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The removal of additional edges in the edge detection of potential field data

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ABSTRACT

Edge detection results of potential field data are used to delineate the horizontal locations of the causative sources, and there are many edge detection filters to finish this work. However, most of balanced edge detection filters produce additional edges which interpret the potential field data that contain positive and negative anomalies. First, we test the application effect of several common balanced edge detection filters, and then analyze the reason that produces additional edges. We present several new edge detection filters depending on the distribution features of different derivatives that will not produce additional edges. The new filters are demonstrated on synthetic gravity anomalies, which show the edges more precisely, and are insensitive to noise. We also apply them to real potential field data because they display the locations of the stratigraphic markers more precisely and clearly.

1. Introduction

Many edge detection filters are presented to recognize the source edges; most of them are the functions of horizontal and vertical derivatives of potential field data. Initially, people (Evjen, 1936; Thurston and Smith, 1997; Cordell and Grauch, 1985; Nabighian, 1984; Roest et al., 1992) directly use the total horizontal derivative, vertical derivative and the sum of them to finish the edge detection task, but they cannot show the edges of the deeper bodies clearly. Sertcelik and Kafadar (2012) used the eigenvalues of the two-dimensional structure tensor to divide the lineaments of the subsurface, but this method cannot also display the edges of the deeper sources clearly. Some people began to study the balanced edge detection filters. Miller and Singh (1994) presented tilt angle filter that is the arc tangle of the ratio of vertical derivative to total horizontal derivative, which can balanced the amplitudes of the anomalies generated by shallow and deep bodies, but this method cannot highlight the edges of the sources clearly. Hsu et al. (1996) generalized the analytic-signal method to higher-order derivatives to increase the resolving power of this method. Verduzco et al. (2004) suggested the use of the total horizontal derivative of the tilt angle to accomplish this work where its maxima can automatically delineate the edges of geological body. The Theta map (Wijns et al., 2005) used the analytic signal to normalize the total horizontal derivative as an edge detection tool, and also use the maxima to identify the edges. Cooper and Cowan (2006) summarized the application effect of different balanced edge detection filters and proposed the normalized directional tilt angel (TDX) filter to detect the source edges. More recently, Cooper and Cowan (2008) proposed an alternative method based on the radio of related normalized standard deviation to enhance the edges.

In our research, we find that the existing balanced edge detection filters produce additional edges in the edge detection of potential field data with positive and negative anomalies. We suggest three new balanced edge detection filters to finish the edge detection task because they will not produce additional edges, and in which the recognized edges are clearer. We also apply them to real potential field data because they can display the edges of the stratigraphic markers more precisely and clearly.

2. Methodologies

Firstly, we show the application effect of different edge detection filters. Fig. 1a shows the original gravity anomaly generated by the sources with depths of 10 and 15 m, respectively, and their densities are +1 and −1 g/cm^3. The white dotted lines express the horizontal locations of the sources. Fig. 1b shows the horizontal derivative of the data in Fig. 1a, and we can see that the maxima of the data are corresponding to the edges of the sources, but it cannot show the edges of the deeper bodies very clearly. Fig. 1c and d shows the TDX and Theta map of the data in Fig. 1a, and their expressions are

$$\mathrm{TDX} = \tan^{-1}\left(\frac{\sqrt{\left(\frac{\partial f}{\partial x}\right)^2+\left(\frac{\partial f}{\partial y}\right)^2}}{\left|\frac{\partial f}{\partial z}\right|}\right) \quad (1)$$

