Computers & Geosciences 41 (2012) 83–87

Contents lists available at SciVerse ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Edge detection in potential fields with the normalized total horizontal derivative

Guoqing Ma*, Lili Li

College of Geoexploration Science and Technology, Jilin University, Changchun, Jilin 130026, China

ARTICLE INFO

Article history:
Received 22 April 2011
Received in revised form
18 August 2011
Accepted 18 August 2011
Available online 1 September 2011

Keywords:
Edge detection
Potential field
Normalized total horizontal derivative

ABSTRACT

Edge detection plays an important role in the interpretation of potential field data. There are many methods based on horizontal and vertical derivatives to delineate the edges of sources. A universal disadvantage of these methods is that they cannot display the large and small amplitude edges simultaneously. In order to solve this problem, a new edge-detection filter is presented (the normalized total horizontal derivative (NTHD) method). The NTHD method is based on the ratio of the horizontal derivative to the maxima of nearby values. The NTHD filter is demonstrated on gravity data and magnetic data from China. The resolving power of the NTHD method is evaluated by comparing the results with those obtained by other similar edge-detection filters based on the horizontal and vertical derivatives. The advantage of the NTHD method in the recognition of source edges is due to the fact that it can make the strong and weak amplitude edges visible simultaneously, and can bring out more details.

1. Introduction

The horizontal location of the edges of causative sources is a commonly requested task in the interpretation of geophysical data; many filters are available to accomplish this task. The vertical derivative has been used for many years to delineate edges in gravity and magnetic field data (Evjen, 1936; Hood and Teskey, 1989; Thurston and Smith, 1997). The maxima of the total horizontal derivative of potential field data are located above abrupt changes of density or magnetization (Cordell, 1979; Cordell and Grauch, 1985); this method has proven to be an effective tool for edge detection. Later, some authors (Nabighian, 1972, 1984; Roest et al., 1992) proved that the maxima of the amplitude of the analytic signal can directly outline the edges of sources. Miller and Singh (1994) introduced the tilt angle to accomplish this task. It is based on the ratio of the total horizontal derivative to the vertical derivative. It is effective in balancing the amplitude of strong and weak anomalies, but it is not primarily an edge-detection method (Cooper and Cowan, 2006). Rajagopalan and Milligan (1995) used the automatic gain control to enhance the aeromagnetic data. This method can balance the amplitude of anomaly, but it is not a satisfactory edge-detection method. It usually widens the scope of anomaly (Cooper, 2005). 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 using the total horizontal derivative of the tilt angle to accomplish this task; its maxima can automatically delineate the edges of sources. Wijns et al. (2005) used the analytic signal amplitude to normalize the total horizontal derivative as an edge-detection filter. More recently, Cooper and Cowan (2008) proposed an alternative method based on the ratio of related normalized standard deviations to outline the edges. In this paper, we present a new edge-detection filter using the normalized total horizontal derivative (NTHD) to delineate the edges of sources.

2. The normalized horizontal derivative

The normalized horizontal derivative is the ratio of the horizontal derivative to the maxima of nearby horizontal derivatives. This method does not require the computation of the vertical derivative, which makes the filter more computationally stable. It can be expressed as

$$NTHD(i,j) = \frac{TDX(i,j)}{\max[TDX(i-m:i+m,\, j-n:j+n)]} \tag{1}$$

where $NTHD(i,j)$ represents the output value of (i,j);

$$TDX = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

represents the total horizontal derivatives; m, n is the size of window (i.e., the size of the sample).

* Corresponding author. Tel.: +86 15843012966.
E-mail address: magq08@mails.jlu.edu.cn (G. Ma).

0098-3004/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cageo.2011.08.016

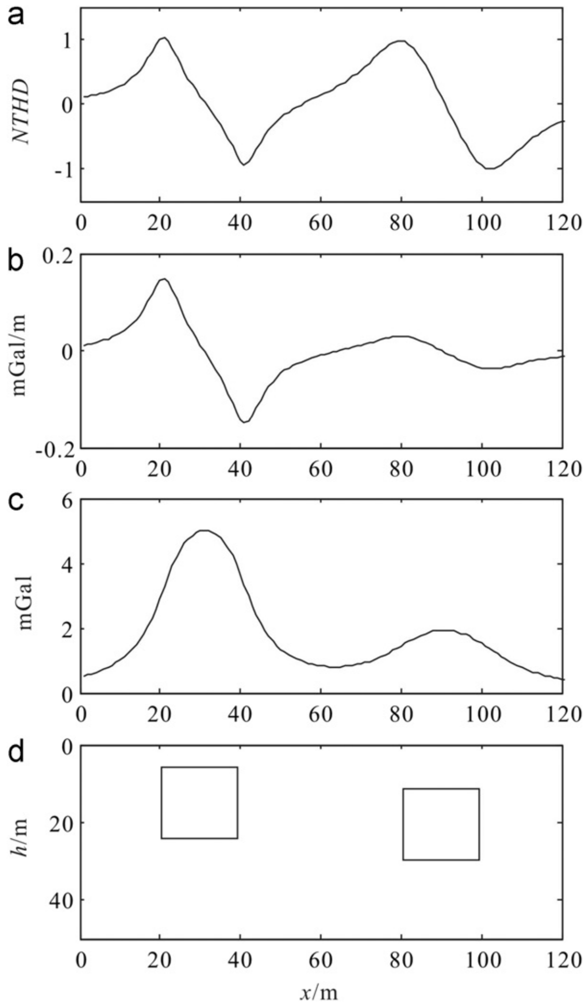

Fig. 1. (a) Normalized horizontal derivative of gravity anomaly. (b) Horizontal derivative of gravity anomaly. (c) Gravity anomaly. (d) Geological model.

