

# High-Resolution Mapping of Magnetic Source Boundaries Using a Skewed-Sigmoid Approach, A Case Study of the Shavaz Deposit in Iran

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## INTRODUCTION & AIM

Geophysical methods are essential for mapping geological structures and mineral resources. Among these, magnetic surveys are popular due to their cost-effectiveness and wide spatial coverage. Interpreting magnetic data helps reveal subsurface features, but enhancing subtle anomalies remains a challenge. Traditional edge detection methods are divided into unbalanced and balanced techniques. Unbalanced filters, such as the Total Horizontal Gradient (THG) and Analytic Signal (AS), effectively outline shallow, high-amplitude sources but struggle with low-amplitude anomalies. Balanced approaches, including Tilt Angle (TA), Theta Map (TM), and Tilt Angle of the Horizontal Gradient (TAHG), aim to detect edges at a varying depths. Recent studies show that TAHG is effective for mapping structures, though it often produces low-resolution edge maps. To address these limitations, this study introduces a method based on a Skewed-Sigmoid function applied to the overall horizontal gradient. The approach enhances edge detection performance, produces high-resolution maps, and minimizes false edges. Its effectiveness is demonstrated using both synthetic models and a real case study from the Shavaz deposit in Iran, highlighting its potential for improved geological interpretation.

## METHOD

The total horizontal gradient (THG) is a well-known technique for edge detection in magnetic data. The THG is mathematically expressed as:

$$THG = \sqrt{\left(\frac{\partial \phi}{\partial X}\right)^2 + \left(\frac{\partial \phi}{\partial Y}\right)^2} \quad (1)$$

where  $\phi$  is the magnetic field. The Skewed-Sigmoid function (Chandra and Sodhi, 2014) closely resembles the inverse tangent function typically utilized for edge detection in magnetic data. This method (SSF) is defined as:

$$SSF = \left( \left( \frac{1}{1 + \exp^{-\Psi}} \right) + \left( \frac{1}{1 + \exp^{-2\Psi}} \right) \right)^2 \quad (2)$$

where

$$\Psi = \frac{\frac{\partial THG}{\partial z}}{\sqrt{\left(\frac{\partial THG}{\partial y}\right)^2 + \left(\frac{\partial THG}{\partial x}\right)^2}} \quad (3)$$

The maxima of the SSF correspond to the boundaries of the magnetic sources. Similar to the TAHG, it does not generate spurious edges in the edge map. However, it can generate the edges with a higher resolution than the TAHG.

## RESULTS & DISCUSSION

### Synthetic Example

In this section, we evaluate the efficiency of the SSF using a synthetic magnetic model. The synthetic model consists of three prisms, as depicted in Figures 1a and b. Table 1 displays the model's parameters. The model's magnetic anomaly is computed using these parameters and depicted in Figure 1c.

Table 1: Parameters of three sources.

Parameters	M1	M2	M3
Coordinates of the center (km, km)	45, 45	100, 100	155, 155
Width (km)	45	45	45
Length (km)	45	45	45
Depth to the top (km)	8	5	3
Depth to bottom (km)	13	10	8
Inclination (°)	90	90	90
Declination (°)	0	0	0
Magnetization (A/m)	0.7	0.8	0.7
Remanent Inclination (°)	30	20	10
Remanent Declination (°)	15	-20	25
Magnetic susceptibility (SI)	-0.001	0.002	0.003

