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## Edge Detection of Potential Field Gradient Tensor Data with Horizontal Second Order Directional Analytic Signal

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## SUMMARY

Potential-field gradient tensor data include nine signal components. They include higher frequency signals than potential field data, which can help to delineate small-scale features of the sources. Edge detection technologies have been widely used to delineate the edges of the sources. We need to develop new edge detector to process the gradient tensor data. There are many methods are used to recognize the edges of the data. The analytic signal method is a widely used edge detection filter. We make some improvements to the analytic signal method, so that it can process the potential-field gradient tensor data. We define a few new filters based on the horizontal directional analytic signal and second order horizontal directional analytic signal. In order to display the large and small amplitude edges simultaneously, we present a normalization method. These methods have been tested on synthetic and real potential-field gradient tensor data to verify the feasibility. Compared to other known balance filters, the normalized second order horizontal directional analytic signal can get the results clearly and precisely.

## Introduction

Edge detection is a requested task in the interpretation of potential-field data, which has been widely used as a tool in exploration technologies for mineral resources. There are many filters are employed to detect and enhance the edge. Roest et al. (1992) proved that the maxima of the amplitude of the analytic signal can directly delineate the edges of sources. Hsu et al. (1996) used the higher order derivatives to enhance the edges, called it as the enhanced analytic signal.

In recent years, potential field gradient tensor data has been widely used. Potential field gradient tensor data can be either measured or numerically calculated from the potential field data. It offers nine components, which include higher frequency signals than potential field data. Therefore, their interpretations allow a high resolution and detailed investigation of the geological structures. This needs developing new methods to interpret them, especial the edge detection of small geology structures. Cooper (2006) and Oruc (2008) proposed directional tilt angle to delineate the edges, but only the vertical direction tilt angle, namely the tilt angle provided by Miller and Singh (1994), can get well results. Beiki (2010) define the directional analytic signal to delineate the edge, which shown better results than traditional analytic signal.

In this paper, we define the second order direction analytic signal, and proposed a new filter based on it. At last, we present a normalized method to enhance the large and small amplitude anomalies simultaneously.

## Second order directional analytic signal

Beiki (2010) define the directional analytic signal to delineate the edge. In order to increase the resolution of the edges, we proposed another method that using the second order derivatives to form the directional analytic signal, called it second order directional analytic signal (SA). The horizontal second order directional analytic signal can be rewritten as

$$SA_x = \sqrt{\left(\frac{\partial G_{xz}}{\partial x}\right)^2 + \left(\frac{\partial G_{xz}}{\partial y}\right)^2 + \left(\frac{\partial G_{xz}}{\partial z}\right)^2} \tag{1}$$

$$SA_y = \sqrt{\left(\frac{\partial G_{yz}}{\partial x}\right)^2 + \left(\frac{\partial G_{yz}}{\partial y}\right)^2 + \left(\frac{\partial G_{yz}}{\partial z}\right)^2} \tag{2}$$

Here the subscripts $x$ and $y$ denote the directions. The maximum values of $SAx$ locate the N-S edges; the maximum values of $SAy$ locate the E-W edges. We combine $SA_x$ and $SA_y$ to define an edge detector:

$$ED\_SA = \sqrt{\left(SA_x\right)^2 + \left(SA_y\right)^2} \tag{3}$$

In order to balance the amplitude of large and small anomalies, we use $G_{zzz}$ to normalize the $ED\_SA$. The expressions is

$$N\_ED\_SA = \tan^{-1}\left(\frac{ED\_SA}{|\partial G_{zz}/\partial z|}\right) \tag{4}$$

$G_{zzz}$ is the vertical derivative of $G_{zz}$, which will increase the effect of noise. We can use the following express to compute the vertical derivative:

$$\frac{\partial G_{zz}}{\partial z} = \frac{\partial^2 G_z}{\partial z^2} = -\left(\frac{\partial G_{zx}}{\partial x} + \frac{\partial G_{zy}}{\partial y}\right) \tag{5}$$

The vertical derivative of $G_{zz}$ can be calculated as the sum of two horizontal derivatives, which computed numerically in spatial domain.

## Synthetic model

Construct two vertical-side prism gravity sources with top depths of 10m and 15m. Figure 1a shows the gravity anomalies. Figure 1b shows the $N\_ED\_SA$ of the data in figure 1a. We can get that $N\_ED\_SA$ can not only balance the weak anomalies.

In order to test the feasibility of the methods proposed above, we choose two other balance filters to compare results. They are total horizontal derivative of the tilt angle (THDR) (Verduzco, 2004) and Theta map (Wijns, 2005). Figure 1c shows the THDR of the data in figure 1a. Figure 1d shows the Theta map of the data in figure 1a. By comparing the results in figure 1, the edges detected by *N_ED_SA* are clearer and more precision compared to other filters, which has the best results.
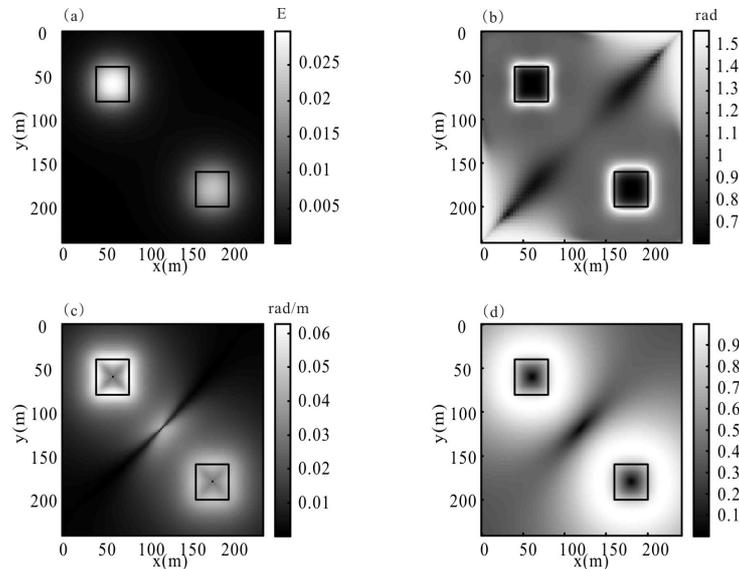


***Figure 1*** *(a) Synthetic gravity anomaly. (b) N_ED_SA of the data in 1a. (c) THDR of the data in 1a. (d) Theta map of the data in 1a.*

## Conclusions

This paper defines the second order directional analytic signal. We use the horizontal second order directional analytic signal to define a new edge detector to process the potential-field gradient tensor data. In order to outline the edges of strong and weak amplitude anomalies simultaneously, we present a normalization method, which can not only balance the amplitude, but also increase the resolution of small amplitude edges. These methods have been tested by comparison to the related high-pass filters with synthetic data. The *N_ED_SA* can enhance the edges more precisely and clearly compared to others.

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