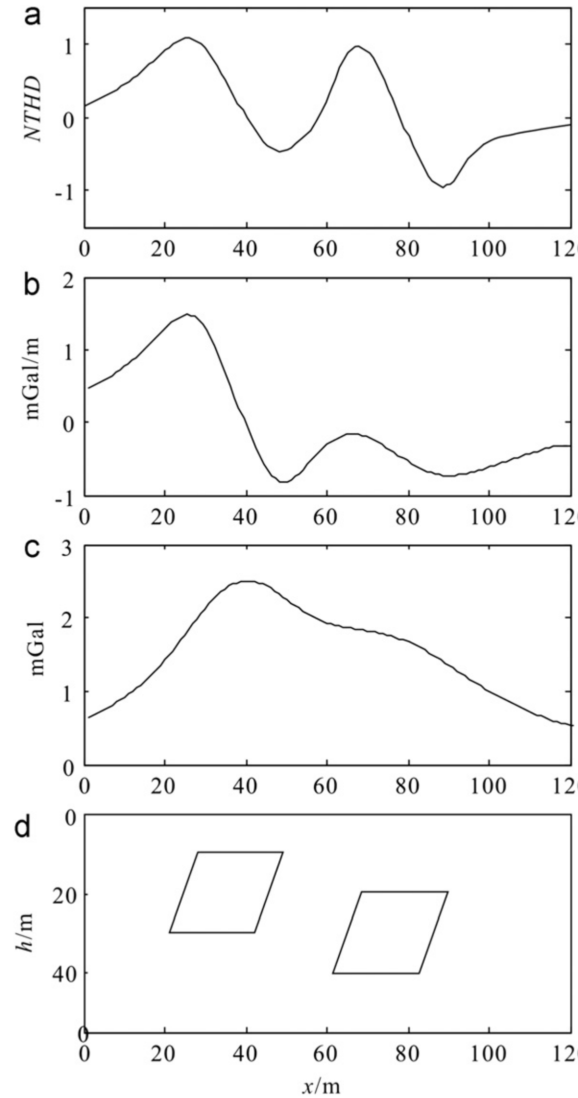

Fig. 2. (a) Normalized horizontal derivative of gravity anomaly. (b) Horizontal derivative of gravity anomaly. (c) Gravity anomaly of geological model. (d) Geological model.

The maxima of the NTHD method are located on the edges of causative sources. The calculation of the NTHD can be implemented in the space or frequency domain, and it can be computed in a given direction. To illustrate the benefit of this method for enhancing edges in potential field data, we use a series of profiles of horizontal derivatives of a gravity anomaly.

Fig. 1c shows the gravity anomaly from a model consisting of two identical prisms at central depths of 15 and 20 m. The model is shown in Fig. 1d. Fig. 1b shows the horizontal derivative of the gravity anomaly. Fig. 1a shows the normalized horizontal derivative of the gravity anomaly. It is clear that the normalized horizontal derivative of the gravity anomaly can recognize the source edges more clearly and precisely. This method can successfully equilibrate the amplitude of the horizontal derivative of geological bodies at different depths. This is an advantage of this method compared to other edge-detection methods.

Fig. 2c shows the gravity anomaly of two geological bodies shown in Fig. 2d. Fig. 2a and b shows the normalized horizontal derivative and the horizontal derivative of the gravity anomaly, respectively. As can be seen from Fig. 2, the normalized horizontal derivative can effectively enhance the edges of geological bodies at different depths. Because of the effect of nonvertical contacts, the recognized edges have tiny deviations to the direction of dip. So, the NTHD method can be used to recognize the source edges in the case of nonvertical contacts.

Fig. 3a shows the normalized horizontal derivative of the magnetic anomaly from a model consisting of a plate at depth of 20 m with an inclination of 0°; the model is shown in Fig. 3f. Fig. 3b–e shows the normalized horizontal derivative of the magnetic anomaly with inclinations of 30°, 45°, 60°, and 90°, respectively. We can see that the normalized horizontal derivative of the magnetic anomaly can enhance the source edges effectively. However, as can be seen from Fig. 3b–d, for the sake of tilt magnetization, the recognized edges are not in agreement with the actual edges, especially, when the inclination is equal to 45°, the minimum of the NTHD method is corresponding to the source edges. When the inclination is near to 0° or 90°, the recognized edges are very precise. So, before using the NTHD method to detect the source edges, we should reduce the anomaly to the pole or the equator.

3. Synthetic gravity anomaly

In order to test the feasibility of the NTHD method, we choose three other similar methods to compare results. They are the total