Aeromagnetic noise reduction and interpretation by Multifractal Singular Value Decomposition

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Abstract. The aeromagnetic signal often has a minority of noise in it, which may be composed of random noise caused by the aircraft itself, fringe pattern noise caused by the differences between the aircraft airlines, or linear features aligned along the declination direction after reduction to the pole, which are usually hard to distinguish visually but will make useful information submerged. In this paper, the aeromagnetic data of a polymetallic deposit-accumulated area in Inner Mongolia Province, northwest China, is taken as an example, from which the aeromagnetic noise is extracted by multifractal singular value decomposition (MSVD), the singular values are automatically fitted into limited number of fractal straight lines according to their inflection points and minimum fitting error, each line represents a certain kind of noise or signal, the noises are chosen and removed in this way. The last two decomposed components are usually a band pass and a low pass filter that can be used for tectonic faults and geological bodies’ interpretation, respectively.

Keywords. Aeromagnetic data, MSVD, noise reduction, interpretation

1. Introduction

Aeromagnetic survey has been broadly used in the fields of geological survey, mineral exploration, geomagnetic navigation and geophysical research. During the survey, there are usually ferromagnet in the aircraft that will produce magnetic field, the plasma generated by vaporization ionization of the projectile could also produce magnetic fields [1], which are similar to random noise. The differences between the aircraft airlines could cause fringe pattern noise. These noises are main interference to the magnetic sensor and they will change with time in the long run. Besides, at low magnetic latitudes, existing magnetic data must have a reduction to the magnetic pole so that the anomalies will be more symmetrical and better located over the target, which will amplify the noise in this direction, the resultant field after reduction to pole is dominated by linear features aligned along the declination direction [2] like fringe pattern noise. These kinds of noise are usually very small in quantity but will make the
2. Principal of the Algorithm

The aeromagnetic data can be decomposed by equation (1), where $U$ and $V$ is a unitary matrix, $S$ is a diagonal matrix with $\sigma_i=\sqrt{\lambda_i}$ (i=1,2,3…r) its singular value and r its rank, $\lambda_i$ is eigenvalue, $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_r \geq \lambda_{r+1} = \cdots = \lambda_n \geq 0$, which are distributed in decreasing order along the main diagonal. The original matrix can be rebuilt with all of the singular values, and also if some specific singular values are selected, some kind of information can be reconstructed. The eigenvalues correspond to the spectral energy densities in equation (2, 3), which represent a fractal/multifractal distribution described by a power law function [4, 6, 7] in equation (4, 5). It does not need to estimate the power spectrum, so there are no map edge effects caused by the power spectrum estimation [8]. The power law function can be automatically fitted into limited number of fractal straight lines when there are inflection points and the fitting errors of all lines reach minimum synchronously, each line represents a certain kind of noise or signal, the eigenvalues of noise are usually very small, different kinds of aeromagnetic noise can be constructed in this way and subtracted from the original aeromagnetic data.

$$A_{m \times n} = U S V'$$  \hspace{1cm} (1)

$$E(\lambda | \lambda \geq \lambda_i) = \sum_{k=1}^{i} \lambda_k$$  \hspace{1cm} (2)

And its relevant proportion is:

$$P(\lambda | \lambda \geq \lambda_i) = \sum_{k=1}^{i} \lambda_k / \sum_{t=1}^{r} \lambda_t$$  \hspace{1cm} (3)

$$E \propto \lambda^\alpha$$  \hspace{1cm} (4)

And its relevant proportion is:

$$P(\lambda | \lambda \geq \lambda_i) \propto \lambda^\alpha$$  \hspace{1cm} (5)

3. Application

3.1. Aeromagnetic data and geology overview

The aeromagnetic data is surveyed in a polymetallic ore field in inner Mongolia, northwest China, longitude [101°00'E, 101°30'E], latitude [39°20'N, 39°40'N], at a scale of 1:50 000. As it is located at a low latitude, the aeromagnetic data is processed by reduction to the pole via standardized polar transform with a declination value of -1.81° and an inclination value of 59.48°, figure 1 is the image after reduction to the pole.
3.2. Aeromagnetic noise reduction by MSVD

As we can see that the aeromagnetic image is very clear because of a high ratio of signal to noise, but it doesn’t mean that the noise doesn’t exist. Because the value of aeromagnetic noise is often very small in quantity, usually concealed and hard to detect visually, but it can be revealed by MSVD.

![Aeromagnetic map](image)

**Figure 1.** Aeromagnetic map

![MSVD curve fitted by weighted least square variance](image)

**Figure 2.** MSVD curve fitted by weighted least square variance

As is shown in figure 2 that the eigenvalues of the original aeromagnetic data are automatically
Figure 3. Decomposed components by MSVD
fitted into nine straight lines by weighted least square approach in log-log coordination, as there are usually turning points that can make the fitting errors of all lines reach minimum synchronously, and the turning points that can be automatically best fitted are the signs of transformation between different matters like noises of no use or signals of geological meaning. Every straight line means some kind of noise or signal. Line y1 to y4 reconstructed and visualized in figure 3a is mainly fringe pattern noise from high to low frequency in the study area, line y5 and y6 are mainly random noise reconstructed and visualized in figure 3b. Line y7 in figure 3c is some kind of noise showing the tectonics caused by some circular and linear structures, and its energy percent is 0.17%. Line y8 is similar to a band pass filter showing the shallow geological structure (figure 3d), the anomalies as shape of strings and beads in it are signs of faults where the high magnetic material concentrates and most of the polymetallic deposits located on them. Line y9 is similar to a low pass filter (figure 3e) showing the deep crustal and mantle structure. So it is clear that the noises are composed of fringe noise, random noise and some pattern of noise, they can be reconstructed by their summation and visualized in figure 3f with its value varies between -0.1.09nT and 1.82nT, which is much smaller than the original aeromagnetic data value that is between -218.04nT and 855.89nT. The total energy percent of these useless noise is just about 0.20%, but they have to be removed before interpretation and inversion. Although its value and energy percent is very small, the more noise it has the more difficult to interpret the decomposed components.

4. Conclusions and discussions

MSVD is a data-driven and self-adaptive method in aeromagnetic denoising, it can automatically detect which kind the noise is, like random noise and fringe pattern noise, and effectively subtract them. Thus making the original data more scientific, meaningful and easy to interpret and inverse. The band pass filter can be used to interpret regional tectonics and related deposits, the low pass filter can be used to interpret the shape of deep crystalline basement. The method also can be used in other study areas in the world.

5. Acknowledgments

This research owe much thanks to China Geological Survey for its funds (Project no. 12120114062001).

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