Edge Detection of Potential Filed Data Using Correlation Coefficients

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SUMMARY

Edge detection is an essential task in the interpretation of potential field data. In this paper, we present a new method to delineate the edges of the sources, which is based on the windowed correlation coefficients of the average and the standard deviation of vertical derivatives. The zero value of the correlation coefficients is used to delineate the geological edges. This method can clearly give resolution of the edges of the deeper and shallower sources. The measure is initially applied on the synthetic gravity data. The test of theoretical models indicates that this method could detect the geological edges in different depths and the result is in accordance with model edges. Finally, this method is applied to gravity data from a portion of Vientiane Basin, Laos. As a result, the method can recognize geologic fractures more clearly. Moreover, it can recognize more geologic details when the window size is small and give superior results when the data are relatively smooth.

Key words: edge detection, correlation coefficient, potential field

INTRODUCTION

Edge detection is an essential task in the interpretation of potential field data. The zero of the vertical derivative is corresponding to the edges of the source (Even, 1936), but it cannot display the edges of deeper source exactly. Tilt angle which is the ratio of the vertical derivative to total horizontal derivative could effectively display the edges of the sources with different depths (Miller and Singh, 1994). Normalized standard deviation (NSTD) is based on ratios of the windowed standard deviation of derivatives of the field. It can make large and small amplitude edges visible simultaneously (Cooper and Cowan, 2008). In this paper, we present a new method which is based on the windowed correlation coefficients of the average and the standard deviation of vertical derivatives to delineate the edges of the sources. The zero value of the correlation coefficients is used to delineate the geological edges. The measure is initially applied on the synthetic gravity data and the real gravity data from a portion of Vientiane Basin, Laos. The test of theoretical models indicates that this method could detect the geological edges in different depth and the result is in accordance with model edges. As a result, it can recognize more geologic details when the window size is small or the data are relatively smooth.

METHOD AND RESULTS

The windowed computation of the standard deviation of an image is a simple measure of the local variability. It has relatively small values when the data are smooth and relatively large values when they are rough, e.g., over edges (Cooper et al., 2008). The zero value of the vertical derivatives can delineate the edges of the sources. The correlation coefficients of the average and the standard deviation of the vertical derivatives could describe their correlation. When the value of the correlation coefficients approximately equal to zero, means there is no correlation between the two elements. Therefore the zero value could delineate the geological edges. The correlation coefficients R are computed by using a moving square window of data points:

$$R = \frac{\mathrm{cov}(\sigma(\frac{\partial f}{\partial z}), \overline{\frac{\partial f}{\partial z}})}{\sqrt{D(\sigma(\frac{\partial f}{\partial z}))D(\overline{\frac{\partial f}{\partial z}})}} \tag{1}$$

The average of the vertical derivative is:

$$\overline{\frac{\partial f}{\partial z}} = \frac{1}{N}\sum_{i=1}^{N}(\frac{\partial f}{\partial z})_i \tag{2}$$

The standard deviation of the vertical derivative is:

$$\sigma(\frac{\partial f}{\partial z}) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}((\frac{\partial f}{\partial z})_i - \frac{1}{N}\sum_{i=1}^{N}(\frac{\partial f}{\partial z})_i)} \tag{3}$$

The covariance of the average and the standard deviation of the vertical derivative is:

$$\mathrm{cov}(\sigma(\frac{\partial f}{\partial z}), \overline{\frac{\partial f}{\partial z}}) = \frac{1}{N}\sum_{i=1}^{N}\left[(\sigma(\frac{\partial f}{\partial z})_i - \frac{1}{N}\sum_{i=1}^{N}\sigma(\frac{\partial f}{\partial z})_i)\times((\overline{\frac{\partial f}{\partial z}})_i - \frac{1}{N}\sum_{i=1}^{N}(\overline{\frac{\partial f}{\partial z}})_i)\right] \tag{4}$$

The variances of the standard deviation of the vertical derivatives and the variances of the average of the vertical derivative respectively are:

$$D(\sigma(\frac{\partial f}{\partial z})) = \frac{1}{N}\sum_{i=1}^{N}\left[\sigma(\frac{\partial f}{\partial z})_i - \frac{1}{N}\sum_{i=1}^{N}\sigma(\frac{\partial f}{\partial z})_i\right]^2 \quad \text{and} \quad D(\overline{\frac{\partial f}{\partial z}}) = \frac{1}{N}\sum_{i=1}^{N}\left[(\overline{\frac{\partial f}{\partial z}})_i - \frac{1}{N}\sum_{i=1}^{N}(\overline{\frac{\partial f}{\partial z}})_i\right]^2 \tag{5}$$

Where f is the magnetic or gravity anomaly and N is the number of the window-covering points.

Test of the method to the gravity data for a vertical finite rectangular and combined model as follows:

