Journal of Applied Geophysics 144 (2017) 50–56

Contents lists available at ScienceDirect

Journal of Applied Geophysics

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

Weighted small subdomain filtering technology

Zhenhua Tai [a], Fengxu Zhang [b,*], Fengqin Zhang [c], Xingzhou Zhang [d], Mengcheng Hao [b]

[a] College of Mining Engineering, Heilongjiang University of Science and Technology, Harbin 150022, China
[b] College of Geo-Exploration Science and Technology, Jilin University, Changchun 130026, China
[c] College of Physics, Jilin University, Changchun 130023, China
[d] College of Earth Sciences, Jilin University, Changchun 130061, China

ARTICLE INFO

Article history:
Received 26 July 2015
Received in revised form 28 June 2017
Accepted 29 June 2017
Available online 30 June 2017

Keywords:
Edge detection
Small subdomain filtering
Numerical difference
Gradient belt
Gravity data

ABSTRACT

A high-resolution method to define the horizontal edges of gravity sources is presented by improving the three-directional small subdomain filtering (TDSSF). This proposed method is the weighted small subdomain filtering (WSSF). The WSSF uses a numerical difference instead of the phase conversion in the TDSSF to reduce the computational complexity. To make the WSSF more insensitive to noise, the numerical difference is combined with the average algorithm. Unlike the TDSSF, the WSSF uses a weighted sum to integrate the numerical difference results along four directions into one contour, for making its interpretation more convenient and accurate. The locations of tightened gradient belts are used to define the edges of sources in the WSSF result. This proposed method is tested on synthetic data. The test results show that the WSSF provides the horizontal edges of sources more clearly and correctly, even if the sources are interfered with one another and the data is corrupted with random noise. Finally, the WSSF and two other known methods are applied to a real data respectively. The detected edges by the WSSF are sharper and more accurate.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Edge detection is a commonly requested task in the interpretation of potential field data. Many methods are available to accomplish this task. The zero of the vertical derivative and the maxima of the horizontal derivative are corresponding to the horizontal locations of the edges of potential field sources (Evjen, 1936; Cordell, 1979; Nabighian, 1984; Blakely and Simpson, 1986; Roest et al., 1992; Thurston and Smith, 1997). These methods can define the edges of shallow bodies, but they cannot obtain the edges of deep bodies clearly. To resolve the above problem and the interference effects caused by nearby sources, Fedi and Florio (2001) presented an enhanced horizontal derivative (EHD) method, which is formed by taking the horizontal derivative of a sum of vertical derivatives of increasing order. Later, Cella et al. (2009) introduced a multiscale edge detection method by improving the EHD, and its final result display subtle detail characteristics of sources in terms of lateral extent, depth and source-type. On the other side, many people began to develop balanced edge detection methods. Miller and Singh (1994) presented a tilt angle method, which is the ratio of the vertical derivative to total horizontal derivative. The tilt angle can effectively balance the amplitudes of anomalies generated by sources with different depths. Verduzco et al. (2004) introduced an improved method by mean of the total horizontal derivative of the tilt angle, which maxima can automatically delineate the edges of sources. Wijns et al. (2005) presented a Theta map method for edge detection, which is the ratio of the analytic signal amplitude to the total horizontal derivative. Cooper and Cowan (2008) introduced an alternative method for edge detection, which is the ratio of related normalized standard deviations. Some people also introduced other ways to outline the edges of sources (such as Rajagopalan and Milligan, 1995; Ma and Li, 2012; Yuan et al., 2014).

The small subdomain filtering (SSF) method was a different approach to define the edges of sources (Yang, 1995). This method outlines the horizontal edges of gravity and magnetic sources by mean of the tightened gradient belts in its final result. However, it is only valid for a part of edges whose anomaly characteristics are significant gradient belts, and unable to define other edges whose anomaly characteristics are non-gradient belts or interfered by nearby sources. To resolve this problem, Zhang et al. (2007) proposed the three-directional small subdomain filtering (TDSSF) method which uses the numerical difference algorithm and calculated in space domain and Fourier domain by turns. The TDSSF defines more detail edges along the *x*-, *y*-, *xy*- and *yx*-directions. However, its final result is composed of four contours corresponding to four directions. And there are some spurious edges in each contour. In the application, these problems require the user to distinguish the true and the spurious edges, and seek the complete information generated by one edge from four contours.

* Corresponding author.
E-mail address: zhangfengxu15@163.com (F. Zhang).

http://dx.doi.org/10.1016/j.jappgeo.2017.06.012
0926-9851/© 2017 Elsevier B.V. All rights reserved.

In this paper, we propose the weighted small subdomain filtering (WSSF) method as a high-resolution edge detection technique on the basis of the SSF and the TDSSF. This proposed method combines the numerical difference and the average algorithm. All calculations are accomplished in space domain to reduce the computational complexity. The numerical difference results along four directions are integrated into one contour by a weighted sum.

2. Theory

2.1. Small subdomain filtering

The SSF is based on a moving average method. Firstly, the calculation window is divided into eight subdomains on the flanks of the center (Fig. 1). Then, the standard deviation and the average of the anomalies of each subdomain are calculated respectively. Finally, the average of the subdomain whose standard deviation is minimum is as the calculation result of the window. In the SSF result, the tightened gradient belt can define the edge of a source. However, this method can only define the edges corresponding to gradient belts in the gravity contour, but cannot define other edges whose anomaly characteristics are non-gradients.

