

# Edge Detection of Gravity Anomalies with Directional Hyperbolic Tilt Angles: Application to Synthetic and Field Data

Ahmad Alvandi\*<sup>1</sup> and Mojtaba Babaei<sup>2</sup>

<sup>1</sup>Young Researchers and Elite Club, Tuyserkan Branch, Islamic Azad University, Tuyserkan, Iran

<sup>2</sup>Department of Physics, Tuyserkan Branch, Islamic Azad University, Tuyserkan, Iran

\*Corresponding Author: sim.alvandi@gmail.com

## ABSTRACT

Edge detection is an image processing method for finding the boundaries of anomalies. Local phase filters have been widely used to detect the edges of the anomalies. There are various filters that are employed to attain edge detection, for example, Analytic signal, tilt angle, directional tilt angle and hyperbolic tilt angle. The tilt angle is a widely used edge detection filter. We make some improvement to tilt angle filter, so that it can process the gravity data. We describe a new filter based on the first order directional hyperbolic tilt angle. Directional hyperbolic tilt angle is used for edge detection of the gravity anomalies by a calculation program based on MATLAB. This filter is applied to synthetic data with and without random noise. Finally, the validity of the filter is tested on a real case from Iran.

**Key words:** Edge Detection, Gravity Anomalies, Hyperbolic Tilt Angle, Salt Dome and Iran.

## INTRODUCTION

Potential field data, especially gravity and magnetic anomalies are generally used to map geological boundaries such as faults and contacts between intrusions and their host rocks. 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 and engineering targets (Blakely and Simpson, 1986; Ardestani, 2005; Ardestani and Motavalli, 2007; Yuan et al., 2014). The measurement of the local phase of potential fields can be useful for their magnetic and gravity interpretation (Cooper and Cowan, 2006 and 2011). There are various local phase filters that have been employed to achieve edge detection, for example, Analytic signal, tilt angle, directional tilt angle, and hyperbolic tilt angle (Pilkington and Keating, 2004; Hoseini et al., 2013; Alvandi and HoseiniAsil, 2014). The tilt angle is a useful form of local phase filter for enhancing subtle detail in gravity data (Cooper and Cowan, 2006). The hyperbolic tilt angle is also less sensitive to noise than the tilt angle but their result is better and clearer than the tilt angle filter (Cooper and Cowan, 2006). In this paper, we define the first order direction hyperbolic tilt angle, and propose a new filter based on it. The method is tested by using synthetic data created for prism models at different depths. In addition, practical utility of the method is demonstrated for a salt dome in Iran.

## METHODOLOGY

Cooper and Cowan (2006) defined the directional tilt angle to delineate the edge. In order to increase the resolution of the edges, we propose another method using the first order derivatives to form the hyperbolic tilt angle, called

first order directional hyperbolic tilt angle (DHT). The first order directional hyperbolic tilt angle can be rewritten as

$$HT_x = \tanh^{-1} \left( \frac{\partial f / \partial x}{\sqrt{((\partial f / \partial z)^2 + (\partial f / \partial y)^2)}} \right) \quad (1)$$

and

$$HT_y = \tanh^{-1} \left( \frac{\partial f / \partial y}{\sqrt{((\partial f / \partial z)^2 + (\partial f / \partial x)^2)}} \right) \quad (2)$$

Here the subscripts x and y denote the directions. We combine  $HT_x$  and  $HT_y$  to define an edge detector as follow:

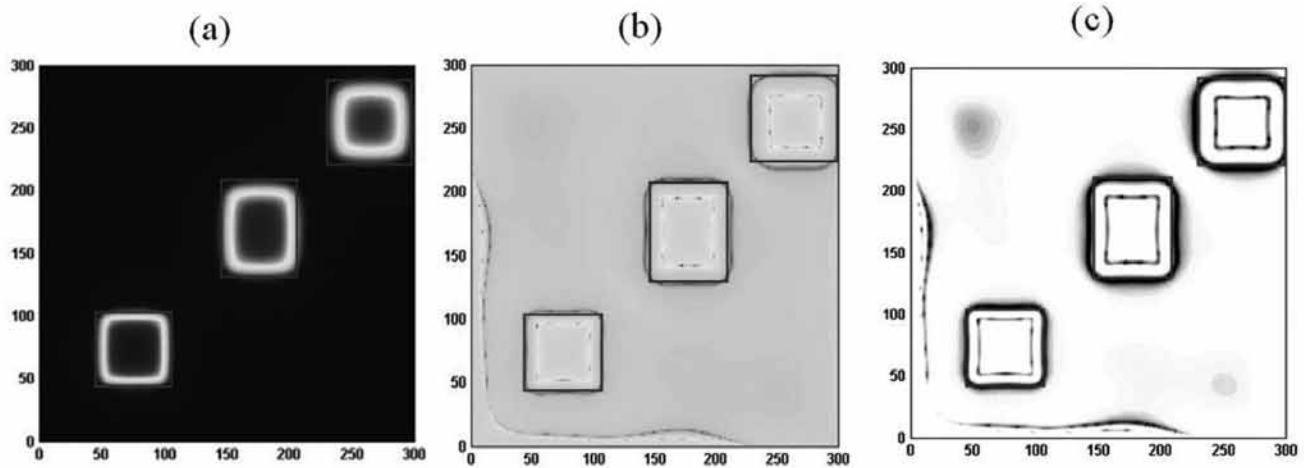
$$HT_{tot} = \sqrt{(HT_x)^2 + (HT_y)^2}$$

