Shahrood University of Technology

JOURNAL OF RESEARCH ON APPLIED GEOPHYSICS

(JRAG)

2026, VOL 12, NO 2
(DOI): 10.22044/JRAG.2026.17604.1386

A combination of the logistic function and the directional Hilbert transform for precise edge detection of gravity data

Ahmad Alvandi [1*]; Vahid E. Ardestani [2]

1. Centre of Hamedan, University of Applied Science and Technology, Tehran, Iran.
2. Institute of Geophysics, University of Tehran, Tehran, Iran.

Received: 13 April 2026 ; Accepted: 19 August 2026

Corresponding author: aalvandi@uast.ac.ir

Keywords

Edge enhancement
Gravity anomaly
Logistic function
Hilbert transform
Slovakia territory

Extended Abstract

Gravity anomalies map feature spatially overlapping fingerprints from a potentially huge number of sources, each with a different shape, depths and densities. In recent decades, geophysicists have developed a variety of image-enhancement filtering algorithms or edge detectors to accurately display the geometry and details of subterranean sources. However, in common filters, the images obtained for deeper sources are usually diffuse or fuzzy, or filters cannot equalize the edges of weak and strong amplitudes at the same time. In order to overcome these problems, in this paper, an effective filter using the combination of the logistic function, the directional Hilbert transform and the total horizontal gradient is introduced, abbreviated as "MLK". The results on the 2D and 3D data with noise and without noise show that MLK proposed filter performs better compared to the other filters. Also, we used the measured complete Bouguer anomaly (CBA) high resolution dataset in Slovakia territory. In addition to gravity map we also used the geological map to control our results as a case study. The primary goal of this research is to compare MLK edge determination filter and to assess the quality of filter and balance signals from shallow and deep geological structures.

Introduction

Gravity method is among the earliest techniques for defining the earth's nature and operations. Despite the advancement of supplementary investigative methods, some of which have improved subsurface information quality, gravity procedure continues to play an essential, and often crucial, role in hydrocarbon and mineral explorations, geological structure investigations, and so on (Ai et al., 2025; Deniz Toktay et al., 2025; Alvandi et al., 2025; Alvandi and Ardestani, 2023). Various filters for processing and analyzing gravity data to produce better results and greater resolution have been created and developed in recent decades (Alvandi et al., 2024; Ai et al., 2024). Image-enhancement filtering methods are employed to aid in the interpretation of gravity data (Alvandi et al., 2023). These methods are often used to determine the horizontal lateral boundaries of gravity data. The most edge detection filters use the amplitude maximum of directional derivatives or a combination of two derivatives to determine the horizontal lateral boundaries. Due to the weakness of the filters in determining the boundaries of geological structures, the identification of deeper sources or the causative subsurface structures with a smaller scope and at the same time with shallow sources or anomalies with a larger scope has led to the creation of more effective filters.

Methodology and Approaches

In this paper, we propose an edge detection effective filter that is based on the logistic function, the total horizontal gradient (THDR) and the orthogonal Hilbert transform for balancing the edges of gravity sources. This modified logistic (MLK) filter is defined in Eq. 1.

$$\mathrm{MLK} = \frac{1}{0.5 + \left(\exp\left(\frac{-\frac{\partial \mathrm{MTH}}{\partial \mathrm{Z}}}{\sqrt{\left(\frac{\partial \mathrm{MTH}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{MTH}}{\partial \mathrm{y}}\right)^2}} \right) \right)} \qquad (1)$$

where

$$\mathrm{MTH} = \frac{\left(\frac{\partial \mathrm{B}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{B}}{\partial \mathrm{y}}\right)^2}{1 + \sqrt{\left(\mathcal{HT}_x\left(\sqrt{\left(\frac{\partial \mathrm{B}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{B}}{\partial \mathrm{y}}\right)^2}\right)\right)^2 + \left(\mathcal{HT}_y\left(\sqrt{\left(\frac{\partial \mathrm{B}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{B}}{\partial \mathrm{y}}\right)^2}\right)\right)^2 + \left(\frac{\partial \mathrm{B}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{B}}{\partial \mathrm{y}}\right)^2}} \tag{2}$$

In equation (1), $\frac{\partial \mathrm{MTH}}{\partial \mathrm{z}}$ is the vertical derivative of MTH and $\sqrt{\left(\frac{\partial \mathrm{MTH}}{\partial \mathrm{x}}\right)^2 + \left(\frac{\partial \mathrm{MTH}}{\partial \mathrm{y}}\right)^2}$ is the amplitude of the horizontal derivative of MTH. In equation (2), $\mathcal{HT}_x$ and $\mathcal{HT}_y$ are the Hilbert transform of the THDR filter in the X- and Y-directions, respectively.

Results and Conclusions

The findings show that the MLK filter can provide the boundaries with high resolution. The usage of an upward continuation filter is suggested to get the required effects while reducing noise. Map of MLK is important because they improve the edges of gravity anomalies when compared to a map of the original anomaly and may be used to discover the existence of subtle gravity and anomalies as well as the location of subsurface anomalies.