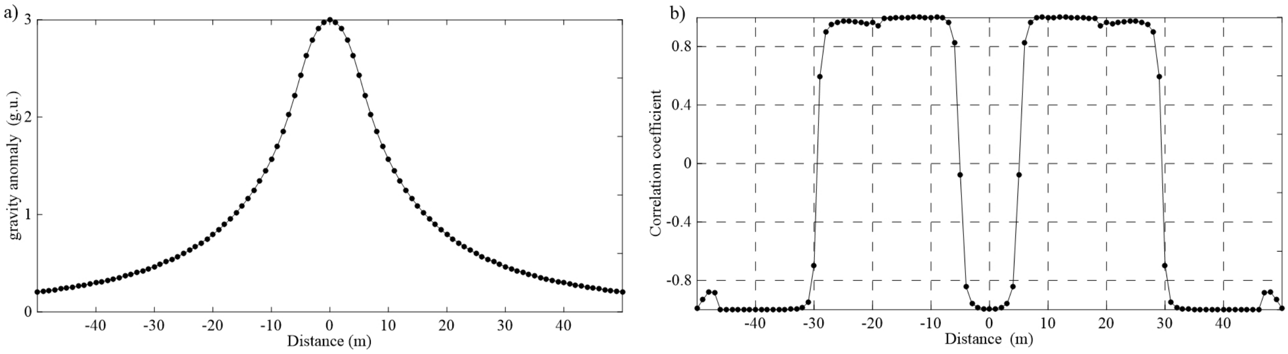

Figure 1: (a) Gravity anomaly from a vertical finite rectangular; its horizontal centre position is 0 m and its width is 10m. Its top and bottom depth are 2m and 30m respectively. Its residual density is 1.0×10^{3}kg/m^3. The data sampling interval is 1 m. (b) Correlation coefficients R in Eq. (1) and the window size is 5. The two points near the zero value correspond the edges of the rectangular's horizontal position.

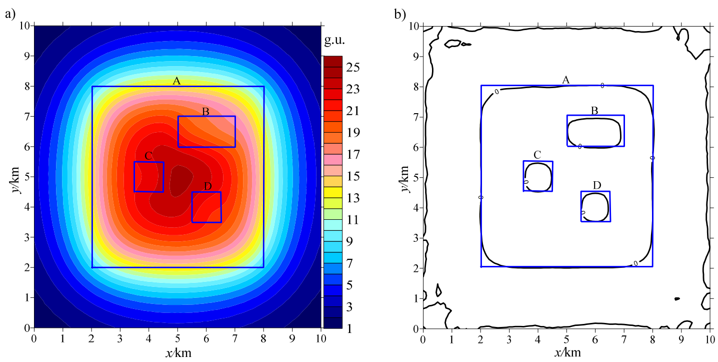

Figure 2: (a) Synthetic gravity data from the body outlined in blue, added random noise with 1% Gaussian white noise. (b) Zero value of the correlation coefficients in Eq. (1) which is in black clearly gives a better resolution of the edges of the shallower and deeper sources simultaneously. And it's insensitive to the noise.

model number	top/bottom depth(km)	residual density (10^3kg/m^3)
A	1.0/2.0	0.1
B	0.5/0.7	-0.1
C	0.4/0.5	-0.1
D	0.4/0.5	-0.1

Table 1: the parameters of the models in figure 2

The application of this method to the field data:

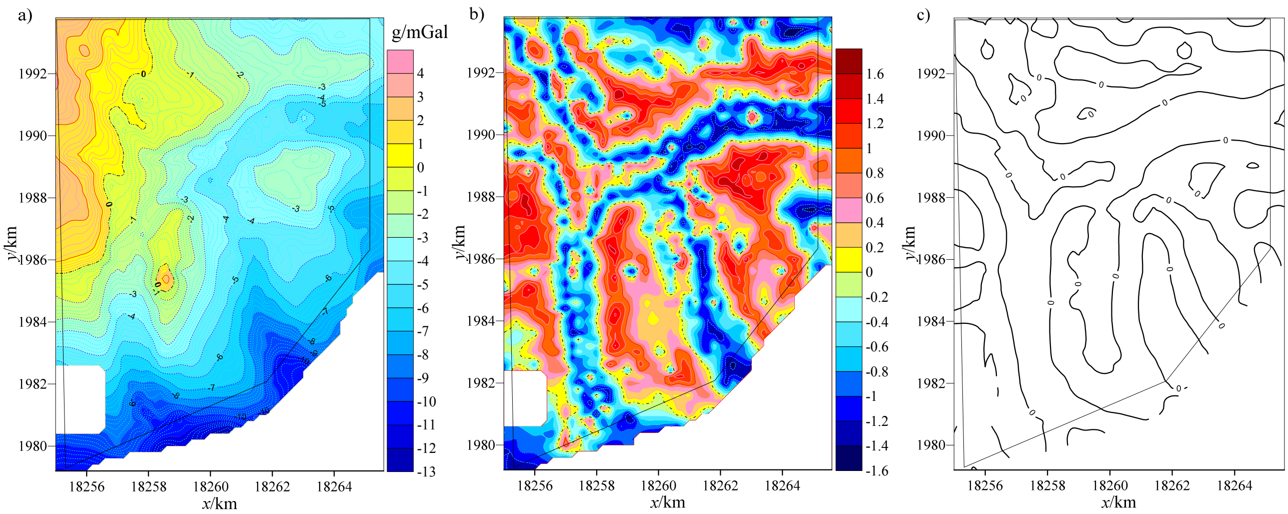

Figure 3 : (a) Bouguer anomaly over a portion of Vientiane Basin, Laos. The grid interval is 0.2 km. (b) Tilt derivative of the data in (a); (c) Zero value of the correlation coefficients of the data in (a). The fractures are mainly south to north and north to west, which can be seen more clearly in it than in (b).

CONCLUSIONS

To address the problems of delineating the edges of the sources in different depths simultaneously, we propose a new edge-detection-method. The method is based on the windowed correlation coefficients of the average and the standard deviation of vertical derivatives. This algorithm is easy to carry out. Besides, noise is effectively suppressed by moving windows. The method clearly gives resolution of the edges of the deeper and shallower sources. It could give more geologic details and superior results when the data are relatively smooth. But the false edges exist, such as in figure 2 (b).

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