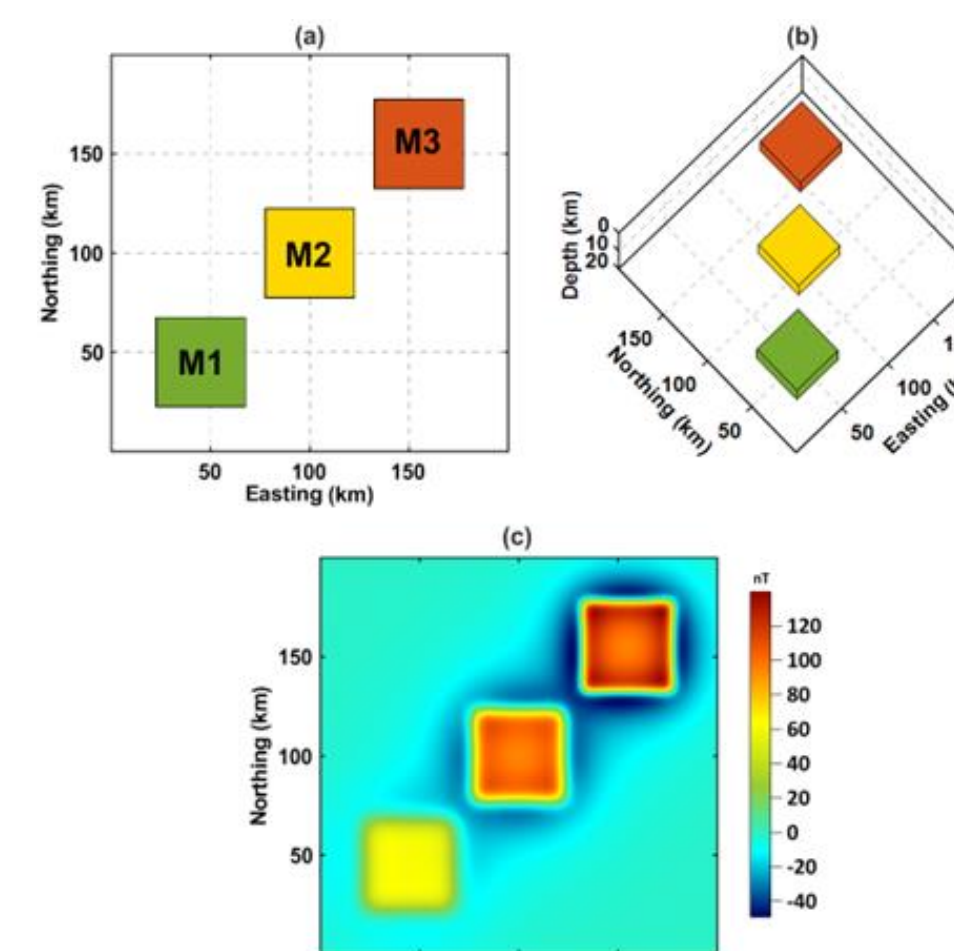


Figure 1: (a) The two-dimensional model; (b) The three-dimensional model; and (c) The magnetic anomaly of the model

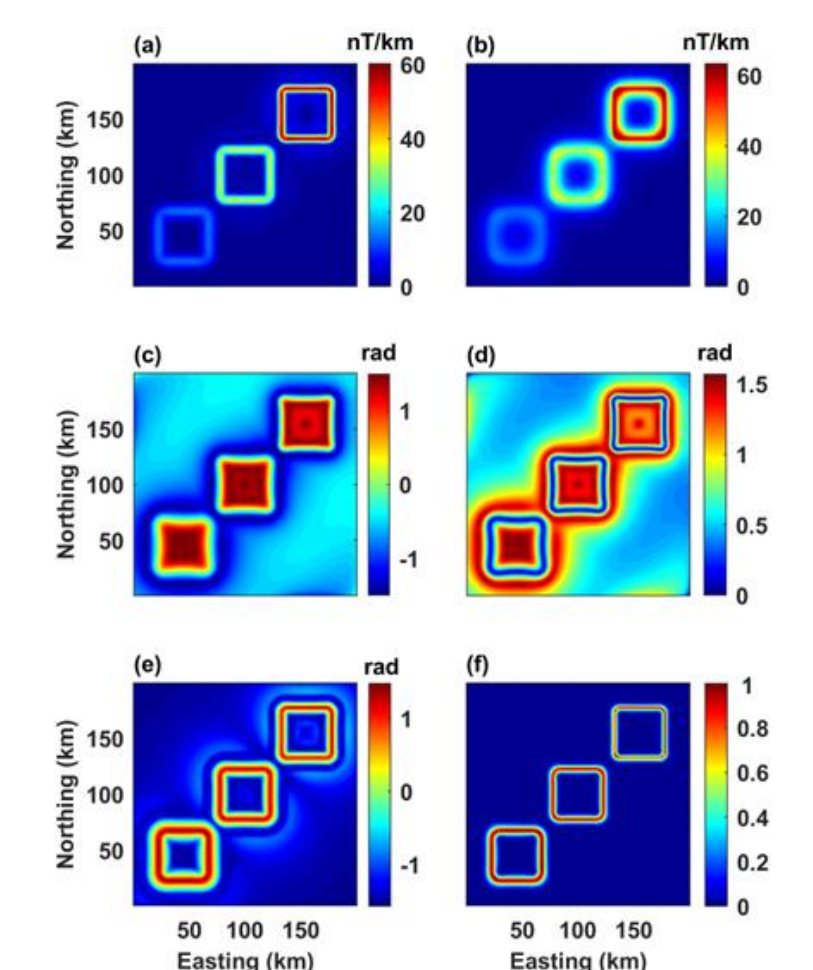


Figure 2: Outcomes of the data presented in figure 1c. (a) THG; (b) As; (c) TA; (d) TM; (e) TAHG and (f) SSF.

