signal is $f(t) = f_0(\mathrm{t}) + \mathrm{n}(\mathrm{t})$, $\mathrm{n}(\mathrm{t})$ is noise, choose Gaussian function $\theta(t) = \frac{1}{\sqrt{2\pi a}} e^{-\frac{t^2}{2a}}$ as smoothing function, scale is 2^j, use formula (1) get the wavelet transform coefficients' modulus maxima points, where is the singular point of signal $f(t)$.Points in Fig. 4 are singular points detected by the method.

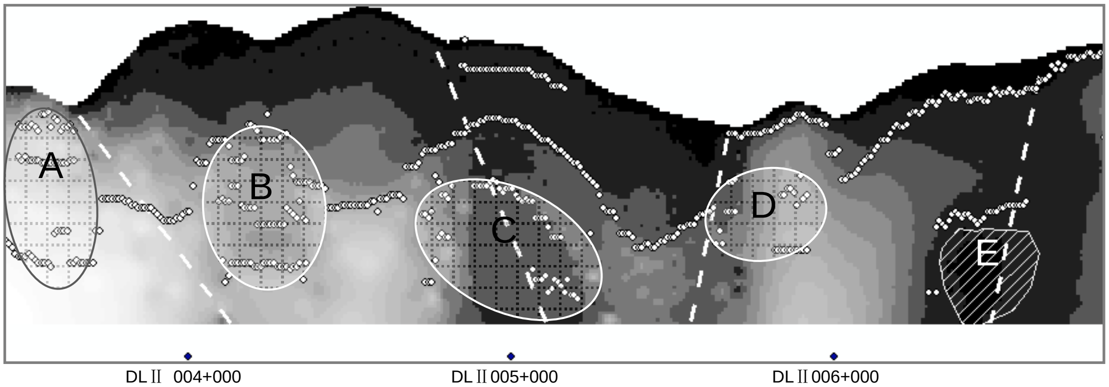

Fig.4 Geological abnormal range divination between stack DL Ⅱ 004+000 and DL Ⅱ 006+000

Finally, Overlay the histogram-equalized image with those abnormal points and analyze abnormal geological range. Points in Fig. 4 are detected abnormal points. There are many abnormal points that nearly can connect to be a continuous interface, which almost consistent with the terrain and reflects a base level of erosion. The stratum under this level has a relatively higher apparent resistivity values.

Besides that, some clustered or messy abnormal points are distributed (or embraced) in grey regions with low apparent resistivity and form abnormal regions(shown as A-E in Fig. 4). Geological data indicates that Dalishu fracture is near B and C; A is in a valley, and a river flows through D; E is lowland; a water burst appeared in borehole XLZK2 in D. It's reasonable to infer that B and C might be fractures, since where the rock is fairly crushed, and this might causes abnormal apparent resistivity, and that the abnormal apparent resistivity in A, D, E might be caused by groundwater.

In the results obtained by conventional methods of geophysical interpretation, there are four abnormalities (shown as three dashed lines and the patch E in Fig. 4). Comparing with them, the method of abnormal points overlaying the histogram-equalized image has finer performance in revealing abnormal range.

3. Conclusions

The combination data mining method based on wavelet transformation and image processing has been proposed to identify abnormal geological range. One-dimensional dyadic wavelet analysis is adopted to detect abnormal points, and then histogram equalization is used to achieve enhanced visual expression for the apparent resistivity image. Finally, overlay the histogram-equalized image with those abnormal points to analyze abnormal geological range. This method has been applied to identify abnormal geological Range in early exploration of Yunnan water diversion project. Comparing with conventional methods of Geophysical interpretation, this method has finer performance in revealing abnormal range. Besides that, it does not depend on people's work experiences, which provides a new path for such problems-solving.

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