Using Steerable Filters to Map Geological Features from HRAM Data of the Foothills of Northeastern British Columbia, Canada

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In the last decade several techniques have been developed to enhance geophysical data in order to extract subtle features that reflect the structural geology of the area. These techniques include curvelet, ridglet and wavelet analysis. Although these techniques provide a powerful tool in extracting linear features from geophysical data, they lack the power to resolve curvilinear or circular features. We believe that curvilinear and circular features are important to map because they reflect certain geological structures such as folds, impact structures and kimberlite pipes that might have significant impact on geophysical data interpretation. For this reason, we tested an image enhancement technique based on steerable filters to map linear, curvilinear and circular features from **H**igh **R**esolution **A**ero**M**agnetic (HRAM) data.

We tested the steerable filters technique on HRAM data from the Foothills of Northeastern British Columbia. The preliminary results of the test are very encouraging. We were able to extract useful features that appear to be related to the geological structure of the area.

Introduction

The crystalline basement rocks of the Western Canada Sedimentary Basin (WCSB) have been extensively deformed over the last two billion years. Some of these deformations have affected the intra-sedimentary rocks and led to the formation of fractures, faults and folds that often appear as linear, curvilinear and to some extent circular features on the HRAM data. These features play a major role in oil, gas, mineral and groundwater exploration because they control structures in the intra-sedimentary section as well as in the crystalline basement rocks. For this reason, we consider mapping these features in HRAM data to be one of the most important stages in geological interpretation of an area.

Traditionally, features detection and mapping in HRAM data is carried out by visual inspection of a set of enhanced and filtered images of the total magnetic intensity. These filters (for example the horizontal gradient and the analytic signal) are carefully designed to image features that are associated with faults, fractures, and geological contacts. Going through this process thoroughly over a full range of wavelengths can be a very tedious operation. We have experimented in the past with alternative techniques such as wavelet analysis (Hassan, 2006). Wavelet analysis is good at mapping linear features but poor at mapping circular features. In this study we are testing steerable filters for the same purpose.

Methodology

Steerable filters were first introduced by Freeman and Adelson in 1991 and since then used widely by many researchers for edge detection, image enhancement and pattern recognition. In this work we adopt the technique described by Mathews and Unser (2004). The term 'steerable filter' is used to describe a class of filters in which a filter of arbitrary orientation is synthesized as a linear combination of a set of 'basis filters'. These basis filters are designed to detect curvilinear or circular features represented as edges or ridges in an image as illustrated in Figure 1.

Freeman and Adelson (1991) proposed an efficient scheme for computing arbitrary rotations of 2D steerable filters (Fig. 1). In this scheme an impulse function $h^{\theta a}(x,y)$ rotated by an arbitrary angle θa was formulated as a linear combination of basis functions $h^{\theta i}(x,y)$ as follows:

$$h^{\theta a}(x,y) = \sum_{i=1}^{m} K_i(\theta_a) \cdot h^{\theta i}(x,y)$$

where $K_i(\theta_a)$ are filter coefficients.

We tested the steerable filters, edge and ridge detectors, on the reduced-to-pole total magnetic intensity grid shown in Figure 2. The results after skeletonization are shown in Figures 3 and 4, respectively. Skeletonization is a process of converting the image into a binary form where we assign a value of one to the signal of interest (here the location of the lineaments) and a value of zero to the background based on a selected threshold value. Comparisons were made to the results of mapping features with traditional mapping techniques.

Results

The results of applying steerable filters on HRAM TMI grid are intriguing. As Figures 3 and 4 shows we were able to extract features that were missed using traditional mapping techniques. Most of the features detected are continuous and highly coherent probably due to high signal/noise ratio. Figures 3 and 4 show that most of the features detected are oriented in the NE-SW and NW-SE direction and these features are conformal with the prominent geological structure of the area.

Conclusions

The results obtained in this test are very promising because we were able to map curvilinear and to some extent circular geological features that were difficult to map using other image enhancing techniques such as FFT or wavelet analysis. In addition to curvilinear and circular features, steerable filters are effective also in mapping lineaments and therefore provide an alternative technique for skeletonization. The features detected by steerable filters also appear to be very continuous and coherent. Mapping geological features using steerable filters, if implemented, would be completely automated and therefore much faster and more cost-effective than manual techniques. The features mapped with steerable filters would provide interpreters with a comprehensive objective dataset of features to use in forming a robust structural interpretation.

References

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Mathews J., and Unser, M., 2004, Design of Steerable Filters for Feature Detection Using Canny-Like Criteria: IEEE Transactions on Pattern Analysis and Machine Intelligence, **26**, 1007-1019.

