An assessment of the Performance of Derivative Based Data Enhancement Techniques in the Presence of Coherent Noise

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SUMMARY

Enhancement of potential field datasets using operators based on one or more of the spatial derivatives is common practice. The performance of these methods in the presence of noise is poorly understood; other than a general acceptance that they can be significantly affected, especially when higher order derivatives are used. Most published descriptions which involve noise tests use random noise and a dense and uniform sampling of the test region. More realistic tests of the effects of noise should account for the incomplete and anisotropic sampling within most datasets and also correlated noise such as due to incorrect levelling. An understanding of the effects of noise on the different methods of enhancement is particularly important when working with lower quality (older) and lower resolution datasets.

Interpretation of geophysical data from West Africa, as part of a major project on the prospectivity of the region, is being undertaken. Much of the data available is of relatively low quality and resolution. An important component of the work will involve determining how best to enhance the gravity and magnetic datasets. Initial results working on gridded data show that the "generalized derivative operator" is the most robust derivative based enhanced product for low resolution data.

Key words: aeromagnetics, coherent noise, levelling artefacts, resolution, spatial derivatives.

INTRODUCTION

A major source of coherent noise in aeromagnetic data is levelling artefacts in the direction parallel to the survey lines. These artefacts reflect the nature of the data acquisition, i.e. more dense sampling and less variation in source-sensor separation in the survey line direction compared with the cross line direction. Spatial derivatives of the data, especially in the cross-line direction, are particularly sensitive to these effects and artefacts are common in such products. This is particularly a problem when working with aeromagnetic with widely spaced survey lines (400 m and more) and with older datasets where knowledge of aircraft position was less constrained than for modern survey.

In addition to the spatial derivatives themselves, various edge enhancement filters have been proposed which combine one or more of the spatial derivatives. These filters are mainly used in mineral exploration industry for emphasizing the fine details of magnetic and gravity images. Such products are likely to be very prone to noise since they combine input which themselves are often noisy. Published descriptions of these filters rarely include realistic noise tests; usually involving introduction of random noise to synthetic data sets where there is a dense and uniform sampling of the calculated gravity or magnetic field.

The research we describe here is part of a larger study of the noise-response characteristics of derivative based filters. In this report we concentrate on aeromagnetic data in gridded form. Other concurrent lines of research involve the effects of irregular sampling, as for example occurs in regional gravity datasets and also the advantages of using measured gradients (gradiometer data), and calculated gradients in directions where sample density is low.

METHOD

In this investigation we have considered levelling related artefacts in airborne magnetic data and their effect on four common edge-enhancement products: 1) analytic signal amplitude - AS (Roest et al. 1992), 2) tilt derivative (angle) - T (Miler and Singh, 1994) and 3) horizontal derivative of tilt angle - THDR (Verduzco et al. 2004), 4) generalized derivative operator – GDO (Cooper and Cowan, 2011). All of the methods require the calculation of first order derivatives, both horizontal (*df/dx* and *df/dy*) and vertical (*df/dz*). Note that in this paper we have denoted *dy* as the derivative perpendicular to survey lines and *dx* as the derivative along the survey lines. The derivatives are then combined in some fashion:

$$|As| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{df}{dy}\right)^2 + \left(\frac{\partial f}{\partial z}\right)^2}, \quad (1)$$

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

$$THDR = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2}, \quad (3)$$

$$GDO = \frac{\left(\frac{\partial f}{\partial x}\sin\theta + \frac{\partial f}{\partial y}\cos\theta\right)\cos\phi + \frac{\partial f}{\partial z}\sin\phi}{\sqrt{\left(\frac{\partial f}{\partial z}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2 + \left(\frac{\partial f}{\partial x}\right)^2}}, \quad (4)$$

(Where θ is the azimuth in the horizontal plane and φ is the elevation in the vertical plane)

RESULTS

We have used gridded aeromagnetic data from West Africa for our experiments. The African data was collected in 1997 with line spacing of 1000 m and nominal terrain clearance of 120 m.

Figure 1 shows TMI data and the three spatial derivative products from the African data. The TMI grid seems noise free. All the spatial derivatives highlight levelling artefacts in the direction parallel to the survey lines. As expected, the noisiest is *dy*. The "cleanest" is *dx*. In an attempt to reduce noise levels, in addition to conventionally levelling methods, the micro-levelling method of Minty (1991) was applied to the data. However, despite significant time and effort there were no improvements and even some minor micro-levelling artefacts were generated.