In the synthetic case, we employed the chosen techniques (THG, AS, TA, TM, TAHG, and SSF) on the magnetic data shown in Figure 1c. Figure 2 displays the outcome of the edge detectors. The results indicate that SSF effectively enhances anomaly boundaries with high resolution, while minimizing blurred responses and spurious edges.

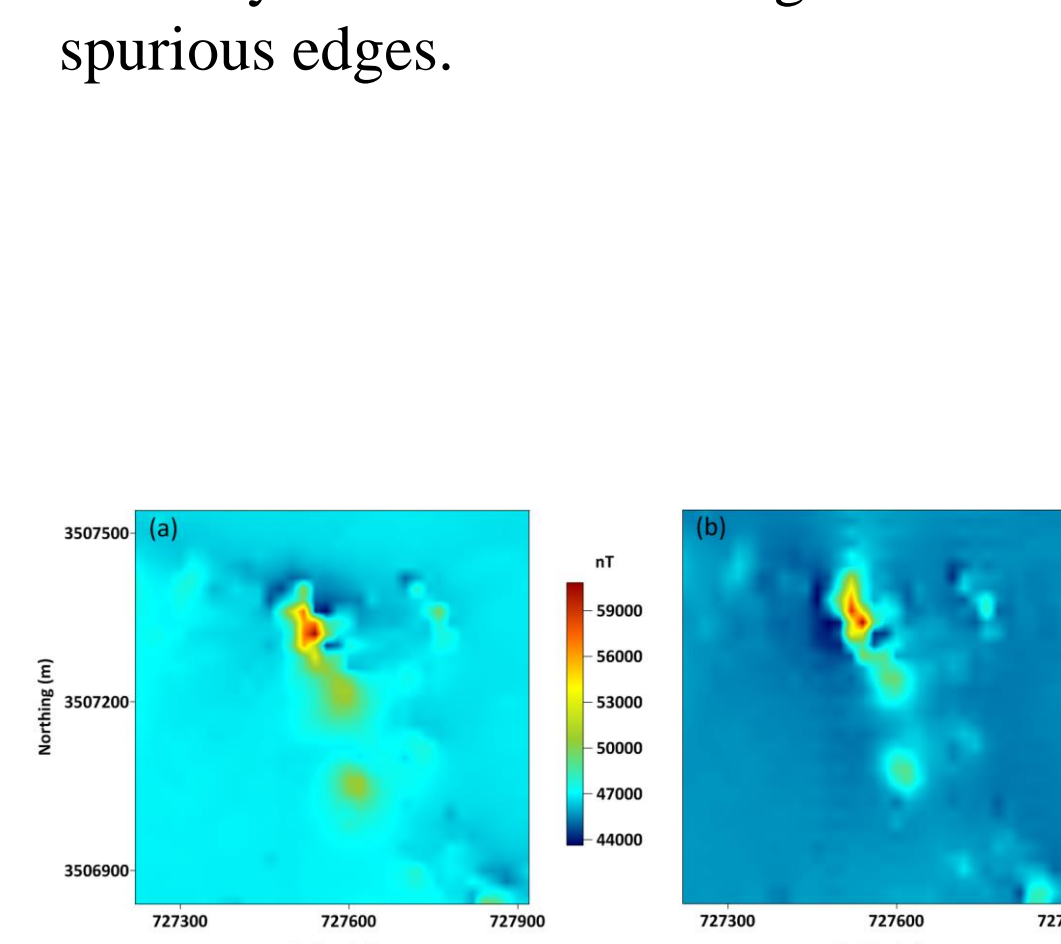


Figure 3: (a) Magnetic anomaly of the Shavaz region; (b) RTP data of Shavaz deposit