Using equations (1) and (2), a normalized version of this filter is established as follow:

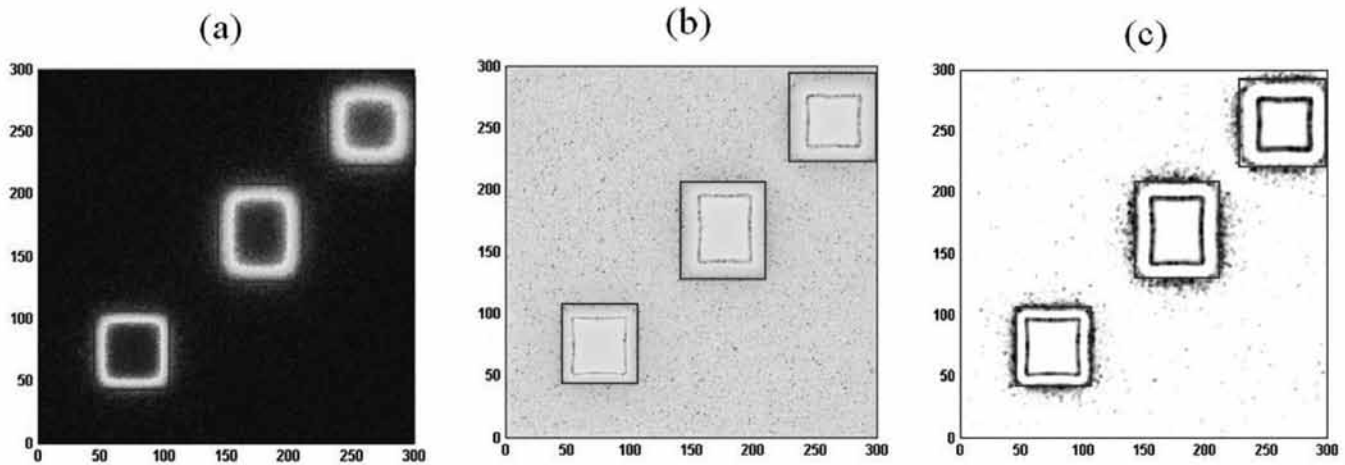
$$DHT = \tanh^{-1} \left( \frac{\sqrt{((\partial f / \partial x)^2 + (\partial f / \partial y)^2)}}{|\partial f / \partial z|} \right) \quad (3)$$

## SYNTHETIC MODEL

Firstly, we constructed three prism shaped gravity sources with top depths of 3m, 5m and 8m. Figure 1(a) shows the gravity anomalies. Figure 1(b) shows the hyperbolic tilt angle of the data in figure 1(a). Figure 1(c) shows



**Figure 1.** (a) Gravity anomaly (mGal), (b) Hyperbolic tilt angle of the data in 1a, (c) Directional hyperbolic tilt angle of the data in 1a.



**Figure 2.** (a) Noisy anomaly map (mGal), (b) Hyperbolic tilt angle of the data in 2a, (c) Directional hyperbolic tilt angle of the data in 2a.

the directional hyperbolic tilt angle of the data in figure 1(a). By comparison among the results in figure 1, the edges detected by DHT are clearer than that obtained by hyperbolic tilt angle filter.

To demonstrate how this method works, the data should be contaminated by random noise. With amplitude equal to 5% of the maximum data amplitude random noise was added to the gravity data set shown in figure 2(a). Figures 2(b) and 2(c) show, respectively, hyperbolic tilt angle map and the outputs of the proposed method. In the case of noisy data, it is seen that the DHT technique produces better result than that from the hyperbolic tilt angle method.

### Field Model

In this section, the real data edge detection is studied. The case study taken up for applying the presently proposed method is the gravity data over a salt dome in Qom province (Aghashahi and Zomorrodian, 1981; Motasharrei et al., 2010). The map of geographic location of Qom area is shown in figure 3a and geological scheme of the study area is shown in figure 3b. Residual gravity anomalies measured over salt dome of Qom is shown in figure 4a. Figure 4b shows the hyperbolic tilt angle of the data in figure 4a. Figure 4c shows the directional hyperbolic tilt angle of the data in figure 4a.