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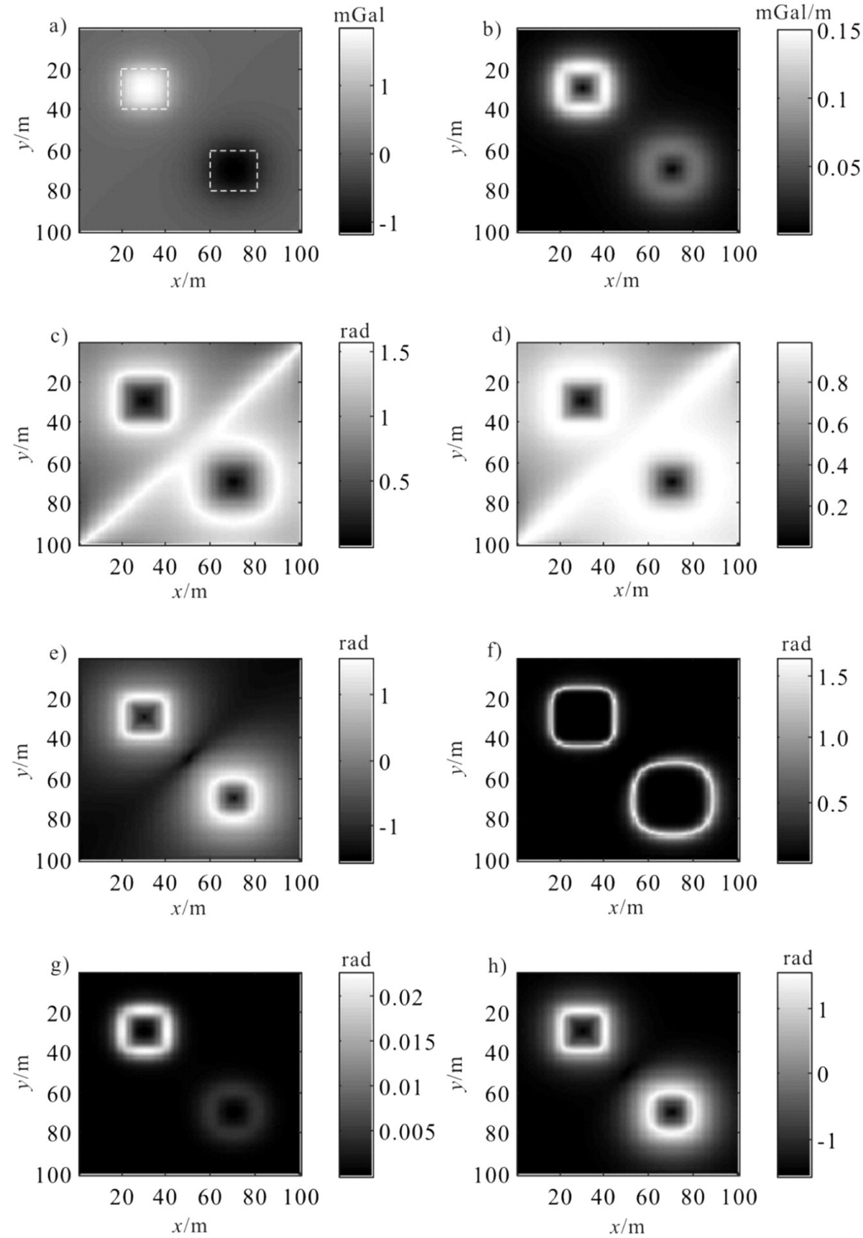

Fig. 1. (a) Composite gravity anomaly of two prisms with depths of 10 and 15 m;(b) total horizontal derivative of the data in panel a; (c) TDX of the data in panel a; (d) Theta map of the data in panel a; (e) balanced total horizontal derivative of the data in panel a; (f) normalized analytic signal of the data in panel a; (g) the eigenvalue λ of the data in panel a; (h) balanced eigenvalue of the data in panel a.

$$\text{Theta} = \frac{\sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}}{\sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}} \tag{2}$$

Where, f represents the original potential field data. The maxima of them can delineate the edges of the sources depending on the features of different derivatives. The edges recognized by them have additional edges, so they are unavailable. In order to reveal the season that they produce additional edges clearly, we use profile gravity anomalies to show the application effect. Fig. 2a shows the gravity anomaly generated by two rectangular prisms with residual densities of $+1$ and -1 g/cm^3. Fig. 2b shows the total horizontal derivative and vertical derivative of the data in Fig. 2a, and we can see that the maxima of the total horizontal derivative and the zero of the vertical derivative are corresponding to the edges of the sources, but we can find that the vertical derivative is zero over the source edges, and it is also zero in the middle of the sources. Theta map and TDX filters get maxima depending on Eqs. (1) and (2) when the vertical derivative is zero, and the values of them are not related to the total horizontal derivative. Fig. 2c and d shows the TDX and Theta map of the data in Fig. 2a, and we can see that the Theta map and TDX filters produce additional edges in the edge detection of the data with positive and negative anomalies, but this type of data is very common in the real geophysical measurement, so the existing balanced edge detection almost has this trouble in the interpretation of real gravity data. Fig. 2e and f shows the TDX and Theta map of vertical magnetic anomaly generated by the prism with susceptibilities of 0.01 and -0.01, and the Theta map and TDX filters also produce additional edges for magnetic anomaly. We can find that the total horizontal derivative does not have additional maximum values, so we should use the functions of total horizontal derivative to recognize the source edges. We present three new edge detection filters which are balanced