The results of edge enhancement techniques applied to the gridded aeromagnetic data from West Africa are shown in (Figure 2). The analytic signal appears to have the low levels of noise and THDR is most affected. However, the best results were achieved using GDO. Even though some of the artefacts remain, there is significant improvement from the previous images. The result for θ = 10 º and smoothing factor of 1 is shown in Figure 2.

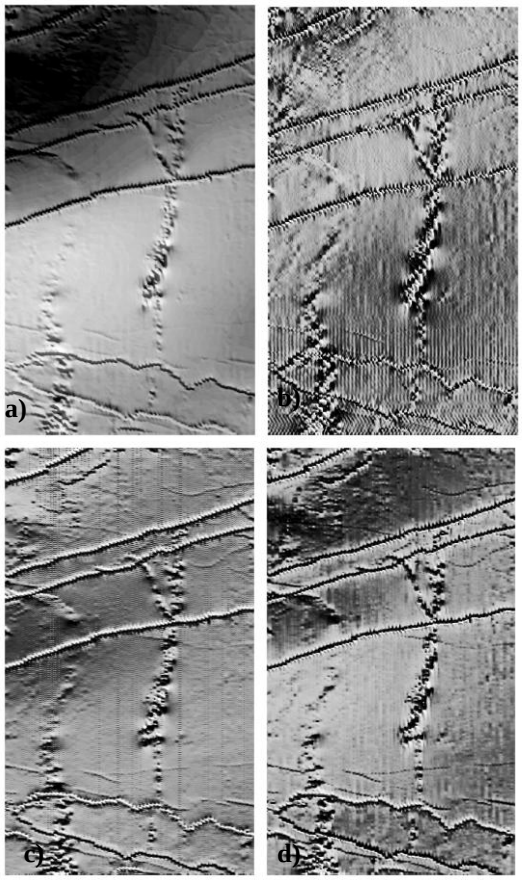

Figure 1. Levelling artefacts in the spatial derivatives, all images are histogram equalised grey scale, white is high and black is low value. All images are NS orientated. a) TMI b) *dy* c) *dx* *and d) dz*

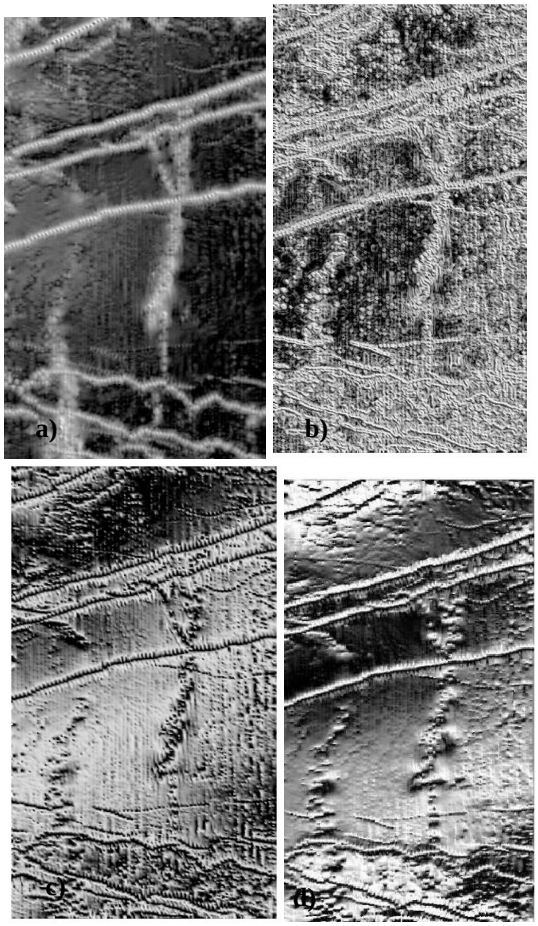

Figure 2. The result of the edge enhancement filters on the aeromagnetic data from West Africa. Survey lines are NS oriented with spacing of 1 km. All images are histogram equalised grey scale, white is high and black is low value. All images are NS orientated. a) AS b)THDR c) T and d) T GDO ($\theta = 10$ º) on the gridded data showing some minor NS elongated artefact, but still improvement from the previously tested edge enhancement techniques

CONCLUSIONS

Low resolution geophysical data are the only source of geophysical information in many parts of the world. Extracting the most information from these data, in the presence of what are commonly high levels of noise, requires careful enhancement. Our initial results suggest that gridded aeromagnetic datasets are most usefully enhanced using the generalised derivative operator of Cowan and Cooper (2011) since this is least affecting by coherent noise associated with incorrect levelling and poor sample density.

On-going research is investigating point based processing of low resolution datasets, including (gravity) data not collected along regular traverses, aiming to understand how best to create enhanced products.

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