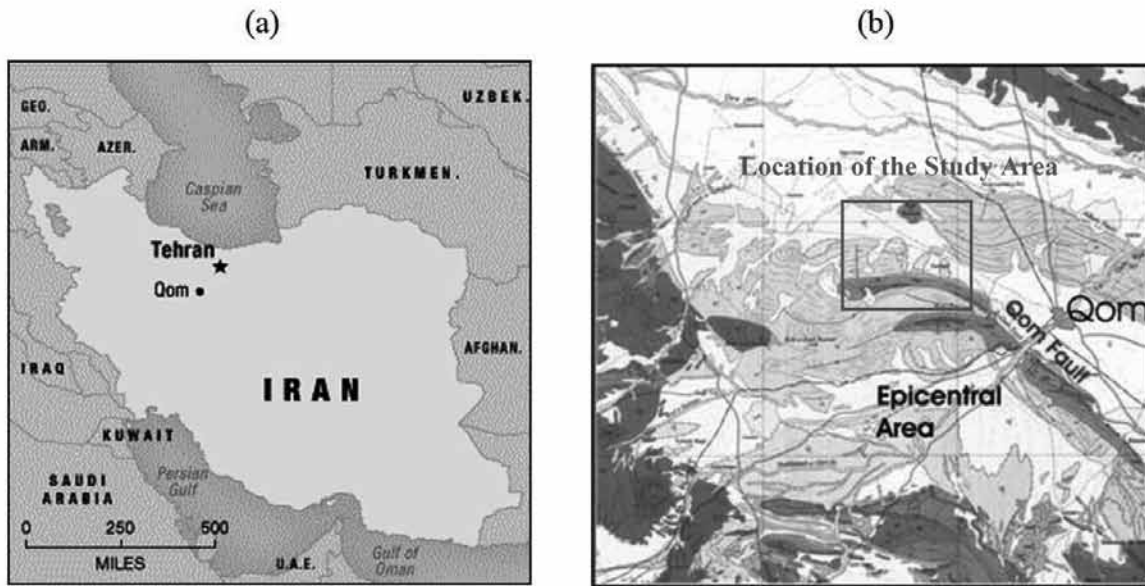


Figure 3. (a) Geographic location of Qom area in the map of Iran, (b) geological scheme of the study area.

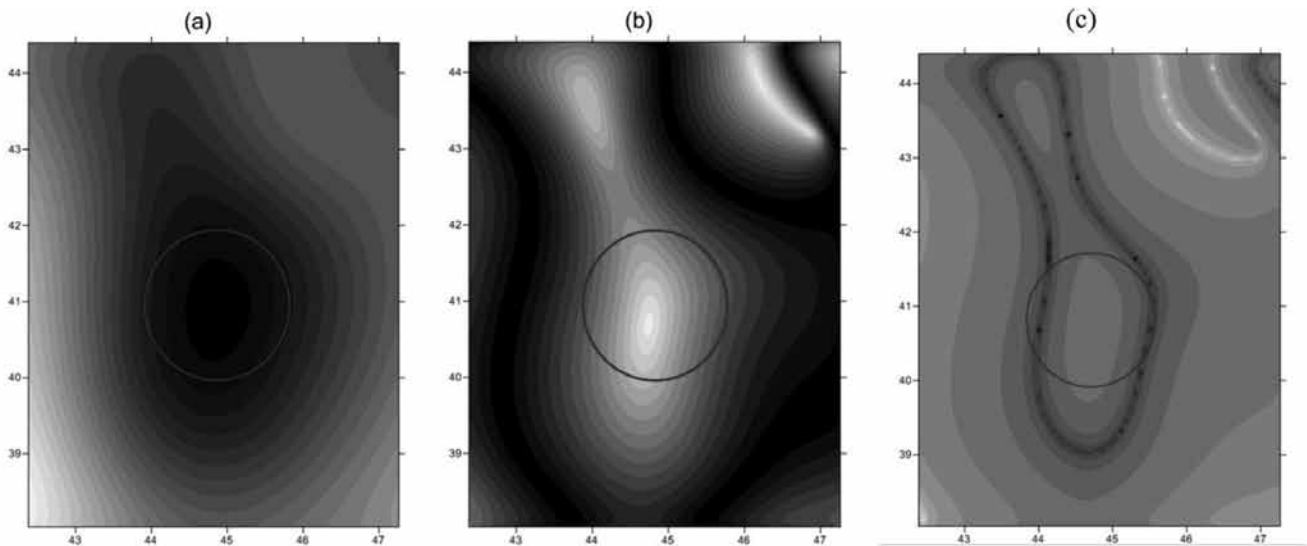


Figure 4. (a) gravity anomaly (mGal), (b) Hyperbolic tilt angle of the data in 4a, (c) Directional hyperbolic tilt angle of the data in 4a.

## CONCLUSIONS

This paper defines the first order directional tilt angle. We use the first order directional tilt angle to define a new edge detector to process the gravity data. This method has been tested by using synthetic data created for prism models at different depths and also real data from a salt dome. The Directional hyperbolic tilt angle proposed and demonstrated in the present paper can reveal the edges more clearly than the hyperbolic tilt angle.

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## Compliance with Ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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