In this paragraph, we take an example to explain the SSF in detail. We suppose there is a gradient belt corresponding to one edge of a gravity source in the contour. Amplitudes of anomalies on both sides of the gradient belt increase gradually from left to right. The calculation window moves from left to right. As shown in Fig. 1, while right subdomains are located on the belt, the standard deviations of right subdomains are higher. One of the averages of left subdomains will be the SSF result, which is equivalent to replace the original anomaly of the window center with the lower value on the left. While the window center is located on the belt, the standard deviations of the left and the right subdomains are similar, and the value is almost unchanged. While left subdomains are located on the belt, the standard deviations of left subdomains are higher. One of the averages of right subdomains will be the SSF result, which is equivalent to replace the original anomaly of the window center with the higher value on the right. The anomaly gradient has been increased, which is equivalent to tighten the gradient belt. Meanwhile, the tightened gradient belt can delineate the edge clearly.

2.2. Three-directional small subdomain filtering

For 1D gravity data, Zhang et al. (2007) found out that the anomalies located on the edges of a vertical prism could be replaced with extreme values in the curve, while the whole data set was moved by a tiny distance along the x-axis and then subtracted from the original set. Then, these two extreme values can be replaced with zero values while the phase of data set is conversed by π/2 in Fourier domain. After the above-mentioned steps, the anomaly characteristics of the two edges have been replaced with gradient belts respectively, and the data set is suitable for using the SSF to define the edges.

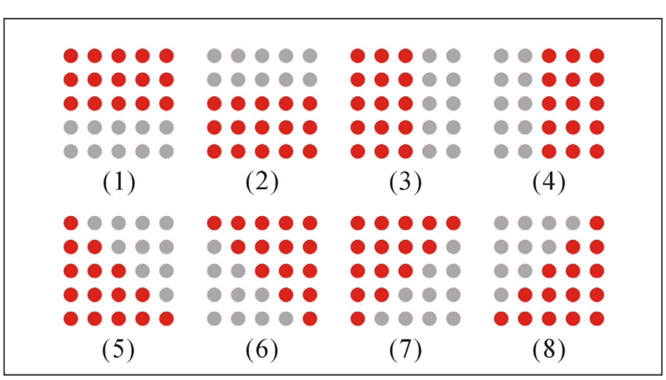

Fig. 1. Subdomain division of the SSF (window size is 5; the red points form the subdomains). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

For 2D gravity data, the TDSSF replaces the anomalies located on the edges with extreme values by the following formulas along four directions (Zhang et al., 2007),

$$x\ \text{direction}: \Delta g_x(i,j) = g(i,j) - g(i + \Delta x/\mathrm{d}x, j) \tag{1}$$

$$y\ \text{direction}: \Delta g_y(i,j) = g(i,j) - g(i, j + \Delta y/\mathrm{d}y) \tag{2}$$

$$xy\ \text{direction}: \Delta g_{xy}(i,j) = g(i,j) - g(i + \Delta x/\mathrm{d}x, j + \Delta y/\mathrm{d}y) \tag{3}$$

$$yx\ \text{direction}: \Delta g_{yx}(i,j) = g(i,j) - g(i - \Delta x/\mathrm{d}x, j + \Delta y/\mathrm{d}y) \tag{4}$$

As shown in Fig. 2, $g\ (i, j)$ represents the gravity data at the point (i, j), and $i = 0, 1\dots M - 1$; $j = 0, 1\dots N - 1$. M and N represent the total number of data along the x- and y-directions; dx and dy represent the sampling interval along the x- and y-directions; and Δx and Δy represent the moving distance along the x- and y-directions.

Then, the phases of the results of aforementioned four formulas need to be conversed by π/2 in Fourier domain respectively. Finally, the SSF can be used to tighten gradient belts in four results. The final results of the TDSSF are displayed in four contours. This method can replace the non-gradient characteristics of the edges with gradient ones. Therefore, the TDSSF can obtain more edge information. However, in the application, it is found out that the TDSSF is very sensitive to noise, due to the simple subtraction of point-to-point, and the phase conversion in Fourier domain increases the computational complexity. Its final interpretation by four contours requires the user to have more geological experiences. These problems limit the application of the TDSSF.

2.3. Weighted small subdomain filtering

In this paper, a high-resolution method (WSSF) is proposed to define the horizontal edges of gravity sources by improving the TDSSF. Theory of the WSSF is as described below.

For Eqs. (1) to (4), the plane coordinates of the whole data set need to be moved by $\Delta x/2$ and $\Delta y/2$ along the x- and y-axis, in order to make sure that the zero-value points in the final results are consistent with the horizontal edges of sources. Therefore, a subtraction method of the

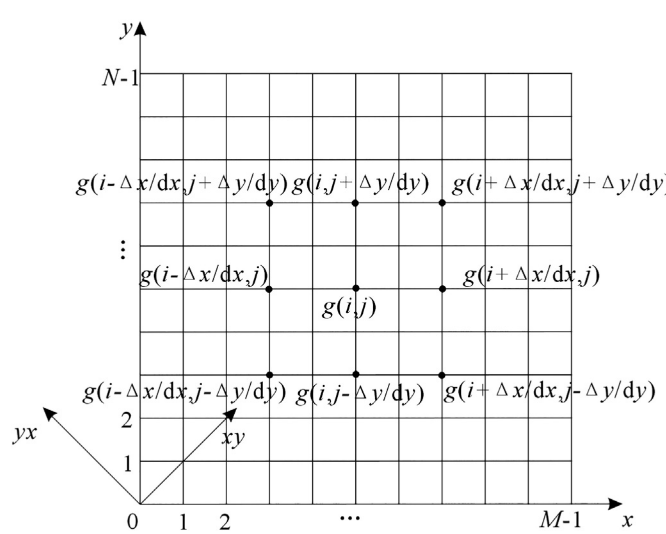

Fig. 2. Distribution of the calculation points of the WSSF.

Download English Version:

https://daneshyari.com/en/article/5787070

Download Persian Version:

https://daneshyari.com/article/5787070

Daneshyari.com