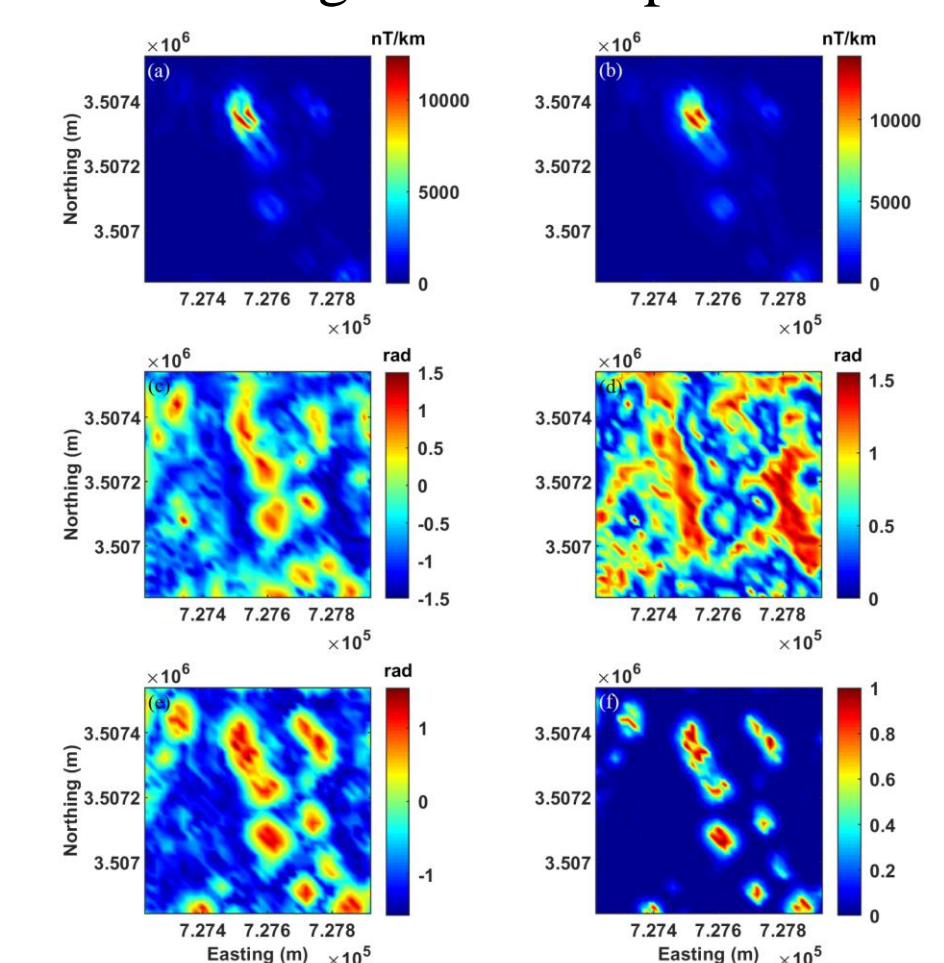


Figure 4: Outcomes of the data presented in figure 3b. (a) THG; (b) As; (c) TA; (d) TM; (e) TAHG and (f) SSF.

### Real Example

In this section, the filter is applied to a real data set of the magnetic field in the Shavaz area. The study area lies within the Central Iran Block, a region known for its significant potential for iron mineralization, particularly hematite and magnetite. Geological reports and earlier studies indicate that Shavaz iron mineralization developed within the sub-fractures of the Dehshir Fault. Figure 3a displays the magnetic data from the research area. In this study, the magnetic data were reduced to the pole (RTP) prior to applying the edge-detection filters. Similar to the earlier section, we evaluated the SSF against the subsequent edge detection filters: THG (Figure 4a), AS (Figure 4b), TA (Figure 4c), TM (Figure 4d), and TAHG (Figure 4e). As expected, the SSF filter clearly delineates the horizontal boundaries of geological structures (Figure 4f).

## CONCLUSION

The Skewed-Sigmoid Filter (SSF) provides high-resolution edge detection for magnetic data, outperforming conventional methods. It accurately delineates both shallow and deep geological structures while minimizing false edges. Applied to synthetic and real datasets from the Shavaz area, SSF shows strong agreement with known geology, making it a valuable tool for mineral exploration and subsurface mapping.

## FUTURE WORK / REFERENCES

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