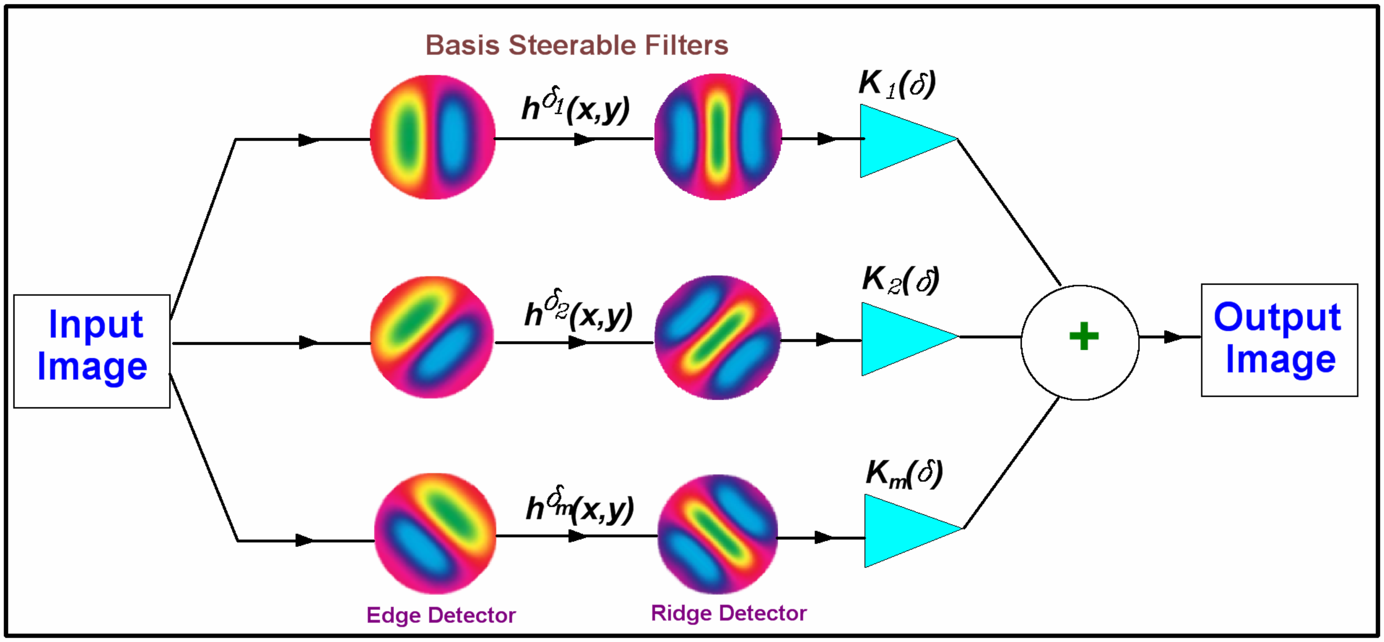

Figure 1. Principle of steerable filters (modified after Freeman and Adelson, 1991)

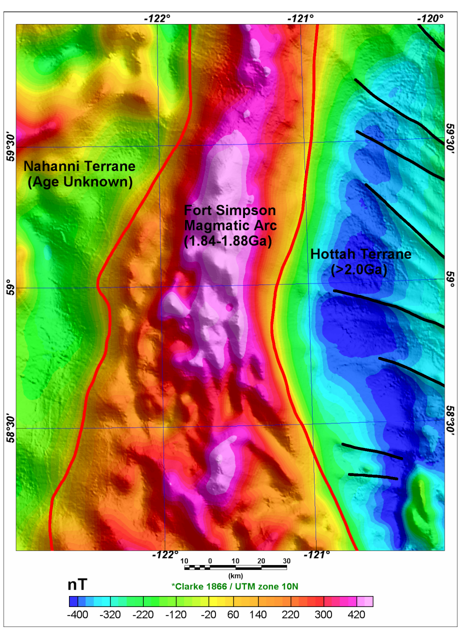

Figure 2. Reduced-to-pole total magnetic intensity with the Precambrian Magnetic Terranes

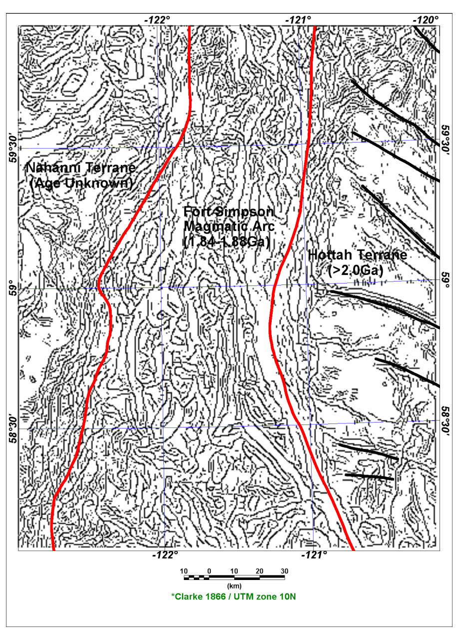

Figure 3. Results of steerable filters applied to Figure 2 using edge detector

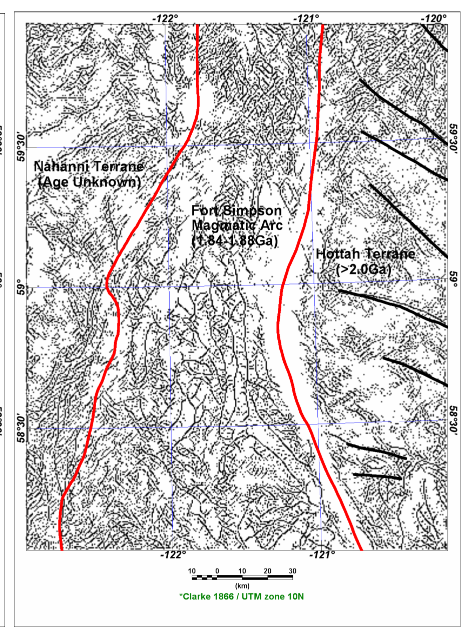

Figure 4. Results of steerable filters applied to Figure 2 using ridge detector